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David Coleman – CWNE #4

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802.11ax

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Introduction

802.11ax is the next fast-approaching Institute of Electrical and Electronics Engineers (IEEE) standard that addresses today's biggest Wi-Fi challenges: high density and performance. It addresses those challenges by increasing capacity by up to four times and improving spectral efficiency to benefit both 2.4 gigahertz (GHz) and 5 GHz bands in a variety of environments.

802.11ax will handle client density more efficiently through a new channel-sharing capability, improve battery life using negotiated wake-time scheduling between APs and clients to preserve energy, and deliver efficiency improvements with at least four times more throughput than 802.11ac.

In this book, you learn about the imminently approaching 802.11ax standard, the key enabling technologies and enhancements in the standard, and Aerohive's family of 802.11ax access point solutions.

About This Book

802.11ax For Dummies, Aerohive Special Edition, consists of five chapters that explore:

- The business need for better Wi-Fi and the 802.11ax vision (Chapter 1)
- Key enabling technologies in 802.11ax (Chapter 2)
- Additional enhancements and design considerations in 802.11ax (Chapter 3)
- The Aerohive family of 802.11ax access points (Chapter 4)
- Ten key things to remember about the new 802.11ax standard (Chapter 5)

There's also a convenient glossary at the end of the book in case you get stuck on any technical terms or acronyms.

Foolish Assumptions

It's been said that most assumptions have outlived their uselessness, but we assume a few things nonetheless!

Mainly, we assume that you're an IT infrastructure professional — someone with networking, wireless, or cloud in their title — and that you work for a medium to large organization or enterprise with robust Wi-Fi business requirements and you're interested in what's next for Wi-Fi.

If any of these assumptions describe you, then this book is for you! If none of these assumptions describe you, keep reading anyway. It's a great book and when you finish reading it, you'll know a few things about the next generation of Wi-Fi.

Icons Used in This Book

Throughout this book, we occasionally use special icons to call attention to important information. Here's what to expect:

REMEMBER

This icon points out information you should commit to your nonvolatile memory, your gray matter, or your noggin — along with anniversaries and birthdays!

TECHNICAL STUFF

You won't find a map of the human genome here, but if you seek to attain the seventh level of NERD-vana, perk up! This icon explains the jargon beneath the jargon!

TIP

Tips are appreciated, never expected — and we sure hope you'll appreciate these tips. This icon points out useful nuggets of information.

WARNING

These alerts point out the stuff your mother warned you about (well, probably not), but they do offer practical advice to help you avoid potentially costly or frustrating mistakes.

Beyond the Book

There's only so much we can cover in 48 short pages, so if you find yourself at the end of this book, thinking, "Where can I learn more?" just go to `www.11ax4dummies.com`. You can also read the latest edition of David Coleman and David Westcott's *CWNA Certified Wireless Network Administrator Study Guide: Exam CWNA-107* (Wiley). You can also download a free 802.11ax poster at `www.aerohive.com/wp-content/uploads/Aerohive_802.11ax_Poster.pdf`.

Where to Go from Here

If you don't know where you're going, any chapter will get you there — but Chapter 1 might be a good place to start! However, if you see a particular topic that piques your interest, feel free to jump ahead to that chapter. Each chapter is written to stand on its own, so you can read this book in any order that suits you (though we don't recommend upside down or backwards).

IN THIS CHAPTER

» Understanding current Wi-Fi network challenges

» Looking ahead to the next Wi-Fi standard

» Considering current and future Wi-Fi use cases

Chapter 1 Recognizing the Business Need for Better Wi-Fi

In this chapter, you look back at the evolution of Wi-Fi standards and the challenges that exist in current Wi-Fi networks, as well as the next Wi-Fi standard — 802.11ax — and Wi-Fi use cases.

Current Wi-Fi Challenges

Since the commercial release of the original 802.11 wireless networking standard over two decades ago, Wi-Fi has evolved with each new protocol theoretically achieving successively higher peak speeds (see the sidebar "Leading up to 802.11ax: a brief Wi-Fi history and amendment timeline").

However, in the real world, the problem isn't how fast Wi-Fi can go, but whether the Wi-Fi network has enough capacity to handle the expanding population of client devices as well as numerous users with diverse networking needs. A Wi-Fi network needs to be designed to address the growing demand for the high volume and diversity of connected devices and services and measured based on the user experience.

LEADING UP TO 802.11ax: A BRIEF WI-FI HISTORY AND AMENDMENT TIMELINE

Delivering a quality Wi-Fi experience can often seem like a complex, ongoing journey through changing standards and emerging technologies, and the continued promise that the next standard will be "the one."

In 1999, wireless was commercially introduced as a "nice to have" with the 802.11a and 802.11b ratifications. 802.11b, the most commonly used standard at the time, had very low speeds — only up to 11 Mbps (much lower than most Ethernet wired networks installed at the time) — but there were no Wi-Fi mobile devices and very few laptops, so 11 Mbps was more than enough.

By 2003, Wi-Fi-enabled mobile devices were being introduced in the market and portable laptops were becoming more standard for both business and personal use. The 802.11g standard was subsequently ratified, delivering up to 54 Mbps speeds.

In 2007, Apple introduced the first iPhone and the smartphone became a modern reality. The 802.11n standard followed in 2009, delivering 100 Mbps of usable throughput. The 802.11n standard also brought about faster theoretical data rates of up to 600 Mbps and supported both 2.4 and 5 GHz devices.

Today, mobile devices are robust enough to replace more expensive laptops, so Wi-Fi has had to catch up. Introduced in 2013, 802.11ac brings us into the age of gigabit Wi-Fi. 802.11ac delivers peak data rates between 433 and 2167 Mbps.

New advances in the basic technologies that underpin Wi-Fi are now being integrated into the 802.11ax standard, which seeks to reach yet another milestone: 10 Gbps — or 5,000 to 10,000 times the performance of the original Wi-Fi standard! However, 802.11ax is *not* just focused on speed but is instead focused on efficiency.

The 802.11n and 802.11ac standards introduced some great new technology, including physical (PHY) and medium access control (MAC) layer enhancements, that helped achieve higher data rates. In essence, bigger highways and faster cars were built. But it led to a few challenges. The issues facing next generation Wi-Fi systems involve degradation to system efficiency due to a growing density of Wi-Fi clients and network traffic with lots of small data frames, such as Voice over Wi-Fi (VoWiFi).

TIP

With an ever-growing number of devices using Wi-Fi, along with the emergence of the Internet of Things (IoT), Wi-Fi networks need to do a better job of managing today's wireless environments, increased data traffic, and a diverse mix of applications and services with differing quality of service (QoS) requirements.

The 802.11ax Vision — More than Just Speeds and Feeds

The next Wi-Fi standard, 802.11ax, is fast approaching — and it's not just about faster Wi-Fi speeds. 802.11ax will bring about a sea change of performance improvements compared to previous 802.11 enhancements. Even the title of the 802.11ax amendment — "High Efficiency" — hints at its many improvements. Previous 802.11 amendments were identified as "High Throughput."

The changes in the 802.11ax standard will improve the way Wi-Fi networks work by leveraging technology that substantially improves capacity, provides better coverage, and even reduces congestion, resulting in a far better user experience overall. It's Wi-Fi for the real world.

The 802.11ax standard and specifications were originally designed to improve Wi-Fi for dense usage scenarios; however, all wireless environments can benefit from 802.11ax enhancements. 802.11ax offers the ability for dozens of devices to *simultaneously* communicate with each access point radio. Using proven Wi-Fi techniques and innovations from the cellular world, the 802.11ax standard is designed to increase capacity by up to four times, mostly by improving spectral efficiency. This will provide benefits in both the 2.4 GHz and 5 GHz bands in a variety of environments including enterprises, schools, retail businesses, hotspots, airports, and even the home.

