WHITE PAPER

802.11ac Demystified

XIRRUS
High Performance Wireless Networks

802.11ac Demystified

Introduction

Millions of new wireless devices are activated every day and it's no wonder—the average wireless user has 2.8 devices. The volume of application traffic used by these devices will overtake the total traffic on wired networks by 2014.[1] Video traffic will account for the majority of this traffic, expected to be up to 70% of global traffic sometime during 2015.[2]

In the enterprise, Wi-Fi device data consumption is expected to surpass wired data usage sometime in 2015.[3] Modern enterprises depend on anytime, anywhere access to communications, cloud services, and business applications including ERP, CRM, business analytics, video conferencing, and collaboration. The trend from desktop and laptops to tablets and smartphones, coupled with corporate acceptance of bring-your-own-device (BYOD) policies are changing the landscape. Wi-Fi networks must supply both higher performance and higher bandwidth. 802.11ac will enable new applications that were previously impractical with Wi-Fi connections, including real-time access to business information and ability to transfer larger amounts of data.

802.11ac is a continuation of the IEEE 802.11 standard; each new standard multiplied the maximum data rate by 5-10x. Figure 1 details the evolution of the IEEE 802.11 Wi-Fi standard, demonstrating how new frequency bands, radio channels, signaling techniques, and multiple antennas have been used to dramatically increase Wi-Fi data rates. To help meet the exploding need for more wireless performance, the IEEE 802.11ac standard is emerging as the next evolutionary step beyond 802.11n.

RATIFICATION YEAR	IEEE STANDARD	BAND		CHANNEL BANDWIDTH	RADIO DESIGN	MAX SPATIAL STREAMS	MAX DATA RATE
		2.4GHZ	5GHZ				
1997	802.11	X		20MHz	SISO	1	2Mbps
1999	802.11a		X	20MHz	SISO	1	54Mbps
1999	802.11b	X		20MHz	SISO	1	11Mbps
2003	802.11g	X		20MHz	SISO	1	54Mbps
2009	802.11n	X	X	20/40MHz	MIMO	4	600Mbps
2014*	802.11ac		X	20/40/80/160MHz	MU-MIMO	8	6.93Gbps

* Planned to be ratified

Figure 1 – IEEE 802.11 Standards Reference

1 http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-481360_ns827_Networking_Solutions_White_Paper.html

2 Cisco VNI.

3 Cisco VNI.

What is IEEE 802.11ac?

IEEE STD 802.11ac is a standard developed by the IEEE that finally breaks the Gigabit-Ethernet barrier with access point (AP) data rates of up to 6.93Gbps. 802.11ac will bring users a number of visible advancements:

- **Data rate.** APs may transmit at a maximum of 6.93Gbps and single clients such as laptops may reach up to 1.73Gbps. These speeds depend on the use of up to eight antennas, along with a corresponding number of radio transmitter/receivers. It should be noted that many mobile clients, including smartphones and tablets normally don't use multiple antennas and are unlikely to operate beyond 433Mbps.

  Roll out of 802.11ac devices is expected in two phases. Wave 1 802.11ac products, first available in consumer products in 2012 and enterprise products in 2013, support 80MHz channels and up to 3 data streams for a maximum data rate of 1.3Gbps. Wave 2 and future products, expected starting in 2014, will add 160MHz channels and up to 8 streams, for a maximum data rate of 6.93Gbps.
- **Rate at range.** Although the maximum distance that a Wi-Fi signal can reach will remain unchanged with 802.11ac, multiple antennas will extend the data rate at every distance. Figure 2 shows how a three antenna 802.11ac AP increases data rate at all distances compared to 802.11n APs with one and three antennas.
- **Multi-user performance.** 802.11ac uses multiple antennas to simultaneously transmit to multiple clients. This alleviates congestion delays, where one client needs to wait for another to complete – much like being delayed behind a slow driver on a single-lane road.

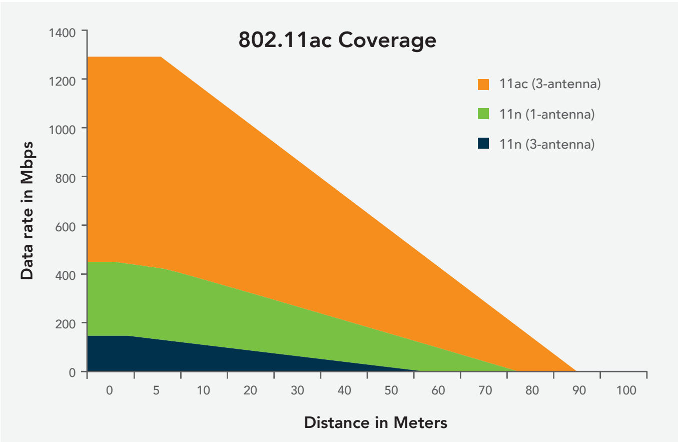

Figure 2 – 802.11ac Rate at Range

IEEE 802.11ac Technological Advancements

The speed, range, and performance advancements of 802.11ac are due to a number of significant technological advancements.

