Notes on the 802.11ax Standard Fall 2021

802.11ax, which is known as Wi-Fi 6 under a new naming convention, is designed specifically for high-density public environments, like trains, stadiums in heavy-usage homes, in apartment buildings and in offices that use bandwidth-hogging applications like videoconferencing.

What problem is 802.11ax trying to solve?

The fundamental problems with Wi-Fi are that bandwidth is shared among endpoint devices, access points can have overlapping coverage areas, especially in dense deployments, and end users can be moving between access points.

The 802.11 protocol uses a carrier sense multiple access (CSMA) method in which the wireless stations (STA) first sense the channel and attempt to avoid collisions by transmitting only when they sense the channel to be idle. That is, when they don't detect any 802.11 signals. When an STA hears another one, it waits for a random amount of time for that STA to stop transmitting before listening again for the channel to be free. When they're able to transmit, STAs transmit their whole packet data.

Wi-Fi STAs may use Request to Send/Clear to Send (RTS/CTS) to mediate access to the shared medium. The Access Point (AP) only issues a CTS packet to one STA at a time, which in turn sends its entire frame to the AP. The STA then waits for an acknowledgement packet (ACK) from the AP indicating that it received the packet correctly. If the STA doesn't get the ACK in time, it assumes the packet collided with some other transmission, moving the STA into a period of binary exponential backoff. It will try to access the medium and re-transmit its packet after the backoff counter expires.

The good news is that 802.11ax promises improved performance, extended coverage and longer battery life. 802.11ax can deliver a single stream at 3.5Gbps, and with new multiplexing technology borrowed from the world of LTE cellular, can deliver four simultaneous streams to a single endpoint for a total theoretical bandwidth of an astounding 14Gbps. This new standard implements several mechanisms to serve more users consistently and provide reliable data throughput in crowded wireless environments.

How does 802.11ax work?

The 802.11ax standard takes a variety of well-understood wireless techniques and combines them in a way that achieves a significant advance over previous standards yet maintains backward compatibility with 802.11ac and 802.11n.

802.11ax delivers a nearly 40 percent increase in pure throughput thanks to higher order QAM modulation, which allows for more data to be transmitted per packet. It also achieves more efficient spectrum utilization. For example, 802.11ax creates broader channels and splits those channels into narrower sub-channels. This increases the total number of available channels, making it easier for endpoints to find a clear path to the access point.

When it comes to downloads from the access point to the end user, early Wi-Fi standards only permitted one transmission at a time per access point. The Wave 2 version of 802.11ac began using Multi-User, Multi-Input, Multiple Output (MU-MIMO), which allowed access points to send up to four streams simultaneously. 802.11ax allows for eight simultaneous streams and makes use of explicit beamforming technology to aim those streams more accurately at the receiver's antenna.

Even more importantly, 802.11ax piggybacks on MU-MIMO with an LTE cellular base station technology called Orthogonal Frequency Division Multiple Access (OFDMA). This allows each MU-MIMO stream to be split in four additional streams, boosting the effective bandwidth per user by four times.

The way Network World columnist Zeus Kerrevala explains **802.11ax**, early Wi-Fi was like a long line of customers in a bank waiting for one teller. MU-MIMO meant four tellers serving four lines of customers. OFDMA means each teller can simultaneously serve four customers.

How is 802.11ax different from 802.11ac?

802.11ac operates in the 5Ghz range only, while 802.11ax operates in both the 2.4Ghz and 5Ghz ranges simultaneously, thus creating many more available channels. For example, early chipsets support a total of 12 channels, eight in the 5Ghz and four in the 2.4Ghz range.

