WHITEPAPER

IEEE 802.11ac: What Does it Mean for Test?

LITEPOINT

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Introduction to 802.11ac

Late in 2008, a new task group (TG) was formed within the IEEE 802 Standards Committee with the goal of creating a new amendment to the 802.11-2007 standard. The new amendment, known as 802.11ac, includes mechanisms to improve the data throughput of the existing Wireless Local Area Networks (WLAN), enabling wireless networks to offer wired network performance.

Since its formation, the TGac has made significant progress in the definition of the technology: in January 2011, the framework specifications for the technology moved into draft form, which then underwent subsequent revisions and is currently available in version D1.1. The draft was completed at the end of 2012, a certification program was established in June 2013, and ratification of the 802.11ac standard is planned for February 2014 (as shown in Figure 1).

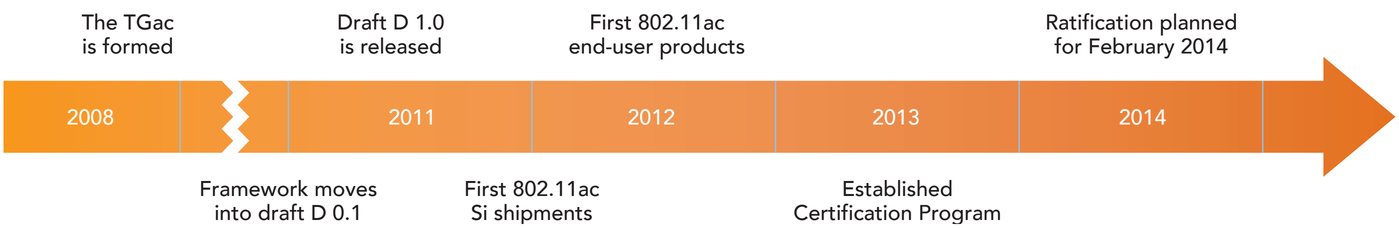


Figure 1: History and Future Dates of the 802.11ac Amendment

Even though the 802.11ac amendment will not be published until early 2014, the draft availability means that the silicon requirements are generally finalized, and chipset companies were able to begin marketing their 802.11ac devices the latter half of 2011. The first 802.11ac silicon shipments began in early 2012. Dozens of routers, access points, and dongles have been introduced to the market since then, and the first 802.11ac-enabled smart phones were introduced in early 2013.

802.11ac is expected to make a substantial impact in the marketplace, with over one billion ICs forecasted to be shipped worldwide by 2015. There are multiple reasons for the very high expectations around 802.11ac. First, not only does the technology promise to deliver for the first time data rates over 1 Gbps, but also includes advanced features to improve the user experience. Similar to LTE Advanced, it employs more spatial streams through 8 x 8 Multiple-Input Multiple-Output (MIMO), offers wider channel bandwidths (up to 80 MHz channels) and even makes use of channel aggregation, for up to 160 MHz of total bandwidth. Furthermore, key to the success of 802.11ac will be that it is an evolutionary technology: it achieves its goals, and breaks a few important paradigms, while building on the existing 802.11n amendment. This is a great advantage since it enables manufacturers and users a relatively easy transition from existing WLAN networks and applications (which use 802.11n or previous amendments), to those that will use 802.11ac.

In this document we will describe the motivations, key features, and market forecast of 802.11ac. We will then review the current 802.11ac physical layer (PHY), and the several applications enabled by the new 802.11ac capabilities. Finally, we will discuss how new 802.11ac specifications impact the requirements for test equipment necessary to validate the technology in both R&D and manufacturing environments.

802.11ac: Overview

Motivations

The purpose of the 802.11ac amendment is to improve the WiFi user experience by providing significantly higher throughput for existing application areas, and to enable new market segments for operation below 6 GHz including distribution of multiple data streams. With data rate over 1 Gbps and several new features, throughput and application-specific performance of 802.11ac promise to be comparable to that of existing wired networks.

Also known as Very High Throughput (VHT), 802.11ac achieves this purpose by building on the existing 802.11n technology. In doing so, it continues the long-existing trend towards higher data rates (Figure 2), to meet the growing application demand for WiFi network capacity and enable WiFi to remain the technology of choice at the edge.

To increase data rates, the TG for 802.11ac has defined an ample set of optional parameters in addition to some that are mandatory. The flexibility built in the technology is typical of the latest wireless technologies (see LTE), and enables chipset and device manufacturers to make the best use of the available resources and tailor their products to the specific need of the targeted application. Specifically, the TGac has defined optional parameters for:

- Channel Bandwidth
- Modulation
- Number of Spatial Streams

An 802.11ac device making use of only the mandatory parameters (80 MHz bandwidth,1 spatial stream, 64 QAM, 5/6 coding with long guard interval) will be capable of a data rate of about 293 Mbps. A device that implements all optional parameters (160 MHz bandwidth, 8 spatial streams, 256QAM, 5/6 coding with short guard interval) will be able to achieve over 6 Gbps.

