LANCOM Whitepaper IEEE 802.11ac

IEEE 802.11ac is a WLAN standard in the 5 GHz frequency band. With gross data rates beyond 1 Gbps, it offers a considerable performance gain compared to the IEEE 802.11n standard. This improvement in performance has become a necessity: With the growing number of mobile devices at the workplace and the convenience of wireless access now taken very much for granted, the demand for bandwidth is on the increase.

This white paper describes the innovations arriving with IEEE 802.11ac and how they impact the performance of WLANs.

What's new with IEEE 802.11ac

A variety of innovations combine to provide the WLAN data rate that is considerably enhanced over the preceding IEEE 802.11n standard. The implementation of the new innovations is taking place in several steps. The first available devices with support for IEEE 802.11ac are described as "Wave 1". These provide a data rate far greater than any previous WLAN device and cross the threshold into Gigabit WLAN. This is accomplished by the following features.

80 MHz channel width

The maximum channel width is increased from 40 MHz to 80 MHz. The number of subcarriers available for data transfer is increased from 108 to 234. This has more than doubled because the transition zone between the two adjacent 40 MHz channels is used for data transfer (fig. 1) and fewer subcarriers are required than pilot carriers (8 instead of 2x6).

Assuming a data rate of 150 Mbps on a 40 MHz channel, the data rate available with an 80 MHz channel width increases to 325 Mbps.

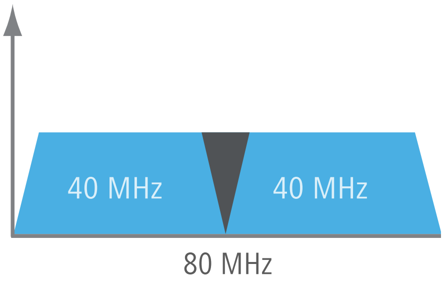

Figure 1: 80 MHz channel width incl. transition zone

256-QAM modulation

QAM (Quadrature Amplitude Modulation) is a modulation method that combines amplitude and phase modulation. The higher the modulation, the greater is the number of bits per transmitted symbol. With the 64-QAM used for the IEEE 802.11n standard, the bit rate is limited to 6 bits per symbol. 256-QAM increases this to 8 bits per symbol, resulting in a 33% improved data rate. In combination with the 80 MHz channel width, the maximum gross data rate increases to 433.33 Mbps. Figure 2 is a schematic representation of the different modulations.

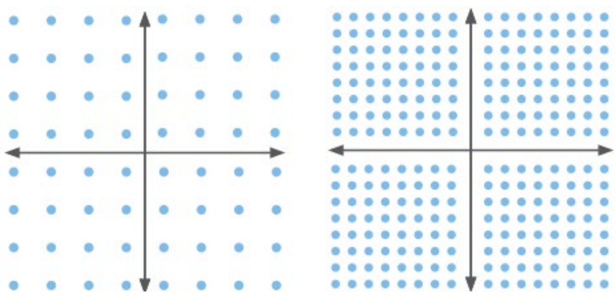

Figure 2: 64-QAM and 256-QAM in comparison

MIMO

MIMO (multiple input multiple output) uses various transmitters and receivers to realize several parallel data streams, known as spatial streams. Reflections and differences in distance between the individual senders and receivers cause the transmit times of the signals to differ. These distinct data streams can be used to carry greater amounts of data. For example, 3x3 MIMO uses three separate transmitters at the access point and three separate receivers at the client to form a Wi-Fi connection. The receiver picks up the signals sent by the separate transmitters (fig. 3). On the basis of the signals received, the access point or client can reassemble the various data packets. The result in this case is an increase in data throughput by a factor of three. If we take the 80 MHz channel width and 256-QAM into account, the result is a gross data rate of 1.3 Gbps.
3x3 MIMO (and less commonly 4x4 MIMO) was previously available with IEEE 802.11n.

Figure 3: 2x2 MIMO

MIMO	80 MHz
1x1	433
2x2	866
3x3	1300
Gross data rate in Mbps depending on MIMO and channel width in Wave 1	

Increased battery lifetime

The gain in speed from IEEE 802.11ac is also relevant to mobile devices such as tablet PCs and smart phones. To reach a higher data rate, less spatial stream are needed, which in turn reduces the power consumption of the WLAN module. In addition, the increased data rates increase the client's battery life even further because the radio module is active less of the time.

Enhancements in Wave 2

The second phase ("Wave 2") of the standard's introduction produces further functions that increase the overall gross data rate while at the same time improving on efficiency.

4x4 MIMO

The enhancement of MIMO to 4x4 with up to four spatial streams is a logical step towards expanding the capacities provided by IEEE 802.11ac. The gross data rate can be improved by a further 33% with 4x4 MIMO.

Multi-user MIMO

Multi-user MIMO (MU-MIMO for short) allows the spatial streams of an access point to be shared between different clients. Normal MIMO allows the use of only a single MIMO configuration. With MU-MIMO, several clients can be provisioned simultaneously, and the overall bandwidth available for parallel data transmission is increased. For example, MU-MIMO enables an access point with 3x3 MIMO to divide its three spatial streams in parallel between a 2x2 MIMO client and a 1x1 MIMO client (such as a notebook or smart phone, fig. 4).

