802.11AC WAVE 2

A RIVERBED XIRRUS WHITE PAPER

riverbed | XIRRUS

Introduction

Wi-Fi has undergone an incredible degree of transformation since the Institute of Electrical and Electronic Engineers (IEEE) first standardized the technology in 1997 as the 802.11 standard. Today, 802.11 wireless systems can communicate over 1000 times faster than the original standard, and there is no end in sight as to where further innovation will take us.

802.11ac is the latest extension to the IEEE Wireless LAN standard and was approved in 2013. It defines wireless technology for Very High Throughput (VHT) networks, providing connection speeds that reach up to several Gigabits per second.

802.11ac has entered the commercial market in two distinct phases, dubbed Wave 1 and Wave 2. This strategy was devised by the Wi-Fi Alliance (WFA), a nonprofit organization composed of companies that work cooperatively to ensure that Wi-Fi technology is interoperable, understandable, and useable. The WFA recognized that 802.11ac is both incrementally and extensively different than its predecessor 802.11n. It determined that the incremental enhancements would significantly improve Wi-Fi performance in a short amount of time, thanks to modest adjustments to end-user products. The more extensive technology changes, however, would produce even greater performance upgrades but would also take the industry longer to implement. Therefore, the decision was made to roll out 802.11ac in two stages (Wave 1 and Wave 2).

802.11ac Wave 2 products began shipping in 2015, and enhanced throughput to a theoretical maximum of 3.47Gbps. More importantly, Wave 2 introduces a technology called MU-MIMO that greatly increase the efficiency of Wi-Fi solutions. This white paper provides an overview of 802.11ac Wave 2 technology and its potential impact on Wi-Fi networks.

Key Features And Comparisons

802.11n technology revolutionized Wi-Fi with the introduction of channel bonding, MIMO (Multiple Input, Multiple Output), and frame aggregation technologies that collectively improved Wi-Fi throughput by more than eight times above the previous standard. 802.11ac incrementally improves on all of these features. Table 1 below shows the key 802.11ac incremental advances from 802.11n for both Wave 1 and Wave 2 phases.

Channel bonding increases the width of the communication channel. Wave 1 expanded maximum channel widths from 40MHz (the 802.11n limit) to 80MHz, while Wave 2 increases it further to 160MHz. Channel bonding at those widths is impossible in the 2.4GHz unlicensed band, so 802.11ac is defined for operation exclusively in the 5GHz unlicensed band.

MIMO technology enables a Wi-Fi radio to transmit multiple 'streams' of data concurrently in order to increase throughput. MIMO operation in 802.11ac increases support from three spatial streams in Wave 1 to four spatial streams in Wave 2. Finally, frame aggregation rises from a maximum of 64 Kbytes in 802.11n to over 1 million bytes in 802.11ac, providing further performance improvements.

Feature	802.11n	802.11ac Wave 1	802.11ac Wave 2
MIMO Spatial Streams	3 streams	3 streams	4 streams
Modulation	64 QAM	256 QAM	256 QAM
Operating Band	2.4 / 5GHz	5GHz Only	5GHz Only
A-MPDU Frame Aggregation	64 Kbytes	1 Mbyte	1 Mbyte
Max Data Rate	450 Mbps	1300 Mbps	3467 Mbps

TABLE 1 – Key Incremental 802.11ac Changes

802.11ac Wave 2 introduces several major technology updates for Wi-Fi (see Table 2). The most significant is a new feature called Multi-User MIMO (MU-MIMO). MU-MIMO is a radical new technology that attempts to support higher density deployments by servicing multiple endpoint devices concurrently. In addition, several channel bonding improvements enhance overall throughput by utilizing wider portions of the 5GHz band as well as enabling more flexible use of the spectrum.

