Wi-Fi 6 in Education: The Next Generation of Wireless

This whitepaper explores the benefits and capabilities of the sixth generation of Wi-Fi in education, based on the 802.11ax amendment to the IEEE 802.11 WLAN standard.

WHITEPAPER
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Introduction

Every new generation of Wi-Fi brings an opportunity to pause and consider the transformational changes that will affect educational institutions in the coming years. Today, Wi-Fi networks already experience bandwidth-intensive media content and several Wi-Fi devices per student. Moving forward, education networks will face a continued dramatic increase in the number of devices, in addition to a diverse range of new technologies that will all heavily rely on Wi-Fi. In fact, 50% of surveyed students who live on campus are already bringing five or more devices with them to school.

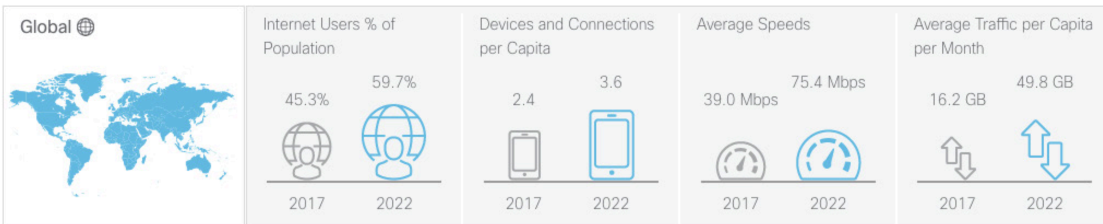


Figure 1. Cisco Visual Networking Index: Forecast and Trends, 2017-2022 Whitepaper

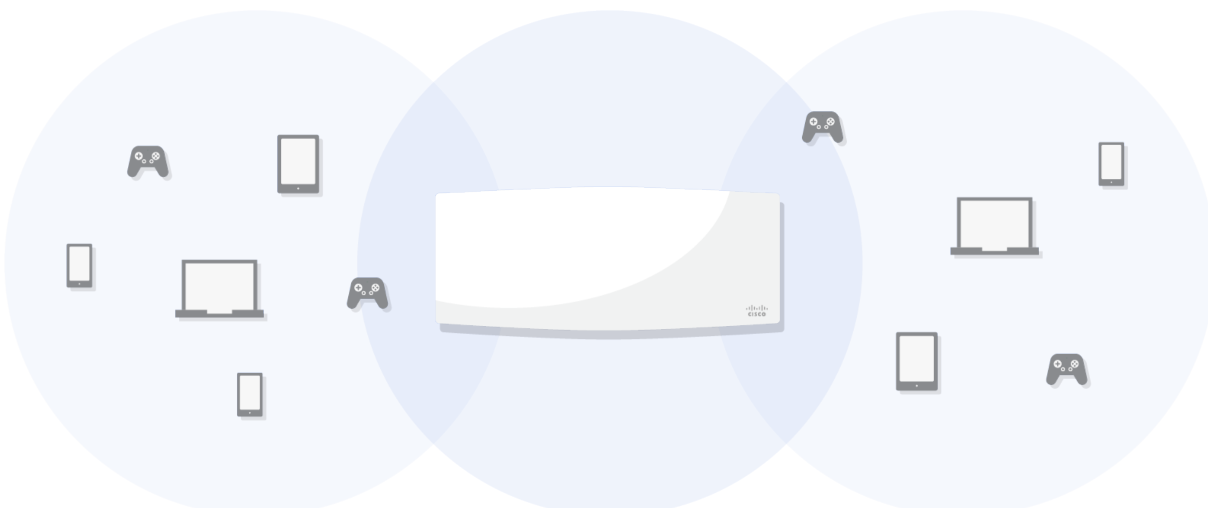
As with previous generations, Wi-Fi 6 (also known as 802.11ax) will improve high density performance and provide faster throughput. In addition, this new generation of Wi-Fi will augment customary speed and density improvements with new capabilities designed for technology trends of the future. IoT connections will represent more than half of all global connected devices by 2022. Virtual and augmented reality network traffic is poised to grow twelve-fold by 2022. Wi-Fi networks of the future need to be nimble and efficient to accommodate increased client density, high throughput requirements, and a diversity of new applications.

Wi-Fi 6 offers several new improvements to make it the highest performing set of wireless protocols ever developed. Not only will Wi-Fi 6 boost overall performance, but it is designed to perform efficiently in real-world scenarios across school districts and college campuses. New features such as OFDMA, uplink MU-MIMO, TWT, BSS color, and new modulation schemes all work together to allow students and staff to experience always-on connectivity without bottlenecks or performance degradation.

Evolution of Wi-Fi

Since 1999, Wi-Fi has evolved rapidly to provide significantly higher throughput and performance. In 2013, 802.11n handed the baton to 802.11ac by providing users with higher speed and higher reliability while conserving power for mobile devices. Over the last several years, 802.11ac Wave 2 has improved maximum data rates beyond 1 Gbps. While 802.11ac Wave 1 and Wave 2 provided significantly increased throughput over older standards, the ability to get reliable multigigabit performance and spectral efficiency was still missing from the 802.11 Wi-Fi standard and required an additional amendment.

