

802.11ac Wave 2

Frequently Asked Questions

Standards, Performance, and Features

Q. What is 802.11ac?

A. 802.11ac is a transformational wireless LAN technology that represents a significant performance increase over its highly successful predecessor, 802.11n. 802.11n provided the wireless connectivity speeds that businesses needed to embrace Wi-Fi in their day-to-day operations and let workers begin using wireless as their primary network medium of choice. The 802.11ac IEEE standard allows for theoretical speeds up to 6.9 Gbps in the 5-GHz band, or 11.5 times those of 802.11n (Table 1). 802.11ac is coming to market in two releases: Wave 1 and Wave 2.

Table 1. Comparing 802.11ac Wave 2, Wave 1, and 802.11n

	802.11n	802.11n	802.11ac Wave 1	802.11ac Wave2	802.11ac
		IEEE Specification	Today	WFA Certification Process Continues	IEEE Specification
Band	2.4 GHz & 5 GHz	2.4 GHz & 5 GHz	5 GHz	5 GHz	5 GHz
MIMO	Single User (SU)	Single User (SU)	Single User (SU)	Multi User (MU)	Multi User (MU)
PHY Rate	450 Mbps	600 Mbps	1.3 Gbps	2.34 Gbps – 3.47 Gbps	6.9 Gbps
Channel Width	20 or 40 MHz	20 or 40 MHz	20, 40, 80 MHz	20, 40, 80, 80-80, 160 MHz	20, 40, 80, 80-80, 160 MHz
Modulation	64 QAM	64 QAM	256 QAM	256 QAM	256 QAM
Spatial Streams	3	4	3	3-4	8
MAC Throughput*	293 Mbps	390 Mbps	845 Mbps	1.52 Gbps- 2.26 Gbps	4.49Gbps

* Assuming a 65% MAC efficiency with highest MCS

Q. What's the functional difference between 802.11ac Wave 1 and Wave 2?

A. Wave 1 products have been in use in the market for about 2.5 years. Wave 2 builds upon Wave 1 with some very significant enhancements:

- Supports speeds to 2.34 Gbps (up from 1.3 Gbps) in the 5 GHz band
- Supports multiuser multiple input, multiple output (MU-MIMO)
- Offers the option of using 160-MHz-wide channels for greater performance
- Offers the option of using a fourth spatial stream for greater performance
- Can run in additional 5-GHz bands around the world

Q. What exactly do these Wave 2 enhancements do, and why do we need them?

A. Table 2 describes the added features and why they are becoming necessary.

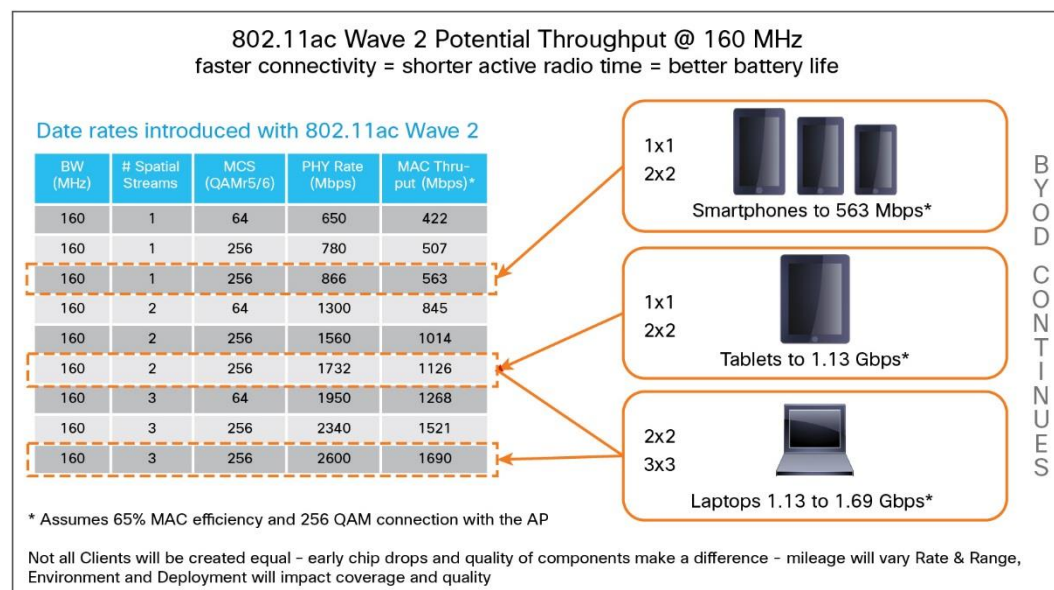
Table 2. 802.11ac Wave 2 as a Business Enabler

