Wi-Fi CERTIFIED™ ac: Significant performance advancements for the world's most loved technology

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Executive summary

Wi-Fi CERTIFIED™ ac: yet another leap forward for Wi-Fi

Wi-Fi CERTIFIED ac is a certification program from Wi-Fi Alliance®, based on the IEEE 802.11ac standard. This new MAC/PHY in the 5 GHz band further improves Wi-Fi performance in data rates, capacity, and robustness. The technology behind Wi-Fi CERTIFIED ac meets the increasing demand on Wi-Fi networks to transport more multimedia traffic, which is latency-sensitive and bandwidth intensive. It is designed to operate in challenging environments that are crowded with a wide range of fixed and mobile devices, often engaged in multiple and concurrent applications.

Efficiency gains mean Wi-Fi CERTIFIED ac will become the dominant MAC/PHY in the 5 GHz band

Wi-Fi CERTIFIED ac products are boosted by wider channels, a more efficient MAC/PHY, and more advanced beamforming capabilities.

The Wi-Fi CERTIFIED ac certification program

Wi-Fi Alliance launched the Wi-Fi CERTIFIED ac certification program in June 2013 and added a second wave of features, including Multi-user MIMO (MU-MIMO) in June 2016. Certification under the Wi-Fi CERTIFIED ac program is open to any type of client device or access point that has also passed the certification tests for Wi-Fi CERTIFIED a/b/g/n, Wi-Fi Protected Access® 2 (WPA2™), and Wi-Fi Multimedia™ (WMM®). As with all Wi-Fi Alliance certification programs, Wi-Fi CERTIFIED ac devices are interoperable with Wi-Fi CERTIFIED equipment from any vendor and are backward compatible with legacy Wi-Fi equipment. While Wi-Fi CERTIFIED ac operates in the 5 GHz band, most Wi-Fi CERTIFIED ac devices are expected to be dual-band, supporting Wi-Fi CERTIFIED n in the 2.4 GHz band.

Four reasons to choose Wi-Fi CERTIFIED ac

- **Higher data rates**
- **More capacity**
- **Ideally suited for multimedia applications such as video, voice and gaming in multi-device environments**
- **Improved robustness**

Why is Wi-Fi CERTIFIED ac better?

- **Wider spectrum channels (up to 160 MHz)**
- **More efficient use of spectrum**
- **Communicate simultaneously with multiple devices**
- **Use of less crowded 5 GHz spectrum band**
- **Expanded support for beamforming**

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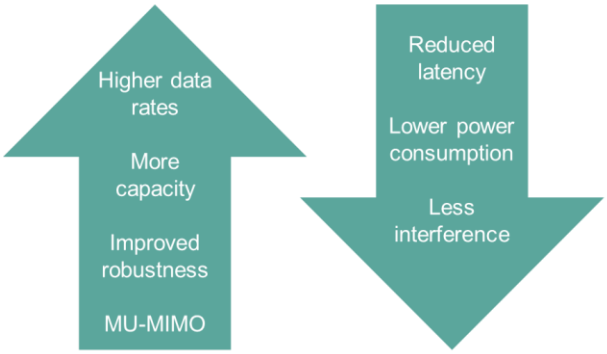
What's new



What's the same

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Introduction: Another leap forward in the evolution of Wi-Fi

Wi-Fi growth follows a virtuous cycle of innovation and adoption. As connectivity gets faster and easier to use, it drives the creation of new and compelling applications. Users then connect more often, consuming more data and increasing their expectations. This prompts more innovation, which leads back to faster and easier connectivity. Throughout this growth cycle, Wi-Fi technology is expected to advance its capabilities in a variety of ways:

- Higher data rates per client device, to deliver a better user experience
- Higher capacity per access point (AP), to transport more traffic
- Optimized performance of multimedia content and real-time traffic such as voice, video and graphic-intensive gaming
- More reliable coverage, to give users a more consistent connection throughout the AP footprint

Wi-Fi CERTIFIED ac products are based on the IEEE 802.11ac specification and push the technology ahead in all of these directions, improving its performance in line with the growing expectations among users. The shift toward the less crowded 5 GHz band, wider channels, higher modulation, MU-MIMO (Downlink), and improved beamforming support allows Wi-Fi CERTIFIED ac to surpass the already impressive performance of Wi-Fi CERTIFIED n.