Feature	802.11n	802.11ac Wave 1	802.11ac Wave 2
MU-MIMO	No	No	Supported
Adjacent Channel Bonding	40MHz	80MHz	160MHz
Non-Adjacent Channel Bond	No	No	80+80MHz
Dynamic Bandwidth Allocation	No	No	Supported
Implicit Feedback Beamforming	Supported	No	No
Explicit Feedback Beamforming	Supported	Supported	Supported

TABLE 2 – Key 802.11ac enhancements

Key Feature Details

Wave 2 Channel Bonding

802.11ac Wave 2 supports the existing bonding methods of 802.11ac Wave 1 (up to 80MHz wide), along with added options for 160MHz wide channels. Wider bonding allows for higher throughput between two wireless devices, but the finite amount of spectrum in the 5GHz band limits the number of ways that wider channels can be formed. Figure 1 shows the FCC Part 15 802.11 Channel Plan. For the 160MHz case there are only two ways to form the adjacent bonds, and both of them use the radar (DFS) channels which are subject to being blocked from use. There are six adjacent channels formable for 80MHz bonding, two of which are in the radar section.

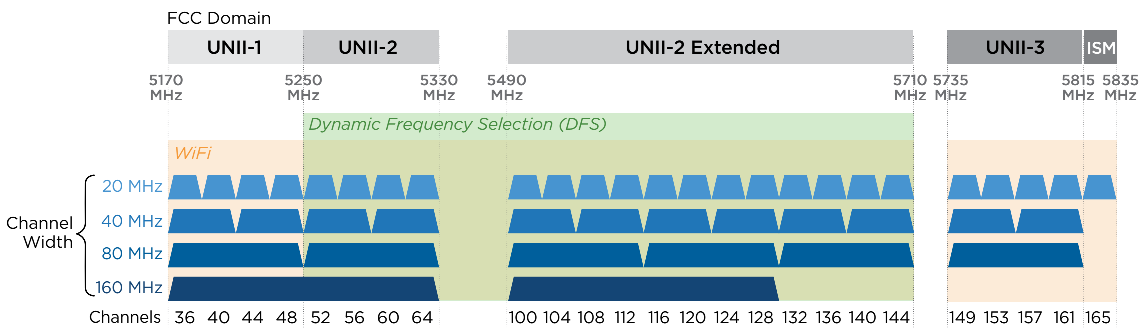

FIGURE 1 – FCC 802.11 Channel allocation

To increase the number of bonding options for 160MHz, Wave 2 introduces a new feature called 80+80 that allows non-adjacent bonding of the 80MHz wide channels. Figure 2 shows 80+80 bonding options. There are thirteen ways to bond two non-adjacent 80MHz channels, five of which avoid the radar channels. However, this feature is not without additional costs. Since the bonding is done on two separate channel sets, it requires two distinct sets of RF chains. This can be accomplished by adding a second RF processing chain to the hardware (at significant cost and power), or by splitting the existing processing chains.

In other words, to support 80+80 channel bonding with four spatial streams, a 4x4 (four transmitting antennas, four receiving antennas) 80MHz MIMO transceiver would have to duplicate its entire signal processing core to service the second channel. This is because spatial stream processing has to be treated separately on a non-contiguous second channel. The alternative is to divide up the four existing processing resources between the two channels to support 80+80MHz in a 2x2 configuration. This is the path being taken by many chip manufacturers. The result is utilization of a wider band, but without any additional throughput.