TECHNICAL STUFF

The goals of the Institute of Electrical and Electronics Engineers (IEEE) 802.11ax task group include:

- Enhancing operation in the 2.4 GHz and 5 GHz band
- Increasing average throughput per station by at least four times in dense deployment scenarios
- Enhancing in both indoor and outdoor environments
- Maintaining or improving power efficiency in stations
- Improving the efficiency of traffic management in a variety of environments

802.11ax focuses on nine main components of enhancement:

- Orthogonal frequency-division multiple access (OFDMA) uplink and downlink (UL/DL) (discussed in Chapter 2)
- Longer orthogonal frequency-domain multiplexing (OFDM) symbol (discussed in Chapter 2)
- Multi-user multiple-input multiple-output (MU-MIMO) 8×8 and UL/DL (discussed in Chapter 2)
- Spatial reuse, also referred to as BSS Coloring (discussed in Chapter 2)
- Target Wake Time (TWT) — power saving (discussed in Chapter 3)
- 1024 quadrature amplitude modulation (1024-QAM) (discussed in Chapter 3)
- New PHY headers (discussed in Chapter 3)
- Enhanced outdoor robustness (discussed in Chapter 3)
- 5 GHz and 2.4 GHz support (discussed in Chapter 3)

See Table 1-1 for a comparison of 802.11ax to the two previous 802.11 standards.

TABLE 1-1 802.11ax, 802.11ac, and 802.11n comparison

	802.11n	802.11ac	802.11ax
Channel Size (megahertz, MHz)	20, 40	20, 40, 80, 80 + 80, and 160	20, 40, 80, 80 + 80, and 160
Subcarrier (kilohertz, KHz)	312.5	312.5	78.125
Symbol Time (microsecond, μs)	3.2	3.2	12.8
Modulation	Binary Phase-Shift Keying (BPSK), Quadrature Phase-Shift Keying (QPSK), 16-QAM, 64-QAM	BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM	BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, 1024-QAM
MU-MIMO	N/A	DL	DL and UL
OFDMA	N/A	N/A	DL and UL

Wi-Fi Use Cases

The primary Wi-Fi use case for early 802.11ax standard development was for high-density network environments, such as large public venues. However, *high density* doesn't just mean hundreds or thousands of Wi-Fi-connected devices in a stadium or large venue. If you need to guarantee an acceptable level of service to all users on your enterprise Wi-Fi network, twenty or more devices is high density.

Today's enterprises are challenged to deal with corporate-owned wireless devices, employee devices, guest devices, wireless security cameras, environmental sensors, and more. These challenges will become even more complex as IoT has the potential to provide wireless access for almost everything.

Even within a private home, a family has numerous Wi-Fi devices including voice-activated smart speakers, laptops, tablets, smartphones, and so on. With all these connected devices, your home can quickly become a Wi-Fi hive of activity!

In addition to the immense growth of client devices, the ever-increasing volume of streaming video is another key use case for newer Wi-Fi technologies. The *Ericsson Mobility Report* predicts that worldwide mobile video traffic (currently 14 exabytes per month) will grow approximately 50 percent annually (to 110 exabytes per month) through 2023, accounting for 75 percent of all mobile data traffic. The report indicates that mobile users offload approximately 65 to 95 percent of their mobile traffic to Wi-Fi, when available. To remain a viable user alternative to cellular networks, Wi-Fi standards must maintain parity with the rapidly evolving 5G cellular standard.

Plus, where video traffic was primarily seen as only as wireless downlink traffic, social network streaming is now generating enormous uplink traffic loads.

TECHNICAL STUFF

In addition to dealing with video's large data objects, streaming video is time-bounded, meaning that latency must be kept low. Delays in transmission due to network congestion or retransmissions required by problems with prevailing radio conditions can result in the dreaded "buffering" message, or worse. To be fair, most high-definition (HD) video traffic only requires between 2 and 20 Mbps, because video can be highly compressed during transmission. 4K video represents, of course, a bigger challenge: Ultra HD Blu-Ray runs at about 82 to 128 Mbps but is still well within the copious bandwidth provisioned by even low-end 802.11ac. With gigabits of performance instantaneously available on each Wi-Fi channel and with HD video becoming more common (or even required in most organizational settings), the biggest challenge will be handling the growth of the WLAN. The number of users, devices, and applications will drive the need for as much throughput and efficiency as possible to address the aggregate demand.

REMEMBER

Finally, according to a report published by PRNewswire.com, 2.4 GHz devices are expected to represent the largest market segment in wireless mesh networks through 2022. Because 802.11ac does not support the 2.4 GHz band, a new Wi-Fi standard is needed to support the expected growth of 2.4 GHz devices, as well as to provide backward compatibility with 802.11n and older Wi-Fi devices.

IN THIS CHAPTER

» Enabling simultaneous communication with multiple Wi-Fi clients

» Using multi-user OFDMA for high efficiency

» Making MU-MIMO a reality in 802.11ax

» Addressing OBSS challenges

Chapter 2 Understanding Key 802.11ax Technologies

In this chapter, you learn about three key enabling technologies in 802.11ax: MU-OFDMA, MU-MIMO, and spatial reuse (basic service set [BSS] coloring).

Multi-User (MU) Defined

Multi-user (MU) applies to multiple technologies in 802.11ax, so it's important to understand that the term *multi-user* does not reference a specific technology. Multi-user (MU) means that transmissions between an access point (AP) and multiple Wi-Fi clients can occur simultaneously, depending on the supported technology.

802.11ax defines the use of multi-user orthogonal frequency division multiple access (MU-OFDMA) and multi-user multiple-input multiple-output (MU-MIMO) technologies.

MU-OFDMA

Orthogonal frequency division multiple access (OFDMA) is arguably the most important new capability in 802.11ax, allowing multiple users with varying bandwidth needs to be served simultaneously. OFDMA is a multi-user version of the orthogonal frequency division multiplexing (OFDM) digital modulation technology currently used for single-user transmissions in 802.11a/g/n/ac radios.

TIP

For backward compatibility, 802.11ax radios also support OFDM.

OFDMA subdivides a Wi-Fi channel into smaller frequency allocations, called resource units (RUs), thereby enabling an access point (AP) to synchronize communication (uplink and downlink) with multiple individual clients assigned to specific RUs. By subdividing the channel, small frames (such as streaming video) can be simultaneously transmitted to multiple users in parallel (see Figure 2-1). The simultaneous transmission cuts down on excessive overhead at the medium access control (MAC) sublayer, as well as medium contention overhead. The AP can allocate the whole channel to a single user or partition it to serve multiple users simultaneously, based on client traffic needs.

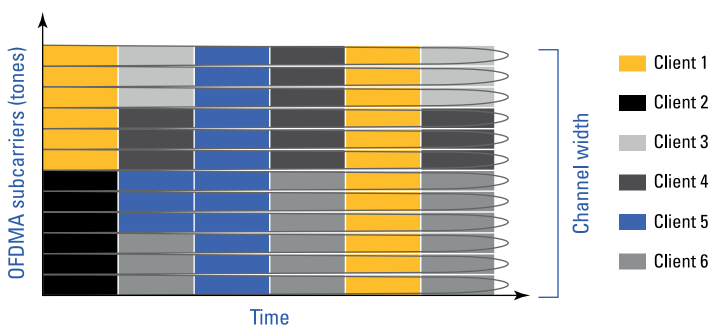


FIGURE 2-1: OFDMA — Orthogonal Frequency Division Multiple Access.

TIP

OFDMA is ideal for most network applications and results in better frequency reuse, reduced latency, and increased efficiency.

Subcarriers

OFDM divides a channel into subcarriers through a mathematical function known as an Inverse Fast Fourier Transform (IFFT). The spacing of the subcarriers is orthogonal, so they don't interfere with one another despite the lack of guard bands between them. This creates signal nulls in the adjacent subcarrier frequencies and prevents intercarrier interference (ICI).

An OFDM 20 MHz 802.11n/ac channel consists of 64 312.5 kHz subcarriers. 802.11ax introduces a longer OFDM symbol time of 12.8 microseconds, which is four times the legacy symbol time of 3.2 microseconds. As a result of the longer symbol time, the subcarrier size and spacing decreases from 312.5 kHz to 78.125 kHz (see Figure 2-2). The narrower subcarrier spacing allows better equalization and enhanced channel robustness. Because of the 78.125 kHz spacing, an OFDMA 20 MHz channel consists of a total of 256 subcarriers.