With Wi-Fi CERTIFIED ac, users are able to run multiple highly demanding applications simultaneously at home. They can run three HD-quality video streams or rapidly synchronize videos, photos, and music before leaving home. In dense enterprise environments, users can use Wi-Fi CERTIFIED ac products for video, telepresence, and industrial applications. In public hotspots,

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Wi-Fi CERTIFIED ac products have greatly increased capacity and reach, which mobile operators can leverage to offload traffic from their heavily used cellular networks.

Wi-Fi Alliance promotes the adoption of 802.11ac through the Wi-Fi CERTIFIED ac program, which provides the basis for interoperability and backward compatibility for equipment submitted by vendors. As with all Wi-Fi CERTIFIED equipment, users can buy and use Wi-Fi CERTIFIED ac products with confidence that they will deliver improved performance and will work out of the box with legacy Wi-Fi equipment, as well as with certified equipment from any vendor.

This paper provides an overview of the performance improvements and key features supported in the
Wi-Fi CERTIFIED ac testing program, and it discusses how they meet the needs of the market. It presents use cases that illustrate environments in which the technology behind Wi-Fi CERTIFIED ac is required to support the wide adoption of emerging usage models. Finally, the paper provides information on the Wi-Fi CERTIFIED ac certification program and explains what the certification process covers.

Meeting the requirements of a more demanding Wi-Fi environment

The introduction of Wi-Fi CERTIFIED ac comes at a time when the confluence of multiple factors has intensified the demands on Wi-Fi. Among many users, Wi-Fi is the preferred connection technology for both fixed and mobile devices, and it is increasingly adopted in consumer electronics (CE) and machine-to-machine (M2M) devices. By 2019, Wi-Fi will carry up to 60% of smartphone and tablet data traffic, reaching more than 115,000 Petabytes or more than six billion Blu-ray movies[1].