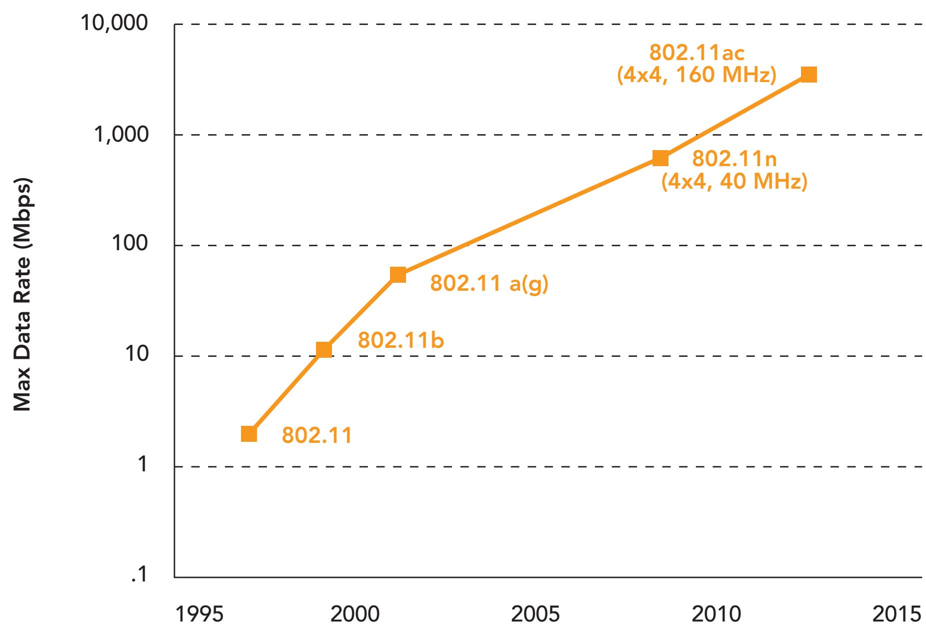


Figure 2. 802.11ac continues the trend of WiFi technologies towards higher data rates

Key Characteristics

802.11ac adopts several features and unique mechanisms to increase throughput, improve the user experience, and more. The key characteristics of this new technology are:

- 5 GHz Frequency Band
- Wide Channel Bandwidth
- New Modulation and Coding Scheme (MCS)
- Backwards Compatibility Coexistence Multiple Spatial Streams Beamforming and Multi-User MIMO Energy Efficiency

5 GHz Frequency Band

Contrary to 802.11n, which operates in both the 2.4 GHz and 5 GHz RF bands, 802.11ac devices will operate only in the 5 GHz RF band. The choice to restrict usage in this band is mainly driven by the wider channel bandwidth requirements for 802.11ac. As the bandwidth increases, channel layout becomes a challenge, especially in the crowded and fragmented 2.4 GHz band. Even in the relatively expansive 5 GHz band, manufacturers will need to adapt automatic radio tuning capabilities to use the available resources wisely and conserve spectrum.

Wide Channel Bandwidth

802.11ac includes both manditory and optional bandwidth enhancements over 802.11n.

In addition to the 20 MHz and 40 MHz channel bandwidths supported by most 802.11n devices today, the 802.11ac draft specifications include a mandatory, contiguous 80 MHz channel bandwidth. The key benefit of this wider bandwidth is that it effectively doubles the PHY rate over that of 802.11n at negligible cost increase for the chipset manufacturer. With 80 MHz contiguous bandwidth mode, not only is the data rate/throughput higher, but also the efficiency of the system increases, and data transfers can be made faster, thus enabling new applications not supported by the current 802.11n specifications.

In addition, the 802.11ac specifications include an optional 160 MHz channel bandwidth, which can be either contiguous or non-contiguous (80+80 MHz). In the non-contiguous case, the frequency spectrum consists of two segments; each segment is transmitted using any two 802.11ac 80 MHz channels, possibly non-adjacent in frequency. Compared with 40/80 MHz transmissions, 160 MHz PHY transmission has the advantages of reducing the complexity of the requirements (e.g. MIMO order, MCS, etc) that allow devices achieve Gbps wireless throughput, and opening the door to more applications. However, 160 MHz bandwidth in the 5 GHz band is not available worldwide, and implementations to support this feature will likely be higher in cost – hence, the decision to make this feature optional in 802.11ac devices.

New Modulation and Coding Scheme (MCS)

802.11ac uses 802..11n OFDM (Orthogonal Frequency Division Multiplexing) modulation, interleaving, and coding architecture. Specifically, both 802.11ac and 802.11n require device support for BPSK, QPSK, 16QAM and 64QAM modulation. However, there are two key differences with respect to the 802.11n specifications.

First of all, 802.11ac includes an approved constellation mapping enhancement, specifically, optional 256QAM (3/4 and 5/6 coding rates) that can be used for both 802.11ac 80 MHz and 160 MHz transmissions. The benefit of 256QAM is that it offers 33% greater throughput than a 64QAM transmission. This increase comes, however, at the cost of less tolerance of bit errors in lossy signal environments. The 256QAM modulation was added as an optional mode, as opposed to a mandatory mode, for the following reasons:

- Allow design flexibility
- Lower implementations cost for applications that do not need the higher modulation
- Ease the adoption of 802.11ac in devices that cannot meet the stringent requirements of the 256QAM mode in terms of:
  - EVM (Error Vector Magnitude)
  - SNR (Signal-to-Noise Ratio)
  - PAPR (Peak-To-Average-Power Ratio)

The second difference to 802.11n is that the number of defined MCS indices is greatly reduced. Only ten single user MCS (0 to 9) are defined in 802.11ac, significantly fewer than the 77 MCS indices specified in 802.11n.

