WiFi 6: A technological leap for Next Generation Enterprise WiFi Networks

Earlier generations of WiFi technology were primarily focussed on increasing peak throughput. With WiFi 6, which is based on the IEEE 802.11ax standard, the focus is on improving the efficiency of the radio link. However, there is a relatively modest increase in peak data rate too.

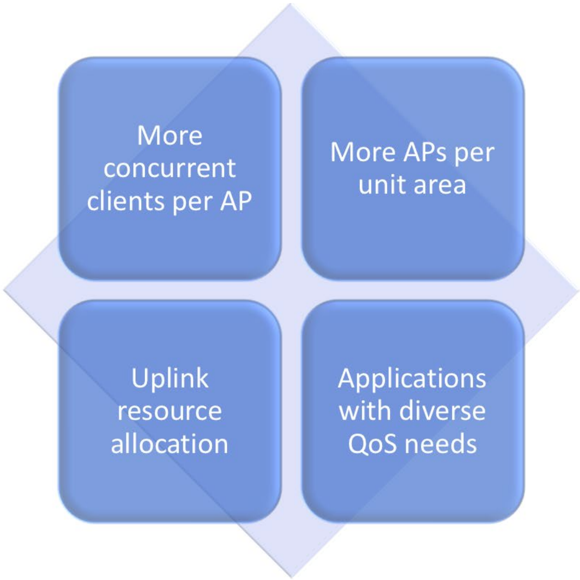

Figure 1: Main Drivers for IEEE 802.11ax Standard

With rapid growth in the use of WiFi in the enterprise, at public venues, and for Mobile Data Offload, WiFi technology needed to evolve to meet the new requirements. The limited amount of unlicensed spectrum in both 2.4GHz and 5GHz bands means that each Access Point (AP) needs to concurrently serve more users in high-density scenarios. Moreover, cell sizes are shrinking, resulting in reduced inter-AP spacing for ultra high-density deployments. From a radio resource management perspective, another major bottleneck has been the loss of valuable airtime due to contention on the uplink, which significantly degrades the end user experience. Lastly, with the increasing diversity in client devices and user applications, the one-size-fits-all approach of resource allocation cannot be relied upon to deliver consistently good QoE.

The challenges presented by the existing WiFi technology led to the formation of the High Efficiency Wireless (HEW) Task Group in the IEEE 802.11 Working Group. The HEW group developed the IEEE 802.11ax standard for Wireless LAN (WLAN). WiFi Alliance (WFA), an industry consortium that certifies WLAN products, decided to create a new label, 'WiFi 6', for IEEE 802.11ax devices. WiFi 6 certified devices will support a subset of the features defined in IEEE802.11ax. The WFA has selected these features keeping in mind the market requirements and the need to develop WiFi 6 products at a fast pace.

WiFi 6 Key Features

WiFi 6 includes a slew of new features to address performance improvements and optimizations across multiple dimensions.