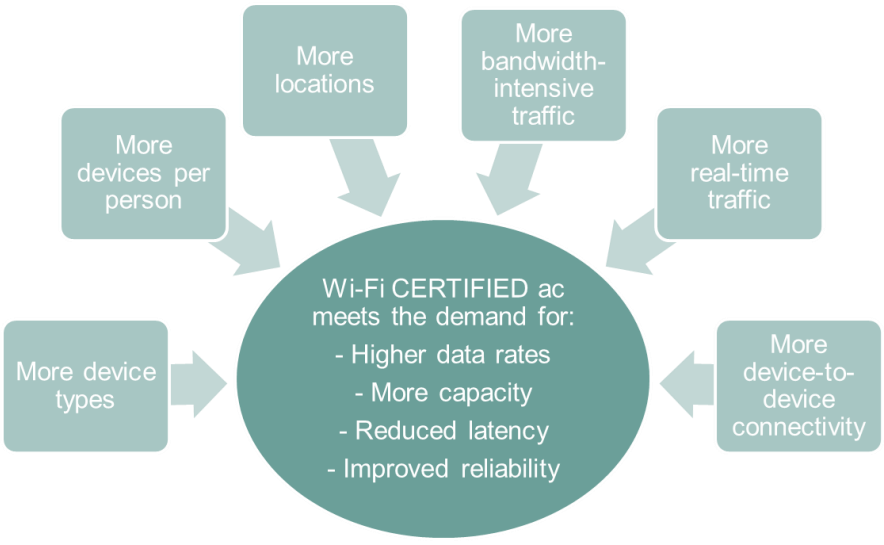

Figure 1. Market drivers to the creation of Wi-Fi CERTIFIED ac

[1] Juniper Research, June 2015

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More device types: Driven by the fast adoption of Wi-Fi-enabled smartphones, tablets, and consumer electronics, the landscape of Wi-Fi devices has become more diversified. In 2012, for the first time, smartphones accounted for more connections at Wi-Fi hotspots than laptops, according to research conducted by Informa Telecoms & Media on behalf of the Wireless Broadband Alliance (WBA)[2]. Tablets accounted for more than 16 percent of connections in 2012 – a remarkable share, given their recent introduction into the market. When laptops were the primary Wi-Fi device, the user base was confined to those with the need and financial means to buy such a device. Today, the increased diversity of devices with Wi-Fi – notably phones, smartphones, and tablets – has continued to propel Wi-Fi forward as one of the world's most loved technologies.

More devices per person: The increased support of Wi-Fi in devices that, until recently, had only cellular or no connectivity also translates into a higher number of Wi-Fi devices per person. Today, virtually all laptops, tablets, and smartphones include Wi-Fi, and many users have at least one of each. Many households have additional devices with Wi-Fi, such as televisions, set-top boxes, speakers, gaming consoles, and cameras. All of these devices compete for the bandwidth that was originally available to one or two devices – and often they do so at the same time. For instance, a user may be working on a laptop while downloading video to a TV, synching other devices in the background, and listening to music streamed from the home server to wireless speakers. With multiple users within the same household, traffic requirements grow quickly.

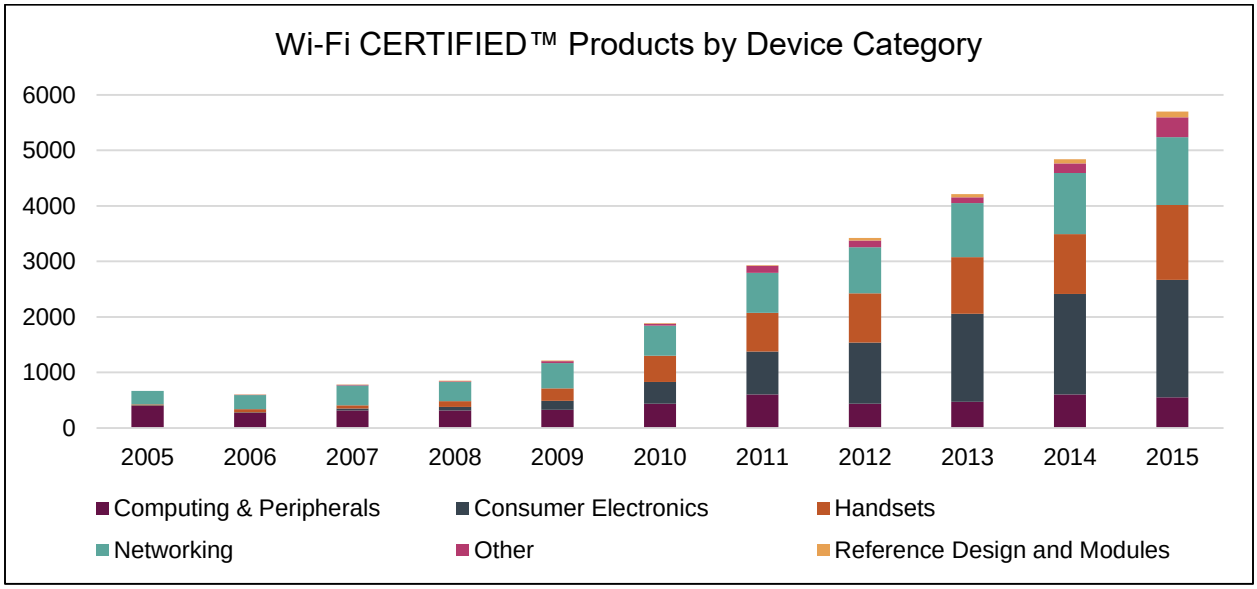

Figure 2. Wi-Fi CERTIFIED Products by Device Category. Source: Wi-Fi Alliance

[2] WBA Wi-Fi Industry Report: Global Trends in Public Wi-Fi, November 2012.