- 802.11n required 77 MCS indices to support “unequal” modulations, e.g. a single user might receive a BPSK-modulated signal on one stream and a 16QAM-modulated signal on another.
- 802.11ac supports only equal modulations. The TGac decided to drop support of unequal modulations because this feature proved not to be successful in the marketplace (very few 802.11n devices actually supported it). Also, given the additional channel bandwidth and modulation options in 802.11ac, the number of possibilities (hence, the number of MCS indices) would be impractical.

Backwards Compatibility

802.11ac provides backwards compatibility with 802.11a and 802.11n devices operating in the 5 GHz band. This means that:

- 802.11ac interworks with devices supporting 802.11a and 802.11n technologies
- 802.11ac frame structures can accommodate transmission with 802.11a and 802.11n devices

The backward compatibility of 802.11ac is a definite advantage of 802.11ac over alternative revolutionary technologies (such as 802.11ad) that also promise to increase data rate over 802.11n, but do not operate with existing WLAN devices. Backward compatibility will ease adoption into the marketplace and ensure 802.11ac devices can seamlessly "plug into" existing WLAN networks.

Coexistence

An important component of the work in TGac is to design mechanisms to coexist with existing networks using 802.11a and 802.11n in the 5 GHz band. Examples of these mechanisms are Clear Channel Assessment (CCA), channel access fairness, and scanning and channel selection mechanisms. Coexistence mechanisms are also being defined to ensure 802.11ac with different channel bandwidths (20/40/80, and up to 160 MHz) interoperate.

Multiple Spatial Streams

802.11ac includes support for up to eight spatial streams, versus four in 802.11n. As in 802.11n, spatial multiplexing of multiple streams of data over the same frequencies takes advantage of the extra degrees of freedom provided by the independent spatial paths to effectively multiply channel capacity. The streams become combined as they pass across the channel, and the task at the receiver is to separate and decode them. Despite the complexity of this technique, manufacturers of 802.11n devices have learned to use the independent paths between multiple antennas to great effect, and can now effectively transpose this knowledge to the making of 802.11ac devices. It is likely that the first 802.11ac silicon will use multiple spatial streams.

Beamforming and Multi-User MIMO

With 802.11n, manufacturers of WiFi devices learned how to use transmit beamforming, that is, the ability to focus RF energy in a given direction to improve delivery to individual stations. 802.11ac builds on this knowledge and includes enhancements such as single sounding and feedback format (vs. multiple in 802.11n).

More importantly with 802.11ac, the TGac has built on the beamforming capabilities of 802.11n new mechanisms that enable an access point (AP) to communicate with multiple client devices in different directions simultaneously using the same channel, multiple antennas, and spatial multiplexing. For example, an eight-antenna AP might be able to use 4x4 MIMO to two physically separated stations at once. To contrast, MIMO devices today only considers point-to-point access to the multiple antennas connected to each individual terminal; hence, the AP must time multiplex to serve multiple clients.

This set of advanced mechanisms takes the name of Multi-User MIMO (MU-MIMO), and it is one of the most interesting enhancements currently on the drawing board of the TGac to increase the efficiency (number of megabits transmitted per megahertz of spectrum, Mbps/MHz) of the newest 802.11 standard.

To use an analogy, MU-MIMO leverages the fundamental of Ethernet switching, by reducing contention: it extends transmit beamforming technology to allow the AP to provide "switched" WiFi with dedicated bandwidth to stations, similar to the way the typical wired Ethernet network works today.

While the promised advantages of MU-MIMO are many and attractive, correctly using the technology requires that chipset designers and manufacturers develop spatial awareness of clients and sophisticated queuing systems that can take advantage of opportunities to transmit to multiple clients when conditions are right. In other words, the increased system capacity comes at the cost of significantly more expensive signal processing and increased complexity. For this reason, MU-MIMO (one transmitting device, multiple receiving devices) is included in the 802.11ac draft specifications only as an optional mode.

Energy Efficiency

A little known fact is that the energy efficiency, described in bits per microjoule, of the 802.11 standards has been increasing since the first amendment of the technology was ratified. Specifically, 802.11ac promises a twofold increase in energy efficiency over the existing 802.11n, as shown in Figure 3. This improvement is an effect of the several enhancements introduced by each amendment to increase the data rate of a transmission, with all other parameters constant (RF frequency, power, and bandwidth).

While the trend is little known, the increasing energy efficiency certainly has numerous benefits for the growing number of portable devices that integrate WiFi, which must work with small batteries and limited power consumption available to support the wireless communications link.