The development of the 802.11ax amendment started in 2013, as a group of technical experts came together to discuss the challenges that Wi-Fi might face in coming years. Wi-Fi was contending with being a victim of its own success, as its use became ubiquitous. Experts noted the projected increase of Wi-Fi devices such as mobile phones, consumer electronics, and IoT devices. With more devices, Wi-Fi would face increasing interference and decreased performance. The group saw a need to get legacy devices, IoT devices, and high-throughput devices to all work together efficiently. The task group discussed problem statements and solutions, ultimately outlining the requirements for Wi-Fi 6, also known as High Efficiency WLAN. This new generation of Wi-Fi will be intelligent enough to enable the dense and pervasive wireless environments in schools of the future.



The Next Generation Wireless Landscape

Looking forward, several trends in education are changing wireless networks as we know them today. From an increasing use of high throughput applications, an increased density of wireless devices, and a shift in where student learning takes place, education institutions will quickly see new wireless requirements emerging.

Higher Throughput Requirements

The total amount of internet traffic from 2017-2022 will be higher than in the previous 32 years of the internet. Wi-Fi will be the transport mechanism for more than half of that traffic. In addition to existing bandwidth challenges, an influx of new Wi-Fi 6 mobile devices is expected to hit networks in late 2019 and 2020. The data traffic per smartphone is expected to increase by ten times from 2016 to 2022. Adding to Wi-Fi data rate requirements, 5G networks will be offloading significant amounts of traffic to Wi-Fi. These developments will cause challenges for Wi-Fi networks, which are already dealing with a steady influx of increasing clients, higher client density, and high throughput applications. Bandwidth-intensive 4K video is expected to grow from three percent of all IP traffic in 2017 to twenty-two percent in 2022. 4K video already challenges networks with 15 to 18 Mbps throughput, but 8K streaming video is coming online as well, consuming roughly 1 Gbps of throughput. Augmented and virtual reality applications will have increasing use, and consume anywhere from 600 Mbps to 1 Gbps of traffic. These new bandwidth challenges will require worldwide Wi-Fi connection speeds to increase 2.2x between 2017 and 2022.

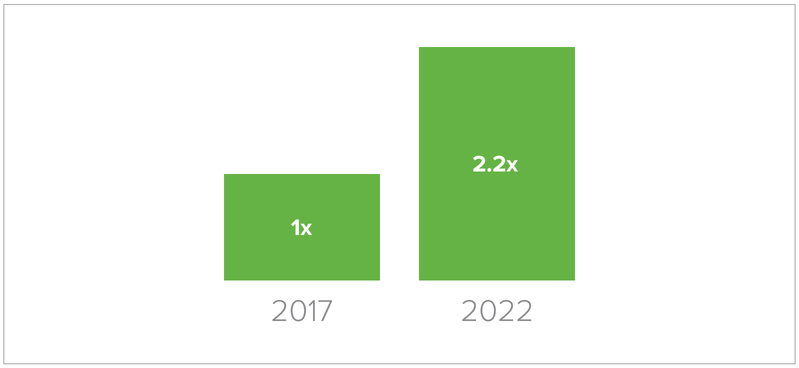


Figure 2. Projected average global Wi-Fi network connection speeds compared to 2017

Higher Density Networks

The next several years will see a 50% increase in networked devices per person, resulting in an average of 3.6 connected devices per person. As device counts increase, users are also expecting a more rich and seamless wireless experience. However, laptops, wearables, and mobile phones will cause significant interference and degraded performance for the rest of the network. In addition to the steady stream of increased clients, network administrators will have to account for dynamic changes as mobile users physically move locations more often. As multiple mobile clients move through spaces that have overlapping coverage from wireless stations (STA), traditional collision avoidance protocols begin to decrease in efficiency. This effect is particularly pronounced at higher data rates and modulation schemes that are more susceptible to noise.