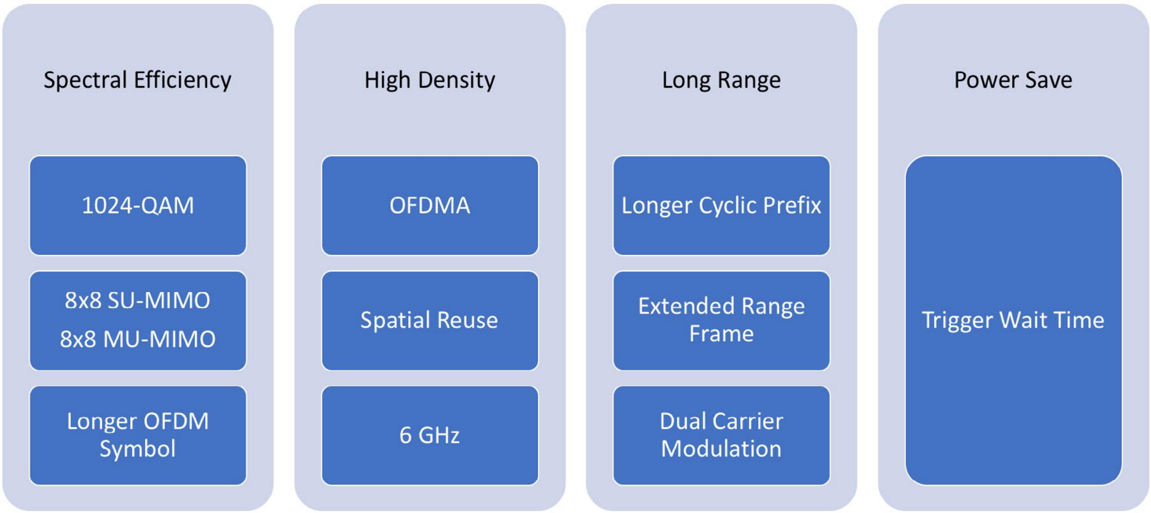

Figure 2: WiFi 6: Key Features

OFDMA

Orthogonal Frequency Division Multiple Access (OFDMA) divides the 20/40/80/160 MHz channel into resource units (RUs). Each RU is further divided into subcarriers, also called "tones", each 78.125 KHz wide. As shown in the representation below, for a 20MHz channel, an RU can consist of 26, 52, 106, or 242 tones—corresponding to RU sizes of approximately 2 MHz, 4 MHz, 8 MHz, and 20 MHz. In each scheduling interval, OFDMA allocates one or more RUs of different widths to multiple users, resulting in an efficient and flexible use of the channel.

Figure 3: RU sizes for 20MHz Channel Bandwidth

OFDMA allows for flexible resource allocation in both uplink and downlink. The table below summarizes possible RU sizes for different channel bandwidths.

Table 1: RU Sizes for Different Bandwidth Options				
RU Size (Number of Tones)	20MHz	40MHz	80MHz	160MHz
26	9	18	37	74
52	4	8	16	32
106	2	4	8	16
242	1	2	4	8
484	N/A	1	2	4
996	N/A	N/A	1	2
2x996	N/A	N/A	N/A	1

Downlink OFDMA

In the downlink, a WiFi 6 AP intelligently schedules clients and allocates resources. In case of OFDMA systems like 802.11ac, the entire 20/40/80 MHz channel is assigned to a single user during one time slot, irrespective of application and/or packet size. Downlink OFDMA uses the channel much more efficiently by distributing the bandwidth among clients, allocating only as much of the channel to each client as needed on a per-frame basis. The AP can choose the users to which it allocates RUs per frame. The resource allocation and scheduling are based on factors such as client capabilities, packet size, required application QoS, and channel conditions.

An 802.11ax AP has the flexibility to allocate any combination of RUs. The figure below shows an example of an AP allocating RUs in three scheduling intervals.

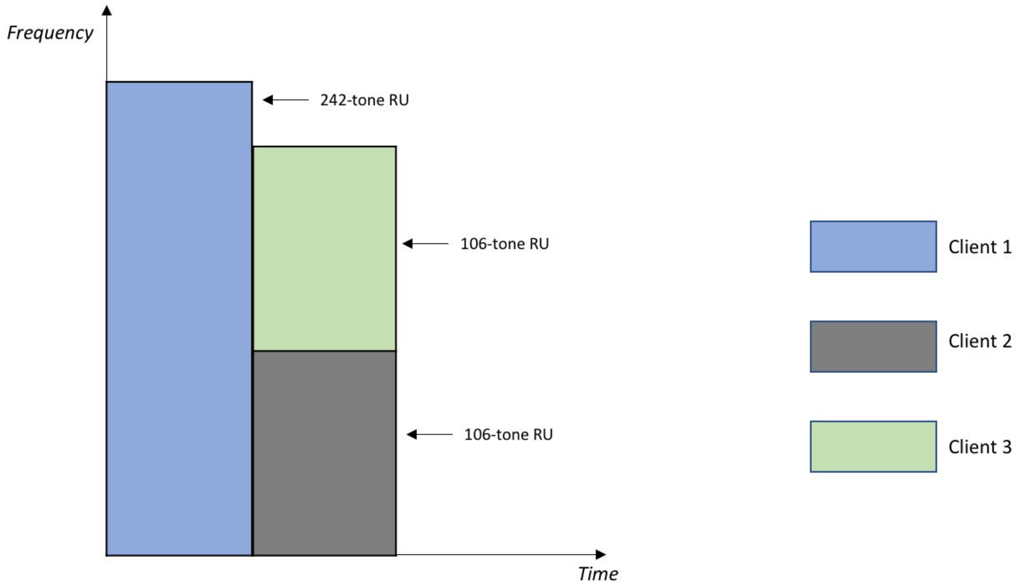

Figure 4: ODFMA Resource Allocation

In the first scheduling interval, the AP allocates the whole 20 MHz channel—a single, 242-tone RU—to Client 1. And in the third interval, it allocates two 106-tone RUs to Client 2 and Client 3.