Wave 2 Feature	Business Drivers and Trends	Detail
Up to 2.34 Gbps in the 5 GHz band	<ul style="list-style-type: none"> Hyper growth in mobile video usage, joining voice over IP 	Higher speeds and efficiencies provide the bandwidth to support latency-sensitive video and voice traffic, as well as high and growing densities of clients
Multuser MIMO (MU-MIMO)	<ul style="list-style-type: none"> High-density wireless: The continued shift to end-user mobility and the increasing volumes of Wi-Fi-enabled Internet of Things (IoT) devices Multiple connected devices per user Interest in the "all wireless office" user experience 	<ul style="list-style-type: none"> Provides concurrent downstream communications to multiple wireless devices for the first time for more efficient use of the spectrum Lets client devices get on and off the network faster, so more clients can use the network
160-MHz channel width	High-speed delivery of large files and data access and movement	Delivers theoretical capacity up to 2.3 Gbps, as compared to: <ul style="list-style-type: none"> 450 Mbps with 802.11n 1.3 Gbps with 802.11ac Wave 1
Fourth spatial stream	Generally, the greater the number of receive antennas, the greater the distance that a particular data rate can be sustained, depending on environment	Supports four transmitting and receiving antennas; previous iterations supported three receive antennas
Additional 5-GHz channels	Greater number of channels provides greater bandwidth and flexibility for RF to move channels in instances of interference	There are about 37 separate channels in the 5-GHz frequency worldwide. Some have been used for other purposes or have not been allowed for Wi-Fi use. As these conditions change, 802.11ac Wave 2 will be able to operate in more and wider channels, providing additional bandwidth available to Wi-Fi and supporting more users, devices, and applications.

Q. What are the new data rates supported with Wave 2?

A. Wave 2 is a superset of 802.11ac Wave 1. As such, it supports all the data rates of 802.11ac Wave 1. With the addition of support for 160-MHz-wide channels and the modulation and coding scheme (MCS) rates of 802.11ac, Wave 2 provides new maximum PHY rates based on the number of spatial streams and modulation shown in Figure 1.

Figure 1. 802.11ac Wave 2 Potential Throughput

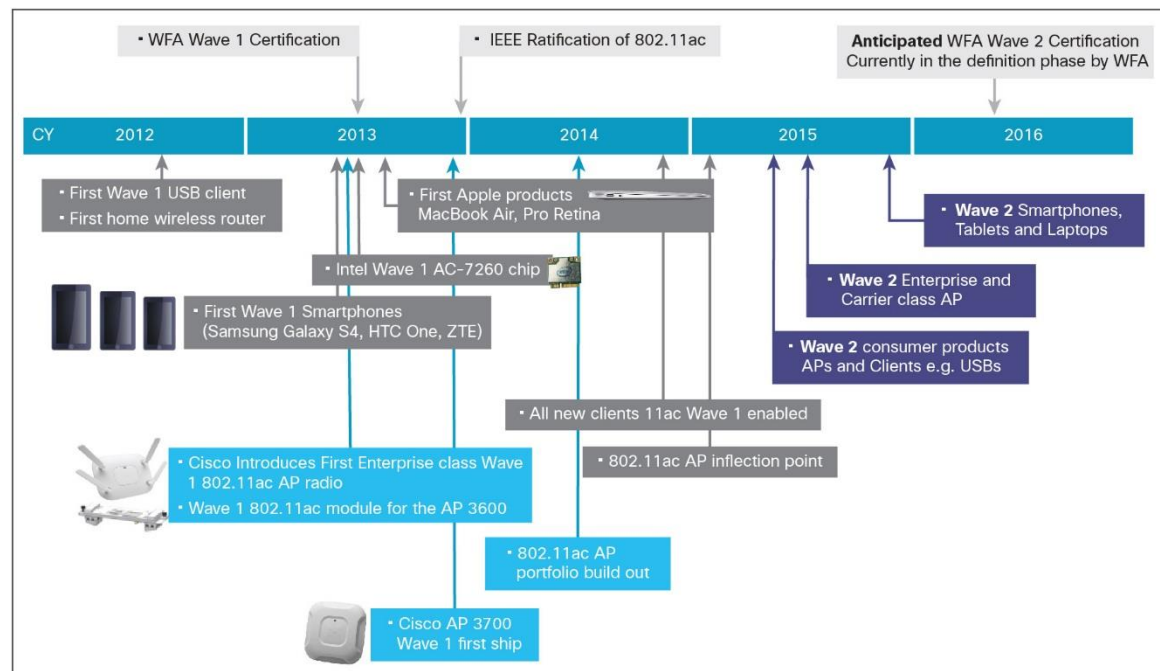


- Q.** What band and channels will 802.11ac Wave 2 operate on?
- A.** In practice, both Waves 1 and 2 apply to the 5-GHz band only. The available bandwidth varies around the world, but today it is typically some subset of 5.15 to 5.35 and 5.47 to 5.85 GHz. The United States makes all of this subset available to WLANs (580 MHz). 802.11ac continues to enable 20- and 40-MHz channels but also adds 80- and 160-MHz channels for greater throughput. However, given that 160 MHz of relatively unused contiguous spectrum is difficult to find, there is an 80+80-MHz mode, which is simply the 160 MHz waveform split into two different 80-MHz frequency segments, enabling them to be placed more flexibly. Note that 20, 40, and 80 MHz are the **only** mandatory channel bandwidths in 802.11ac.