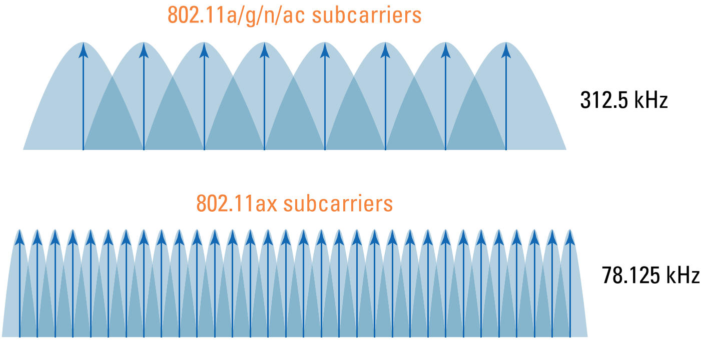


FIGURE 2-2: OFDM and OFDMA subcarriers.

TECHNICAL STUFF

There are three types of subcarriers for 802.11ax:

- **Data subcarriers:** These subcarriers will use the same modulation and coding schemes (MCSs) as 802.11ac as well as two new MCSs with the addition of 1024 quadrature amplitude modulation (1024-QAM).

- **Pilot subcarriers:** These subcarriers are used for synchronization between the transmitter and receiver and don't carry any modulated data.
- **Unused subcarriers:** The remaining unused subcarriers are mainly used as guard carriers or null subcarriers against interference from adjacent channels or subchannels.

Resource units (RUs)

When an 802.11n/ac AP transmits to 802.11n/ac clients on an OFDM channel, the entire frequency space of the channel is used for each independent downlink transmission. When using a 20 MHz OFDM channel, all subcarriers are used for each independent transmission. In other words, the entire 20 MHz channel is needed for the communication between the AP and a single OFDM client. The same holds true for any uplink transmission from a single 802.11n/ac client to the 802.11n/ac AP. The entire 20 MHz OFDM channel is needed for the client transmission to the AP.

As shown in Figure 2-3, an OFDMA channel consists of a total of 256 subcarriers. These subcarriers can be grouped into smaller subchannels know as resource units (RUs). When subdividing a 20 MHz channel, an 802.11ax AP can designate 26, 52, 106, and 242 subcarrier RUs, which roughly equates to 2 MHz, 4 MHz, 8 MHz, and 20 MHz channels, respectively.

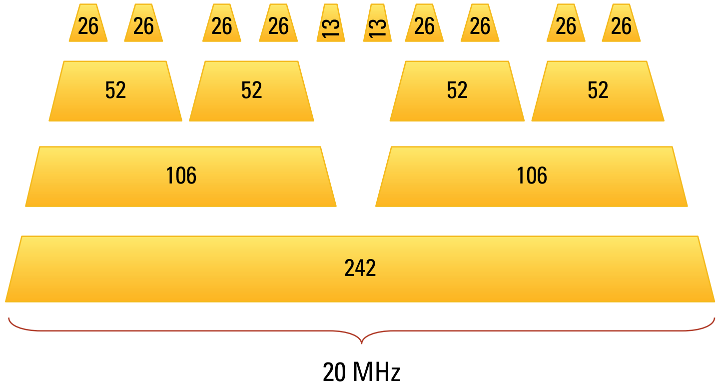


FIGURE 2-3: OFDMA Resource Units – 20 MHz channel.

The 802.11ax AP dictates how many RUs are used within a 20 MHz channel and different combinations can be used. The AP may allocate the whole channel to only one client at a time or it may partition the channel to serve multiple clients simultaneously. For example, an 802.11ax AP could simultaneously communicate (uplink or downlink) with one 802.11ax client using an 8 MHz subchannel and three other 802.11ax clients using 4 MHz subchannels.

In addition to 20 MHz channels, 40, 80, and even 160 MHz channels can also be partitioned into various combinations of RUs as shown in Table 2-1. For example, if an 80 MHz channel was subdivided using strictly 26 subcarrier RUs, 37 802.11ax clients could theoretically communicate simultaneously using their OFDMA capabilities.

TIP

Most real-world 802.11ax deployments will likely use 20 MHz channels with a maximum of nine clients participating in multiuser OFDMA transmissions per transmission opportunity (TXOP). Remember, the whole point of OFDMA is to make use of smaller subchannels.

TABLE 2-1 Resource Units and Wide Channels

Resource Units (RUs)	20 MHz channel	40 MHz channel	80 MHz channel	160 MHz channel	80 + 80 MHz channel
996 (2x) subcarriers	n/a	n/a	n/a	1 client	1 client
996 subcarriers	n/a	n/a	1 client	2 clients	2 clients
484 subcarriers	n/a	1 client	2 clients	4 clients	4 clients
242 subcarriers	1 client	2 clients	4 clients	8 clients	8 clients
106 subcarriers	2 clients	4 clients	8 clients	16 clients	16 clients
52 subcarriers	4 clients	8 clients	16 clients	32 clients	32 clients
26 subcarriers	9 clients	18 clients	37 clients	74 clients	74 clients

TECHNICAL STUFF

Remember that 802.11ax APs can transmit downlink to multiple 802.11ax clients as well as synchronize simultaneous uplink transmissions from multiple 802.11ax clients. Synchronized uplink transmission is a capability never seen before with Wi-Fi communications. In both cases, *trigger frames* are needed to bring about the necessary frame exchanges for multi-user communications. For example, a trigger frame is used to allocate RUs to 802.11ax clients. Trigger frames are also used to query 802.11ax clients about buffered data and about the quality of service (QoS) category of data intended for uplink OFDMA transmissions. 802.11ax clients respond with *buffer status reports* which assists the AP in allocating RUSs for synchronized uplink transmissions.

Also, understand that the rules of medium contention still apply. The AP still has to compete for a *transmission opportunity (TXOP)* against legacy 802.11 stations. Once the AP has a TXOP, the AP is then in control of up to nine 802.11ax client stations for either downlink or uplink transmissions within a 20 MHz channel The number of RUs used can vary on a per TXOP basis.

MU-MIMO

Introduced in 802.11ac, multi-user, multiple-input multiple-output (MU-MIMO) technology theoretically allows multiple frames to be transmitted to different receivers at the same time and on the same channel, using multiple spatial streams to provide greater efficiency (see Figure 2-4). MU-MIMO provides spatial diversity by transmitting unique modulated data streams to multiple clients simultaneously. 802.11ac only defined downlink (DL) MU-MIMO and it is not widely implemented for the following reasons:

- Very few MU-MIMO-capable 802.11ac clients exist in the current marketplace, and the technology is rarely used in the enterprise. Many client devices are single antenna, and many dual antenna clients switch to single stream mode for DL MU-MIMO to protect against interference.
- MU-MIMO requires sizable physical distance between the clients, as well as the AP, for spatial diversity, which may limit its usefulness. Most enterprise Wi-Fi deployments involve a high density of users, which is not conducive to MU-MIMO.
- MU-MIMO requires transmit beamforming (TXBF), which requires sounding frames. The sounding frames add excessive overhead, especially when the bulk of data frames are small, and may negatively impact performance gains.

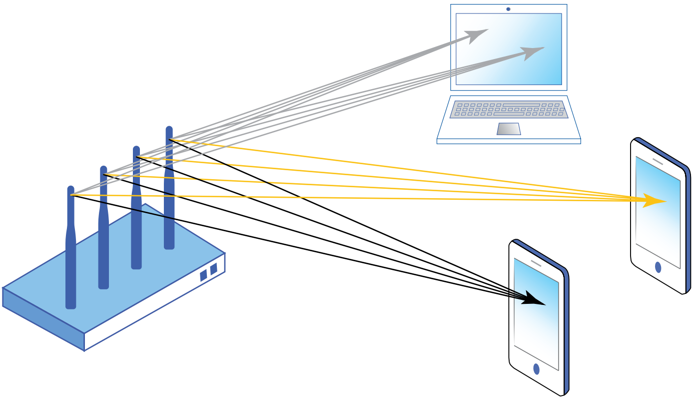


FIGURE 2-4: MU-MIMO — multi-user multiple input multiple output.

