WHITE PAPER

a Hewlett Packard Enterprise company

802.11AX—WAIT, DID WE JUST BUILD A WIRELESS SWITCH?

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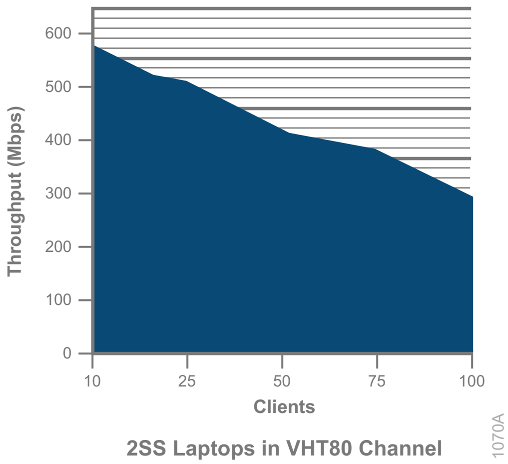
Introduction

With the initial versions of 802.11ax (Wi-Fi 6) coming out, some of the most interesting features and enhancements revolve around how it will handle communicating with multiple clients. Currently clients and wireless access points (APs) have to listen to see if someone else is transmitting before they can send traffic. It's similar to how Ethernet worked in the past with bridges. On a shared medium, more clients mean more fighting over who gets to transmit and longer wait times before each client could send data. Performance is fine with a small number of clients, but as the number of clients increased, the available bandwidth of the network decreases. In a wireless network, an AP with 100 clients can transmit only about 40% of the data that an AP with 10 clients can transmit, as shown in Figure 1.

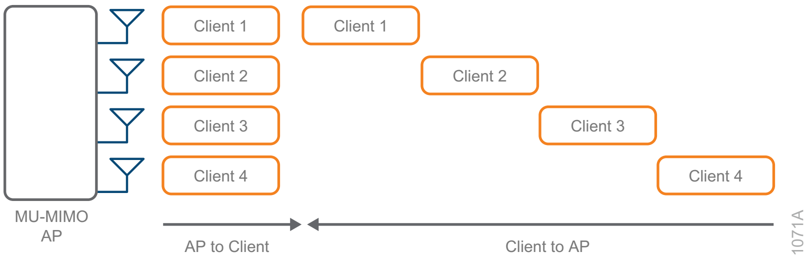
Figure 1 *The effect of performance on a shared medium as client count increases.*



Increasing the speed of the network helps. Clients can transmit faster and get off the air sooner so that others can transmit, but there are diminishing returns—doubling the bandwidth doesn't allow you to support twice as many clients. Latency-sensitive traffic such as voice and video is the most affected. At some point, clients have to wait so long to transmit that the user experience suffers.

On the wired side of the world, the introduction of switching took care of this issue decades ago. Ethernet switching allows clients to send traffic on the wire whenever they want because the connection to the network is no longer a shared medium.

Figure 2 *MU-MIMO in down direction only; upload is single client at a time.*

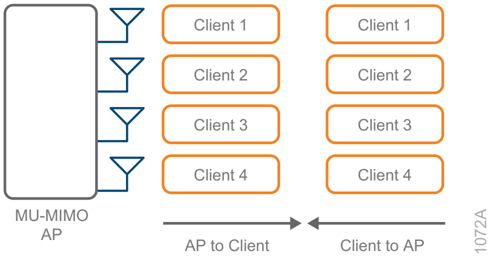


In the wireless world, 802.11ac began to address this issue with multi-user MIMO (MU-MIMO), which allows the AP to transmit to up to four clients at the same time. Although this helps improve performance, its function is situational and is only supported from the AP to the client. Uplink traffic from the client to the AP is still one device at a time, as shown in Figure 2.

802.11AX TO THE RESCUE

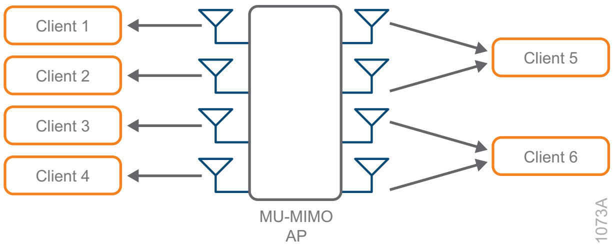
With 802.11ax, MU-MIMO has been enhanced to support uplink traffic, from the client to the AP, and will support up to eight clients at a time (802.11ac allowed for eight, but no one implemented more than four). This doubles the number of devices to which an AP can talk, and because traffic is supported in both directions, clients can transmit simultaneously back to the AP, similar to how an eight-port switch would work on a wired network.

Figure 3 *MU-MIMO down and up*



Because Wi-Fi networks aren't limited by wires, though, we can use multiple antennas to increase the bandwidth to clients that support MU-MIMO. In Figure 4, clients 5 and 6 are both receiving data from two antennas, doubling their potential bandwidth.