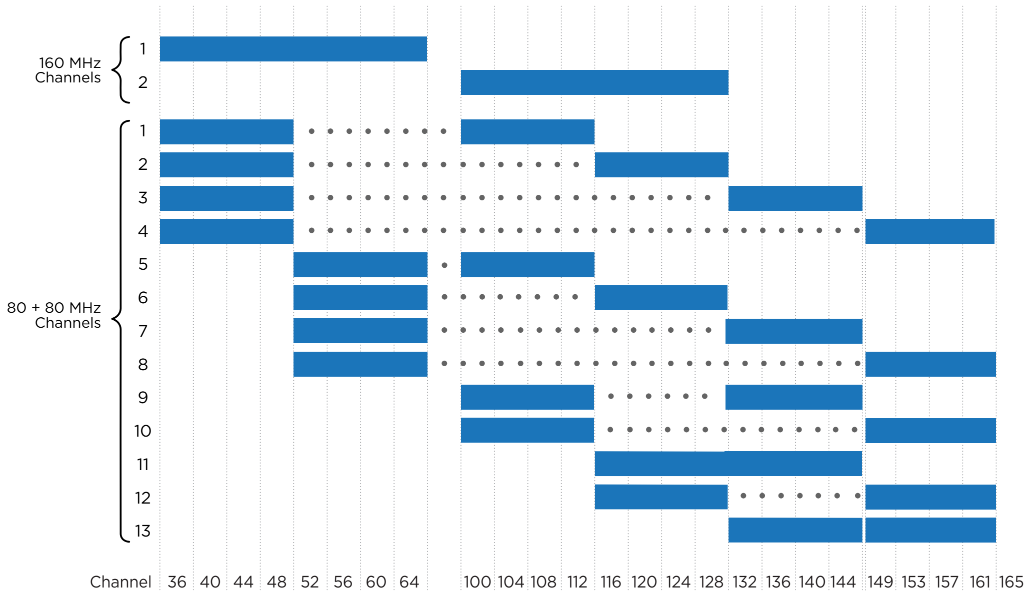

FIGURE 2 – 802.11ac 80+80 Channel Bonding Options

Dynamic Bandwidth Allocation, another novel component of 802.11ac, allows two APs to occupy adjacent 40MHz wide channels and collaboratively share the combined 80MHz channel between them. A new feature in 802.11ac allows clients to declare the desired width of the band in a frame's preamble, creating a mechanism for changing the width of the band on a frame-by-frame basis (see Figure 3).

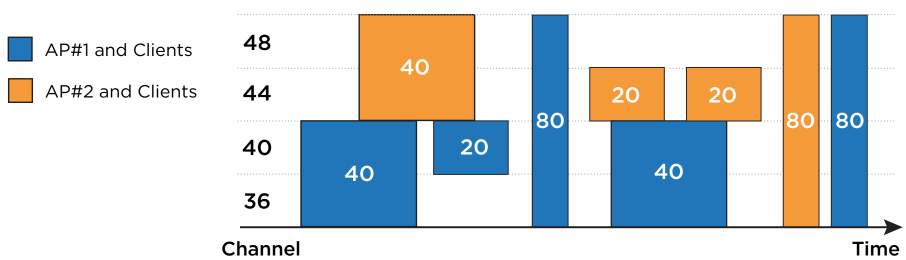

FIGURE 3 – Dynamic Bandwidth Allocation

Wave 2 MU-MIMO

Multi-User MIMO allows the spatial streams of an access point (AP) to be allocated across multiple receiving clients. This is a significant change from previous MIMO systems.

Single User MIMO (SU-MIMO), which is employed in 802.11ac Wave 1 systems, uses all of the spatial streams for a single connection between the AP and the client. The client must support the same antenna configuration as the AP, however, in order to utilize the full connection rate. Therefore, a 4x4 system requires four antennas on either side of the link between AP and client. But what if a client only has one antenna? Under these circumstances the client can still connect to the AP, but only at 1x1 rates. In these cases the AP is connecting to the client at less than its maximum throughput capability. Over-the-air bandwidth is therefore being 'lost' while the AP communicates to a less capable client. See *Figure 4*.

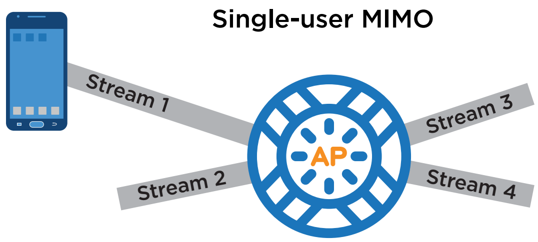

FIGURE 4 – Single-User 4x4 MIMO System Communicating to 1x1 Client

MU-MIMO addresses this inefficiency by allowing the AP to split up its spatial streams and apply them concurrently to multiple clients. For instance, if a 4x4 MU-MIMO AP connects to a 2x2 client, it can also simultaneously connect to two other 1x1 clients using its third and fourth spatial streams. All devices are then operating at their full connection capability and the RF is being used much more efficiently.