To address these issues, there are some significant MU-MIMO enhancements proposed in the 802.11ax draft amendment including grouping sounding frames, data frames, and other frames among multiple users to reduce overhead and increase uplink response time. Trigger frames would also be used to signal 802.11ax clients to participate in uplink MU-MIMO communications.

A key difference between 802.11ac MU-MIMO and 802.11ax MU-MIMO is how many MU-MIMO clients communicate with an AP at the same time. 802.11ac is limited to a MU-MIMO group of only four clients. 802.11ax is designed to support up to 8x8x8 MU-MIMO in both downlink and uplink, which allows it to serve up to eight users simultaneously and provide significantly higher data throughput. Be aware that support for uplink MU-MIMO will not be available in the first generation of 802.11ax client radios.

TECHNICAL STUFF

The minimum RU size for MU-MIMO (downlink or uplink) is 106 subcarriers or greater.

802.11ax allows for simultaneous use of both MU-OFDMA and MU-MIMO, but this is not expected to be widely implemented. Table 2-2 compares MU-OFDMA and MU-MIMO.

TIP

MU-MIMO would theoretically be a favorable option in very low client density, high-bandwidth application environments where large packets are transmitted.

TABLE 2-2 MU-OFDMA and MU-MIMO Comparison

MU-OFDMA	MU-MIMO
Increased efficiency	Increased capacity
Reduced latency	Higher data rates per user
Best for low-bandwidth applications	Best for high-bandwidth applications
Best with small packets	Best with large packets

REMEMBER

Don't confuse OFDMA with MU-MIMO. OFDMA enables multi-user access by subdividing a channel. MU-MIMO enables multi-user access by using different spatial streams.

Spatial Reuse (BSS Coloring)

Wi-Fi uses radio frequency (RF) communication which is a half-duplex medium — only one radio can transmit on a frequency domain or channel at any given time. Everyone must take turns because if everyone "talks" at the same time, no data is communicated because no one is "listening."

Carrier sense with multiple access collision avoidance (CSMA/CA) is the method used in Wi-Fi networks to ensure that only one radio can transmit on the same channel at any given time. An 802.11 radio will defer transmissions if it hears the physical (PHY) preamble transmissions of any other 802.11 radio at a signal detect (SD) threshold of four decibels (dB) or greater. CSMA/CA consumes a lot of the available bandwidth. This problem is referred to as contention overhead. Unnecessary medium contention overhead that occurs when too many APs and clients hear each other on the same channel is called an *overlapping basic service set (OBSS)*, also commonly referred to as *co-channel interference (CCI)*, shown in Figure 2-5.

For example, if AP-1 on channel 6 hears the preamble transmission of a nearby AP (AP-2), also transmitting on channel 6, AP-1 will defer and can't transmit at the same time. Likewise, all the clients associated to AP-1 must also defer transmission if they hear the preamble transmission of AP-2. All these deferrals create medium contention overhead and consume valuable airtime because you have two basic service sets on the same channel that can hear each other, in the manner of OBSS.

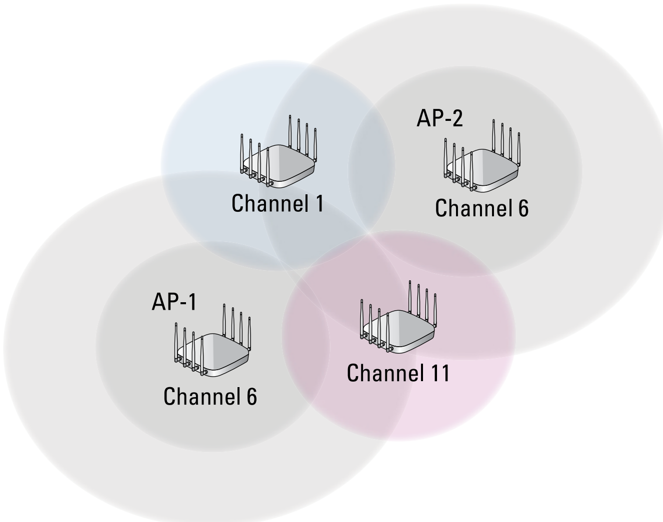


FIGURE 2-5: OBSS — Overlapping basic service set.

In reality, Wi-Fi clients are the primary cause of OBSS interference. As shown in Figure 2-6, if a client associated to AP-2 is transmitting on channel 36, it is possible that AP-1 (and any clients associated to AP-1) will hear the PHY preamble of the client and must defer any transmissions.

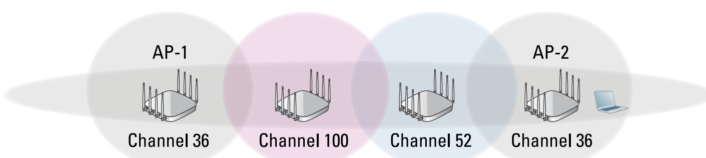
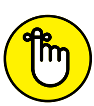


FIGURE 2-6: OBSS interference caused by client.



REMEMBER

Due to the mobile nature of Wi-Fi client devices, OBSS interference isn't static: It changes as client devices move.

All this congestion and medium contention overhead means that efficiency at the MAC sublayer drops. This is further exacerbated by the fact that the bulk of data frames in a network are small (less than 256 bytes) and OBSS in dense deployments often unnecessarily blocks transmissions. Thus, the average transmission control protocol (TCP) throughput under ideal conditions in legacy a/b/g networks is roughly 40 to 50 percent of advertised data rates, and 60 to 70 percent of advertised data rates in 802.11n/ac networks. To increase capacity in dense environments, frequency reuse between basic service sets needs to be increased.

802.11ax was also tasked with addressing the OBSS challenge by improving spatial reuse, which is often referred to as BSS coloring. *BSS coloring* is a mechanism, originally introduced in 802.11ah, to address medium contention overhead due to OBSS by assigning a different "color" — a number between 0 and 7 that is added to the PHY header of the 802.11ax frame — to each BSS in an environment (see Figure 2-7).

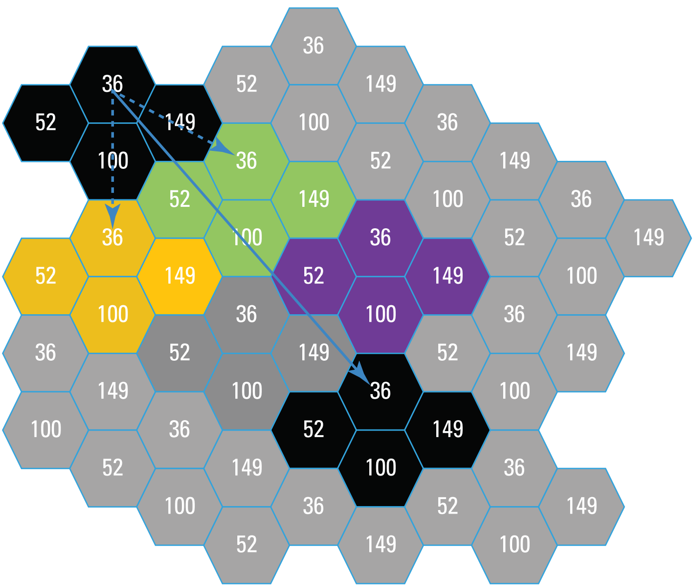


FIGURE 2-7: BSS coloring.

REMEMBER

BSS coloring detects a color bit in the PHY header of an 802.11ax frame transmission. This means that legacy 802.11a/b/g/n clients will not be able to interpret the color bits because they use a different PHY header format.