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More locations: Now more than ever, users have an increased propensity to use Wi-Fi not just in the office and living room, but also throughout the house and the backyard. Home users expect Wi-Fi connectivity to go past walls and at least one floor, and prefer the flexibility of placing an AP in a convenient location – for example, next to the broadband modem in the home office in the basement.

In the enterprise, employees expect to connect throughout the campus, from office, to conference room, to lobbies and corridors. This creates the need for more consistent and reliable coverage within the existing footprint.

More bandwidth-intensive traffic: The growth of available applications and content, both online and stored in home servers, contributes to the growth of traffic. Applications such as video streaming and photo sharing create additional demand on Wi-Fi networks. Users expect to be able to use these applications in any location, whether at home, work, or a public gathering, and at any time of day, no matter if other users are also contributing to a congested network. Most of the time, users have at least one device at arm's reach and plenty of recent and compelling content from a variety of sources.

More real-time traffic: Traffic loads are growing, and the type of traffic is changing, too. Applications for voice and graphics-intensive gaming require real-time connectivity. Latency has a negative impact on the quality of experience (QoE). The multiple real-time traffic streams generated within a household or office at the same time require products that can deliver low latency.

More device-to-device connectivity: New use cases and applications are emerging that extend beyond traditional network connections, instead allowing for content to be shared directly with nearby devices, without the mediation of a home server or an AP. With Wi-Fi CERTIFIED Wi-Fi Direct™ and Wi-Fi CERTIFIED Miracast™, Wi-Fi offers robust device-to-device connectivity that is especially well suited for multimedia content, which is likely to further contribute to the increase in traffic load as users start to stream content to their preferred display devices, rather than move to the device that stores the content they want to access.

Why upgrade to Wi-Fi CERTIFIED ac?

The improved performance of Wi-Fi CERTIFIED ac addresses the increased demands on wireless connectivity that the previous section presents. It is not all – or perhaps even primarily – about the increase in data rates that individual users see. The increase in overall network capacity, the low latency, and the high robustness contribute to meeting the demand from environments with more mobile devices and multimedia traffic.

The most noticeable or valuable benefits of Wi-Fi CERTIFIED ac vary greatly across users and environments:

- **Improved use of the 5 GHz band.** With wider channels, more of the available spectrum can be used for faster and more efficient transmission.

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- **High network capacity** is crucial to meeting the cumulative high traffic load from a large number of devices connected to the same AP. Increased capacity allows each AP to support a greater number of devices.
- **High data rates** to individual devices are most prized by users who run concurrent applications, particularly those generating rich multimedia content
- The higher data rate translates into not only higher QoE, but also faster content delivery (e.g., for large downloads) and **less power consumption**, due to Wi-Fi CERTIFIED ac's ability to power the transmitter less frequently than previous versions to download or upload the same content
- **Low latency** helps enhance the performance of real-time applications such as voice, multimedia streaming, and gaming. A low latency is necessary to provide a high-quality, smooth multimedia experience.
- **Improved robustness** makes the Wi-Fi experience uniform across the coverage area. Users do not want to move to a different room to get better connectivity; they expect to have a consistent coverage level throughout the house or office and to be able to connect everywhere within the AP coverage area.

Use cases: Residential and enterprise

The improved performance with Wi-Fi CERTIFIED ac products substantially changes the end-user experience in many use cases, and it may be necessary to support specific applications, especially in difficult RF environments with a high density of active devices engaging in bandwidth-intensive and latency-sensitive applications. The tables below provide some examples of these use cases for consumers (Table 1) and enterprises (**Error! Reference source not found.**).