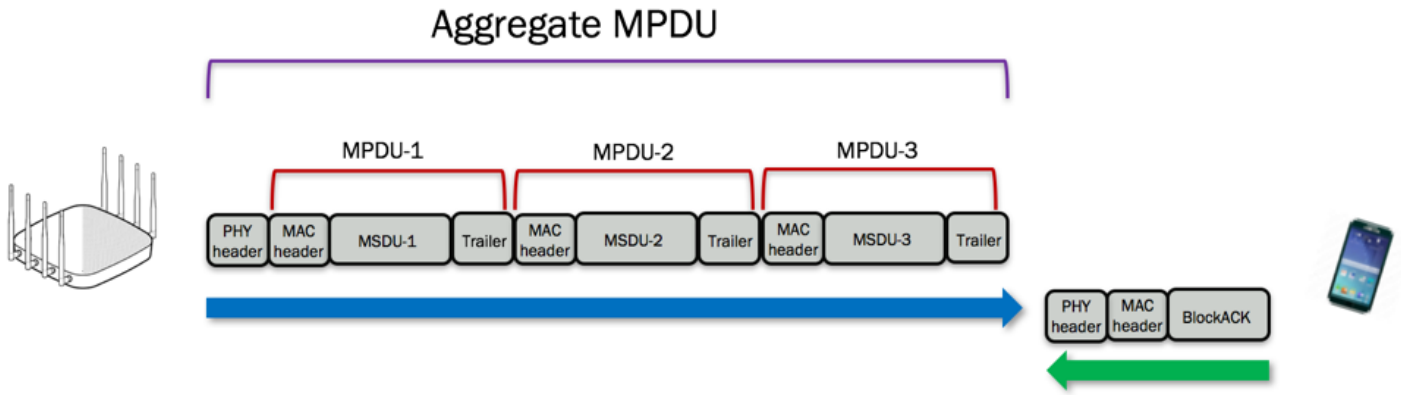
With 802.11ac, MU-MIMO is limited to downlink transmissions only. 802.11ax creates MU-MIMO connections so that with downlink MU-MIMO an access point may transmit concurrently to multiple receivers and with uplink MU-MIMO an endpoint may simultaneously receive from multiple transmitters.

802.11ax supports up to eight MU-MIMO transmissions at a time, up from four with 802.11ac. OFDMA is new with 802.11ax, as are several other technologies, like trigger-based random access, dynamic fragmentation and spatial frequency re-use, all aimed at improving efficiency.

Notes on 802.ax Frame Aggregation

An 802.11 *MAC Service Data Unit (MSDU)* is the layer 3–7 payload of an 802.11 data frame. An 802.11 *MAC Protocol Data Unit (MPDU)* is essentially a technical term for wireless frame. An MPDU consists of a frame header, body and trailer with the MSDU payload encapsulated in the frame body.

802.11n defined two methods of frame aggregation. The first method of frame aggregation known as *Aggregate MAC Service Data Unit (A-MSDU)* aggregates multiple MSDUs into a single frame transmission. As shown in Figure 1, the second method known as *Aggregate MAC Protocol Data Unit (A-MPDU)* aggregates multiple frames into a single transmission followed by a Block Acknowledgement.



A-MPDU quickly became the most commonly used method of frame aggregation because there is less retransmission overhead when Block Acknowledgements are utilized. For this reason, the 802.11ac amendment only defined the use of A-MPDU aggregation. All 802.11ac frames are transmitted using the Aggregate MAC Protocol Data Unit (A-MPDU) format. Although A-MPDU is required for 802.11ac transmission, it should be noted that A-MSDU and A-MPDU can be used together. The payload of an A-MPDU transmission can be multiple A-MSDUs.

802.11ax defines multiple enhancements at the Physical Layer, such as OFDMA to improve efficiency. A lesser-known efficiency enhancement actually resides in the MAC sublayer.

Prior to Wi-Fi 6, the individual MPDUs must all be of the same 802.11e QoS access category when A-MPDU frame aggregation is used. Voice MPDUs cannot be mixed with Best Effort or Video MPDUs within the same aggregated frame. 802.11ax introduces ***Multi-Traffic Identifier Aggregated MAC Protocol Data Unit (Multi-TID AMPDU)***, which allows the aggregation of frames from multiple traffic identifiers (TIDs), from the same or different QoS access categories. The ability to mix MPDUs of different QoS traffic classes allows 802.11ax radios to aggregate more efficiently, reducing overhead and thus increasing throughput and therefore overall network efficiency.