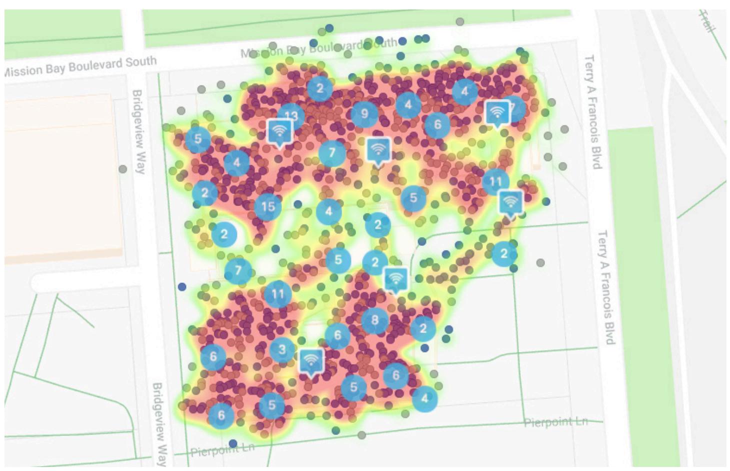


Figure 3. Example of a high-density network

Changing Network Needs

With four times as many Wi-Fi connected devices as humans on the planet, the world's population is more connected than ever before. The days of students being tethered to computer labs are on the decline. The previous five Wi-Fi generations assisted this untethering transition, and the next generation looks to push the bounds of mobility even further. Wi-Fi 6 will lay the groundwork for the growing use of applications like collaborative HD video streaming, augmented reality in the classroom, virtual reality learning, and IoT. IoT devices will represent more than half of all global connected devices and connections by 2022, and 80% of new IoT projects will be wireless. IoT devices are provided benefits with Wi-Fi 6, potentially allowing three times better power efficiency, and additional spectral efficiency. This will lower the barrier of development for robots, wireless-dependent asset tracking, sophisticated sensors, and more.

Wi-Fi 6: Capabilities and Benefits

Despite the challenges in the changing wireless landscape, users expect wireless deployments to be pervasive, and to support high capacity and a high density of clients. Wi-Fi 6 is designed to meet these changing needs — performance that will exceed 802.11ac Wave 2 by over 3-4 times, support for higher density with more efficient airtime, support for a higher scale of client devices, and significant battery saving. While Wi-Fi 6 will be able to deliver theoretical data-rate growth of around 37%, its largest benefit is the ability to deliver high-efficiency performance in real-world environments. As the number of clients increase, Wi-Fi 6 will be able to sustain far more consistent data throughput than previous 802.11n and 802.11ac amendments. There are controlled environments with a very small amount of clients where previous generations of Wi-Fi may provide higher throughput. This is due to the longer frames and wider guard intervals of 802.11ax, which help provide resiliency.

In addition to consistent real-world data throughput, Wi-Fi 6 comes with the additional benefits of wider coverage ranges, better reliability, better IoT operation, and more.

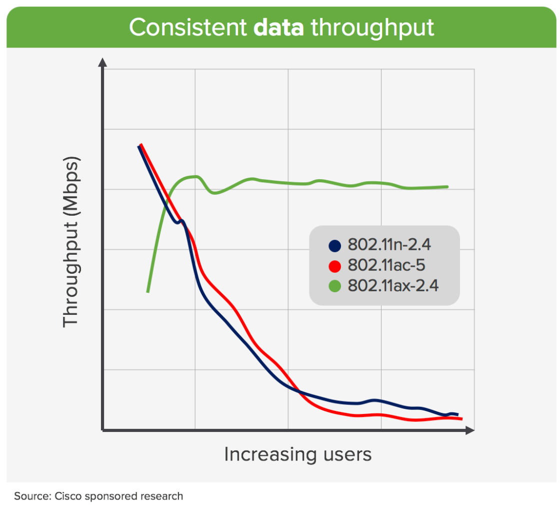


Figure 4. Data throughput with increasing users for 802.11ax compared to 802.11ac and 802.11n based on Cisco-sponsored research

Several new technologies, such as OFDMA, help contribute to the new benefits for next generation wireless networks. Borrowed from LTE technology, OFDMA helps to significantly reduce overhead and latency. IoT devices will enjoy improved efficiencies since the 2.4 GHz spectrum has been added to 802.11ax, along with power saving features like Target Wake Time (TWT).

Wi-Fi 6 Benefits

- Consistent data throughput in dense environments
- Wider coverage range
- Increased reliability and reduced disconnections
- Additional frequency spectrum for IoT and other devices
- Power savings for wireless devices
- Improved outdoor performance

CAPABILITIES	WI-FI 5 (802.11AC)	WI-FI 6 (802.11AX)
Standard Description	Very high throughput	High throughput & high efficiency
Operates in Spectrum	5 GHz only	2.4 & 5 GHz
OFDMA	N/A	DL/UL (MU-OFDMA)
MU-MIMO	Downlink only	Downlink & uplink
Channel Width	20, 40, 80, 80+80, 160 MHz	20, 40, 80, 80+80, 160 MHz
Guard Interval	800/400 ns	800/1600/3200 ns
Frequency Modulation	256 QAM with MCS 1 to 9	1024 QAM with MCS 1 to 11
Power Save	STBC, U-APSD	STBC, U-APSD, Target Wait Time (TWT)
Spectral Efficiency	N/A	BSS coloring

Table 1. 802.11ax and 802.11ac capability comparisons

OPERATION IN BOTH 2.4 AND 5 GHZ SPECTRUM

While 802.11n enhanced operation with both the 2.4 GHz and 5 GHz bands, 802.11ac only focused on 5 GHz. 802.11ax adds additional spatial streams by supporting both the 2.4 and 5 GHz bands. In addition, 802.11ax operates in 20, 40, and 80 MHz — similar to 802.11ac. Since 160 MHz is not recommended for enterprise deployments, it is not covered in this white paper. The added 2.4 GHz spectrum provides several benefits for longer range outdoor use cases and improved coverage for IoT devices. While the spectrum is noisy and congested, the better propagation abilities of 2.4 GHz combined with efficiency improvements of 802.11ax should help maximize the potential of the 2.4 GHz band.