IEEE 802.11ac Standard Ratification and Deployment Timelines

- Q.** Why are there two 802.11ac “waves”?
- A.** The 802.11ac IEEE standard is being introduced to the market in a series of “waves” (releases) of new products and technology. The reason is that the capabilities in 802.11ac are numerous, and delivering them in waves allows the industry to take advantage of many without having to wait for all capabilities to be available. The standard defines a framework that provides a significant step beyond 802.11n and allows for growth into the future.
- Q.** When can we anticipate 802.11ac Wave 2 products?
- A.** Many industry analysts expect that the initial consumer-focused products providing Wave 2 support will become available toward the middle of 2015 (Figure 2). Enterprise and carrier-class Wave 2 clients and infrastructure products will follow three to six months later. This is very similar to how the 802.11ac Wave 1 products were introduced to the market.

Figure 2. Anticipated 802.11ac Wave 2 Deployment Timeline



Note that both consumer-class and enterprise-class products including features for Wave 2 will likely appear in the market before the Wi-Fi Alliance launches its certification program. Of course, any product launched into the market before certification may run the risk of noncompliance with interoperability between 802.11ac devices and clients. But Cisco is confident its access points will be certifiable by the Alliance once the certification program actually launches (expected in the middle to the second half of 2016).

- Q.** When 802.11ac Wave 2 clients ship, will they be full-featured?
- A.** It is expected that one- and two-spatial-stream clients will make up the bulk of Wave 2 clients, followed by three-spatial-stream clients. This is similar to what we see today with the mix of 802.11ac Wave 1 client devices. Consumer Wave 2 solutions are expected in mid-2015, and enterprise-class Wave 2 client solutions will emerge near the end of 2015.

Upgrades and Compatibility

- Q.** Are Wave 1 hardware and Wave 2 hardware compatible with each other?
- A.** No. 802.11ac Wave 1 required new hardware in both access points and client devices to deliver channel widths up to 80 MHz, 256 quadrature amplitude modulation (256-QAM), and up to three spatial streams. The result was a maximum data rate of 1.3 Gbps, or about three times the top-end 802.11n products in the market. Similarly, Wave 2, a superset of Wave 1, requires new hardware in both access points and client devices to support the additional 802.11ac capabilities such as MU-MIMO, channel widths up to 160 MHz, and the potential for a fourth spatial stream.
- Q.** Will 802.11ac Wave 2 continue to support 802.11ac Wave 1 and other 5-GHz protocols?
- A.** Yes, 802.11ac Wave 2 access points will interoperate with 802.11ac Wave 1, 802.11n, and 802.11a client devices. Support for all Wave 2 features, however, requires Wave 2 support in both the access point and in the client.

Multi-User MIMO (MU-MIMO) vs. Single-User MIMO (SU-MIMO)

- Q.** What is MU-MIMO, and how will it help my network?
- A.** MU-MIMO stands for multiuser multiple input, multiple output, and is a brand new feature introduced with 802.11ac Wave 2. Wave 2 MU-MIMO support is required on both the access point and client device to work. As noted in Table 1, it operates in the downstream direction, access point to client, and allows an access point to transmit to multiple client devices simultaneously.

This differs from Wave 1 and previous single-user (SU)-MIMO 802.11 iterations, in which an access point transmits to a single client device at a time very quickly and efficiently (Figures 3 and 4).