Figure 4 *8x8:8 MU-MIMO to single and dual stream clients*

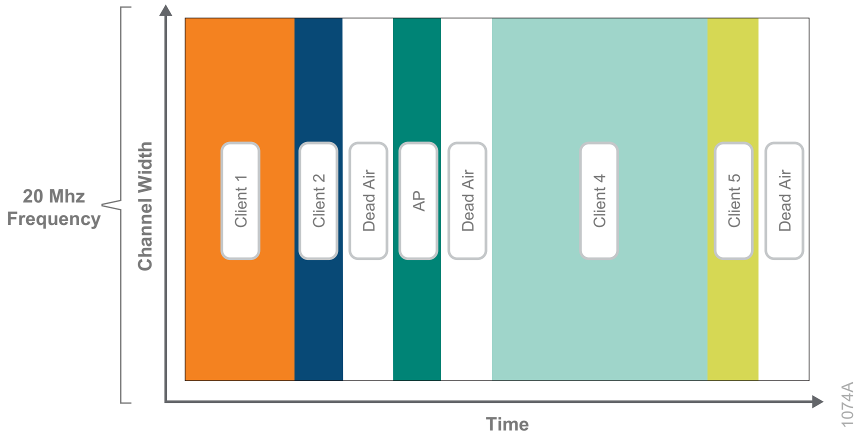


OFDMA

The most significant new feature of the 802.11ax standard is OFDMA (orthogonal frequency-division multiple access) which replaces OFDM (orthogonal frequency-division multiplexing).

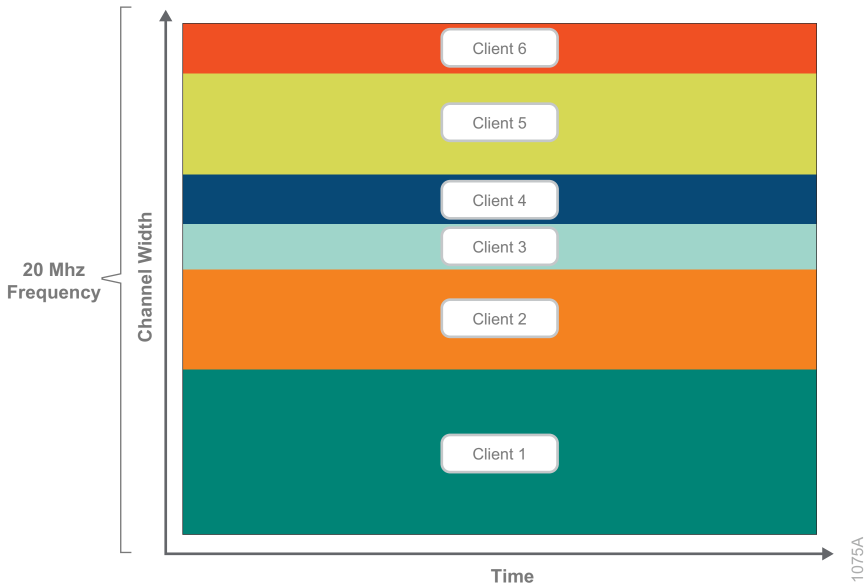
OFDMA modifies a Wi-Fi characteristic—to date frames have been transmitted consecutively using the entire channel. For example, if a client is connected to a 20 MHz wide channel and sends data, the entire channel is taken up (Figure 5), and then the AP and clients take turns, one at a time, sending data on the channel.

Figure 5 *OFDM operation today—one client transmits, then others contend for airtime and transmit.*



OFDMA changes that behavior. The channel can be divided up into smaller sub-channels, and data can be sent from the AP to multiple clients at a time. A 20 MHz wide channel supports up to nine clients, and the number of sub-channels can be adjusted so that fewer higher speed clients or more lower speed clients can be supported. Sub-channel use is dynamic and can be adjusted every transmission cycle, depending on client data needs.

Figure 6 *OFDMA operation in 802.11ax—multiple clients share the channel and transmit at the same time*



Wider channels can support even more sub-channels. An 80 MHz wide channel can support up to 37 clients at a time. Like MU-MIMO, OFDMA supports downlink traffic, from the AP to the clients, and uplink traffic, from the clients to the AP (similar to Figure 3 but with more clients). If MU-MIMO is a high speed 8-port switch, then OFDMA is a lower speed 37 port switch.

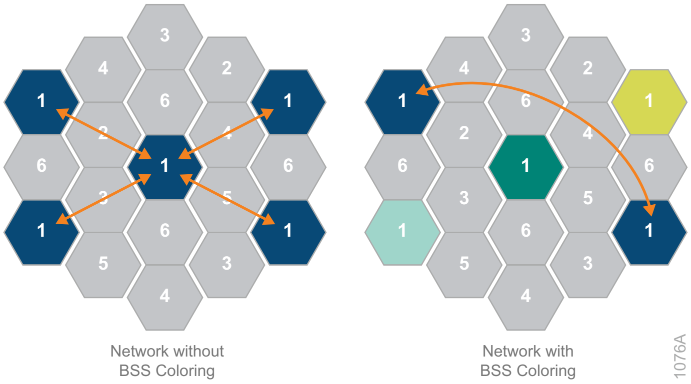
BSS Coloring

So far, we have talked about features that help maintain performance as the number of devices grows, reduce latency and jitter, and operate more efficiently but not really adding capacity. Wireless networks have a limited number of channels on which an AP can operate. If multiple APs are on the same channel and placed close together, they will interfere with each other and add no benefit to the network because when one AP is transmitting data, the other APs on the same channel have to wait before they can send.