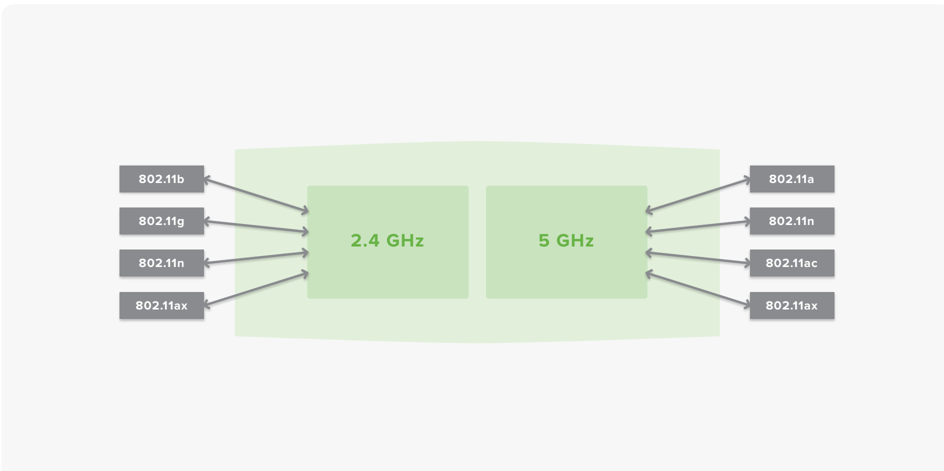


Figure 5. 802.11ax operates in both the 2.4 and 5 GHz spectrum

OFDM TO OFDMA

One of the biggest benefits of 802.11ax is the transition from Orthogonal Frequency Division Multiplexing (OFDM) towards Orthogonal Frequency Division Multiple Access (OFDMA). With 802.11n and 802.11ac, OFDM offers the ability to divide bandwidth into multiple frequency subchannels. With 802.11ax, OFDMA enhances the network efficiency by multiplexing users in frequency and space, minimizing contention for wireless medium. The increasing amount of connected devices, such as IoT devices, can place 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. OFDMA allows more efficient transmission of data to multiple devices, allowing for a 20 MHz channel to be split into small resource units (RUs) or sub-channels. 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 9 clients using 9 RUs. Additionally, the data can also be modulated using MCS10 or 11 to increase throughput. This is predicted to have transformational effects on Wi-Fi efficiency, as well as chipset design for IoT devices. New chipsets can be designed more elegantly, as they no longer have to operate on 40 MHz or 80 MHz channels.

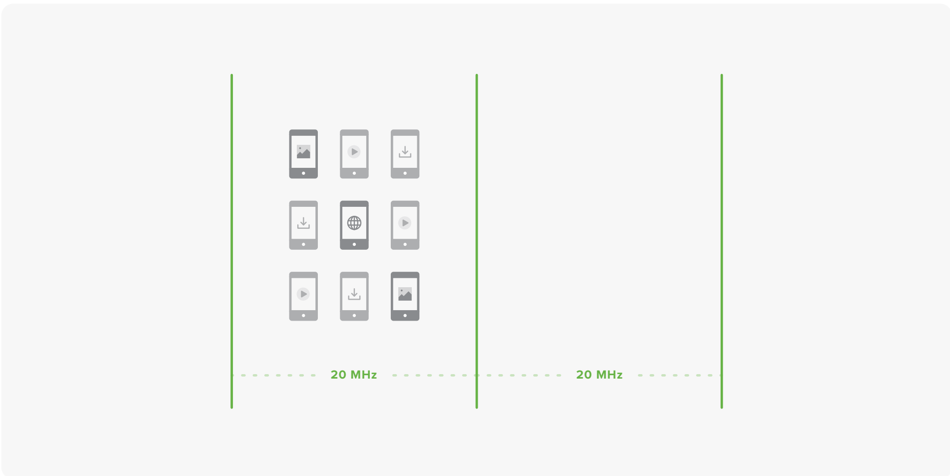


Figure 6. Nine resource units (RUs) in a single 20 MHz channel

Even with 802.11ac Wave 2 networks, schools that deploy high-density wireless deployments with 5 GHz do not need to configure 80 MHz channels, but instead can choose the narrower 40 MHz or standardize on 20 MHz in order to focus on capacity and reuse of channels. With 802.11ax, customers get the ability to divide the channel width even smaller slots such as 2 MHz to tackle transmission to multiple IoT devices.

Since most traffic consists of downloads (from AP to clients), downlink OFDMA is of particular interest for most deployments. 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. A student who is posting on Twitter can now simultaneously send data within a channel that is also sending high-definition video.

MULTI-USER MIMO

MU-MIMO is technology that allows an AP to service multiple clients simultaneously across a supported number of wireless streams or channels. While this capability existed in 802.11ac, multi-user MIMO will now add communication in the upstream direction. With 8x8 support, which was added during the 802.11n amendment, new APs can now support four simultaneous 2x2 MU-MIMO clients in both the upstream and downstream directions. MU-MIMO will work together with OFDMA to allow multiple clients to communicate simultaneously across multiple frequency ranges as well as multiple spatial streams.