Figure 3. SU-MIMO Operation

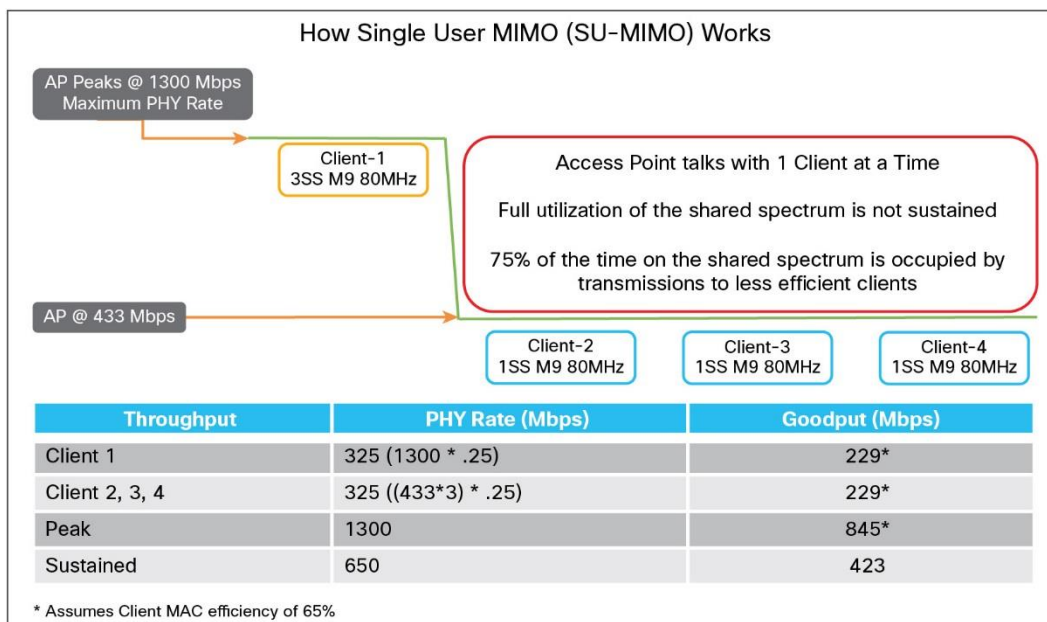
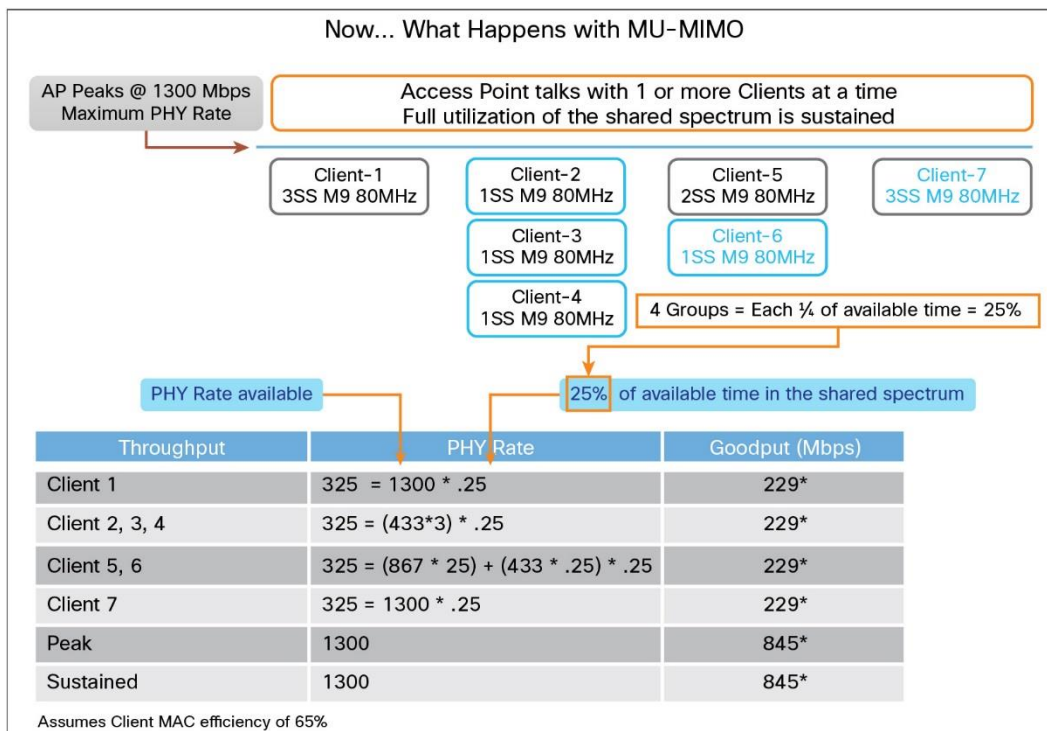


Figure 4. MU-MIMO Operation



For an overview of MIMO technology, watch the MU-MIMO Deep Dive at Wireless Field Day, 7 August 2014, with Cisco's Matt Silverman: <http://techfieldday.com/video/cisco-mu-mimo-deep-dive/>

- Q.** Is MU-MIMO backward compatible with 802.11ac Wave 1 or other legacy protocols?
- A.** No. MU-MIMO is not backward compatible via software with 802.11ac Wave 1 or any other legacy 802.11 Wi-Fi client devices.
- Q.** How does MU-MIMO compare to SU-MIMO?
- A.** SU-MIMO communicates with a single Wi-Fi client device at a time, while MU-MIMO is able to transmit to multiple Wi-Fi client devices concurrently on the downlink (access point to client).
- Q.** How many clients will be supported with MU-MIMO?

- A.** The 802.11ac Wave 2 standard limits itself to communicating with a maximum of four clients at a time, using up to a total of eight spatial streams (for all clients) or a maximum of four spatial streams per client in a MU-MIMO transmission. So an access point can transmit to two clients with one spatial stream each (1+1), or four spatial streams to each (4+4), or four clients each with two spatial streams (2+2+2+2), or some irregular combination (such as 1+2+3 or 2+3+3).