This has led to designs with more lower-bandwidth channels to reduce interference. 40 MHz-wide channels are the norm in office deployments, with 20 MHz wide channels used in high density offices or in environments where there are fewer channels available because of noisy RF neighborhoods.

BSS coloring allows the network to assign a "color" tag to a channel and reduce the threshold for interference. Network performance is improved because APs on the same channel can be closer together and still transmit at the same time as long as they are different colors. Because we can have fewer channels, it may also be possible for organizations to use wider channels, such as 80Mhz channels in some or all of their network.

Figure 7 *Left—without BSS coloring, all overlapping channels interfere. Right—with BSS coloring, only matching colors interfere.*



If MU-MIMO and OFDMA make the wireless network behave more like a switched environment, then BSS coloring adds switching capacity to the network.

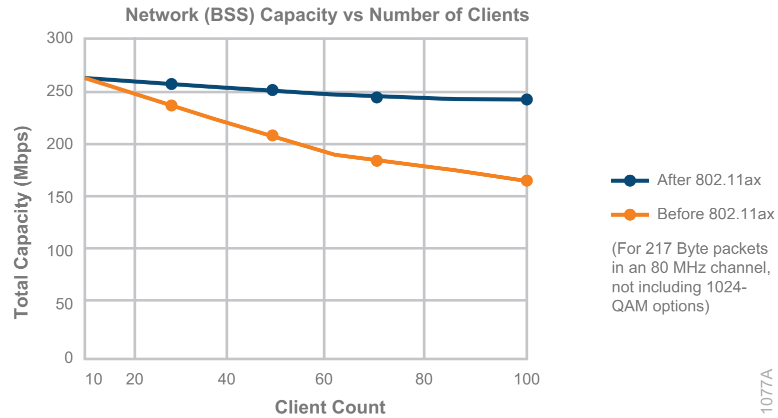
SUMMARY

So, did we build a wireless switch? With MU-MIMO, an AP can behave like a high speed, 600 Mbps per client 8 port switch, great for large file transfers and high-performance clients. OFDMA allows an AP to behave like a lower speed, ~25 Mbps per client 37 port switch, good for normal network use and voice and video streaming. An AP can switch back and forth between these two modes every transmit cycle as the needs of the clients change. We don't have a dedicated connection for each device like you would in a wired network, but we are able to adjust the amount of network capacity allocated to each device depending on need, which is something wired networking can't do. Although we don't have a full-duplex switch, we effectively have time-division duplexing that emulates full-duplex over shared/half-duplex mediums.

In the end, we gain a lot of the benefits of switching and wireless and 802.11ax is likely to be the point where we think of Wi-Fi less like an old bridged network and more like a high-speed modern switched network.

The effect is that the network can greatly optimize/improve airtime utilization. The more clients that tried to transmit on legacy networks, the longer it took to decide who got to transmit, and the more performance suffered. With 802.11ax, multiple clients can transmit at once (Figure 8) and performance is maintained at close to the maximum rate an AP can transmit, even with a large number of clients.

Figure 8 802.11ax network capacity vs. legacy wireless



The obvious use case for 802.11ax is high-density environments, and with the number of IoT and BYOD devices users carry increasing rapidly, a few years from now typical office environments might look like high-density networks today. A lot of more common office scenarios will see benefits from 802.11ax as well, so it's not just high-density environments. Voice and other latency and jitter sensitive traffic will perform much better.

In the past, to support more voice traffic, we added more smaller channels—otherwise, transmit delays stacked up as more clients contended for airtime and performance suffered. Now that we can transmit to multiple clients at once performance scales with channel size, we have the opportunity to run wider channels for more capacity and not stack up delay because clients have more opportunities to transmit. BSS coloring allows for more channel-reuse, adding capacity, and possibly more importantly, it should mean better performance in noisy RF environments due to improved interference handling, a situation that is very common in urban office environments.

BEFORE I SEND YOU ON YOUR WAY...

Now, all of this doesn't just happen at once. 802.11ax features are coming in waves with the initial release scheduled for late '18 and early '19 and the second wave about two years later. Another consideration is that for these new multi-user features to work, the clients on the network need to support 802.11ax and it will take a while before there are enough clients to so that these multi-user features make a big impact in most networks.

802.11ax is complex, much more so than previous wireless standards. A lot of the functionality we have talked about will rely on traffic schedulers in the APs—to figure out the best mode to run in and how to transmit to clients in the most efficient way, as well as how to signal clients for multi-user uploads. Software running 802.11ax APs is going to be critical, and large differences in performance from vendors using the same Wi-Fi chipsets are possible. Only companies with experience and knowledge will be the best positioned to deliver on the promises of 802.11ax.

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