Uplink OFDMA

The WiFi uplink is a distributed form of communication because the transmitters (i.e., clients) cannot coordinate their schedules (unlike the downlink, where the AP is both the transmitter and the scheduler). Prior to WiFi 6, uplink transmissions were uncoordinated: clients contended for the medium using CSMA/CA and, based on randomly distributed timing, sent packets to the AP. This works reasonably well for single or sparse AP deployments, but for dense deployments, this can cause high uplink contention in presence of a large number of clients.

WiFi 6 makes the uplink more efficient by enabling the AP to manage the uplink resource allocation via mechanisms that essentially coordinate the transmission schedule among clients while using CSMA-CA to ensure that the medium is available for transmission. The schedule is announced to clients using Trigger Frames. This leads to reduced uplink contention, thereby improving capacity and user experience. Clients can also use opportunistic OFDM-based access for uplink transmissions.

MU-MIMO

Multiple Input Multiple Output (MIMO) refers to the use of multiple antennas on WiFi APs and clients to increase data rates (via spatial multiplexing) and reduce interference (via beamforming). Single-user MIMO (SU-MIMO) refers to the use of multiple antennas for transmitting multiple, simultaneous "streams" of data between an AP and a client on the same channel.

Multi-user MIMO (MU-MIMO) uses the multiple-antenna streams not to improve the transmission to a single user but to simultaneously serve multiple users, i.e., to improve capacity rather than user data rates. The figure below shows an example of MU-MIMO where 8 streams on the AP can simultaneously serve 4 clients, each with support for two streams.

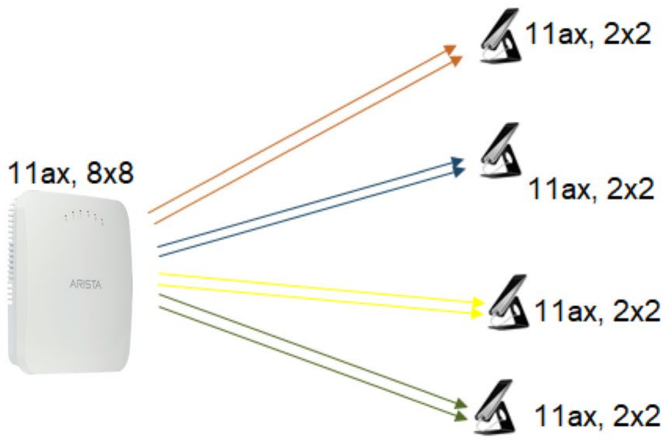

Figure 5: DL Multi-User MIMO

Downlink MU-MIMO

Depending on the channel conditions of a client, an AP can use SU-MIMO to improve the client's data rates or reduce its error rates. Both, however, are per-link improvements. In dense environments, the ability of an AP to serve more users is more important than simply boosting individual user data rates; downlink MU-MIMO can help in such deployments by allocating resources in spatial domain, thus complementing the frequency domain scheduled via OFDMA. WiFi 6 supports 8x8 MIMO in both uplink and downlink.

In most common scenarios, APs will have more antennas than clients. Hence, SU-MIMO cannot be exploited fully. However, with MU-MIMO, this asymmetry can be exploited to serve multiple clients with fewer antennas than the AP. For instance, with an 8x8 AP, it is possible to serve 8 1x1 clients or 4 2x2 clients with MU-MIMO. Clients with different antenna counts can also be served together, e.g. an 8x8 AP can serve 2 2x2 clients and 4 1x1 clients using MU-MIMO.