Consumer use cases
Families can watch up to three lightly compressed HD videos simultaneously in different parts of the house. A movie can be transferred from a central media server to a Wi-Fi television in a bedroom, while a YouTube video is played on a tablet, and another movie is streamed to a living room television. Hotels, schools, and other public spaces have similar use cases.
Do a rapid sync-and-go before leaving on a trip – downloading video from a Wi-Fi camcorder or photos from a Wi-Fi camera to a smartphone or a tablet to take along and show to friends. A 900 MB MPEG4 video from the camcorder will take less than 10 seconds to download over a Wi-Fi CERTIFIED ac device. Similarly, an album of 150 JPEG photos, each 1.25 MB in size, will take less than two seconds over a Wi-Fi CERTIFIED ac network. In this case, the sync can take place directly between the devices, without AP participation.
View photographs across devices while kids watch movies in their room. Parents may be in the living room with friends and want to use their TV or tablet to show vacation photos stored on their network-attached storage (NAS). They have many high-quality photos (10 MB each) and want to go through most of the photos quickly so they can linger on the best ones. To accomplish this, Wi-Fi CERTIFIED ac provides a low latency link for a smooth presentation.

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Play graphics-intensive, latency-sensitive games that are installed on a desktop, but may be played on a TV screen and using a game console, which can be located in opposite ends of a house, separated by floors or walls. In this case, latency becomes the key metric of a good user experience, and Wi-Fi CERTIFIED ac helps deliver the low latency required for a satisfactory gaming experience.

Table 1. Consumer use cases

Enterprise use cases
Display lightly compressed HD content from a laptop screen to a monitor or a projector when working from an office. Employees may prefer a larger screen when at the desk or to share content with colleagues. In this case, HD-quality content can be shared from the laptop to the monitor by connecting directly, without the mediation of an AP.
Support video demonstrations or telepresence between presenters and the public – or groups of meeting participants – at different locations, with screens and cameras connected wirelessly to the local Wi-Fi AP. In this case, a large screen may be used and a high-definition concurrent uplink and downlink video connection may be required, in addition to a low latency.
Transfer video, voice, and data using multiple concurrent streams. In a dense office environment where APs serve clusters of highly active employees, each AP is used to simultaneously contact remote colleagues and clients, engage in voice or video calls, share desktops, and send large data files.

Table 2. Enterprise use cases

Technology overview

The technology behind Wi-Fi CERTIFIED ac combines a more effective use of available spectrum with new features. The program was launched in 2013, and an update in 2016 adds a second wave of features to further meet the demand for higher performance and more capacity on Wi-Fi networks. Some of the features in the Wi-Fi CERTIFIED ac program are mandatory for all devices (Table 3). Other features are optional because some APs and STAs may not require them or are not well suited to supporting them. For instance, phones and M2M modules may not have the form factor to accommodate the multiple antennas that MIMO and beamforming require. Cost, size, and power consumption considerations also play a role, and optional features give vendors flexibility and an opportunity to differentiate equipment.

MU-MIMO (Downlink): Starting in June 2016, Wi-Fi CERTIFIED ac includes support for downlink MU-MIMO. MU-MIMO (Downlink) increases overall network throughput by transmitting to multiple different receivers simultaneously. Similar to MIMO (see below), multiple antennas in the AP transmit multiple spatial streams to STAs. However, these spatial streams can be received by different STAs at the same time, resulting in an increase in overall network throughput.

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Continued MIMO support: Wi-Fi CERTIFIED n introduced the use of MIMO in Wi-Fi, and Wi-Fi CERTIFIED ac continues to support this capability. Multiple antennas in the AP and in the STA allow Wi-Fi to use multiple spatial streams, which provide an increase in capacity – and hence a more effective use of the spectrum available. MIMO uses multipath to send and receive the signal over multiple spatially separated paths on the same channel at the same time.

Channel size: The increased data rates in Wi-Fi CERTIFIED ac are largely due to the increase in channel width. Wi-Fi CERTIFIED a, b, and g were developed with 20 MHz channels. With Wi-Fi CERTIFIED n, the maximum channel width doubled to 40 MHz. Wi-Fi CERTIFIED ac pushes the envelope and adds support to channel widths up to 160 MHz in the 5 GHz band. This leads to more efficient use of the equipment and of the overall available spectrum, and a more cost-efficient use of network resources as it leads to lower per-bit costs of the Wi-Fi infrastructure.