When an 802.11ax radio is listening to the medium and hears the PHY header of an 802.11ax frame sent by another 802.11ax radio, the listening radio will check the BSS color bit of the transmitting radio. Channel access is dependent on the color detected:

- If the color bit is the same, then the frame is considered an *intra-BSS* transmission and the listening radio will defer.
- If the color bit is different, then the frame is considered an *inter-BSS* transmission from an OBSS and the listening radio treats the medium as busy only for the time it took to determine the color bit was different.

802.11ax radios can adjust the carrier sense operation based on the color of the BSS to improve spatial reuse efficiency and performance. Depending on the BSS from which the traffic is generated, the station can use different sensitivity thresholds to transmit or defer. This results in higher overall performance. Using adaptive clear channel assessment (CCA), an 802.11ax radio can raise the SD threshold for inter-BSS frames while maintaining a lower threshold for intra-BSS frames. BSS coloring can thus potentially decrease the channel contention problem that is symptomatic of existing low SD thresholds.

IN THIS CHAPTER

» Conserving power with TWT

» Achieving higher data speeds with 1024-QAM

» Defining new frame formats

» Exploring 802.11ax design considerations

Chapter 3

Looking at Other 802.11ax Enhancements and Design Considerations

In this chapter, you learn about several other 802.11ax enhancements including target wake time (TWT), 1024 quadrature amplitude modulation (1024-QAM), and new frame formats, as well as design considerations when deploying 802.11ax technology.

Target Wake Time (TWT)

Target wake time (TWT) is a power-saving mechanism originally defined in the 802.11ah-2016 amendment. A TWT is a negotiated agreement, based on expected traffic activity between the access point (AP) and Wi-Fi clients, to specify a scheduled target wake-up time for clients in power-save (PS) mode. In addition to the power-saving benefits, the negotiated TWTs allow an AP to manage client activity by scheduling client stations to operate at different times and therefore minimize contention between the clients.

A TWT reduces the required amount of time that a client in PS mode needs to be awake. This allows the client to sleep longer and reduces energy consumption. As opposed to legacy client power-saving mechanisms, which require sleeping client devices to wake-up in microsecond intervals, TWT could theoretically allow client devices to sleep for hours. TWT is thus an ideal power-saving method for mobile devices and Internet of Things (IoT) devices that need to conserve battery life.

TIP

It remains to be seen if IoT device manufacturers will take advantage of 802.11ax radios in their IoT devices as opposed to other communication technologies such as Bluetooth Mesh, Thread, and Zigbee.

TWT setup frames are used between the AP and the client to negotiate a scheduled TWT. For each 802.11ax client there can be as many as 8 separate negotiated scheduled wake-up agreements for different types of application traffic. 802.11ax has also extended TWT functionality to include a non-negotiated TWT capability. An AP can create wake-up schedules and deliver TWT values to the 802.11ax clients via a broadcast TWT procedure.

1024-QAM

Although the primary goal of 802.11ax is better efficiency, more speed isn't a bad thing. And better efficiency and more speed aren't mutually exclusive goals. *Quadrature amplitude modulation (QAM)* uses both the phase and amplitude of an RF signal to represent data bits. 802.11ax will support 1024-QAM and new modulation and coding schemes (MCSs) that define higher data rates.

For comparison, 256-QAM (introduced in 802.11ac) modulates 8 bits per symbol, whereas 1024-QAM modulates 10 bits per symbol — a potential 20 percent increase in data throughput. This throughput is achieved using more efficient packaging of data for the same spectrum — analogous to using a double-decker bus to make the best use of a bus lane.

802.11ax also introduces two new MCSs: MCS-10 and MCS-11, which will most likely be optional. 1024-QAM can only be used with 242-subcarrier resource units (RUs) or larger. This means that at least a full 20 MHz channel will be needed for 1024-QAM.

Much like 256-QAM, very high signal-to-noise ratio (SNR) thresholds (35 dB or more) will be needed in order for 802.11ax radios to use 1024-QAM modulation. Pristine RF environments with a low noise floor and close proximity between an 802.11ax AP and 802.11ax client will most likely be needed.

The number of points in the modulation constellation determines the number of bits conveyed with each symbol. Figure 3-1 shows a comparison of constellation charts between 256-QAM and 1024-QAM modulation. As you can see, 1024-QAM has many more constellation points. *Error vector magnitude (EVM)* is a measure used to quantify the performance of a radio receiver or transmitter in regard to modulation accuracy. With QAM modulation, EVM is a measure of how far a received signal is from a constellation point. 802.11ax radios that use 1024-QAM modulation will need strong EVM and receive sensitivity capabilities.

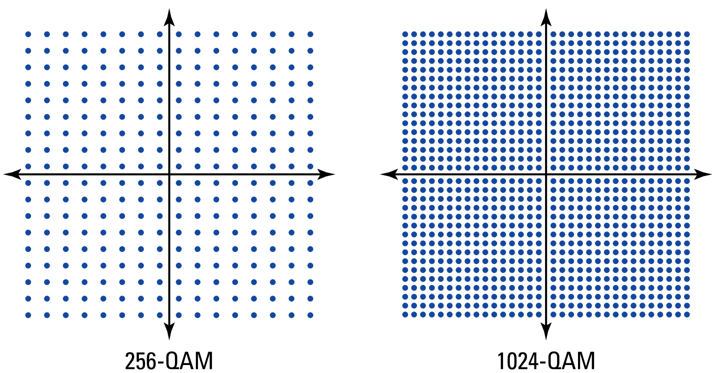


FIGURE 3-1: 256- and 1024-QAM.

New PHY Headers

Added to all 802.11 frames is a physical (PHY) header that contains a preamble and other information used for initial setup of communications between two radios. The 802.11ax amendment also defines four new PHY headers to support high efficiency (HE) radio transmission, as follows:

- **HE SU:** The high efficiency single-user PHY header is used for single-user transmissions.
- **HE MU:** The high efficiency multi-user PHY header is used for transmissions to one or more users. This format information

is used for both multi-user multiple-input multiple-output (MU-MIMO) and multi-user orthogonal frequency domain multiple access (MU-OFDMA), as well as resource unit (RU) allocation (see Chapter 2).

- **HE ER SU:** The high efficiency extended-range single-user format is intended for a single user. Portions of this PHY header are boosted by 3 dB to enhance outdoor communications and range.
- **HE TB:** The high efficiency trigger-based format is for a transmission that is a response to a trigger frame. In other words, this PPDU format is used for uplink communications.

TECHNICAL STUFF

The preamble is used for synchronization between transmitting and receiving radios and consists of two parts: legacy and high efficiency (HE). The legacy preamble is easily decodable by legacy stations (STAs) and is included for backward compatibility. The HE preamble components are used to communicate information between 802.11ax radios about OFDMA, MU-MIMO, BSS coloring, and more.

WHY WE CAN'T YET ABANDON 2.4 GHz

With lots of spectrum at 5 GHz, you may be wondering why 2.4 GHz has not been abandoned? Yes, it's crowded, it's old, and 802.11ac did not support it. Even 802.11n, which does support 2.4 GHz, is limited by the availability of only three 20 MHz channels (1, 6, and 11.)

But at the end of the day, it's still spectrum that can be used for Wi-Fi, and we need to make the most of it.

Consider the following 2.4 GHz realities:

- **Range:** Due to the wavelength properties of an RF signal, the effective range of a lower frequency is a greater distance than a higher frequency.

  More importantly, consider rate versus range — how much data you can send over a given distance per unit of time. This is a factor of more than just range or frequency alone. You also need to consider transmit power, channel bandwidth, MCS, protocol overhead, traffic type (class and quality of service), and more.

- **Installed base:** There are hundreds of millions of 2.4 GHz Wi-Fi devices still in use today. Many of these are mission-critical, such as in medical and security applications, and many of these are expensive and cannot be easily replaced, let alone upgraded to the latest Wi-Fi standards. You simply need to wait until all these devices die a natural death before 5 GHz, or at least a more contemporary Wi-Fi technology, is an option.