FROM 4X4 TO 8X8

Most enterprise 802.11ac access points offer four transmit and four receive chains within an access point, designated as 4x4. While 802.11n and 802.11ac theoretically supported the ability to pursue an 8x8 architecture, none of the enterprise chipsets provide such a capability. In 802.11ac the limited benefits and increased costs of 8x8 chipsets resulted in very little adoption. As radio technologies have improved, the 8x8 functionality will finally be fully commercially supported with most enterprise 802.11ax chipsets. The transition from form factors with fewer antennas (e.g. 2x2 or 4x4) towards those supporting 8x8 offers increased upstream and downstream throughput, and significantly improved reliability due to the additional transmit and receive antennas.

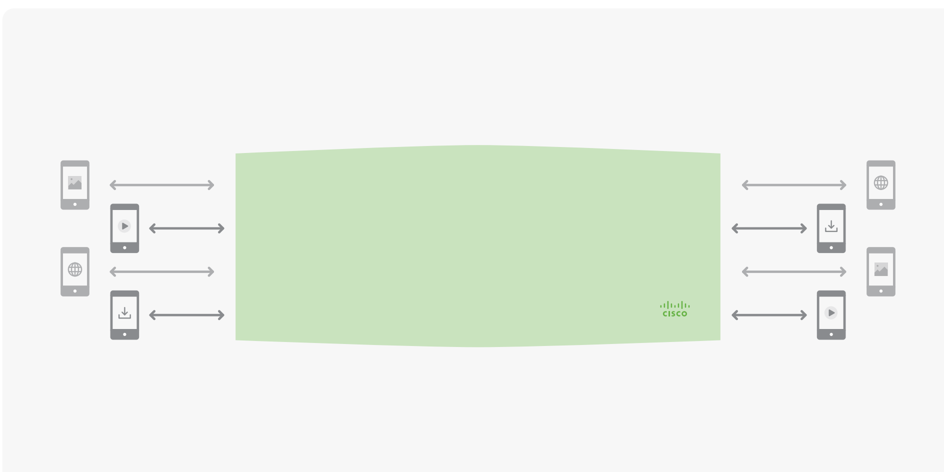


Figure 7. Access points compliant with the 802.11ax standard can serve eight 1x1 clients simultaneously in both the upstream and downstream direction

The 8 receivers and transmitters will allow for higher throughputs for clients in close proximity to an 802.11ax AP, while also providing the capability to serve clients at longer range. 8x8 APs are expected to improve coverage by 10-20%, so that fewer APs can be used per coverage area. With eight transmit and receive antennas, the power per radio chain reduces, helping to improve RF fidelity at higher data rates. This also benefits legacy clients, as we can see a multi-antenna 802.11ac client below experiencing higher throughputs than 4x4 at similar RF power levels.

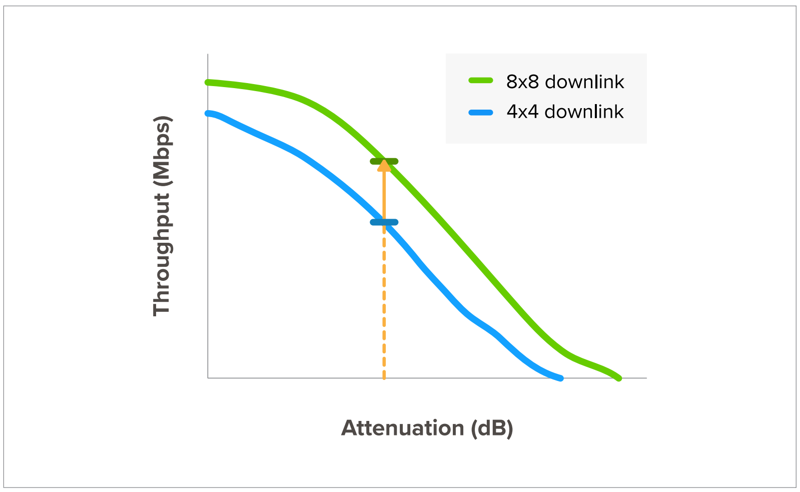


Figure 8. Improved RF fidelity for 8x8 vs. 4x4 for a 3x3 client

256 QAM TO 1024 QAM

Quadrature Amplitude Modulation (QAM) simply enables more 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. In optimal conditions where a single client is near the access point (AP), it may be possible to achieve 2.5x increase in throughput and 1.2 Gbps per spatial stream. When coupled with OFDMA, 1024 QAM significantly improves the noise threshold, offering high performance at bandwidth of 20 MHz or less.

With 256-QAM, the number of bits transmitted per OFDM symbol was 8, and 1024-QAM increases that to 10 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.