Spectrum bands: One of the most significant aspects of Wi-Fi CERTIFIED ac is the shift of Wi-Fi traffic from the 2.4 GHz band to the 5 GHz band.

Wi-Fi CERTIFIED ac works only in the 5 GHz band, because only this band has sufficient spectrum to accommodate the wider channels supported by Wi-Fi CERTIFIED ac. However, most Wi-Fi CERTIFIED ac devices include a Wi-Fi CERTIFIED n chipset that transmits in the 2.4 GHz band, bringing to market Wi-Fi CERTIFIED ac equipment that is fully compatible with legacy Wi-Fi.

The trend toward a greater use of the 5 GHz band, however, can have a substantial impact on user experience because it reduces the load on the densely used 2.4 GHz band. Without taking into account the new features supported by Wi-Fi CERTIFIED ac, 5 GHz users benefit from less crowded spectrum and lower interference levels. This translates into more reliable connectivity and faster data rates.

Beamforming: Wi-Fi CERTIFIED ac expands MIMO capabilities by adding beamforming as an optional feature. Beamforming allows Wi-Fi equipment to steer the transmitter beam to the receiver using feedback from the receiver. Wi-Fi CERTIFIED ac supports transmit beamforming, in which the transmitting device sends the signal over multiple antennas and the receiving device requires just one antenna.

The ability to selectively steer the transmit beam to the receiving device improves the link budget, especially in environments with high levels of fading. In terms of performance, beamforming extends the network footprint by reaching more distant locations and minimizing spots with limited or no coverage.

Higher modulation and coding schemes: In order to transmit digital data to a device over Wi-Fi, the data must first be converted to an analog signal. This process, and the encoding of the data, can be done with various modulation types. Both Wi-Fi CERTIFIED n and Wi-Fi CERTIFIED ac mandate the support for 64 quadrature amplitude modulation (QAM). Wi-Fi CERTIFIED ac introduces optional support for the higher-order 256 QAM, using a coding rate of 3/4 or 5/6, which improves the data rate to STAs by increasing the number of bits per symbol. The impact on actual network throughput is variable, because it depends on which STAs within the coverage area can move to 256 QAM, and that depends on the RF environment and the location of the devices. Because the increased throughput to 256 QAM STAs is achieved through more effective spectrum

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use, the higher-order modulations also bring an overall increase in network capacity and hence a benefit to all STAs within the network, even if they do not use 256 QAM.

Power consumption: An indirect but welcome effect of the increase in data rate to individual STAs and the more efficient modulation is a reduction in the power consumed by a STA to transmit the same traffic load. As STAs spend a shorter time transmitting, their per-bit power consumption correspondingly decreases. Of course, shorter transmission times may encourage higher traffic loads, because users can use their devices more intensively (e.g., pack more video downloads into the same time). When this is the case, the overall battery life of the device might not increase – or the change might be less than expected if traffic load has stayed the same.

Mandatory feature	Benefit
5 GHz spectrum band	Less intensely used spectrum with higher throughput
20 MHz, 40 MHz and 80 MHz channelization	Increases data rate
Two spatial streams for non-mobile APs, one for mobile APs[3] and STAs	Increases data rate and spectral efficiency
64 QAM modulation	Improves spectral efficiency
Clear channel assessment (CCA) on secondary channels	Improves network performance and fairness of resource allocation among devices
Clear to send (CTS) with bandwidth indication	Optimizes network performance and mitigates interference when using 80 MHz channels
Receive (Rx) Aggregate MAC protocol data unit (A-MPDU) and transmit (Tx) A-MPDU	Improves efficiency through a reduction in overhead; increases the size of MAC protocol frames
Very-high-throughput (VHT) A-MPDU delimiter for Rx and Tx for single MPDU	Mitigates interference and increases data rates
Short guard interval (SGI)	Higher data rates (note this feature became mandatory in June 2016)

Table 3. Mandatory features in Wi-Fi CERTIFIED ac

[3] Mobile APs are devices, such as mobile Wi-Fi routers, that can be battery powered.