Uplink MU-MIMO

Uplink MU-MIMO is especially useful for uplink-heavy applications such as social media, content sharing, and video calls. As with the downlink, uplink MU-MIMO increases capacity compared to the SU-MIMO case. This results in a better user experience when uploading content. Early WiFi 6 clients might not support uplink MU-MIMO and for the ones that do, the implementation is not yet mature across client manufacturers.

Long Symbol Duration and Guard Interval

A key characteristic of WiFi 6 is the narrower subcarrier spacing (78.125 KHz, compared to 312.25 KHz for 802.11ac). As discussed earlier, OFDMA combines sub-carriers to form resource units (RUs), or sub-channels, of different widths. Each sub-channel needs at least one "pilot" sub-carrier used by the receiver to estimate channel behavior. A smaller sub-carrier spacing results in a smaller fraction of the sub-channel being used by pilots, thereby improving spectral efficiency. A smaller sub-carrier spacing also means a proportionately longer OFDM symbol duration (12.8 µs, compared to 3.2 µs in 802.11ac). Longer symbol durations help in propagation environments with large delay spreads; this makes 802.11ax better suited to environments where the propagation distances are typically large, such as outdoor deployments.

WiFi 6 also supports longer guard intervals (GI) : 0.8 µs, 1.6 µs, and 3.2 µs, compared to 0.4 µs and 0.8 µs for 802.11ac). The longer symbol duration means that the GI efficiently uses only a small portion of the OFDM symbol. As with longer symbol times, longer GI help in propagation environments with large delay spreads and provide better protection against Inter-symbol Interference arising out of multipath. Longer GI, however, result in lower data rates because more of the symbol is used up by the cyclic prefix. The figure below illustrates the different GI values supported.

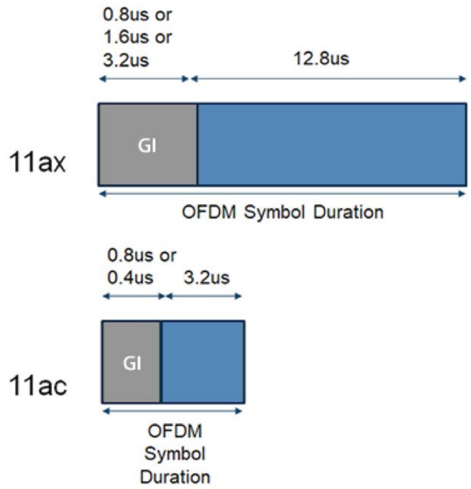

Figure 6: Symbol Duration

1024 QAM

WiFi 6 supports two new Modulation and Coding Schemes (MCS): MCS 10 and MCS 11. These correspond to 1024-QAM, i.e., 10 bits per modulation symbol (the highest in 802.11ac is MCS 9 with 256-QAM). The table below illustrates peak data rate improvement from the use of 1024-QAM and longer symbol duration.

Table 2: Peak Data Rates Evolution

Protocol	Bandwidth (MHz)	Streams	Peak Rate (Mbps)
11n	40	4	600
11ac	160	8	6933
11ax	160	8	9806

Spatial Reuse

WiFi operates in the 2.4GHz and 5GHz bands, both of which are unlicensed, i.e. anyone can use these bands, as long as national regulatory rules pertaining to these bands are adhered to. Carrier Sense mechanisms defined in the IEEE 802.11 standard enable multiple APs and clients to operate on the same channel in these bands. However, in dense deployments, when the number of APs and clients is very high, channels can get highly congested, thereby increasing the amount of time that APs and clients spend in carrier sensing and contention resolution using backoffs.

In earlier versions of WiFi, the Clear Channel Assessment (CCA) threshold was fixed to -82 dBm, which meant that if an ongoing transmission was detected at -82 dBm or higher, all other potential transmitters had to back off. WiFi 6 provides a more flexible spatial channel reuse. With WiFi 6, an AP or client that wants to transmit on a currently busy channel can dynamically modify the CCA thresholds.To avoid interference, however, raising the CCA threshold above -82 dBm means that the AP must reduce its transmit power.

The figure below illustrates the use of dynamic thresholds. TX_PWR is the transmission power in dBm at the output of the antenna connector. TX_PWRref , OBSS_PDmax and OBSS_PDmin are defined in the IEEE 802.11ax standard.