Eight Simultaneous Data Streams

The use of up to eight simultaneous data streams from eight antennas is a key element of 802.11ac, allowing up to 6.93Gbps of throughput. This allows signals to be transmitted from and received by multiple antennas, increasing the data rate between endpoints. This doubles the earlier 802.11n standard of four streams which were able to transmit up to 600Mbps.

However enabling 8 antennas on a single mobile device needs further technology advances. The currently available Wave 1 products support up to 3 data streams and initial round of Wave 2 products are expected to support up to 4 streams.

Multi-user Multiple-Input-Multiple-Output (MU-MIMO)

802.11ac also introduces the concept of parallel transport through MU-MIMO, where multiple clients receive packets concurrently from a single AP. This allows an AP to transmit data to multiple client devices in the same frequency spectrum at the same time, increasing overall wireless system performance.

With 802.11n, whenever the AP transmitted data, all of the traffic at any instant of time was directed to a single client. As a consequence, if a set of devices included a mix of fast and slow client clients, the fast traffic was often substantially delayed by the transmission to slower clients. 802.11ac MU-MIMO works by directing some of the spatial streams to one client and other spatial streams to other clients, up to four at a time. MU-MIMO is especially effective where there are a large number of clients, for example, in stadiums, near hotspots, and in large enterprises.

Figure 3 is one example of MU-MIMO at work. The transmitter, an AP, wishes to transmit two data streams (blue and green in the figure) to a laptop and a smartphone, respectively. The AP has four antennas, the laptop has three, and the smartphone has one. In this case, the AP uses three of its antennas to transmit to the laptop. The data stream destined for the laptop is divided into three streams and is transmitted to all three receiver antennas. The fourth AP antenna simultaneously transmits its stream to the smartphone.

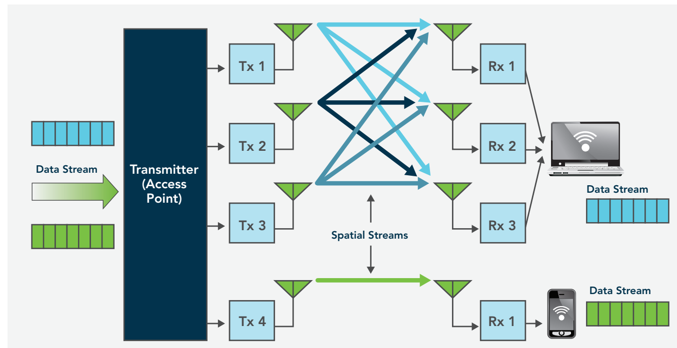

Figure 3 – 802.11ac MU-MIMO

Higher Precision and Sensitivity

In order to increase the transport rate, 802.11ac makes use of a higher rate modulation scheme known as 256-QAM, which transmits 33% more data than the 64-QAM used in the 802.11n standard. The signal level that receivers must distinguish is significantly smaller, requiring more sensitive receivers and higher precision transmitters. 802.11ac still supports lower QAM levels, which are used for extended range transmission and areas of client congestion.

80 and 160MHz Channel Widths

802.11n used a basic channel width of 20MHz with the ability to bond two channels into a 40MHz channel. 802.11ac uses 80MHz and 160MHz bandwidths while still supporting 20 and 40MHz channels. Bonding of two 40MHz channels to 80MHz results in a 117% increase in data rate over 40MHz, while bonding of two 80MHz channels results in a 333% gain over a single 40MHz channel. Wave 1 802.11ac products will support 20, 40, and 80MHz channels.