It is impossible for the access point to transmit more spatial streams than it has antennas, and even then it is better to use one antenna for extra reliability, not an extra stream. So a four-antenna access point will likely support only 1+1, 1+1+1, and 1+2 combinations.

- Q.** Will MU-MIMO work in the downstream direction only?
- A.** The 802.11ac standard defines only downlink (DL) MU-MIMO, which is for the access point sending to multiple clients concurrently. The uplink version, with multiple clients coordinating to transmit separate packets to the access point at the same time, was considered for 802.11ac but was deemed too difficult to address in a reasonable time. Certainly most traffic flows in the downlink direction, so DL-MU-MIMO helps with the most pressing problem.

Uplink (UL) MU-MIMO, however, is a key feature planned by the 802.11ax High Efficiency WLAN working group in the IEEE, which is defining the next-generation 802.11 Wi-Fi specification, with a proposed target of mid-2019/2020 for a finalized standard.

- Q.** How many spatial streams and client devices can MU-MIMO support?
- A.** MU-MIMO, as defined in 802.11ac, can work with clients with any number of antennas and spatial streams. However, no one client can receive more than four spatial streams in a multiuser transmission (for more than four spatial streams, a single-user transmission is used instead, up to eight spatial streams).

Effectively implementing support for MU-MIMO requires that the access point have more antennas than spatial streams being delivered to any one client. Cisco remains the only access point vendor in the industry delivering 4x4 antenna support (four transmit and four receive antennas). With our extensive RF experience and track record, we are well positioned to bring to market a robust implementation of MU-MIMO in a Wave 2 solution.

- Q.** Will clients require new hardware to take advantage of Wave 2 802.11ac?
- A.** Both access points and clients will require new hardware to take advantage of Wave 2 802.11ac. Going from 80 MHz to 160 MHz, and from SU-MIMO to MU-MIMO, are significant technical challenges. Wave 2 access points will be backward compatible with older clients from an interoperability standpoint. But the new enhancements will function only when access points and clients both support the new hardware.

- Q. Will clients require new antenna designs or configurations to take advantage of 802.11ac?
- A. Antenna design does not have to change, since 802.11ac occupies the same spectrum as 802.11a and 802.11n at 5 GHz. Existing antennas are already designed to efficiently radiate signals across this band. To be sure, 802.11ac signals are wider than 802.11a/n signals, but they still fall entirely within the existing 5-GHz band.

Beamforming and Cisco ClientLink in 802.11ac Wave 2

- Q. 802.11ac uses explicit beamforming. How does it work and why is it beneficial?
- A. Beamforming involves an AP focusing RF signals directly at an intended client and vice versa in order to improve throughput to that client. Explicit beamforming requires information to be sent from the client device to the access point in order to work. The additional information makes the beamforming more accurate; the tradeoff is that it places more data in the airwaves.

In a departure from 802.11n, 802.11ac defines only one beamforming sounding method, namely explicit sounding. Although this method is optional, it means that an 802.11ac access point-to-client pair that implements the 802.11ac sounding protocol can perform beamforming. If the access point implements the beamformer side and the client implements the beamformee side (which may be typical), unidirectional beamforming is achieved. But if the access point and client implement both beamformer and beamformee functionality, bidirectional beamforming is achieved. Given the enormous advantages of beamforming, as demonstrated by Cisco's own ClientLink, and the increased likelihood of finding other devices that implement the same flavor of sounding, Cisco expects that 802.11ac access points and clients are more likely to perform 802.11ac sounding and beamforming.

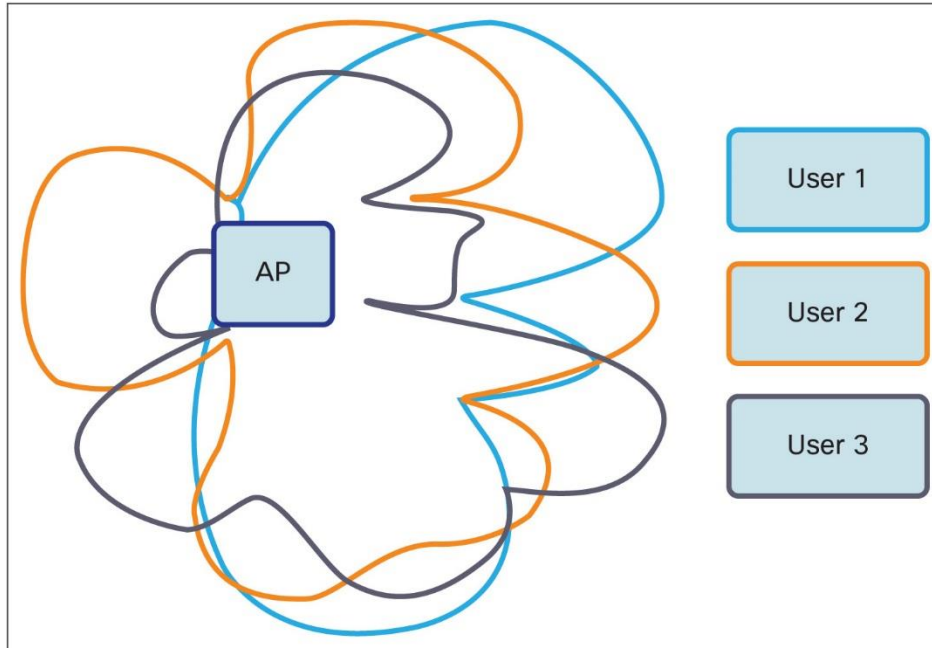
However, the 802.11ac amendment is silent on how an 802.11ac access point might beamform to an 802.11a or 802.11n client. For this, adopters must look to their vendor to go beyond 802.11ac and to deliver beamforming across the client mix.