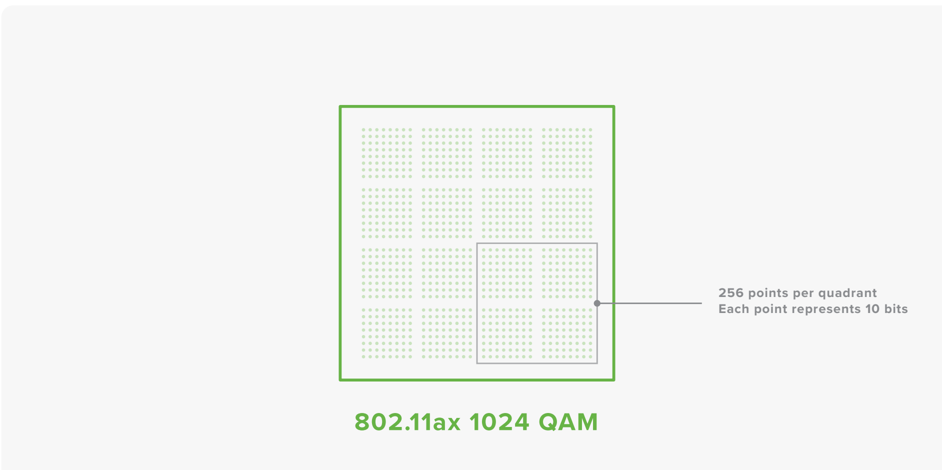


Figure 9. Wi-Fi 6 features 1024 QAM (10 bits per symbol)

MCS RATES 10 AND 11

With two additional Modulation and Coding Sets (MCS), 802.11ax is able to deliver a throughput improvements over previous generations of Wi-Fi. For example, 802.11ac, using a 20MHz channel and MCS8 could reach peak throughput of 86.7 Mbps. 802.11ax is able to use MCS11 in a 20MHz channel, and deliver 143.4 Mbps, a 65% increase.

MCS	MODULATION	CODING	20 MHZ CHANNELS		40 MHZ CHANNELS		80 MHZ CHANNELS	
			DATA RATE		DATA RATE		DATA RATE	
			1600 NS	800 NS	1600 NS	800 NS	1600 NS	800 NS
0	BPSK	1/2	4	4	8	9	17	18
1	QPSK	1/2	16	17	33	34	68	72
2	QPSK	3/4	24	26	49	52	102	108
3	16-QAM	1/2	33	34	65	69	136	144
4	16-QAM	3/4	49	52	98	103	204	216
5	64-QAM	2/3	65	69	130	138	272	288
6	64-QAM	3/4	73	77	146	155	306	324
7	64-QAM	5/6	81	86	163	172	340	360
8	256-QAM	3/4	98	103	195	207	408	432
9	256-QAM	5/6	108	115	217	229	453	480
10	1024-QAM	3/4	122	129	244	258	510	540
11	1024-QAM	5/6	135	143	271	287	567	600

Table 2. 802.11ax MCS Chart, single spatial stream

BSS COLORING

Wi-Fi is no longer considered a nice to have but a necessity. As wireless adoption in schools grows, so does the network interference. In order to ensure good performance, it is important to minimize performance impacts due to interference. With previous generations of Wi-Fi, medium contention and congestion could affect 40-60% of data rates, and required careful channel planning. In order to manage interference, Cisco introduced RX-SOP to adjust Wi-Fi signal levels on APs in highly congested areas. Since RX-SOP is implemented at an AP level, as opposed to client level, the signal levels have to be carefully planned. With BSS coloring, the same concept is expanded to AP and client. This is implemented using a 6-bit BSS color preamble. If, for a given transmission, the BSS color value is the same as that of the receiving station, the channel is considered busy. If the BSS color value is different, the channel is considered free for transmission.

Wi-Fi has a collision avoidance technology called CSMA/CA, which helps avoid interference, but as congestion increases on the wireless network, throughput can be greatly reduced. Using CSMA/CA, access points increase the length of of time between transmissions if colliding signals are detected to reduce overall collisions. This can work well across a few wireless devices, but in dense environments with several overlapping transmissions, overall throughput efficiency decreases drastically. CSMA/CA consumes significant amounts of bandwidth, meaning that the overall TCP throughput as a percentage of the overall network capacity decreases. BSS color adds a simple color bit, resulting in reduced bandwidth overhead and increased efficiency.

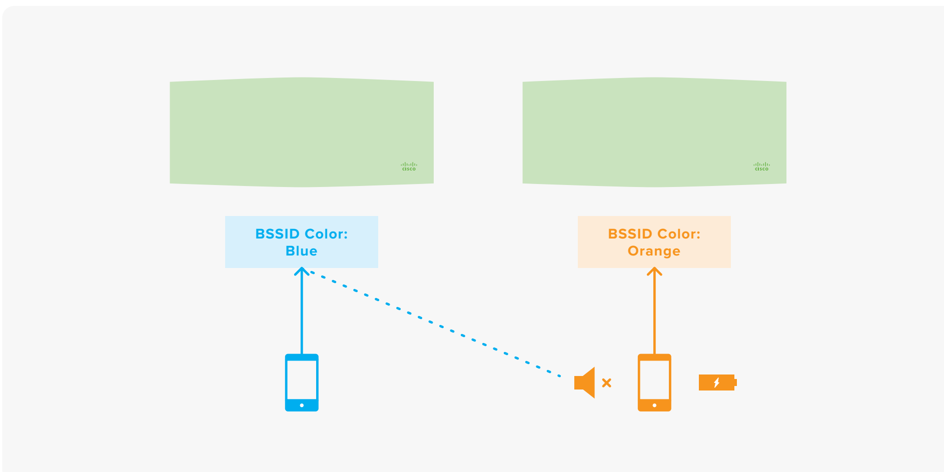


Figure 10. BSS color reduces co-channel interference

TARGET WAKE TIME

To enable this capability, the access point defines a set of target wake times (TWT) and sleep times (TWT SPs) 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 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.