MU-MIMO operation is limited by the AP's antenna configuration. The maximum number of clients communicating concurrently with the AP is equal to the number of TX chains (spatial streams) that the AP has. For example, a 4x4 AP can support at most four 1x1 MU-MIMO clients. It is then up to the AP to form transmission groups from the clients associated to it. So if the 4x4 AP has 40 1x1 clients associated, it can place them into ten transmit groups of four devices each. The AP then services the various transmission groups according to its programmed policies.

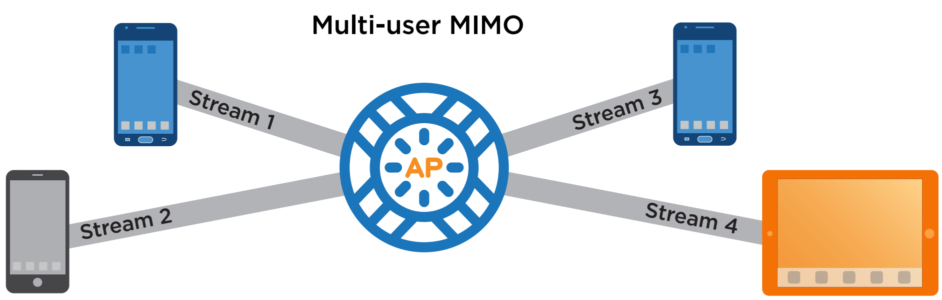

FIGURE 5 – Multi-User 4x4 MIMO System Communicating to 4 1x1 Clients

MU-MIMO is a big technological step forward for Wi-Fi that relies on a critical feature known as beamforming. Beamforming was first introduced in 802.11n for MIMO communication. Essentially, it is a way to characterize and compensate for the distortions present in the airspace between two devices.

Beamforming relies on determining the characteristics of the RF channel. The most accurate way to do this is to measure the channel directly during operation in a process called 'channel sounding.' With this method, the AP sends a pre-known sounding frame to a receiving client. The receiving client measures the difference between the original frame and the received frame. It then sends the measured differences back to the AP. The AP now knows the outbound RF characteristics of the channel and can apply adjustments to its transmitted frames.

For Wave 2 MU-MIMO, each receiving client is in a different physical position relative to the AP, and channel conditions from client to client are unique. As a result, every client must receive a separate sounding frame and send a corresponding beamforming feedback matrix back to the AP. The AP uses each feedback matrix to calculate a specific beamforming solution for the matching client, and then employs that solution concurrently in the frame transmission. One of the challenging parts of MU-MIMO is that in relying upon beamforming to strengthen the spatial streams to the intended recipient devices, the AP must also attenuate or nullify the same spatial streams for the unintended recipients.

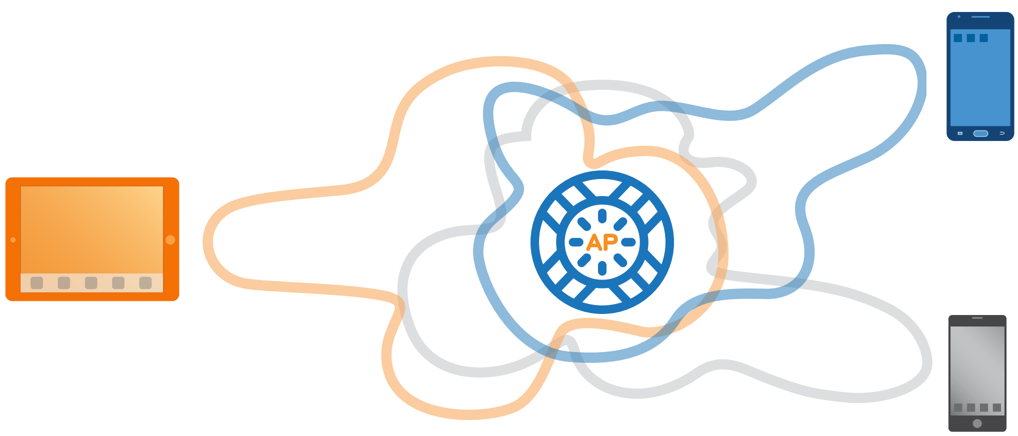

FIGURE 6 – 3x3 AP MU-MIMO Beamforming to Three 1x1 Clients

Compatibility

There are two compatibility dimensions to consider for 802.11ac Wave 2. The first is backward compatibility with existing 802.11ac Wave 1 products and other previous devices. The second is the compatibility of Wave 2 devices with each other.