- Q. Will Cisco ClientLink 3.0 operate with 802.11ac Wave 2 in the same manner that it works with 802.11ac Wave 1, providing beamforming for 802.11ac and non-802.11ac clients?
- A. Yes. ClientLink 3.0 will be extended to 802.11ac Wave 2, and will provide full IEEE 802.11ac sounding to both 802.11ac Wave 1 and 2 clients. It will also deliver the classic ClientLink improvements for both 802.11a/n clients and the 802.11ac Wave 1 and 2 clients that do not support 802.11ac sounding. This approach will offer tremendous improvements in reliability and rate at range regardless of the client mix (including low-end BYODs).
- Q. How are beamforming, MU-MIMO and ClientLink related?
- A. Cisco ClientLink is a type of beamforming called **implicit** beamforming. It does not require support on the part of the client device in order to work, making it universally functional and reducing traffic over the airwaves. Think of MU-MIMO as ClientLink on steroids. ClientLink directs energy to one client at a time, whereas MU-MIMO directs energy to one client *and* steers that energy away from other clients addressed by the MU-MIMO transmission **and** directs energy for a second client to that second client **and** steers the second lot of energy away from the first and subsequent clients (and so forth if there is a third or fourth client).

MU-MIMO in 802.11ac Wave 2 sends to multiple receivers (Figure 5):

- An access point with four antennas sends one stream each to three smartphones, all at the same time.
- The access point must beamform one space-time stream to each receiver and simultaneously null-steer that space-time stream to the two other receivers.

Figure 5. MU-MIMO Communicates with Multiple Clients



Considerations with Gigabit WLAN Speeds and Beyond

- Q.** How will 802.11ac Wave 2 access points handle throughput greater than 1 Gbps?
- A.** The potential throughput of a wireless client is dependent upon a number of factors, including number of spatial streams supported, distance from the access point, quality of signal maintained between the client and access point, potential sources of interference and signal obstruction, and the quality of the client device and access point.

For example, consumer-grade access points are built with a very different set of users and requirements in mind than enterprise and carrier-class access points. Cisco ClientLink technology is focused primarily on creating the highest possible quality connection with individual client devices, including consumer-grade devices. As such, client devices connected with a ClientLink-enabled access point enjoy a much more robust connection with the access point and, as a by-product, higher performance and throughput on the downlink from access point to client.

Also, traffic from two active radios aggregated together in the access point could provide up to twice the above throughput with a dual 5-GHz radio configuration (Figure 6).

A. So that each access point needs only a single uplink to the wired infrastructure, even with 1-Gbps+ speeds, Cisco recently announced [Cisco Catalyst® Multigigabit Switching](#) technology based on the [NBASE-T Alliance](#). This technology will be introduced on the Cisco Catalyst 4500E, 3850, and 3560-CX Series Switches in preparation for select Wave 2 access points from Cisco that will incorporate the same Ethernet technology based on the NBASE-T Alliance standard. The standard adds support for 2.5-Gbps and 5-Gbps speeds to Fast Ethernet, 1 Gbps, and 10 Gbps over copper cabling (Figure 7).

- Supports **Multiple Gigabit** speeds FE, 1G, **2.5G**, **5G** and 10G
- Cat 5E Cabling supporting **2.5G & 5G** up to 100m with PoE/UPOE
Cat 6 Cabling supporting to 10G up to 55m with **PoE+/UPOE**
Cat 6a Cabling supporting to 10G up to 100m with **PoE+/UPOE**
- PoE+ and UPOE on Cat 5E and Cat 6/6a

- Q.** What cable category will I need to connect an 802.11ac Wave 2 access point?
- A.** Customers will have a wide variety of cabling choices when connecting to Multigigabit Ethernet ports based on the NBASE-T Alliance standard (Table 3).