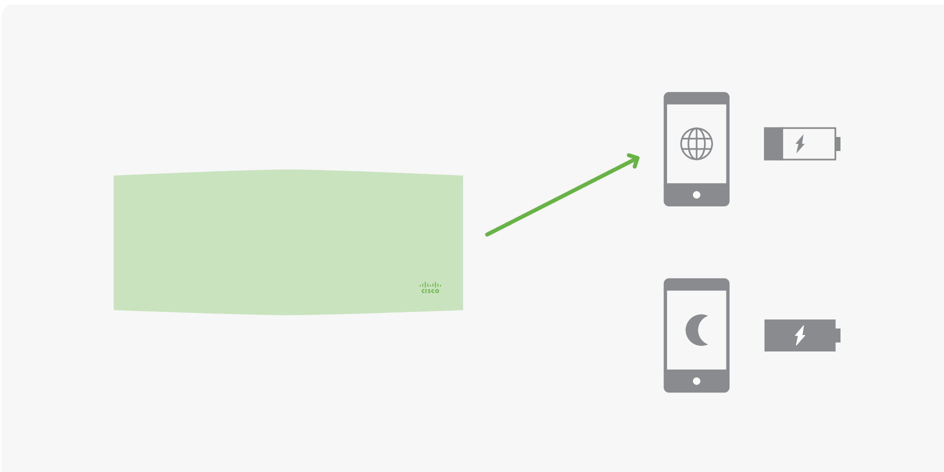


Figure 11. Target wake time (TWT) allows APs to initiate wake time triggers to clients

Wi-Fi 6 will incorporate numerous other capabilities in addition to the eight detailed above. Another goal of the Wi-Fi 6 task group was to address improved performance in outdoor environments. This is accomplished in Wi-Fi 6 with a new packet structure to allow for more robust communication in complex outdoor environments.

Along with a longer list of additional capabilities, 802.11ax radios will also be able to communicate with radios compliant with previous generations of Wi-Fi. Similar to 802.11ac, 802.11ax will be backwards-compatible with legacy 802.11a/b/g/n/ac Wi-Fi amendments.

Deploying Wi-Fi 6

Timelines and Considerations

The 802.11ax amendment to the Wi-Fi standard is still being ratified as of mid-2019, and likely will not be finalized by the Wi-Fi Alliance and IEEE until late 2019. There may be additional ratifications if changes are made to the standard, similar to the 802.11ac ratification process. Timing of an upgrade will depend on individual network needs, as administrators will need to consider their upgrade cycle, and the need for additional throughput or density headroom. Network administrators may want to prepare in advance for the upcoming deluge of Wi-Fi 6 compatible devices by tuning their networks after accounting for the new capabilities like MU-MIMO and OFDMA.

802.11ax clients started hitting the marketplace in early 2019, and will continue throughout the end of 2019 and 2020. The critical inflection point where most shipping devices will be Wi-Fi 6 compatible will likely occur towards the latter half of 2020. Device manufacturers will likely be highly incentivized to push new Wi-Fi 6 clients to consumers, as they can market the new power saving benefits due to TWT and increased efficiency. Since 802.11ax APs are backwards-compatible with previous 802.11a/b/g/n/ac client devices, administrators can begin upgrading their wireless networks now if throughput and density requirements are paramount. While performance improvements can be recognized immediately with 8x8 APs, the vast majority of impact will be felt as new 802.11ax clients enter the market in 2019 and 2020.

BENEFITS DUE TO CAPABILITIES	LEGACY CLIENTS	WI-FI 6 CLIENTS
Higher throughput upstream and downstream due to 8x8	Yes	Yes
Higher reliability upstream and downstream due to 8x8	Yes	Yes
Airtime efficiency and higher throughput due to OFDMA	No*	Yes
More battery life due to TWT	No*	Yes
Airtime efficiency and more battery life due to BSS color	No*	Yes
Higher throughput due to MU-MIMO	No*	Yes

Table 3. Comparison of benefits received by Wi-Fi 6 clients and legacy clients in 802.11ax wireless networks
** Indirect benefit to legacy clients because 802.11ax clients get offline faster*

With new 802.11ax clients and multigigabit APs hitting the market, network administrators will also have to avoid bottlenecks in the rest of their network. New high throughput aggregation and access layer switches might be considered, in addition to 802.3at PoE support, as most 802.11ax access point power requirements will exceed 802.3af PoE thresholds.