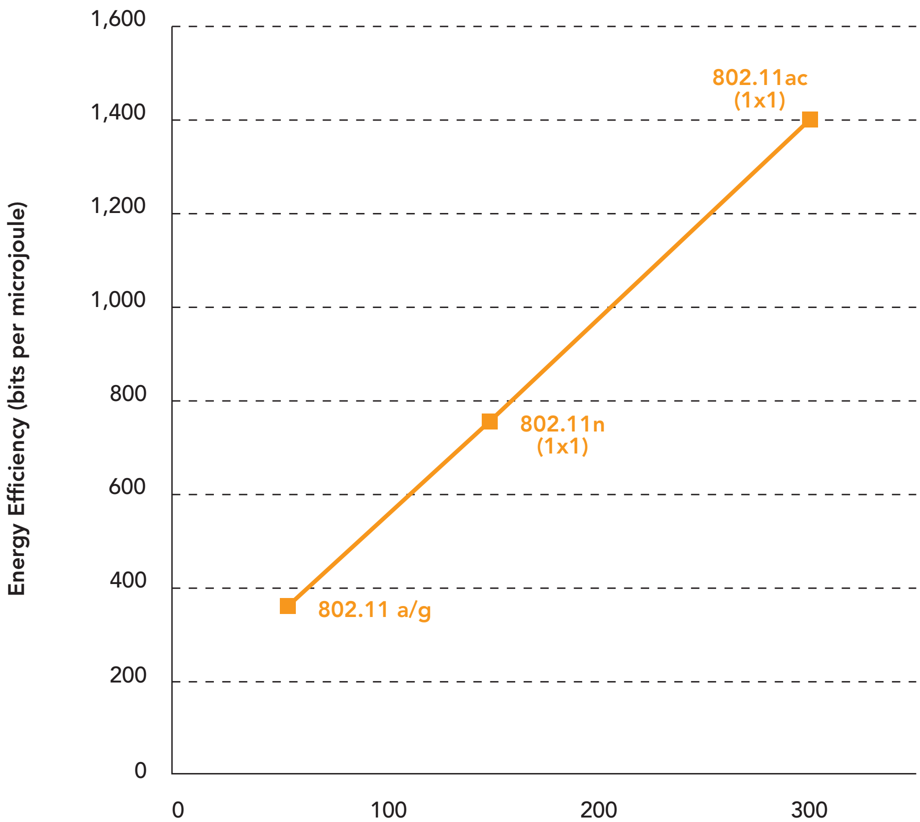


Figure 3. 802.11ac offers improved energy efficiency over previous 802.11 standards

Market Forecast

The number of wireless devices that support 802.11n has been growing rapidly in the several past years, and this growth is expected to continue in the future. Not only devices that have traditionally used previous amendments (802.11a/b/g) are adopting the newer technology, but also wireless is moving into a growing number of devices that previously did not have this capability.

In 2012, over 1.4 billion devices were shipped containing WiFi functionality, including smartphones, tablets, PCs, routers/access points, Internet access devices, automotive infotainment, and assorted consumer electronics products (sources: IDC, IHS, and Gartner, March 2013). The consumption of WiFi ICs is expected to grow more than 25% in 2013 to over 1.8 billion units. Smartphone and tablets make up the lion's share of those shipments (over 58%). Some estimates put the installed base of "Internet of Things" devices at between 30 and 50 billion by the year 2020, many of those being WiFi-enabled.

The 802.11ac standard will definitely play an important role in this growth, by both replacing 802.11n in current devices and opening the door to new applications – similarly to what 802.11n has done in the past years. The first 802.11ac silicon shipments began in early 2012, and end-user products appeared in the marketplace in the third quarter of the same year. The real impact of 802.11ac, however, will probably be felt in 2014 and beyond. In 2015, shipments of 802.11ac-equipped mobile devices are forecast to approach 1 billion (Figure 4), accounting for nearly half of the entire WLAN market in that year.

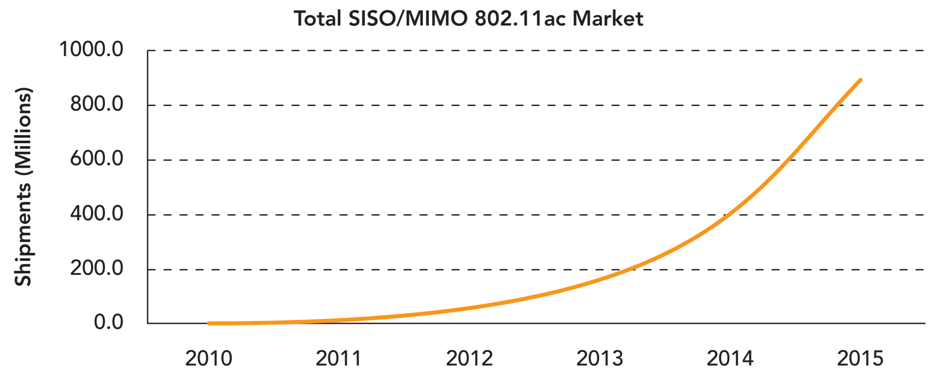


Figure 4. World market forecast of 802.11ac unit shipments.

Specifications

As mentioned, 802.11ac PHY is based on the well known OFDM PHY used for 802.11n, with some important modifications necessary to meet the 802.11ac's goals. Some of the key technical specifications that distinguish 802.11ac from 802.11n are summarized in Table 1, and discussed below.

As will be discussed, some differences have a significant impact on the requirements for the test equipment needed to verify the functionality of 802.11ac-enabled devices. This topic will be the subject of a later part of this document.