Like all 802.11 standards, Wave 2 technology has been specifically drafted to support operation of all predecessor technologies so that Wave 2 APs will work with all existing Wi-Fi clients in the field. However, Wave 1 clients are only SU-MIMO capable. They are not forward compatible with Wave 2 APs and therefore not able to participate in MU-MIMO communications. This is because they lack the beamforming feedback and group forming protocols needed to form MU-MIMO groups.

Deployment Considerations

As clearly evident from a review of its capabilities, 802.11ac Wave 2 delivers significant enhancements to Wi-Fi technology. By increasing speed and adding simultaneous multi-user communications, Wave 2 brings Wi-Fi closer to the point where it can replace wired Ethernet as the connection of choice. These enhancements ultimately provide users with a better performing and more reliable online experience in which Wi-Fi operates as a utility – a resource that's always available and which users can simply count on as a predictable part of their lives.

Reaping the benefits of Wave 2 requires client devices that support Wave 2 standards. When should an organization make the investment necessary to upgrade to Wave 2? And what considerations should be made in advance of this decision?

A key element for any organization to consider is where they find themselves in their own technology refresh cycle. If existing infrastructure is old and under stress, upgrading or adding new equipment to address the issue now is the most essential step. The prompt timing of the upgrade will likely be far more impactful than whatever specific technology gets deployed under the hood.

Ideally, a more long-term view for the network should be adopted. Unfortunately, in most cases it is very difficult to know what requirements a wireless network will face in the next two years of its lifespan, let alone in the next five. As with most technology transitions, it comes down to deploying the newest technology wherever possible, but making sure to not put off needed improvements just for the sake of installing the latest solution.

Many organizations, especially larger ones, introduce new infrastructure over time. This is often the best way to incorporate new technology – through incremental upgrades that, in effect, test the waters before moving on to ubiquitous adoption.

Cost is often a significant factor in these decisions. New technology can be more expensive than the previous generation. Cost of the Wave 2 access points are more affordable since the introduction of Wave 2 products in 2015. The time is right to take advantage of this powerful Wi-Fi technology. With the enhancements and theoretical speeds of up to 3.47Gbps, you can reap the benefits of Wave 2 products for a long time.

Conclusion

The 802.11ac Wave 2 technology has become a mainstream Wi-Fi connectivity solution for businesses today. The technology has proved to deliver tangible benefits over previous standards. As part of your client refresh cycle, deploy Wave 2 compatible clients to take full advantage of the improvements in Wave 2.

The benefits of Wave 2 will certainly come to bear within the lifespan of a deployment installed today. Organizations must pay close attention to the value and impact of these products, as the current offerings provide a significant price performance benefits. Deciding how and when to use this technology, however, will depend on each organization's unique timing, budget, and needs.

Learn More

For more information on Riverbed Xirrus including customer stories, product information, and a free trial, visit us at Riverbed.com/Xirrus.

World Headquarters
Riverbed Xirrus
680 Folsom St., 6th Floor
San Francisco, CA 94107 USA
Tel: +1 (877) 483-7233

Sunnyvale Office
Riverbed Xirrus
525 Almanor Ave., 5th Floor
Sunnyvale, CA 94085 USA
Tel: +1 (408) 664-3000

EMEA Office
Riverbed Xirrus
Maxis 1, 1st Floor
Western Road, Bracknell
Berkshire. RG12 1RT, UK
Tel: +44 1344 401900

MS-369_XRS_WP_US_051518