BREAKING THE GIGABIT-PER-SECOND BARRIER WITH 802.11AC

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Wireless LAN throughputs have come a long way in the past 20 years. Especially since the adoption of the first 802.11 standard in 1997, there has been a steady exponential growth in the maximum available data rate as illustrated by Figure 1. While current IEEE 802.11n devices have reached data rates of up to 600 Mb/s, the 802.11ac task group started working on an amendment to achieve aggregate throughputs beyond 1 Gb/s in the 5 GHz band. This is the first time that a 802.11 amendment is targeting to improve the total network throughput rather than only improving the throughput of a single link. In the 802.11ac draft standard, throughput is increased by the following mechanisms:

- Multi-user multiple-input multiple-output (MU-MIMO)
- Larger channel bandwidths of 80 and 160 MHz
- 256-quadrature amplitude modulation (QAM)

MU-MIMO

Most wireless networks have multiple active clients that share the available bandwidth. If this sharing is done in time, then the overall throughput can only be increased by increasing the link rate for all clients. Many clients cannot transmit at the highest 802.11ac rates though because they only have one or two antennas. For such clients, MU-MIMO is the solution to get significant network throughput gains. A MU-MIMO capable transmitter can transmit multiple packets simultaneously to multiple clients. In 802.11ac, a MU-MIMO mode is defined with up to eight spatial streams divided across up to four different clients. For example, in 80 MHz mode it would be possible to send packets to four clients simultaneously at a data rate per client of 866.6 Mb/s, assuming all clients can receive two spatial streams. This means the total data rate of 3.46 Gb/s is four times larger than it would have been without MU-MIMO. The data rate per client is also larger, because the MU-MIMO packets can be transmitted at the maximum data rate per client while without MU-MIMO, each client can only be transmitted to about a quarter of the time such that the effective per-user throughput is a quarter of its maximum. In practice, the throughput gain of MU-MIMO is reduced a bit by the fact that acknowledgments are still sent sequentially in time. Also, depending on the signal-to-noise ratios for all clients, it may not be possible to maintain the maximum data rates in a MU-MIMO packet because a MU-MIMO link does lose some signal-to-noise ratio relative to a single-user link. One of the challenges in launching successful MU-MIMO products will be how to do the link adaptation in an environment with changing numbers of clients and potential switches between single-user and multi-user packets. The 802.11ac draft standard provides mechanisms for clients to recommend a certain modulation and coding scheme (MCS), but it is up to vendors how they actually use such mechanisms to do the link adaptation. Another challenge will be how to deal with time variation in the channel because MU-MIMO requires accurate channel knowledge in order to minimize inter-user interference. The draft 802.11ac standard specifies a single method of explicit compressed beamforming feedback to enable both MU-MIMO and single-user beamforming. The fact that a single method was picked is expected to help in market adoption and ensuring interoperability. This is in contrast to 802.11n where the presence of multiple feedback options avoided widespread adoption of beamforming.

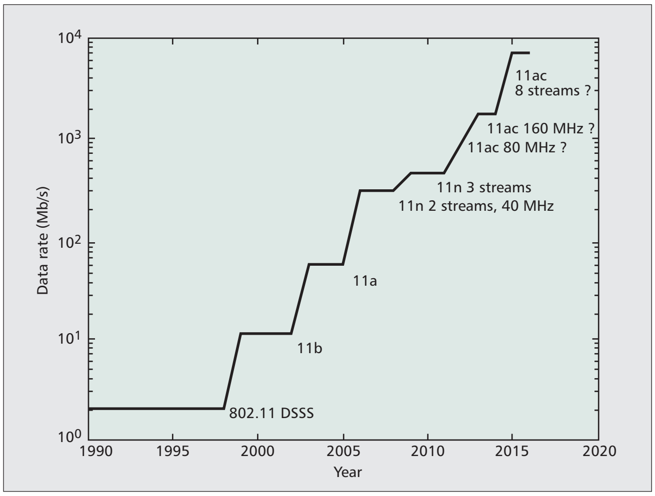

Figure 1. *Historical growth of maximum WLAN data rate based on availability dates of devices.*

LARGER BANDWIDTH

In 802.11n, channel bandwidths of 20 and 40 MHz are defined. In 802.11ac, 2 more bandwidths of 80 and 160 MHz are introduced. The 80 MHz mode uses two adjacent 40 MHz channels with some extra subcarriers to fill the unused tones between two adjacent 40 MHz channels. The 160 MHz mode uses two separate 80 MHz channels without any tone filling in the middle of these two subchannels. The two 80 MHz channels do not have to be adjacent. This increases the probability of finding a 160 MHz channel at the cost of additional hardware to send an receive in two non-adjacent 80 MHz channels. In a 160 MHz channel, a data rate of 866.6 Mb/s can be achieved for a single spatial stream using 256-QAM, rate 5/6 coding, and a short guard interval. With the maximum number of spatial streams of eight, data rates up to 6.933 Gb/s are possible.

256-QAM

The highest order constellation in wireless LAN has been 64-QAM ever since the adoption of the 802.11a standard. With the current state of the art in radio frequency (RF) technology, it was believed that 256-QAM should be possible to provide a further boost on data rates in 802.11ac. The maximum coding rate of 5/6 stays the same as in 802.11n. With 256-QAM, the maximum single user rate for an 80 MHz device with two spatial streams becomes 866.6 Mb/s vs. 650 Mb/s for the largest 64-QAM rate.

INTEROPERABILITY

Devices that implement the new 802.11ac standard have to be fully interoperable with 802.11n and 802.11a. Notice that 802.11ac only applies to the 5 GHz band, as there is no room in the 2.4 GHz band for the 80 and 160 MHz channels. Coexistence with existing 802.11a/n devices is ensured by having a backward compatible preamble. The first part of the 802.11ac preamble is identical to 802.11a up to and including the 11a signal field. The signal field contains a length field and a 6 Mb/s rate indication, to ensure that any existing 11a/n device will defer for the correct packet duration.

CONCLUSION

The 802.11ac standard will push wireless LAN throughputs over the gigabit-per-second barrier in the coming years. Rather than only improving single link throughput by using more bandwidth and 256-QAM, 802.11ac also improves network throughput by adding MU-MIMO capability. MU-MIMO makes it possible to achieve large throughputs cost effectively by having relatively simple client devices with just one or two antennas that can be simultaneously transmitted to by an access point that may have up to eight antennas.