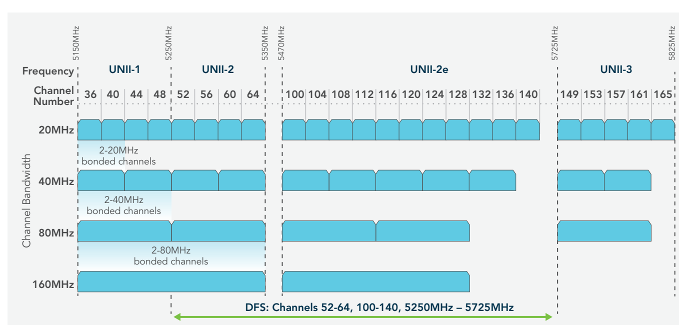

Figure 4 – Channel Bonding

802.11ac operates exclusively in the 5GHz frequency range. This avoids the congested 2.4GHz range that can experience interference from microwave ovens, Bluetooth headsets and other devices. Figure 4 illustrates the channels available for 20MHz basic channels and 40/80/160Mhz bonded channels. The allocation varies slightly by nation, but in the United States the following numbers of channels are available in each size; the variation is due to possible interference from weather radar:

- 20-25 20 MHz channels
- 8-12 40 MHz channels
- 4-6 80 MHz channels
- 1-2 160 MHz channels

In addition, 802.11ac provides for 160MHz channels to be constructed from non-contiguous 80MHz channels. This offer an additional 13 combinations of 160MHz channels.

Beam Forming

Beam forming is a technique that optimizes communications between APs and clients to counter interference. In beam forming, the AP communicates with clients to determine the types of impairment that exist between them. The AP then "pre-codes" the transmitted frame with the inverse of impairment such that when the next frame is received with better signal integrity. Since no two clients are in the same location and may move, beam forming must be applied on a client-by-client basis and constantly.

Sample Data Rates

IEEE 802.11ac data rates are dependent on the number of spatial streams used by MU-MIMO, 80 vs. 160MHz channel widths, the number of transmit antennas, and the type of modulation. Figure 5 shows the maximum data rate achievable at each level, with many additional lower rates occurring at each level dependent on signal level, signal to noise ratio, and other conditions.

MAXIMUM DATA RATE	# TRANSMIT ANTENNAS	BAND-WIDTH (MHz)	# STREAMS	MODULATION	
293Mbps	1	40	1	64-QAM	Wave 1
433Mbps	1	80	1	256-QAM	
867Mbps	2	80	2	256-QAM	
1.299Gbps	3	80	3	256-QAM	
1.730Gbps	4	80	4	256-QAM	Wave 2+
3.470Gbps	8	80	8	256-QAM	
867Mbps	1	160	1	256-QAM	
1.730Gbps	2	160	2	256-QAM	
3.470Gbps	8	160	4	256-QAM	
6.930Gbps	8	160	8	256-QAM	

Figure 5 – Sample Data Rates

802.11ac Use Cases

The higher bandwidth and MU-MIMO capabilities inherent in 802.11ac will allow business applications that were previously impractical over Wi-Fi.

The 802.11ac Wi-Fi networks will allow:

- Large data transfers. In the past it was impractical to replicate large amounts of data to portable devices and to keep them in sync.
- Wireless displays. Tablets will soon be every bit as capable as laptop computers, but lack screen area. As they become the platform of choice for business users, the ability to link wirelessly to wireless-capable LCD displays and projectors will become possible.
- Real-time updates. A wide range of time-critical applications, including ERP, CRM, business analytics, stock trading, competitive bits, and sales lead opportunities will be empowered by 802.11ac 5GHz availability.
- Video conferencing. Reliable, distortion free one-on-one and multi-party video conference will become the standard with 802.11ac. No special equipment or facility reservations will be necessary.
- Collaboration. Cooperative, real-time work on data files and documents, for business analysis, for planning will be enabled by 802.11ac's dependable availability.

802.11ac Deployment Considerations

The theoretical data rates described in this white paper are just that, theoretical. For 802.11ac deployments, and in fact for all Wi-Fi deployments, IT managers and users must be made aware that of factors that affect real-world performance. The following are some important considerations in the deployment of Wi-Fi networks that include 802.11ac:

- Wireless networks are not wired networks. Wired network users who share a Gigabit network can expect to see bursts of up to 900Mbps, depending on their hardware. The maximum Wi-Fi data rates shown in Figure 5 are reduced by signaling overhead and media contention. Most 802.11ac users will see data rates less than 100Mbps as the effective bandwidth is shared among all devices connecting to a given radio.
- Migration to 802.11ac will take time. Older Wi-Fi technologies will continue to be with us for years. In order for 802.11ac to provide maximum data rates, it is important to keep interference from earlier Wi-Fi standards at a minimum. 802.11n devices, for example, operating in the 5GHz band can slow down 802.11ac devices to 300Mbps or 450Mbps depending on the 2x2 or 3x3 MIMO technology used.