Table 3. Cabling Options for Multigigabit Ethernet Ports

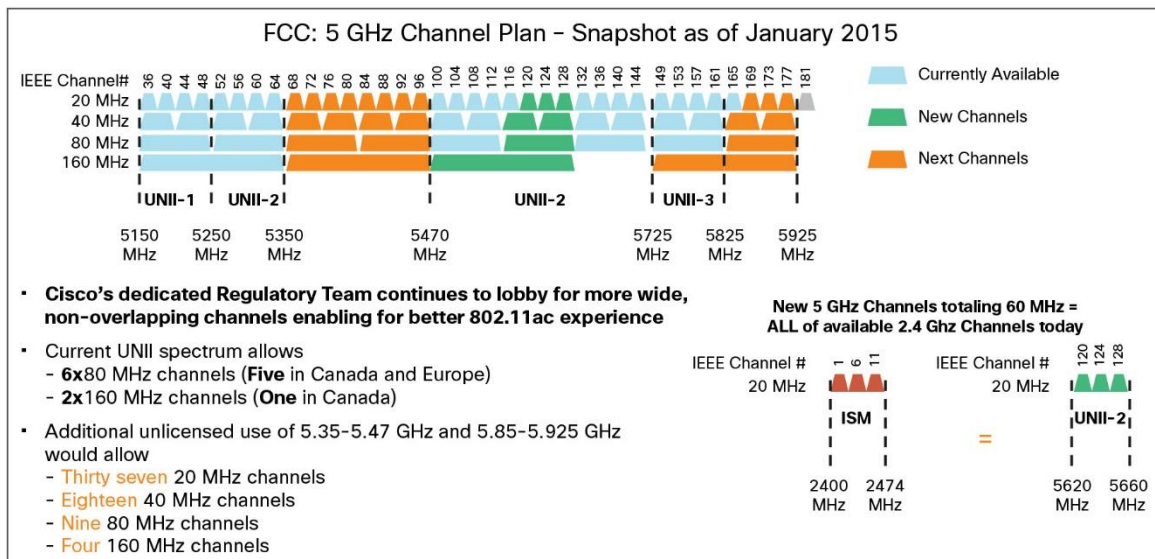
Cable Type	FE	1G	2.5G	5G	10G
Cat5e	•	•	•	• 100m	
Cat6	•	•	•	•	• 55m
Cat6a	•	•	•	•	• 100m

As Table 3 indicates, Multigigabit Ethernet will provide support for up to 5 Gbps over Category 5e cabling and will still provide full PoE support - a full five times the throughput of existing Category 5e infrastructure to 100m (meters). With existing Category 6 and 6a cabling, Multigigabit Ethernet will add support for 2.5 Gbps and 5 Gbps to the existing 1-Gbps and 10-Gbps choices customers have today, and will also provide full PoE support based on the IEEE P802.3bt working group (<http://www.ieee802.org/3/bt/index.html>).

- Q.** Is there sufficient spectrum availability to support 802.11ac Wave 2?
- A.** Wireless spectrum availability varies by geographic market. The expansion of the 5-GHz band worldwide is of particular interest for two reasons:
- Overcrowding concerns with the 2.4-GHz spectrum, its limited number of channels, and its limited number of channels that do not overlap
 - The wider channels supported under 802.11ac (Wave 1 channels up to 80 MHz wide and 160-MHz-wide channels in Wave 2) require 5 GHz
- Q.** What progress is being made in expanding the 5-GHz band?
- A.** In the past two years a number of countries have expanded their allowable 5-GHz channels. For example:
- Australia, New Zealand, and Brazil added 5470 through 5725, excluding 5600 to 5650
 - China added 5150 to 5350

Also, the U.S. Federal Communications Commission (FCC) has captured a lot of attention in the past year with its plans to open up 200 MHz of additional 5-GHz spectrum. Figure 8 shows a snapshot of the FCC's 5-GHz channel plan as of January 2015.