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Optional features	Benefit
Three spatial streams in APs and STAs	Increases per-device throughput
256 QAM higher-order modulation (3/4 rate, or 3/4 and 5/6 rate)	Higher data rates. It is ideally suited to mobile STAs with antenna size limitations, such as smartphones
Transmit beamforming (TxBF)	Improves coverage reliability by steering the transmitted signal to the receiver. It requires a transmitter with multiple antennas
Aggregation of MPDUs and MSDUs (MAC service data unit) in the receive link	Higher transmit efficiency of data transfers that use aggregation (e.g., compressed video and gaming)
Low-density parity check (LDPC)	Increases robustness of link between Wi-Fi CERTIFIED ac devices (high data rates, low latency and high robustness), and lower power consumption
Transmit space-time block coding (STBC) in the AP	Improves reception at the STA when multiple-antenna APs are used, obtained by spreading the transmitted signal over multiple antennas to improve reception

Table 4. Optional features in Wi-Fi CERTIFIED ac

Optional second wave features	Benefit
Four spatial streams in APs and STAs	Increases per-device throughput
Multi-User MIMO (Downlink)	Provides a significant increase in overall network throughput by transmitting to multiple different receivers simultaneously
160 MHz channelization	Doubles the data rate compared to 80 MHz channels
Extended 5 GHz channel support for STAs	Improves performance by spreading the load of Wi-Fi traffic across more channels
Request to send (RTS) with BW Signaling	Optimizes network performance and mitigates interference

Table 5. Optional second wave features in Wi-Fi CERTIFIED ac

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The Wi-Fi CERTIFIED ac certification program

The Wi-Fi CERTIFIED ac certification program tests and certifies interoperability of critical features of the IEEE 802.11ac standard[4]. It ensures that equipment conforms to the specifications, interoperates with equipment from multiple vendors, and meets performance thresholds.

The certification program is open to any type of Wi-Fi equipment, including APs and STAs, but it is not mandatory for equipment submitted for Wi-Fi certification. Wi-Fi CERTIFIED ac complements Wi-Fi CERTIFIED b, g, and n in the 2.4 GHz band, and will become the prevalent MAC/PHY in the 5 GHz band as the next step in the Wi-Fi evolution, beyond Wi-Fi CERTIFIED a and Wi-Fi CERTIFIED n.

Wi-Fi CERTIFIED ac retains the interoperability common to all Wi-Fi Alliance CERTIFIED programs, which ensures:

- Interoperability with Wi-Fi CERTIFIED equipment from any vendor
- Backwards compatibility with previously certified equipment operating in similar frequency bands
- Seamless integration of the functionality provided by certification programs such as Wi-Fi Protected Access 2 (WPA2) (security), Wi-Fi Multimedia (WMM) (quality of service) and Wi-Fi Protected Setup™ (ease of use).

Both the AP and the STA, or the two connected STAs, need to be Wi-Fi CERTIFIED ac to benefit from Wi-Fi CERTIFIED ac functionality. Legacy STAs may indirectly benefit from connecting to Wi-Fi CERTIFIED ac networks, because the increased efficiency and spectrum utilization may free up network resources that legacy devices can use.

To be certified under the ac program, equipment is required to have passed the certification test plans for:

- MAC/PHY: a, n (for single-mode, 5 GHz devices); a, b, g, n (for dual-mode, 2.4 GHz and 5 GHz devices)
- Security: WPA2
- QoS: WMM

Users can search for Wi-Fi CERTIFIED ac products within the Wi-Fi Alliance's Product Finder or by checking a product's interoperability certificate. This certificate shows all program certifications for a device, the spectrum bands used (either 2.4 GHz or 5 GHz, or both) and the optional features supported (for a definition of mandatory and optional Wi-Fi CERTIFIED ac features, see Table 3 and Table 4).

[4] IEEE P802.11ac-2013, "IEEE Standard for IT - Telecommunications and Information Exchange Between Systems - LAN/MAN - Specific Requirements - Part 11: Wireless LAN Medium Access Control and Physical Layer Specifications – Amendment 4: Enhancements for Very High Throughput for operation in bands below 6 GHz,", December 2013.