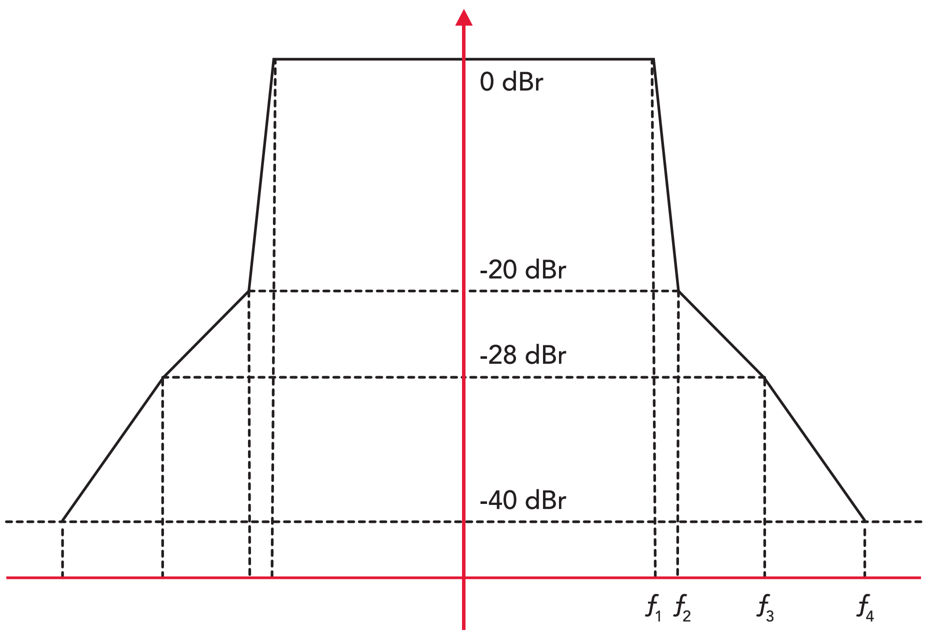
Table 1. Comparison of 802.11ac and 802.11n Technical Specifications

Technical Specification	802.11n	802.11ac
Frequency	2.4, 4.9, 5 GHz	5 GHz
Modulation Scheme	OFDM	OFDM
Channel Bandwidth	20, 40 MHz	20, 40, 80 MHz (160 MHz optional)
Nominal Data Rate, Single Stream	Up to 150 Mbps (1x1, 40 MHz)	Up to 433 Mbps (1x1, 80 MHz) Up to 867 Mbps (1x1, 160 MHz)
Aggregate Nominal Data Rate, Multiple Streams	Up to 600 Mbps (4x4, 40 MHz)	Up to 1.73 Gbps (4x4, 80 MHz) Up to 3.47 Gbps (4x4, 160 MHz)
Time to Stream 1.5hr HD	~ 30 min (4x4, 40 MHz)	~ 15 min (4x4, 80 MHz)
Spectral Efficiency	15 bps/Hz (4x4, 40 MHz)	21.665 bps/Hz (4x4, 80 MHz)
EIRP	22-36 dBm	22-29 dBm
Range	12-70 m indoor	12-35 m indoor
Through Walls	Y	Y
Non-Line-of-Sight	Y	Y
World-Wide Availability	Y	Y limited in China

Channels

Figure 5 describes the spectral mask specifications for 802.11ac devices to operate with 20, 40, 80 and contiguous 160 MHz channel bandwidth. Importantly, the widest channel occupies a wide range of frequencies of 240 MHz: as will be discussed later, this requires manufactures to have proper care in choosing the test equipment for their devices, to ensure it can transmit (capture) the 802.11ac signals to (from) their devices.

Given the limited spectrum availability, and significant design and test challenges, the 160 MHz channel is specified "optional" in the currently available 802.11ac draft (D1.1).



Channel Size	f_1	f_2	f_3	f_4
20 MHz	9 MHz	11 MHz	20 MHz	30 MHz
40 MHz	19 MHz	21 MHz	40 MHz	60 MHz
80 MHz	39 MHz	41 MHz	80 MHz	120 MHz
160 MHz	79 MHz	81 MHz	160 MHz	240 MHz

Figure 5. Spectral Mask for 20, 40, 80, and contiguous 160 MHz Channels.

In addition to a contiguous 160 MHz channel, the TGac has also specified an optional non-contiguous 160 MHz channel, which uses two nonadjacent 80 MHz channels. Creating the proper spectral mask for the channel requires the following steps:

1. The 80 MHz spectral mask is placed on each of the two 80 MHz segments
2. Where both masks of the two 80 MHz channels have values between -20 dBr and -40 dBr:
   - The resulting mask value is the sum of the two mask values in the linear domain
3. Where neither mask has value between 0 dBr and -20 dBr:
   - The resulting mask value is the highest of the two masks
4. For any other frequency region,
   - The resulting mask value is a linear interpolation in the dB domain between the two nearest frequency points with defined mask values

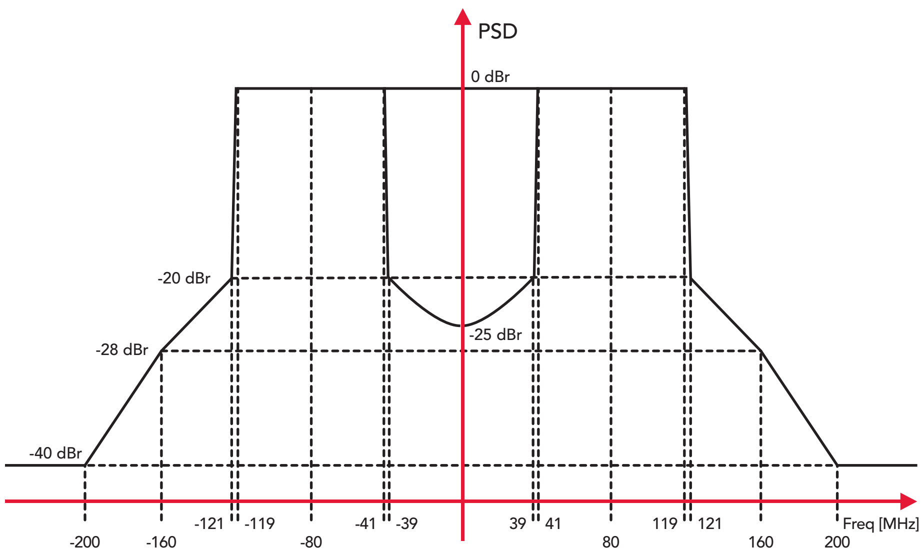


Figure 6 shows an example of a transmit spectral mask for a non-contiguous transmission using two 80 MHz channels where the center frequencies of the two 80 MHz channels are separated by 160 MHz.

