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INTRODUCTION

Wi-Fi has become such an amazingly successful technology because it has continuously advanced while remaining backwards compatible.

The prior generation of Wi-Fi is known as Wi-Fi-certified 802.11n. 802.11n became popular because it improved performance significantly and aided enterprises in dealing with the rapid growth in mobile devices.

Since 802.11n became the standard interface on PCs, tablets and smartphones, the applications used by these devices have continued to progress. Mobile technology has encountered the next frontier – video.

Whether delivering YouTube to smartphones or moving HDTV signals around the office or home, video has become a significant driver of network traffic, chiefly because it requires one or two orders of magnitude more bandwidth than other IP services and is a continuous traffic stream rather than bursty email or web traffic.

The recent move to cloud-based services for companies is also stressing the bandwidth of today's networks due to the shift to having documents downloaded on demand to mobile devices rather than being stored locally.

The next step in improving performance and handling the explosion in numbers of mobile devices connecting to the networks is 802.11ac which was recently ratified as a standard by the IEEE in December 2013.

The Wi-Fi Alliance has been certifying the current generation of 802.11ac products, often referred to as Wave 1, since June 2013. 802.11ac delivers data rates up to 1.3 Gbps today and even higher in the second wave of products expected in 2015-2016.

The purpose of this paper is to provide a level of guidance towards the migration to 802.11ac.

802.11AC: THE BASICS

Why 802.11ac?

On average, there are 40 mobile apps on every smartphone and that number is growing on a daily basis. 310 billion mobile app downloads are expected by 2016, and 70% of smartphones will be 802.11ac-ready by 2015.

And don't forget about tablets. They generate nearly 3½ times more traffic than smartphones. Networks must contend with this higher demand. As of June 2014, over 600 802.11ac products were Wi-Fi-certified for interoperability, including over 375 client devices.

Enterprises have also grown more reliant on higher bandwidth, latency-sensitive applications. For example, virtual desktop infrastructures (VDI) are characterized by bursty, delay-sensitive traffic because processing occurs in the data center instead of locally.

HD video-capable mobile devices are proliferating. And users increasingly rely on them for fast and efficient mobile telepresence. Collaborative programs like Microsoft Lync, Apple FaceTime, Google Hangouts, Skype, WebEx and Citrix GoToMeeting create two-way video traffic across the network.

The use of podcasting and streaming has also skyrocketed. It is therefore only natural to see a huge increase in the consumption of multimedia on mobile devices in the residence hall. Due to the pervasiveness of wireless in some environments, the smart classroom has now become virtualized, which allows its capabilities to be delivered anywhere there is capacity to receive it.

The 80/20 rule for download and upload direction no longer exists. New app behavior has completely transformed traffic patterns. For example, smartphones synchronize all photos to cloud-based storage when a user walks into a building and connects to a Wi-Fi network.

Mobile apps are constantly updated in the background over the Wi-Fi or cellular network without IT or user intervention. Apps download new advertisement screens and software updates, issue stay-alive pings, and multiple devices continuously authenticate and synchronize while roaming.

IPTV and other locally generated video streaming are focused on the residence hall as well. The cable TV infrastructure is aging and campuses do not have the resources required to maintain separate networks. Combine that with the demand to propagate locally generated content, and many campuses are replacing their cable systems with some variant of IPTV.

Digital signage is receiving more play as well. Originally, digital signage was conceived as a static medium to replace paper bulletin boards in residence halls and other campus venues. Now, digital signage is used to stream multimedia news channels and other locally generated video clips along with their static information components.

More non-multimedia residential hall services are moving to IP as a transport. These services can impact the performance of latency-sensitive multimedia applications in those environments. Examples include physical security systems (door locks and video surveillance), vending machines, parking enforcement devices, and HVAC and other sensor-based systems.

We can think of 802.11ac as the next evolutionary step after 802.11n, along the path running from 802.11b to 802.11a/g, then 802.11n, and now 802.11ac.

802.11ac is a set of physical layer enhancements for higher throughput in the 5-GHz band, chiefly with video in mind, and to achieve this it extends the techniques pioneered in 802.11n: More antennas, wider channels, more spatial streams – along with a number of new features to boost throughput and reliability.