- **Infrastructures must be upgraded as well.** The bandwidth required out of 802.11ac APs will certainly exceed 1Gbps and may reach 10Gbps. The links from the APs to the core network must keep pace with this need. Centralized firewalls, LAN controllers, and authentication servers may also reach their limits. Migration to a decentralized architecture, with intelligence at the edge of the network may be a more scalable solution, avoiding single points of failure.
- **More power.** The power required by multi-antenna APs handling 802.11ac speeds will likely require more power. As you are planning to deploy 802.11ac in your environment power planning from your access switches should be carefully considered.
- **A new site survey may be needed.** Wireless networks established as recently as a few years ago were probably designed for coverage and not capacity. APs were placed so that there were no dead zones, without considering future capacity needs. With the increasing use of mobile devices, new site surveys that ensure enough bandwidth for anticipated usage should precede deployment of 802.11ac APs.
- **Companies need to manage application usage.** With 802.11ac, a range of applications are now practical on mobile devices that were previously only used over wired networks or on laptops. Uncontrolled use of Wi-Fi bandwidth can cause wireless networks to quickly degrade. Network control elements must prioritize and control use of applications.

Conclusion

802.11ac is an excellent evolutionary step in Wi-Fi technology with new, significant technology. There are some challenges, however, in getting the most from the technology. Careful planning that includes anticipated usage over the next five years must precede deployments. APs that have the capacity, expandability, and control to handle the integration and migration to 802.11ac must be selected.

Glossary

Access Point	Often a wireless router, a device that connects wireless devices to another network.
AP	See Access Point
Bandwidth	The maximum transmission capacity of a communications channel, measured in bits per second.
BSSID	Basic Service Set Identifier. A unique address that identifies the access point/router that creates a wireless network. (See SSID)
Channel	One portion of the available radio spectrum that devices on a wireless network use to communicate.
DFS	Dynamic Frequency Selection. A technique for automatic selection of the most noise free channel.
Dual-band	A Wi-Fi device that can operate in both the 2.4GHz and 5GHz bands.
ESSID	Extended Service Set Identifier. A name used to identify a wireless network. (See SSID)
Gbps	Gigabits per second. A measure of data speed – roughly 1 billion bits per second.
GHz	Giga-hertz. A measurement of frequency – 1 billion cycles per second.
GI	Guard Interval. An interval of dead time between Wi-Fi transmissions. 802.11ac uses reduced guard intervals.
Hotspot	A location where users can access the Internet using Wi-Fi enabled devices free or for a fee.
Mbps	Megabits per second. A measure of data speed – roughly 1 million bits per second.
MCS	Modulation and Coding Scheme. The technique use to encode over the air data. For example, 256-QAM.
MHz	Mega-hertz. A measurement of frequency – 1 million cycles per second.
MIMO	Multiple-Input-Multiple-Output. A signal processing technique that uses multiple receivers and transmitters in both the AP and client.
MU-MIMO	Multi-user MIMO. An advanced technique that allows APs to transmit to simultaneously multiple clients at the same time using multiple antennas.
PHY	The lowest, physical layer of the OSI Network Model. In Wi-Fi, the PHY defines parameters such as data rates, modulation method, signaling parameters, synchronization, etc.
QAM	Quadrature Amplitude Modulation. An MCS technique that uses a combination of phase shifting and amplitude to represent data bits.
Router	A wireless router accepts connections from wireless devices to a network and may include a firewall for security, application control, and local address assignment.
SISO	Single-Input-Single-Output. A signal processing technique that uses one radio and stream at a time.
Site survey	A complete building survey to plan AP placement.
Sounding	A two conversations between APs and clients to determine any signal degradations between them.
SSID	A unique 32-character network name that differentiates one wireless LAN from another. (See BSSID, ESSID)
Client	Wi-Fi clients include laptop computers, smartphones, tablets that communicate with APs and each other.
TxBF	Transmit Beam Forming. An advanced technique that pre-codes a transmission so as to anticipate the effects of attenuation and interference. APs and clients use sounding to establish TxBF parameters.
VoWiFi	Voice over Wi-Fi. Voice over IP technology transported to the client via Wi-Fi.

About Xirrus, Inc.

Xirrus is the leading provider of high-performance wireless networks. Xirrus' Array-based solutions perform under the most demanding circumstances with wired-like reliability and superior security. The Xirrus wireless solutions provide a vital strategic business and IT infrastructure advantage to the education, healthcare, government and enterprise industries that depend on wireless to operate business-critical applications. Headquartered in Thousand Oaks, CA, Xirrus is a privately held company that designs and manufactures its products and solutions in the USA. For more information please visit: www.xirrus.com and follow us on Twitter: @Xirrus.

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