With regards to 5G cellular networks, the higher throughput capabilities of Wi-Fi 6 will help to offload cellular traffic. In fact, 71% of 5G traffic is expected to be offloaded onto Wi-Fi or small-cell networks in 2022. This is a marked increase compared to 4G, which will see 59% traffic offloading. As 5G cellular becomes widespread, it is widely expected to become the dominant technology in outdoor environments, similar to LTE.

Real-World Environments: Wi-Fi 6 in Education

Wi-Fi 6 will begin to have an immediate impact for those managing wireless networks for education institutions. Many schools are hampered by congestion of Wi-Fi in inherently high density areas, like classrooms, stadiums, and libraries, leading students to complain about the Wi-Fi connection every chance they get. In fact, 45% of higher education students in a recent survey stated that wireless access needed improvements on campus. With Wi-Fi 6, performance of indoor and outdoor Wi-Fi technologies will vastly improve the student experience across several different use cases.

FUTURE-PROOFED ENVIRONMENT

Students are often the earliest adopters of new wireless devices, so the expected inflection point of 802.11ax clients will likely happen faster at schools than elsewhere. These devices hit all at once when students return from winter or summer breaks. Therefore, being prepared to support hundreds, or thousands, of new Wi-Fi 6 devices in addition to legacy devices is paramount to students success. Plus, with most schools aspiring to provide outdoor wireless, 802.11ax helps improve robustness in noisy outdoor scenarios with longer OFDM symbols.

DIGITAL LEARNING TECHNOLOGIES

Schools and universities are seeing increased use of new learning technologies like immersive learning via augmented and virtual reality. The prices on AR/VR have come down significantly and these technologies are highly effective for learning in both school districts and higher education. In addition, tiny single-board computers, video, and collaboration technologies are infiltrating classrooms and lecture halls at alarming rates, and networks need to support these technologies, on top of student devices all at once as to not interrupt learning.

EVENT SPACES

Stadiums, event spaces, and sports fields are increasingly seeing increased devices as viewers stream media and engage with their surroundings. Traffic patterns in stadiums are highly variable and face bursts of traffic around specific events, which can cause congestion in the network. Students and guests want to enrich their experience by following supplemental event content on mobile applications. Meanwhile, the physical density of clients is one of the highest density environments that Wi-Fi networks will experience, causing major wireless interference complications.

BYOD AND 1:1 DEVICE PROGRAMS

Students across primary and higher education institutions bring several devices with them to campus, on top of school provided devices, learning technologies, and IoT. Being able to support all of these devices at once, in high density areas, is key to ensuring a positive experience.

Real-World Examples: Wi-Fi 6 in Education

Many education institutions today are already preparing for what the future of technology will bring. Wi-Fi 6 not only promises to bring higher density, throughput, and reliability to education networks, but also ensures that students and staff can focus on collaborating and learning, rather than losing connections or having technology troubles. Some education institutions are already starting to deploy Wi-Fi 6 today to future-proof their environments for tomorrow.

ALBANY STATE UNIVERSITY

By embracing the new wireless standard, Albany State University is able to utilize fewer APs to serve the same number of clients. With Wi-Fi 6 compatible APs deployed in the student union, housing common rooms, and gaming areas, students immediately noticed that the internet no longer slowed down, even when at capacity in high-density areas. This allows students to watch videos, stream music, and use social media with their friends, all at the same time.

WILD ROSE SCHOOL DIVISION

At Wild Rose School Division (WRSD), the rapid increase in student and IoT devices posed a unique networking obstacle for the district to overcome. As a rural school district, many students don't have internet access at home, so they are even more dependent on school networks. Additionally, learning no longer just takes place in the classroom, with students learning wherever they go, using high-bandwidth applications in the hallways and outside. Plus, teachers are starting to use tiny, single-board computers and VR headsets more regularly. To accommodate this, the IT team started deploying Wi-Fi 6 compatible APs to support the increasing use of technologies by students and staff.

PIKES PEAK COMMUNITY COLLEGE

At Pikes Peak Community College (PPCC), their new Wi-Fi 6 compatible APs not only provide better connections for students and staff, but prepare them for the increasing number of IoT devices they predict will hit the network. In recent years, the PPCC IT team has received a dramatic increase in requests to implement more technologies on campus to improve student experiences. Wireless door locks, medical devices, AR/VR, Apple TVs, security cameras, and other devices continue to be added to the wireless network. With Wi-Fi 6, PPCC is ready for this increase in IoT devices, while being able to do more with less hardware.

Summary

Wi-Fi 6 can provide wireless networks with significantly higher throughput over 802.11ac (Wi-Fi 5) Wave 2, particularly in high density situations. This increase in performance is much more pronounced with the increase of Wi-Fi 6 clients, which will command significant bandwidth requirements. With various innovations, the new 802.11ax amendment will help enhance the reliability and efficiency of previous standards by automatically mitigating the effects of overlapping networks. The increase in Wi-Fi performance combined with 5G cellular networks will lay the foundation for an exciting future of new technologies for classrooms, college campuses, and the IoT space. As bandwidth requirements and the number of devices continue to increase, education institutions will need to be ready for whatever technology comes their way, while still providing an excellent student experience.

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