  Even today, many new IoT devices and even some new laptops and smartphones only support 2.4 GHz. Device vendors choose this option because costs are reduced over dual-band capabilities, and no one should be surprised at how many price-sensitive users there are — and always will be — in the world.
- **Looking ahead:** Even as people eventually realized that 5 GHz was a much larger chunk of spectrum than 2.4 GHz, it was still underutilized until 802.11n became well-established — and that was only about five years ago. Adoption has been swift, to the point that many now have concerns about crowding in the 5 GHz bands. But 2.4 GHz is still here to relieve the pressure — and good Wi-Fi infrastructure systems, properly implemented and configured, can automatically move traffic to an optimal frequency band and channel.

802.11ax, unlike 802.11ac, will be able to operate at both 2.4 and 5 GHz. Thus, 2.4 GHz remains a vital element in any good long-term Wi-Fi strategy. The bottom line is that the world can't abandon 2.4 GHz any time soon, even if a big chunk of new unlicensed spectrum became available — which is very unlikely. 2.4 GHz will continue to provide a highway for tens of millions of devices for the foreseeable future.

Design Considerations

Some important design considerations for 802.11ax include:

- **Power over Ethernet (PoE):** Will 802.11ax APs work with standard 802.3af PoE? Wi-Fi manufacturers will be adding more radio chains to their 802.11ax access points. Most 802.11ax APs will be dual-band 4x4:4 APs and there will even be 8x8:8 APs. 802.11ax APs will also require much more processing power than previous generations of enterprise APs. The extra radio chains and processor capabilities will require more power. The 15.4 watts (W) provided by standard 802.11af PoE will not be adequate. 802.3at PoE Plus power will be required. PoE Plus requirements for 802.11ax APs should be considered a standard requirement. This may require upgrades of access layer switches as well as recalculation of PoE power budgets.

- **MultiGig:** Will 2.5 Gig Ethernet ports for 802.11ax access points be needed? The whole point of 802.11ax is to cut down on medium contention and airtime consumption. Logic dictates that if Wi-Fi becomes more efficient, the user traffic generated by a dual-frequency 802.11ax AP could potentially exceed 1 Gigabit. The fear is that a standard Gigabit Ethernet wired uplink port could be a bottleneck and therefore 2.5 Gigabit uplink ports will be needed. However, in the real-world, we probably will still not exceed 1 Gigabit until there is a wide proliferation of 802.11ax clients. Regardless, most WLAN vendor 802.11ax APs will include at least one 802.3bz MultiGig Ethernet port capable of a 2.5 Gigabit wired uplink.
- **Client devices:** Will there be any 8x8:8 802.11ax clients? Most 802.11ax mobile client devices will use dual-frequency 2x2:2 radios because an 8x8:8 radio would drain battery life. There are currently no 4x4:4 802.11ax clients; however, in the future, you might see some 4x4:4 client radios in high-end laptops.

  802.11ax clients take full advantage of 802.11ax high efficiency capabilities such as multi-user OFDMA. Although there will be no physical (PHY) layer improvements with legacy clients, there will be performance improvements as a result of newer hardware capabilities of the new 802.11ax APs, such as stronger CPUs and better memory handling. Additionally, as you see more 802.11ax clients mixed into the client population, the efficiency improvements gained by 802.11ax client devices will free valuable airtime for those older clients, therefore improving the overall efficiency of the wireless network.

IN THIS CHAPTER

» Deploying 802.11ax in high performance environments

» Looking at 802.11ax for indoor and industrial environments

Chapter 4 Exploring the Aerohive 802.11ax Family

In this chapter, you learn about Aerohive's 802.11ax family of access points which are designed for high performance environments and combine the latest in Wi-Fi and Ethernet standards with Aerohive's software-defined Wi-Fi architecture.

AP630

The AP630 is designed for high performance environments, combining the latest in Wi-Fi standards (IEEE 802.11ax technology) with Aerohive's HiveOS software and HiveManager network management system.

The AP630 (see Figure 4-1) also enables Internet of Things (IoT) readiness with built-in Bluetooth Low Energy (BLE) and Universal Serial Bus (USB) ports.

The AP630 is designed for:

- **High performance indoor environments** with high definition (HD) video streaming, large file transfers, and HD video collaboration applications

FIGURE 4-1: The AP630.

- **High client density environments** where most or all clients are 802.11ac or newer
- Environments expecting to use **Voice over Wi-Fi** (VoWiFi) in addition to data
- Environments expected to use **IoT applications** like BLE at deployment or in the future

AP650 and AP650X

The AP650 and AP650X (see Figure 4-2) are designed for high performance environments, combining the latest in Wi-Fi standards (IEEE 802.11ax technology), the latest in Ethernet standards (2.5 Gigabit capability), and Aerohive's software-defined dual 5 gigahertz (GHz) radios for indoor and industrial environments. AP650 and 650X have integrated BLE and USB connectivity for enhanced location-driven services and the capability to provide additional wireless access options for IoT and other devices.

TECHNICAL STUFF

Dual 5 GHz 4x4:4 software-defined radios (SDRs) in the AP650 and AP650X provide superior flexibility, performance, and return on investment (ROI) compared to legacy access points with only a single 5 GHz radio.

FIGURE 4-2: The AP650 and AP650X.

The AP650 is designed for:

- **High performance indoor environments**: HD video streaming, large file transfers, and HD video collaboration applications
- **Very high client density environments:** where density and performance are key requirements
- Environments expecting to use **VoWiFi** in addition to data
- Environments expected to use **IoT applications** like BLE at deployment or in the future

The AP650X is designed for:

- **Industrial deployments like warehouses** running high bandwidth applications and/or high client densities with extreme temperature ranges
- **Lecture halls or auditorium-like environments** requiring specialized Wi-Fi setup using a mix of omni/sector antennas

See Table 4-1 for a comparison of Aerohive's 802.11ax family of access points.

TABLE 4-1 Aerohive 802.11ax AP Family Comparison

	AP630	AP650	AP650X
Environment	indoor – plenum		
Radio Technology	Dual frequency 802.11ax radios	Dual frequency 802.11ax radios; Dual 5 GHz capability w/software selectable radio	
Performance	4x:4 MU-MIMO & OFDMA UL/DL		
Security	Trusted Platform Module (TPM) security chip		
Power	802.3at Power over Ethernet (PoE+)	802.3at Power over Ethernet (PoE+), direct current (DC)	
Interfaces	2 x Gigabit Ethernet (2 x PoE) with link aggregation	2.5G + 1G (2 x PoE) with link aggregation	
IoT	USB + BLE		
Operating Temp	0°C to 40°C (32°F to 104°F)		-20°C to 55°C (-4°F to 131°F)
Deployment	HiveManager cloud and on-premises		

Aerohive's family of 802.11ax access points also features a new twist mount bracket designed to radically simplify installation. Traditional mounting brackets are often poorly designed and cumbersome; the new design from Aerohive makes it easy for anyone to place and lock an access point in position in a matter of seconds. See Figure 4-3.

FIGURE 4-3: Aerohive's mounting bracket.

IN THIS CHAPTER

» Getting ready for the next Wi-Fi standard

» Supporting legacy Wi-Fi devices

» Looking at high-density use cases

» Achieving high efficiency and high performance

» Improving Wi-Fi security

Chapter 5

Ten Things You Need to Know about 802.11ax

In this chapter, we point out ten key things to keep in mind about the new 802.11ax Wi-Fi standard.

- **It's a Wi-Fi paradigm shift.** The new 802.11ax standard doesn't just push the envelope with regard to Wi-Fi speeds — up to 10 Gbps. It introduces numerous performance improvements as well. In fact, it's been dubbed "High Efficiency" unlike previous 802.11 amendments that were labeled "High Throughput." 802.11ax is not just about better throughput. The 802.11ax standard will substantially improve capacity, provide better coverage, and reduce congestion in Wi-Fi networks.
- **The standard isn't yet finalized.** Completion of the 802.11ax standard is on the horizon and full certification will start in 2019. However just like 802.11n and 802.11ac, the core requirements of the chipsets are defined long before final certification and commercial 802.11ax products are now being manufactured. Only the overall process, operations, and — dare we say — politics are still being debated and delaying the official certification.