In the same way that chip vendors have now switched production almost completely to 802.11n, even for low-cost, low-power applications such as smartphones, we can confidently predict that 802.11ac will become the de facto standard for 5-GHz Wi-Fi equipment in the coming year. There are already over 375 client devices certified for 802.11ac today.

802.11ac: Technology overview

802.11ac brings about some very significant changes both in terms of RF spectrum utilization as well as technology features that will greatly enhance performance. Some of these changes will occur immediately while others will occur further down the road. Some of the key changes are listed here. For a more detailed look at 802.11ac, please refer www.802-11ac.net.

Backward compatibility and coexistence with devices in 5-GHz band

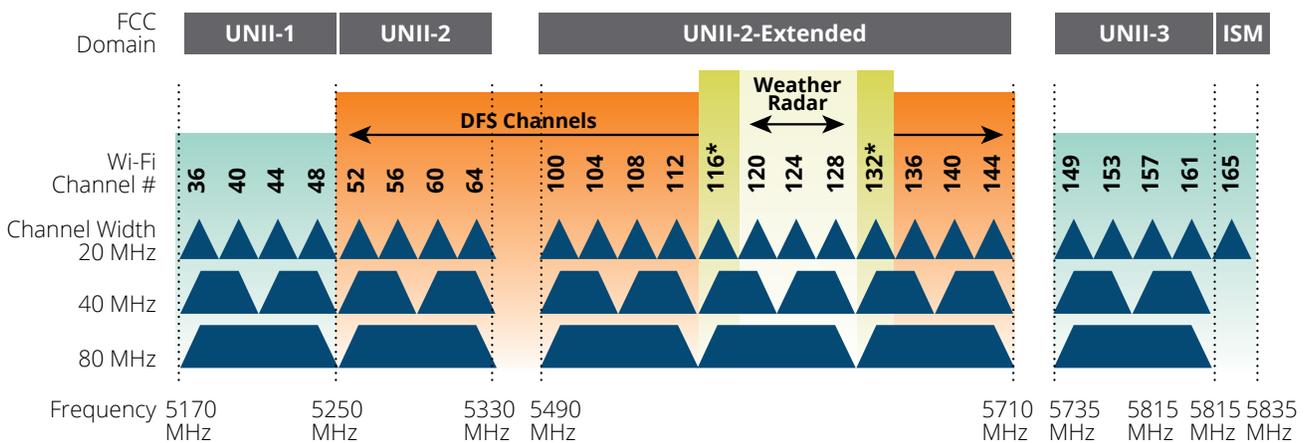
802.11ac access points are typically backwards compatible with 802.11a/b/g/n and are designed with dual-band radios that enable support of the 802.11ac (and 802.11a/n) clients on the 5-GHz radio while supporting 802.11b/g/n clients on the 2.4-GHz radio.

This will allow for a gradual migration away from these legacy devices to 802.11ac on a more time-manageable schedule. Note that not all of the features from 802.11ac will be available for use with these legacy devices.

RF spectrum

802.11ac will only operate in the 5-GHz radio spectrum (country-specific restrictions apply and some channels require Dynamic Frequency Selection):

- 5.150 to 5.250 GHz
- 5.250 to 5.350 GHz
- 5.470 to 5.725 GHz
- 5.725 to 5.850 GHz



*Channels 116 and 132 are Doppler Radar channels that may be used in some cases.

Figure 1

Multistation MAC throughput > 1 Gbps

The table below shows several of the data rates for 802.11ac. Actual link rates will vary greatly based on external factors such as distances to/from AP, signal-to-noise ratio, and proximity to other radio devices.

256 quadrature amplitude modulation (QAM)

802.11ac continues to exploit the limits of modulation and coding techniques, this time with the leap from 64-QAM to 256-QAM modulation that enables an improvement of up to 33%. It is important to note that the range for maximum 802.11ac rates are not the same as 802.11n because 256-QAM requires a higher signal-to-noise ratio (minimum 6-dB higher) to decode 802.11ac signals. These rates will only be achievable when clients are near the AP.