Figure 6. Example of 802.11ac 160 MHz Non-Contiguous Channel.

Channelization

As mentioned, the choice to restrict usage of 802.11ac in the 5 GHz RF band only was dictated by the wider channel bandwidth requirements for 802.11ac, which makes channel layout challenging in the crowded 2.4 GHz band. Even in the 5 GHz spectrum, however, the availability of 80 MHz and 160 MHz channel is somewhat limited, especially in some regions.

Figure 7 shows the current spectrum availability for 802.11ac operation, by geography. Availability is greatest in the US, with five 80 MHz channels and two 160 MHz channels. Europe and Japan follow closely, lacking only the highest frequency 80 MHz channel. In India and China, the availability is roughly halved due to reduced spectrum availability.

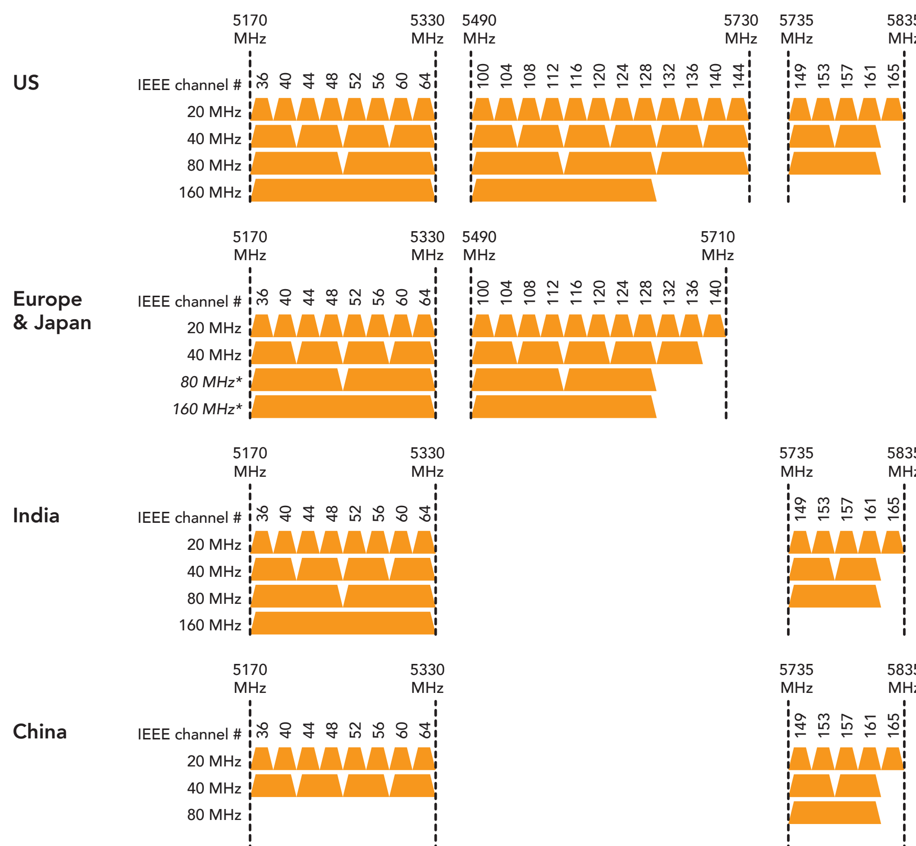


Figure 7. Current spectrum availability for 802.11ac operation in select geographic markets

Constellation Mapping

One method to increase data rates and spectral efficiency in communication systems is to transmit more bits per symbol by moving to a higher-order constellation. However, if the mean energy of the constellation is to remain the same, the constellation points are closer together and are thus more susceptible to noise and other corruption.

Recently, advances in both chip manufacturing technology and processing power have made it possible to use more sensitive coding techniques that depend on finer distinctions in the received signal as well as more aggressive error correction codes that use fewer check bits for the same amount of data. These advances have encouraged the adoption of the optional 256QAM constellation mapping in 802.11ac. The 64QAM constellation mapping, defined in the 802.11n standard, will remain mandatory for 802.11ac devices.

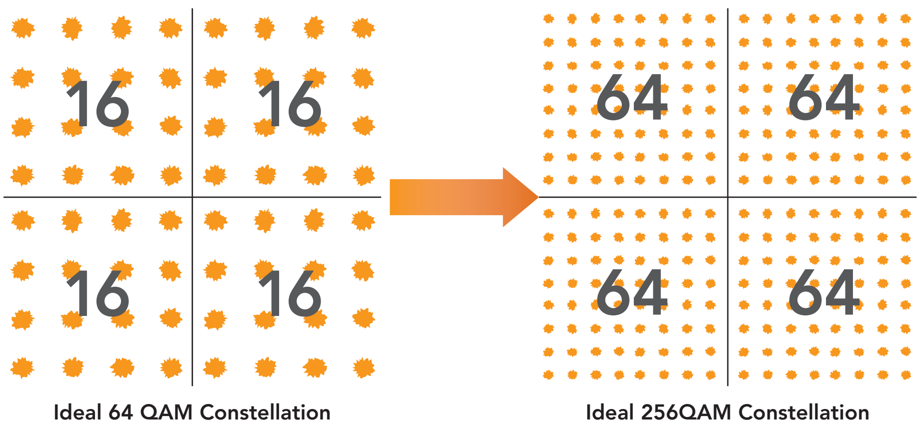


Figure 8. The 802.11ac standard include the definition of the optional constellation bit encoding for 256QAM (right, with 64 bits for quadrant), which trades resilience to noise and interference for much faster data rates and higher levels of spectral efficiency when compared to the constellation for 64QAM (left, with 16 bits for quadrant)