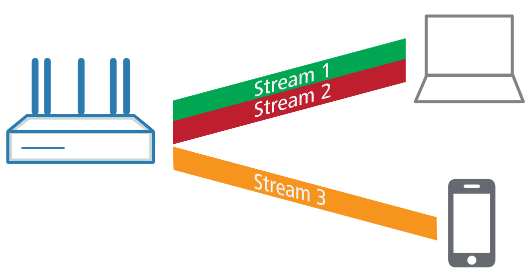

Figure 4: Multi-user MIMO

Beamforming

Beamforming enables an access point to control the strength of the signal in relation to the direction. For example, certain clients can be offered a particularly good connection while the other clients not using the signals are subjected to less interference. In combination with MU-MIMO, the various clients receive dedicated spatial streams with a minimum of interference, which has a positive influence on the available gross data rates for all of the clients (fig. 5).

Although beamforming was an option with IEEE 802.11n, it was never specified precisely. This resulted in proprietary implementations, which only operate with specific hardware. With IEEE 802.11ac, beamforming is specified within the standard, so compatibility is assured.

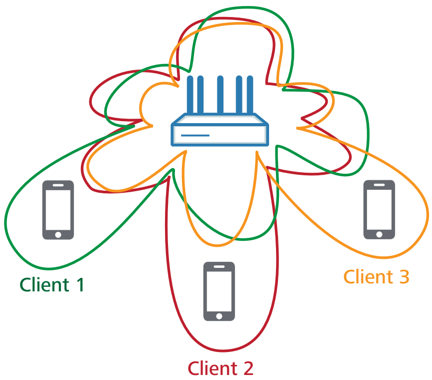

Figure 5: Beamforming

160 MHz channel width

A further increase of channel width up to 160 MHz doubles the performance yet again. This is implemented either with a single 160 MHz channel or by combining two directly adjacent 80 MHz channels in order to achieve the corresponding performance. For each of these methods, a total of 468 subcarriers are available for data transfer, whereby no distinction is made between the operation of a contiguous 160 MHz channel or two separate 80 MHz channels. This function is particularly interesting due to the limitations of finding a contiguous 160 MHz spectrum in the 5 GHz frequency band (see fig. 5 and section DFS).

MIMO	80 MHz	160 MHz
1x1	433	866
2x2	866	1733
3x3	1300	2600
4x4	1733	3466

The standard's maximum gross data rate in Mbps depending on MIMO and channel width

Outlook

There are further functions that are described in the standard IEEE 802.11ac, but which are not mandatory for wave 1 or wave 2. Among others, support for up to eight spatial streams could be possible.

Infrastructure requirements

The infrastructure must meet a number of requirements to exploit the full speed of IEEE 802.11ac, from Wave 1 onwards:

- IEEE 802.11ac clients are required to take advantage of the new standard.
- Gigabit switches with at least 1 Gbps or better 10 Gbps uplink ports to exploit the high transmission rates.
- IEEE 802.3af to power the access points via Ethernet. With 3x3 dual radio access points, 802.3at (PoE+) is recommended for full power.
- Dual radio access points supporting IEEE 802.11ac at 5 GHz for maximum performance and 2.4 GHz for access by older clients.

DFS

Dynamic Frequency Selection (DFS) is a mechanism required to operate Wi-Fi in the full 5 GHz frequency band by both the European regulatory authority ETSI and the United States FCC. DFS is used to automatically switch the Wi-Fi channel if it detects a radar pattern which takes priority and requires a change of channel. Examples include weather radar, ship radar, and military applications operating in the 5 GHz frequency band. DFS is obligatory in Europe and the United States for the frequency ranges 5.25 – 5.35 GHz and 5.47 – 5.725 GHz, corresponding to the channels 52 – 64 and 100 – 140. These are marked in blue in the frequency overview (fig. 6). The illustration shows just how the wide channels (80 and 160 MHz) used by IEEE 802.11ac require particular conditions. There are very a few ways of realizing the planned 160 MHz channel bandwidth. It is easier to operate narrower channel widths, but of course the maximum data throughput decreases. For this reason the planning of IEEE 802.11ac infrastructures demands a close consideration of the Wi-Fi environment.

The following is worth noting when planning the channels:

- A high proportion of non-overlapping channels is required to avoid interference.
- Channel widths of 80 MHz and 160 MHz can probably be used only under very limited circumstances.
- With IEEE 802.11ac, narrower channel widths still offer considerably higher throughput rates than equivalent IEEE 802.11n channels.

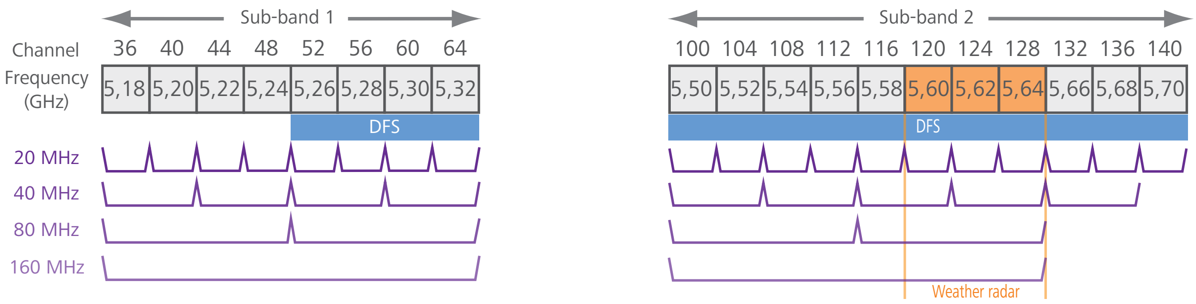

Figure 6: Channels in the 5 GHz frequency band

Summary

By crossing the Gigabit threshold, the performance difference between wired and wireless networking has become a lot smaller or even negligible. The increased battery life of mobile devices is another aspect of improved mobile and wireless working.