802.11AC THEORETICAL LINK RATES RATES				
Channel bandwidth	Transmit-receive antennas	Modulation and coding	Typical client type	Data rate
40 MHz	1x1	256-QAM 5/6, short guard interval	Smartphone	200 Mbps
40 MHz	3x3	256-QAM 5/6, short guard interval	Laptop	600 Mbps
80 MHz	1x1	256-QAM 5/6, short guard interval	Smartphone, Tablet	433 Mbps
80 MHz	2x2	256-QAM 5/6, short guard interval	Laptop, Tablet	867 Mbps
80 MHz	3x3	256-QAM 5/6, short guard interval	Laptop	1.3 Gbps

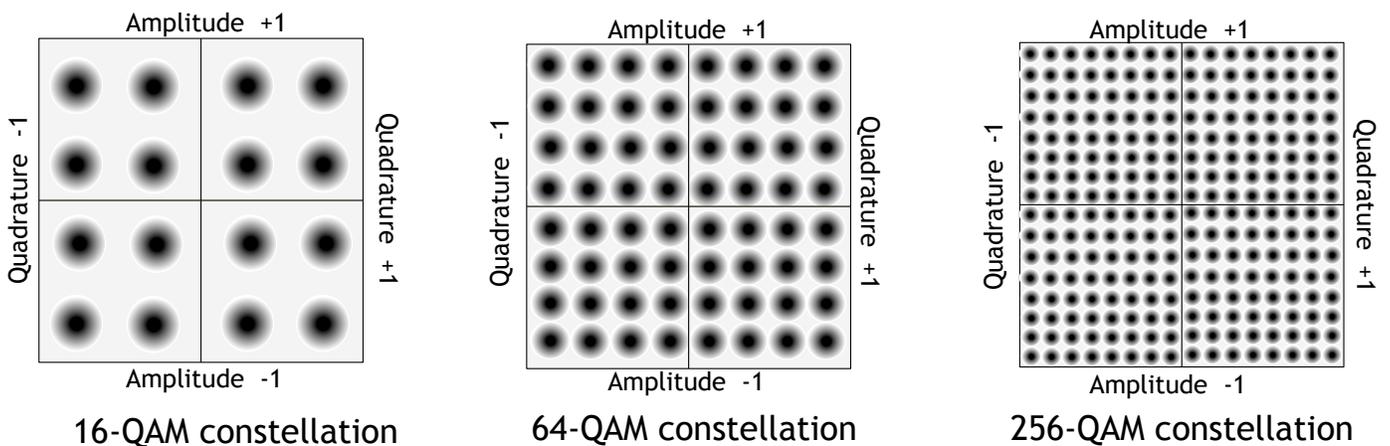


Figure 2: Constellation diagrams for 16-, 64-, 256-QAM

256-QAM, rate 3/4 and 5/6 are added as optional modes. For the basic case of one spatial stream in a 20-MHz channel, this extends the previous highest rate of 802.11n from 65 Mbps (long guard interval) to 78 Mbps and 86.7 Mbps respectively, a 20% and 33% improvement. Note that 802.11ac does not offer every rate option for every MIMO combination.

Beamforming

Beamforming is a technique implemented in digital signal processing (DSP) logic which allows the sender of the RF transmission to direct its energy towards a receiver to increase signal-to-noise ratio, thus improving the range and throughput of an AP. Beamforming is expected to become more prevalent with 802.11ac than previously with 802.11n because there is a single method, explicit beamforming, in the standard now.

Signals sent on separate antennas are coordinated to combine constructively at the receive antenna. The phases of these transmit signals are manipulated to improve directivity, thus enhancing the range for a given client.

The directed antenna radiation pattern looks something similar to the picture below, and efficient steering of individual streams in such a system provides overall gain which results in better SNR, and thus better modulation and data rates.