MCS

As mentioned, the number of MCA in 802.11ac is greatly reduced in comparison to 802.11n. Table 2 shows the 802.11ac single user MCS indices, and corresponding modulation and coding rate.

Table 2. 802.11ac single user MCS indices

MCS	Modulation	Coding Rate
0	BPSK	1/2
1	QPSK	1/2
2	QPSK	3/4
3	16-QAM	1/2
4	16-QAM	3/4
5	64-QAM	2/3
6	64-QAM	3/4
7	64-QAM	5/6
8	256-QAM	3/4
9	256-QAM	5/6

Transmitter Constellation Error

The transmitter constellation error is defined as the relative constellation RMS error, calculated by first averaging over subcarriers, frequency segments, OFDM frames and spatial streams. The most recent 802.11ac draft specifies that this value shall not exceed a data-rate dependent value according to Table 3, assuming that the transmitted signal is at least 19 frames with 16 symbols per frame and contains random data. (Note that the transmitter constellation error requirement is the same regardless of the signal bandwidth.)

The introduction of the higher modulation, namely the 256QAM mode, requires the 802.11ac transmitters to perform with significantly better accuracy (lower constellation error) than what required to existing 802.11n transmitters. Precisely, down to -32 dB constellation error should be demonstrated by devices that want to operate using the optional 256QAM. Not only does this requirement puts significant pressure on designers and manufacturers of 802.11ac devices, but also, as we will be discussed later, has an obvious impact on the performance of the test equipment used to verify the transmitter performance.

Table 3. Data-rate dependent maximum transmitter constellation error for 802.11ac devices

Modulation	Coding Rate	Relative constellation error (dB)
BPSK	1/2	-5
QPSK	1/2	-10
QPSK	3/4	-13
16-QAM	1/2	-16
16-QAM	3/4	-19
64-QAM	2/3	-22
64-QAM	3/4	-25
64-QAM	5/6	-28
256-QAM	3/4	-30
256-QAM	5/6	-32

Applications

The single-link and multi-station enhancements supported by 802.11ac can improve the performance and user experience in well-known WLAN applications, and enable several new ones, particularly in the following markets:

- Access Points
- Home Entertainment
- Portable Computing
- PC Peripherals
- Mobile Phones
- Mobile Entertainment

Access Points

Access Points (APs) will use the enhanced MIMO capabilities of 802.11ac to effectively increase the capacity of any home or business WLAN network. With its enhanced multiple-stream technology and new MU-MIMO capabilities, 802.11ac promises to increase the network capacity substantially, and more effectively support the need of the APs to connect with a growing number and variety of wireless-enabled devices used inside the home. APs were some of the very first MIMO 802.11ac-enabled products to hit the market in the second half of 2012.

Home Entertainment

802.11ac can be used in TVs, Set-Top Boxes, and Networked Game Consoles to enable in-home distribution of HDTV and other content, including simultaneous streaming of HD video to multiple clients throughout the home. These devices and applications suffer less from the space and power constraints typical of mobile devices, and are some of the best candidates for the successful application of the 802.11ac newly enhanced MIMO techniques (up to 4x4 MIMO - and beyond).

Mobile Entertainment

The increased data rate and higher energy efficiency of 802.11ac are ideal for applications in mobile entertainment devices such as music players, handheld gaming devices, and wireless-enabled cameras and camcorders. Without adding too much to the limited power consumption availability of these devices, 802.11ac can enable, for example, the rapid synchronization and backup of large data files between these devices and a personal computer (PC) or tablet. Due to constraints in term of both power consumption and physical space, it is likely that first generations of these devices will use only SISO or 2x2 MIMO 802.11ac chipsets.

Portable Computing

Portable computing devices such as PCs, laptops, slates and tablets, are obvious ideal candidates for 802.11ac. The growing number of wireless applications supported by these devices, and the increasing demand for faster connectivity by their users, will be the key drivers for adoption of 802.11ac. Portable computing devices will use 802.11ac, as mentioned, for rapid synchronization and backup of large data files with other 802.11ac-enabled devices, or for the streaming of HD video and other content.

PC Peripherals

The enhanced throughput of 802.11ac might enable, in the future, replacing with a wireless link the wired connection between portable computing devices and their peripheral devices. A promising application is, for example, wireless displays for laptops. To enable the very high throughput necessary for these applications will require device manufacturers to overcome the challenges of implementing MIMO 802.11ac techniques in the form factors of these devices.

Mobile Phones

Mobile phones, specifically smartphones, can use 802.11ac to communicate with mobile entertainment devices and portable computing devices for the rapic synchronization of large data file, and more in general to support the growing demand of faster data transfer by their users. These devices need high throughput but are also generally small and conscious about power consumption, hence, 802.11ac will probably be implemented single stream only. The first 802.11ac-enabled smartphones were introduced in early 2013.