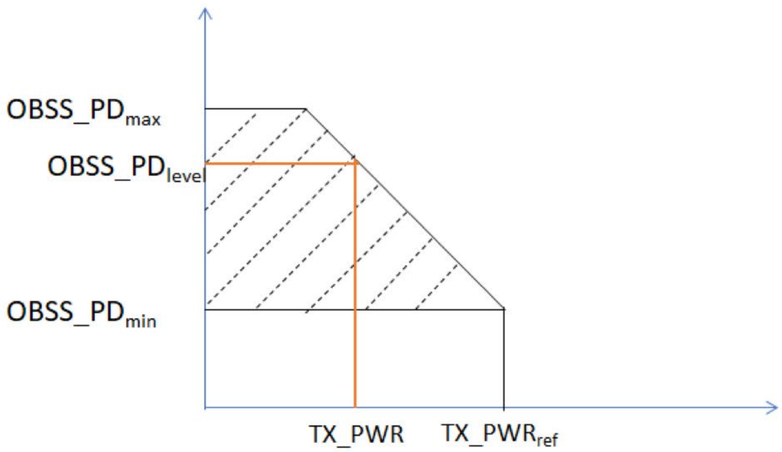

Figure 7: Power back-off

Target Wait Time

Power Save (PS) mechanisms have been a part of previous generations of WiFi. However, these are rudimentary in nature and do not take into account the diversity of client types and user applications. Target wake time (TWT) allows an AP to manage activity in the BSS to minimize contention between clients and to reduce the amount of time for which a client in PS mode needs to be awake. An AP achieves this by scheduling clients to operate at non-overlapping times and/or frequencies, and by concentrating AP-client frame exchanges in predefined service periods. TWT schedules can be of two types: i) Broadcast, for a group of clients and ii) Individual, for specific clients. The figure below illustrates an example of Individual TWT.

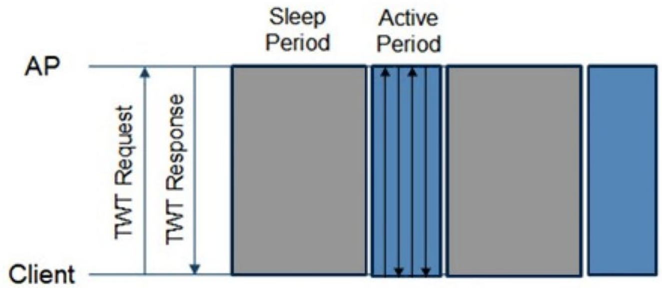

Figure 8: TWT Example

Extended Range

To support large cells, WiFi 6 also defines the Extended Range (ER) BSS. The same AP can advertise two types of BSS: ER and non-ER, with the former expected to have a larger coverage area than the latter. This differentiation is achieved by advertising ER BSS with a special ER beacon that uses a 242-tone RU transmitted in the primary 20 MHz channel.The ER feature is supported only for SU transmissions, i.e. it cannot be combined with OFDMA and/or SU-MIMO/MU-MIMO. In addition, the HE ER SU PPDU supports only a single 242-tone or 106-tone RU. The HE ER SU PPDU format is similar to the HE SU PPDU format, except that the HE-SIG-A field is repeated. This effectively boosts the HE-SIG-A field by 3dB, thus improving the reception at cell edge.

Dual Carrier Modulation (DCM)

For robust reception in challenging scenarios, WiFi 6 also supports DCM for MCS 0,1,3, and 4 (BPSK, QPSK and 16-QAM modulations). DCM modulates the same information on a pair of sub-carriers. This effectively halves the transmission rate compared to non-DCM transmission. DCM is supported only for 1 and 2 stream non-MU-MIMO transmissions and cannot be combined with Space-Time Block Coding (STBC). DCM is applicable to the HE-SIG-B and Data fields only.

Conclusion

WiFi 6 is a technological leap for next-generation enterprise wireless networks. It includes a slew of features to improve the coverage, capacity and spectral efficiency of WiFi networks. OFDMA and DL/UL MU-MIMO are two key features that are expected to improve the overall system capacity and enhance end user Quality of Experience. Arista Networks is committed to deliver high-quality WiFi 6 Access Points with support for all the key features highlighted in this document. For details, visit https://www.arista.com/en/products/cognitive-wifi.

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