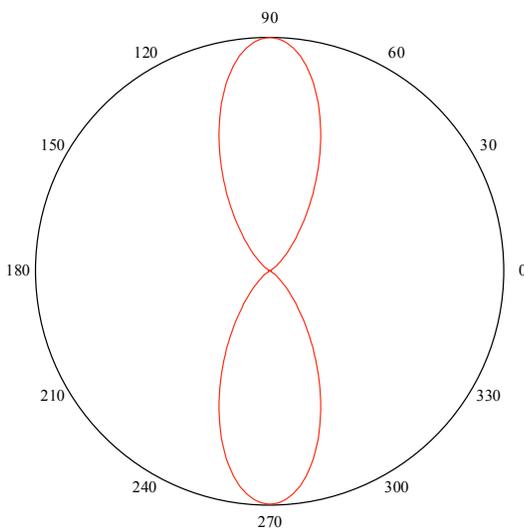


Figure 3: Linear plot depicting beamforming to direct signal energy

Greater channel width

Initially 802.11ac doubles the channel width to a maximum of 80 MHz while continuing to support configuration with 20- or 40-MHz channels. The standard is designed to allow for dynamic per packet negotiation of channel width so that when there is interference, the AP can fall back to 40- or 20-MHz channels temporarily.

What is coming next: 802.11ac Wave 2

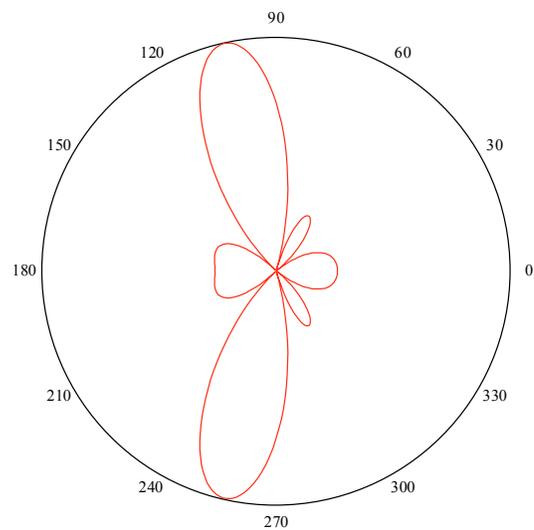
The next version of 802.11ac has been termed in the industry as Wave 2 and includes the following expected further enhancements.

Spatial streams are extended to four

It is expected that the new chipsets will increase support from three to four spatial streams. However, it is highly unlikely that there will be many, if any, clients that support this extension due to need to also add an additional antenna and the increased battery drain in mobile devices. It is expected that the benefit will come only when combined with multi-user MIMO (MU-MIMO) to enable transmission of more streams to several users simultaneously.

Downlink MU-MIMO

Thus far, all 802.11 communications has been point-to-point (one-to-one) or broadcast (one-to-all). With future versions of 802.11ac, a new feature allows an AP to transmit different streams to several targeted clients simultaneously.



For example, the AP could transmit one spatial stream to smartphone A while transmitting two spatial streams to laptop B. The one catch with MU-MIMO is that it will require new client hardware since the AP and client need to be designed with the MU-MIMO capability. Therefore, it will likely take until 2016, after the Wave 2 chipsets appear, for clients to become pervasive and be able to leverage the benefits of MU-MIMO.

Wider channels extend to 160 MHz

This feature that is more likely to show up in consumer products than enterprise products enables the AP and clients to again double the channel bandwidth from 80 to 160 MHz. Where this will benefit users is the home environment where there is a single AP.

Most enterprises are not likely to deploy 160-MHz channels because there are only two channels available when DFS-frequencies are included. With only two channels available it is highly likely that there will always be someone transmitting over the air and hence the APs will have to fall back to 80- or 40-MHz operation due to the congestion such that clients will not be able to take advantage of the 160-MHz rates.

Therefore, it is quite likely that enterprise APs will not implement or certify for 160-MHz operation. It will probably take governments opening up additional frequencies in the future in the 5-GHz band before one can truly leverage these wider channels in the enterprise.

These enhancements will further improve performance once there is a wide adoption of 802.11ac Wave 2 clients in the market but the biggest performance boost comes from the jump to 802.11ac Wave 1 that is available and shipping today.

Why you should move to 802.11ac now

The biggest jump in performance from 802.11ac for the enterprise is here today with the current Wave 1 products and the future Wave 2 will only provide a marginal boost in maximum performance.