Typical 802.11ac Configurations

Table 4 presents some examples of 802.11ac configurations between an AP and another 802.11ac-enabled network client device (STA). The PHY link rate and aggregate capacity assume 256QAM, rate 5/6, and short guard interval (400 ns).

Table 4. Examples of 802.11ac configurations (all rates assume 256QAM, rate 5/6)

Configuration	Typical Client (STA) Form Factor	PHY Link Rate	Aggregate Capacity
1-antenna AP, 1-antenna STA, 80MHz	Mobile Phone, Mobile Entertainment Device	433 Mbit/s	433 Mbit/s
2-antenna AP, 2-antenna STA, 80MHz	Tablet, Laptop, Networked Game Console	867 Mbit/s	867 Mbit/s
1-antenna AP, 1-antenna STA, 160MHz	Mobile Phone, Mobile Entertainment Device	867 Mbit/s	867 Mbit/s
2-antenna AP, 2-antenna STA, 160MHz	Tablet, Laptop, Networked Game Console	1.73 Gbit/s	1.73 Gbit/s
4-antenna AP, 4 1-antenna STAs, 160MHz (MU-MIMO)	Mobile Phone, Mobile Entertainment Device	867 Mbit/s to each STA	3.47 Gbit/s
8-antenna AP, 160MHz (MU-MIMO) • 1 4-antenna STA • 1 2-antenna STA • 2 1-antenna STAs	TV, Set-Top Box, Tablet, Laptop, Networked Game Console, Mobile Phone	3.47 Gbit/s to 4-antenna STA 1.73 Gbit/s to 2-antenna STA 867 Mbit/s to 1-antenna STA	6.93 Gbit/s
8-antenna AP, 4 2-antenna STAs, 160MHz (MU-MIMO)	TV, Set-Top Box, Tablet, Laptop, PC	1.73 Gbit/s to each STA	6.93 Gbit/s

Testing 802.11ac

Not surprisingly, the important changes in 802.11ac with respect to 802.11n challenge designers and manufacturers of 802.11ac devices in several, significant ways. Not only do they need to work with the design implications of 8 spatial streams, wider bandwidth, and more, but also face significant test challenges. Specifically, they require test systems that are flexible enough to evolve with the latest 802.11 standard. As a minimum, any test equipment they choose to test their new 802.11ac devices will require:

- wide VSA/VSG IF bandwidth
- full support to 802.11ac MIMO enhancements
- improved modulation accuracy for 802.11ac transmitter modulation testing

VSA/VSG IF Bandwidth

802.11ac presents significant new challenges for test due to the bandwidth increase. 802.11ac effectively obsoletes most (if not all) available test equipment combining a vector signal analyzer and vector signal generator (VSA/VSG) in a single box, which simply do not have the required 120 MHz or 240 MHz IF bandwidth for testing the 80 MHz or 160 MHz channels of the new technology. In choosing equipment for 802.11 testing today, device manufacturers should ensure that it is capable of testing the very wide 802.11ac spectrum mask.

Support to 802.11ac MIMO Enhancements

Not only does 802.11ac present challenges for bandwidth, it also drives MIMO test requirements. Correct MIMO testing requires independent capture and generation of the signals to and from the 802.11ac device, which uses up to 8 spatial streams and several other enhancements to improve performance over existing 802.11n MIMO systems.

To verify MIMO performance accurately, especially in an R&D environment, 802.11ac-capable test equipment should support up to 8 independent VSA and VSG resources, as well as include support to the new 802.11ac MIMO enhancements.

Improved VSA/VSG EVM

As the requirements for the modulation accuracy (relative constellation RMS error) of the 802.11ac transmitter rise, so do the requirements of the equipment necessary to test it. The transmitter modulation accuracy is measured by the error vector magnitude, EVM, and requires the VSA and test equipment to add negligible (ideally, zero) distortion to the captured signal. The distortion added by the VSA is also measured in terms of EVM and, typically, chipset makers want their test equipment to perform at least 10 dB better than the silicon specification. For 802.11ac-capable test equipment, this translates into a requirement for the maximum EVM of the VSA of:

Max device EVM (-32 dB at 256QAM) − 10 dB = -42 dB

Device makers should select their test equipment to meet or exceed this performance.

Concluding Remarks

802.11ac represents a significant evolution in WLAN communication systems. 802.11ac devices make use of OFDM modulation principles as 802.11n, but use wider channel bandwidth, higher modulation, more stream, and enhanced MIMO techniques to increase throughput and enable faster, new applications. Designers and manufacturers of 802.11ac devices need to understand the requirements for this new technology not only to create their products, but also to ensure that their test equipment is able to tackle the raising challenges of accurately testing their performance.

To learn more about 802.11ac testing, please contact LitePoint at sales@litepoint.com

Appendix I: References

802.11ac Documents

- IEEE P802.11ac/D1.1: Draft Amendment 5: Enhancements for Very High Throughput in Bands below 6 GHz

Status of Project IEEE 802.11ac

- http://www.ieee802.org/11/Reports/tgac_update.htm

Official IEEE 802 Project Timelines

- http://www.ieee802.org/11/Reports/802.11_Timelines.htm

Appendix II: Curiosities

Why is It Called "ac"?

The name should have been "ag" but it was skipped to avoid confusion with 802.11a/g.

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