REMEMBER

This is the same process that occurred with 802.11n and 802.11ac. Final approval of the standard usually lags new prestandard product releases. Once the standard is finalized, firmware or software updates are typically provided by the product vendors to achieve full compliance in their early release products.

» **You won't need to rip-and-replace your existing Wi-Fi installations.** Market dominance for 802.11ax products isn't anticipated until late 2020 in terms of total sales. Therefore, don't expect to perform a wholesale rip-and-replace of your existing 802.11ac installations in the near term. However, if you expect your next upgrade to last 5+ years, it only makes sense to upgrade with 802.11ax technology. Additionally, if your organization still has legacy 802.11a/b/g/n APs deployed, go ahead and consider an enterprise-wide upgrade.

  Some organizations will, of course, need the performance boost embodied in 802.11ax right away because the demands on their networks are growing at a rapid pace. Most end-user organizations, however, will follow a pattern well-established with 802.11n and 802.11ac — augmentation of existing infrastructure to add new (greenfield) capacity and planned replacements of older technologies.

» **Look forward to a little backward compatibility.** Unlike the 802.11ac standard, 802.11ax supports both 2.4 and 5 GHz wireless devices, so 802.11n (and potentially 802.11g and 802.11b) devices will be able to run on 802.11ax Wi-Fi networks. This is critical for many legacy specialized devices, particularly in healthcare and industrial automation, as vendors in these verticals tend to move slowly to update their devices to the latest Wi-Fi standards.

» **Your smarthome is a high-density Wi-Fi environment.** The primary use case defined for 802.11ax is high density network environments. But high-density doesn't just mean stadiums, hospitals, and warehouses. Today's smarthomes quickly become "high density" with 20 or more wireless devices — anything from smartphones, tablets, laptops, game consoles, and television receivers to security cameras, baby monitors, and smart thermostats and appliances — connecting to a home Wi-Fi network.

» **RU ready for simultaneous multi-user Wi-Fi access?** Multi-user orthogonal frequency division multiple access (OFDMA) is easily the most important new capability in

802.11ax. It subdivides a channel into smaller frequency allocations, called *resource units (RUs)*, thereby enabling an access point (AP) to synchronize communication (uplink and downlink) with multiple individual clients assigned to the RUs.

- **MU-MIMO enhancements are coming.** Several enhancements to MU-MIMO proposed in 802.11ax include grouping sounding frames, data frames, and other frames among multiple users to reduce overhead and increase uplink response time. Another key difference is how many MU-MIMO clients communicate with an AP at the same time: 802.11ac is limited to a MU-MIMO group of only four clients, whereas 802.11ax supports up to 8x8x8 MU-MIMO in both downlink and uplink, which allows it to serve up to eight users simultaneously.
- **No more OBSSessing over spatial reuse.** Basic service set (BSS) coloring addresses medium contention overhead due to overlapping basic service sets (OBSS) by assigning a different "color" to each BSS in an environment to decrease channel contention with adaptive signal detect (SD) thresholds.
- **No qualms about higher data speeds either.** Quadrature amplitude modulation (QAM) effectively doubles bandwidth by combining two amplitude-modulated signals into a single channel. 802.11ax will support 1024-QAM and new modulation and coding schemes (MCS) that define higher data rates providing a potential 20 percent increase in data throughput over 256-QAM (introduced in 802.11ac).
- **Wi-Fi security will be better.** Although the 802.11ax standard itself doesn't specify any new security enhancements or requirements, it does require WPA3 security as a prerequisite. As a result, 802.11ax devices will include the latest security design features and capabilities to address modern threats that did not exist just a few years ago when 802.11ac was released — not to mention 802.11n and 802.11g (released in 2009 and 2003, respectively). The Wi-Fi Protected Access Version 3 (WPA3) security protocol, introduces security enhancements, most importantly, Simultaneous Authentication of Equals (SAE) as a replacement for WPA2-Personal's Pre-Shared Key (PSK). WPA3 also requires Protected Management Frames (PMF) for more robust protection against brute force attacks. Additionally, WPA3 provides for an optional 192-bit encryption suite.

Glossary

802.11ac: The most current IEEE Wi-Fi standard that has been widely adopted. Released in 2013, 802.11ac operates in the 5 GHz frequency band and supports up to eight spatial streams, 256-QAM, and downlink MU-MIMO. *See also* Institute of Electrical and Electronics Engineers (IEEE), gigahertz (GHz), quadrature amplitude modulation (QAM), *and* multi-user multiple-input multiple-output (MU-MIMO).

802.11ah: ("Wi-Fi HaLow"): An IEEE Wi-Fi standard that uses 900 MHz license-exempt bands to provide extended range networks and low energy consumption. *See also* Institute of Electrical and Electronics Engineers (IEEE) *and* megahertz (MHz).

802.11ax: The IEEE draft standard that will be the successor to 802.11ac and is focused primarily on high efficiency (HE). *See also* Institute of Electrical and Electronics Engineers (IEEE) and 802.11ac.

802.3bz: The IEEE standard that defines 2.5 and 5 gigabit per second (Gbit/s) wire speeds in Ethernet wired networks. *See also* Institute of Electrical and Electronics Engineers (IEEE) *and* Ethernet.

access point (AP): An RF device that allows wireless devices to connect to a network. An access point usually functions as a wireless portal to pre-existing network resources. See also radio frequency (RF).

AP: *See* access point (AP).

basic service set (BSS): A set of APs and clients that can communicate with each other at the PHY layer in a WLAN architecture. *See also* access point (AP), physical (PHY) layer, *and* wireless local area network (WLAN).

BLE: *See* Bluetooth Low Energy.

Bluetooth: A wireless technology standard for data exchange over short distances between fixed and mobile devices using short-wavelength UHF radio waves in the 2.4 to 2.485 GHz ISM band. *See also* ultra-high frequency (UHF), gigahertz (GHz), *and* industrial, scientific, and medical (ISM) band.

Bluetooth Low Energy (BLE): A WPAN technology designed by the Bluetooth SIG. BLE operates in the classic Bluetooth ISM band (2.4 – 2.4835 GHz) using different channels (40 2-MHz channels compared to 79 1-MHz channels in classic Bluetooth) and provides significantly lower power consumption and cost than classic Bluetooth for applications such as healthcare, fitness, security, and home entertainment. *See also* wireless personal area network (WPAN), Bluetooth Special Interest Group (Bluetooth SIG), Bluetooth, industrial, scientific, and medical (ISM) band, Gigahertz (GHz), *and* Megahertz (MHz).

BSS: *See* base service set (BSS).

carrier sense with multiple access collision avoidance (CSMA/CA): A Wi-Fi network protocol which checks to ensure no other wireless node is transmitting before attempting to send a packet across the network. If another transmitting node is detected, the node waits for a random period (backoff factor) then checks again to ensure no other wireless node is transmitting before attempting to send the packet across the network.

CCA: *See* clear channel assessment (CCA).

CCI: *See* co-channel interference (CCI).

clear channel assessment (CCA): A carrier sense mechanism used in Wi-Fi networks to determine whether a medium is idle or not.

Clear to Send (CTS): An optional flow control mechanism used in 802.11 networks to reduce frame collisions. *See also* Request to Send (RTS).

CLI: *See* command-line interface (CLI).

co-channel interference (CCI): *See* overlapping basic service set (OBSS).

command-line interface (CLI): A text-based console used to interact with a hardware or software device.

CSMA/CA: *See* carrier sense with multiple access collision avoidance (CSMA/CA).

dB: *See* decibel (dB).

decibel (dB): A unit used to measure the intensity of sound or the power level of an electrical signal by comparing it with a given logarithmic scale.

DL: *See* downlink (DL).

downlink (DL): The transmission from an AP to a Wi-Fi client device. *See also* access point (AP) and uplink (UL).

error vector magnitude (EVM): A measure used to quantify the performance of a radio transmitter or receiver.