Key benefits of moving to 802.11ac today include:

- The performance is boosted from 450 Mbps to now deliver up to 1.3 Gbps (three-times faster).
- Even legacy 802.11n devices see better performance due to improved radio and antenna designs in 802.11ac APs.
- A single 802.11ac radio can accommodate more users and Wi-Fi devices than previous standards (802.11a/b/g/n).
- 802.11ac will support higher data rate over longer distances. This is due to the more aggressive error correction codes supported by 802.11ac as well as a quieter RF environment.
- 802.11ac uses beamforming to improve signal-to-noise ratio. This results in better wireless throughput performance.
- 802.11ac uses 256-QAM that provides a 33% increase in throughput over 64-QAM used in 802.11n.
- The largest boost in performance can be seen with smartphone clients, which are typically the slowest devices on your network. This is critical given the rapid adoption of smartphone clients in order to prevent them from slowing down your network.
- Since 802.11ac operates in the 5-GHz spectrum, there is lower interference from other wireless devices. There are more non-overlapping channels (23 20-MHz channels) in 5 GHz which provides for greater design flexibility.
- Some 802.11ac APs available today, such as the 220 series and 270 series APs from Aruba Networks, have built-in advanced cellular coexistence filtering that mitigates interference from cellular networks. This is critical since the newer LTE and TD-LTE channels (channels 7, 38, 40, 41) have sidebands that overlap with the 2.4-GHz radio where your legacy 802.11n devices operate.

ARUBA'S RECOMMENDATIONS FOR 802.11AC MIGRATION

General

The vast majority of customers that deployed WLANs based on 802.11a/b/g and first-generation 802.11n technologies are currently going through a refresh cycle to transition to 802.11ac.

One of the most common questions Aruba receives is “Why can’t I just replace all of my existing APs with new APs?” The answer is that it depends on the original AP density and the types of applications and devices that are expected to use the new network.

Capacity

For capacity planning purposes, plan on upload speeds being equal to download speeds. In addition:

- Plan for at least three devices per user: a laptop, a tablet, and a smartphone. The number of devices per user also has ramifications in the design of VLANs and subnets. Consider if all devices will be active simultaneously, which also impacts AP density.
- Plan for AP density to support 40-60 active devices, although up to 255 devices can be supported per radio depending on their bandwidth requirements as seen in many real-world high density customer environments.
- Enable ClientMatch™ technology to eliminate sticky clients and perform band steering and load balancing in order to ensure clients associate with the best radio to maximize the network performance.
- Use Adaptive Radio Management™ (ARM) technology to maintain channel and power settings and that you maximize client connectivity in the deployment.
- Utilize a capacity-based deployment for all office and education settings.
- Deploy 802.3af or 802.3at (preferred) power on edge switches and utilize the Aruba S2500 and S3500 to support the required uplink capacity of gigabit Wi-Fi.
- All current Mobility Controllers using ArubaOS™ 6.3 or greater can be used for 802.11ac. However, network performance will vary depending on the controller model. Normal standalone master controller scaling still applies when migrating to 802.11ac. To maximize capacity the 7200 series Mobility Controller is highly recommended. Evaluate the potential increase in processing requirements for the data plane to ensure that it will meet the performance requirements; if not, consider upgrading the controller.
- While 802.11ac Wave 1 performance over the wire does not exceed 1 Gbps in typical deployments, the Aruba 220 series of APs have two Ethernet ports that support link aggregation when connected to a switch that supports LACP. This enables these two Ethernet ports to be used for redundancy across different closet switches as wireless access becomes business critical.

RF planning

A virtual site survey should be performed with VisualRF Plan and compared with the current deployment. The new survey provides a comparison of the current deployment to a more optimal 802.11ac network in the same space to determine if one-for-one replacement is viable.

In enterprise networks, the five available 80-MHz channels, of which three require DFS, should be sufficient for overlapping APs to provide contiguous coverage. Three-channel plans have been used in the 2.4-GHz band for years, although some networks may have reason to prefer a higher number of smaller-width channels.