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Summary

Wi-Fi's proliferation around the world and growth in Wi-Fi adoption and use has increased the demand on Wi-Fi performance along multiple dimensions to accommodate increasing volumes of real-time and bandwidth-intensive content in multi-device environments. Driven by an increasing penetration of mobile Wi-Fi devices such as smartphones and tablets, the more widespread consumption of multimedia content shared or streamed, and an overall shift of traffic toward wireless technologies, Cisco's VNI shows that Wi-Fi carries roughly half of mobile traffic today and will carry 60 percent by 2019.

Wi-Fi CERTIFIED ac is the first generation of Wi-Fi that can deliver gigabit per second data rates, and the program continues to innovate with the addition of a second wave of features that help meet today's demanding applications. Wi-Fi CERTIFIED ac brings to the market a new MAC/PHY that leverages wider spectrum channels, the less intensively used 5 GHz band, beamforming, and higher modulation to meet new performance requirements and usher Wi-Fi to the gigabit data-rate level.

Wi-Fi Alliance encourages the market adoption of Wi-Fi CERTIFIED ac, based on the IEEE 802.11ac standard amendment, through a certification program that tests for specification compliance, minimum performance requirements, interoperability across vendors, and backwards compatibility.

List of acronyms

A-MPDU	Aggregate MPDU
AP	Access point
ASD	Application-specific device
ATL	[Wi-Fi Alliance] Authorized Test Laboratory
BYOD	Bring your own device
CAD	Computer-aided design
CCA	Clear channel assessment
CE	Consumer electronics
CTS	Clear to send
CWG-RF	Converged Wireless Group Radio Frequency
DL	Downlink
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet protocol
IT	Information technology
JPEG	Joint Photographic Experts Group

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LAN	Local area network
LDPC	Low-density parity check
M2M	Machine to machine
MAC	Media access control (layer)
MAN	Metropolitan area network
MIMO	Multiple input, multiple output
MPDU	MAC protocol data unit
MPEG	Moving Picture Experts Group
MSDU	MAC service data unit
MU-MIMO	Multi-user MIMO
PHY	Physical (layer)
PMF	Protected Management Frames
PVR	Personal video recorder
QAM	Quadrature amplitude modulation
QoE	Quality of experience
QoS	Quality of service
RF	Radio frequency
RFID	Radio-frequency identification
RTLS	Real-time location system
RTS	Request to send
Rx	Receive
SGA	Short guard interval
STA	Station
STBC	Transmit space-time block coding
TCO	Total cost of ownership
Tx	Transmit
TxBF	Transmit beamforming
UDP	User datagram protocol
VHT	Very high throughput
VNI	Cisco Virtual Networking Index
WBA	Wireless Broadband Alliance
WLAN	Wireless LAN
WMM®	Wi-Fi Multimedia™
WPA2™	Wi-Fi Protected Access® 2

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Further information resources

An up-to-date list of certified products can be found in the Product Finder on the Wi-Fi Alliance website. Users can search for Wi-Fi CERTIFIED equipment by multiple criteria, including product category, manufacturer, certification date and features supported, and can view the interoperability certificate for certified products.

For further information on Wi-Fi Alliance certification programs and for white papers on Wi-Fi–related topics, please visit www.wi-fi.org.

About Wi-Fi Alliance

www.wi-fi.org

Wi-Fi Alliance® is a global non-profit industry association – our members are the worldwide network of companies that brings you Wi-Fi®. The members of our collaboration forum come from across the Wi-Fi ecosystem and share a common vision of connecting everyone and everything, everywhere. Since 2000, the Wi-Fi CERTIFIED™ seal of approval designates products with proven interoperability, industry-standard security protections, and the latest technology. Wi-Fi Alliance has certified more than 30,000 products, delivering the best user experience and encouraging the expanded use of Wi-Fi products and services in new and established markets. Today, billions of Wi-Fi products carry a significant portion of the world's data traffic in an ever-expanding variety of applications.

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