Ethernet: A family of technologies commonly used in wired computer networking. Defined in the IEEE 802.3 standard.

gigahertz (GHz): A measure of bandwidth in a digital signal. One gigahertz is equal to one billion hertz.

GHz: *See* gigahertz (GHz).

IEEE: *See* Institute of Electrical and Electronics Engineers (IEEE).

industrial, scientific, and medical (ISM) band: The parts of the RF radio spectrum that are reserved for industrial, scientific, and medical requirements. *See also* radio frequency (RF).

Institute of Electrical and Electronics Engineers (IEEE): A technical professional organization that promotes the advancement of technology.

Internet of Things (IoT): A system of smart, connected devices.

Internet Protocol (IP): The method by which data is sent between devices on a network such as the Internet.

Inverse Fast Fourier Transform (IFFT): An algorithm that samples a signal over a period of time (or space) and divides it into frequency components.

IoT: *See* Internet of Things (IoT).

IP: *See* Internet Protocol (IP).

ISM: *See* industrial, scientific, and medical (ISM) band.

ITU: *See* International Telecommunications Union (ITU).

kHz: *See* kilohertz (kHz).

kilohertz (kHz): A measure of bandwidth in a digital signal. One kilohertz is equal to one thousand hertz.

LAN: local area network.

MAC sublayer: *See* medium access control (MAC) sublayer.

MCS: *See* modulation and coding scheme (MCS).

medium access control (MAC) sublayer: A sublayer defined at the data link layer that provides flow control and multiplexing for the transmission medium.

megahertz (MHz): A measure of bandwidth in a digital signal. One megahertz is equal to one million hertz.

MHz: *See* megahertz (MHz).

microsecond (μS): One millionth of a second.

modulation and coding scheme (MCS): Describes the combination of the radio carrier modulation scheme and the coding scheme to determine the data rate of a wireless network connection.

MU: *See* multi-user (MU).

multi-user (MU): Transmissions between an AP and multiple Wi-Fi clients can occur simultaneously, depending on the supporting technology. *See also* access point (AP).

MU-MIMO: *See* multi-user multiple-input multiple-output (MU-MIMO).

multi-user multiple-input multiple-output (MU-MIMO): Technology that theoretically allows multiple frames to be transmitted to different receivers at the same time and on the same channel, using multiple spatial streams to provide greater efficiency. See also radio frequency (RF).

OBSS: *See* overlapping base service set (OBSS).

OFDM: *See* orthogonal frequency-division multiplexing (OFDM).

OFDMA: *See* orthogonal frequency-division multiple access (OFDMA).

orthogonal frequency-division multiple access (OFDMA): A method that allows multiple users with varying bandwidth needs to be served simultaneously by subdividing a channel into smaller frequency allocations, called RUs. See also resource units (RUs).

orthogonal frequency-division multiplexing (OFDM): A method that divides a channel into subcarriers through a mathematical function known as IFFT. *See also* Inverse Fast Fourier Transform (IFFT).

overlapping basic service set (OBSS): Degenerative medium contention overhead that occurs when too many APs and clients hear each other on the same channel.

phase-shift keying (PSK): A digital modulation process used in Wi-Fi networks to convey data by changing (modulating) the phase of a reference signal (the carrier wave).

PHY: *See* physical (PHY) layer.

physical (PHY) layer: Refers to the circuitry required to implement physical layer functions and connect a MAC sublayer device to a physical medium. *See also* medium access control (MAC) sublayer.

PoE+: *See* Power over Ethernet plus (PoE+).

Power over Ethernet plus (PoE+): An IEEE standard that provides up to 25 watts of power for "Type 2" devices.

power-save (PS) mode: An optional mode for 802.11 client stations. A wireless client can shut down some of the transceiver components for a period of time to conserve power.

PS mode: *See* power-save (PS) mode.

PSK: *See* phase-shift keying (PSK).

QAM: *See* Quadrature Amplitude Modulation (QAM).

Quadrature Amplitude Modulation (QAM): A modulation scheme that conveys data by changing some aspect of a carrier signal or the carrier wave in response to a data signal.

radio frequency (RF): An electromagnetic wave frequency used in radio communication.

Request to Send (RTS): An optional flow control mechanism used in 802.11 networks to reduce frame collisions. *See also* Clear to Send (CTS).

resource units (RUs): A frequency allocation that has been partitioned from an OFDMA channel.

RF: *See* radio frequency (RF).

RTS: *See* Request to Send (RTS).

RUs: *See* resource units (RUs).

SDR: *See* software-defined radio (SDR).

SD threshold: *See* signal detect (SD) threshold.

SFO: *See* sampling frequency offset (SFO).

signal detect (SD) threshold: A listening threshold used by 802.11 radios to identify any 802.11 preamble transmissions from another transmitting 802.11 radio.

signal-to-noise ratio (SNR): The ratio of the strength of an electrical or other signal carrying information to that of the ambient noise floor, generally expressed in dB. *See also* decibels (dB).

SNR: *See* signal-to-noise ratio (SNR).

software-defined radio (SDR): A radio communication system where traditional hardware components are instead implemented in software.

STA: *See* station (STA).

station (STA): An 802.11 radio. The radio can reside in an AP or be used as a client station.

Target Wake Time (TWT): A function that permits an AP and client stations to negotiate a specific time or set of times for individual stations to access the medium. *See also* access point (AP).

TCP: *See* transmission control protocol (TCP).

TPM: *See* Trusted Platform Module (TPM).

transmission control protocol (TCP): A standard that defines how to establish and maintain a network conversation.

transmission opportunity (TXOP): A period of time in which an 802.11 radio has control of the RF medium and can transmit. *See also* radio frequency (RF).

transmit beamforming (TXBF): A method that allows a multiple-input/multiple-output (MIMO) transmitter using multiple antennas to adjust the phase and amplitude of the outgoing transmissions in a coordinated method.

Trusted Platform Module (TPM): A specialized chip on an endpoint device that stores encryption keys specific to the host system for hardware authentication.

TWT: *See* Target Wake Time (TWT).

TXBF: *See* transmit beamforming (TXBF).

TXOP: *See* transmission opportunity (TXOP).

UL: *See* uplink (UL).

ultra-high frequency (UHF): The ITU designation for RF frequencies between 300 MHz and 3 GHz. *See also* International Telecommunications Union (ITU), radio frequency (RF), megahertz (MHz), *and* gigahertz (GHz).

Universal Serial Bus (USB): An industry standard developed to define cables, connectors, and protocols for connection, communication, and power supply between personal computers and peripheral devices.

Uplink (UL): The transmission from a client Wi-Fi device to an AP. *See also* access point (AP) *and* downlink (DL).

Voice over IP (VoIP): A methodology and group of technologies for the delivery of voice communications and multimedia sessions over IP networks, such as the Internet.

Voice over Wi-Fi (VoWiFi): Commercial telephony services delivered over a Wi-Fi network using VoIP technologies. *See also* Voice over IP (VoIP).

VoIP: *See* Voice over IP (VoIP).

VoWiFi: *See* Voice over Wi-Fi (VoWiFi).

wireless local area network (WLAN): A wireless network that links two or more devices using wireless communication within a limited area such as a home, school, office building, or warehouse.

WLAN: *See* wireless local area network (WLAN).

Prepare yourself for the coming Wi-Fi paradigm shift

Past 802.11 amendments have delivered higher data rates and wider channels but haven't addressed efficiency challenges in Wi-Fi networks. Wi-Fi traffic jams are still inevitable. Despite the higher data rates and 40/80/160 MHz channels used by 802.11n/ac radios, multiple factors create traffic congestion in 802.11 networks. The 802.11ax draft amendment focuses on *high efficiency* with technology to address the inefficient use of the Wi-Fi medium.

Inside…

- Understand current Wi-Fi challenges
- Explore 802.11ax Wi-Fi use cases
- Learn how OFDMA improves efficiency
- Implement downlink and uplink Multi-User (MU) communication
- Address OBSS problems with Spatial Reuse improvements
- Extend Wi-Fi device battery life with TWT

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