Figure 8. FCC's 5-GHz Channel Plan

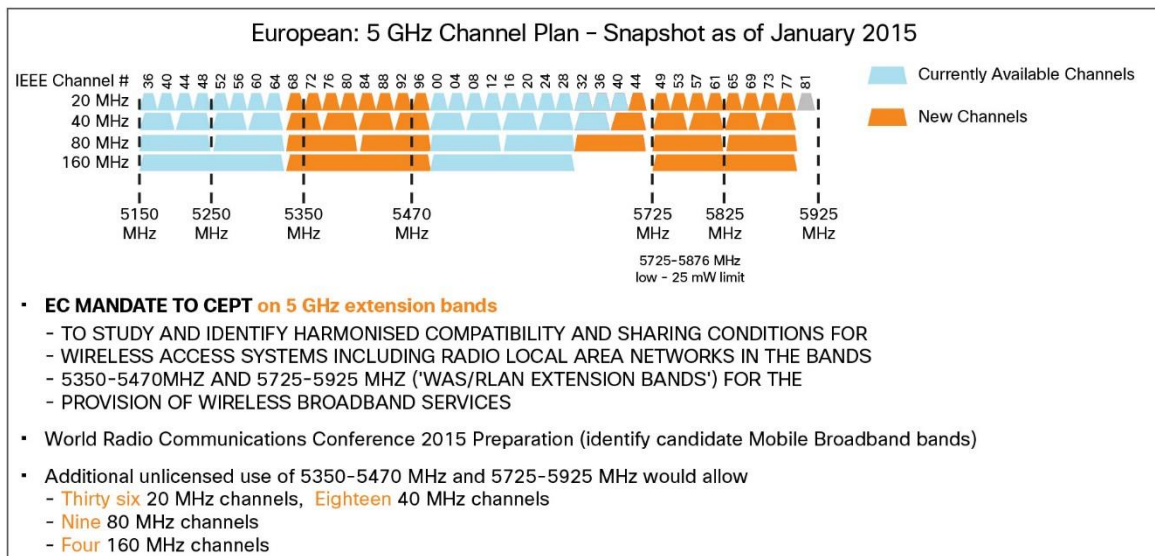


Q. What about other countries?

Canada is aligned with the FCC's 5-GHz activity; timelines will follow FCC orders by about 24 months.

The European Commission is likewise extremely busy in this same scenario, with multiple working groups allocated to studying and coming back with proposals to open up additional wireless spectrum (Figure 9).

Figure 9. European 5-GHz Channel Plan



- Q.** Will 802.11ac be allowed in all countries and regulatory domains?
- A.** All countries and regulatory domains that allow 802.11n at 40 MHz will also allow 802.11ac at 20 and 40 MHz. The 80-, 160-, and 80+80-MHz channels are new features, and discussions between the industry and regulators are ongoing in many parts of the world. At the present time, operation at greater than 40 MHz is allowed in the United States, the European Union, Australia, New Zealand, Brazil, and South Africa, and no obstacle is expected in multiple other countries. A few countries continue to study the implication of operation at greater than 40 MHz, even though 802.11ac has been ratified by the IEEE.
- Q.** Does Cisco get involved in helping open up spectrum for 802.11ac Wave 2?
- A.** Cisco has a dedicated team championing and optimizing regulatory requirements in the Wi-Fi marketplace and continuously engages with all global regulatory organizations, such as the FCC in the United States and the European Telecommunications Standards Institute (ETSI) in the European Union, to promote more spectrum commercialization. As proof, the FCC recently opened up a sixth nonoverlapping 80-MHz channel for 802.11ac operations (UNII-2). This new channel was discussed by Chris Spain in his May 2014 blog post, ["What, Why, Where, When, How: The New FCC Ruling Around 5 GHz."](#)

Industry Certification and the Wi-Fi Alliance

- Q.** What role does the Wi-Fi Alliance play in 802.11ac?
- A.** The Wi-Fi Alliance is a nonprofit organization founded in 1999 that brings together an assortment of chipset vendors, wireless client vendors, and access point vendors. The organization promotes Wi-Fi and provides a forum for all vendors to collaborate within the standards, define a set of capabilities for all vendors to adhere to, and ultimately perform interoperability testing with a goal to ensure that end customers can be assured a level of interworking when selecting products for their networks.

In support of 802.11ac Wave 1, the Alliance created a [certification program for 802.11ac Wave 1](#) with a definition of mandatory and optional features that are a subset of the IEEE 802.11ac standard. To find a list of the Cisco 802.11ac Wave 1 certified products, go to: http://www.wi-fi.org/product-finder-results?sort_by=default&sort_order=desc&certifications=12&keywords=cisco

For Wave 2, the Alliance is extremely busy in defining a similar certification program, and Cisco as well as other members are actively engaged in this process. We estimate that the Alliance's certification program for Wave 2 will officially be launched in mid-2016.

Cisco and 802.11ac

- Q.** What is Cisco's industry involvement with 802.11ac specifications?
- A.** Cisco, along with a number of other vendors, worked with the IEEE in creating the 802.11ac amendment and continued that collaboration within the Wi-Fi Alliance in the definition of the 802.11ac interoperability and certification process. Cisco continues to perform research and development to support additional 802.11 wireless standards and technologies. The timing and ability to support new 802.11 wireless standards such as 802.11ac is dependent on ratification of the new IEEE standards and creation of industry interoperability testing certifications by the Wi-Fi Alliance.

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- Q.** What are Cisco's plans to support 802.11ac Wave 2?
- A.** Cisco expects to begin introducing Wave 2 access point products later in 2015. Stay tuned for additional details as 2015 unfolds and Cisco gets closer to bringing these Wave 2 products to market.

Until that time, Cisco's existing best-in-class 802.11ac Wave 1 product portfolio represents the industry's widest offering of 802.11ac Wave 1 solutions, providing companies of all sizes and market segments multiple options for introducing Gigabit wireless into their network to meet their business needs. For more information, please visit these sites:

- <http://www.cisco.com/go/wireless>
- <http://www.cisco.com/go/80211ac>
- <http://blogs.cisco.com/wireless>



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