Channel width selection

For high-density deployments (APs are placed <50 feet apart)

Greenfield deployment: Use 80 MHz with DFS support. The use of DFS channels needs to be assessed on a case-by-case basis.

Certain verticals like healthcare try to avoid deploying APs in the DFS channel to avoid radar triggered channel shifts, given mission critical services like heart rate monitors and IV pumps are running on Wi-Fi. In case DFS channels are not present, using 40 MHz is recommended.

Brownfield deployment: In a brown field deployment where the customer is migrating from a legacy 802.11a/b/g/n AP to 802.11ac AP and there will be a mix of Wi-Fi technologies, you can utilize 80- or 40-MHz channels.

If you are utilizing the wider 80-MHz channels, then you should perform interoperability tests with a sample set of your client devices to ensure the legacy clients do not cause implementation issues in which case you would need to limit your network to 40-MHz channels until your clients are updated.

This is more pronounced in environments where the IT department does not have control over the devices that users bring in, such as at universities.

For environments where IT has control over the device, it is recommended to update the client wireless chipset driver to the latest version and run some tests between 802.11n and 802.11ac APs when 802.11ac is deployed using 80-MHz channels.

For ultra-high-density deployments (APs are placed less than <40 feet apart)

Leverage as many of the following practices as possible:

- Leverage 20- or 40-MHz channels to enable more re-use throughout the network.
- Use cell size reduction in order to restrict the cell size to reduce 802.11-based interference.
- Use DFS channels as appropriate to expand available channels and enable more re-use.

Upgrading from 802.11a/b/g to 802.11ac

One-for-one AP replacement

When planning a one-for-one AP replacement, the guidance is as follows,

- If the existing network is planned for 5-GHz coverage based on capacity then one-for-one AP replacement with 802.11ac AP is viable.
- If the existing network is planned for legacy 802.11a/b/g or is an 802.11n network planned for 2.4-GHz based on coverage then planning on redesigning the network is recommended. Redesigning includes a combination of both physical and virtual survey.

Mixing 802.11ac and 802.11a/b/g/n APs

As per the standard 802.11ac is backwards compatible with 802.11n. The APs can co-exist in the same network, similarly 802.11ac and 802.11n clients can co-exist in the same network as well.

Most brownfield deployments 802.11ac APs will be rolled out in phases which will require mixing 802.11n and 802.11ac APs in the same campus where the 802.11ac APs are first deployed in areas requiring higher performance or supporting higher client densities.

STRATEGY AND PLANNING FOR 802.11AC MIGRATION

If you have an existing network that was planned well for 802.11n and was designed for density (with a signal threshold of -65 dBm) then a one-to-one replacement of the 802.11n APs with 802.11ac AP can be performed.

For greenfield environments and migration from an older 802.11a/b/g to 802.11ac network, performing a virtual site survey, or RF plan, is recommended. For a migration from a non-Aruba wireless network to Aruba 802.11ac deployment, a predeployment site survey is recommended.

Site planning basics

The purpose of this section is to provide network engineers with the tools they need to conduct a successful site survey and plan to implement an Aruba wireless network. This assumes an understanding of RF and WLAN networking technology, terminology, and industry standards.

An Aruba WLAN should be planned by an engineer who successfully has passed the CWNP examination for certified wireless network administrator (CWNA), Aruba-Certified Mobility Professional (ACMP) or equivalent.

Planning process

Before you deploy a wireless network, you must evaluate the environment. When you understand the environment, you can properly select Aruba APs and antennas and determine their placement for optimal RF coverage.

Perform an initial environment evaluation

You must know what to look for and questions to ask to effectively determine the environment type and the appropriate deployment type.

Select the proper APs and antennas for the deployment

You must understand Aruba AP and antenna types to determine the products that are best suited for the environment to provide optimal performance and RF coverage. Refer to the Aruba antenna matrix for assistance with selection.

Enter the collected and determined information into VisualRF

VisualRF™ is the Aruba predeployment site planning tool. In most instances, you can perform a standard deployment based on the VisualRF output without a physical site survey. This is called a virtual site survey.

For complex deployments, you can use VisualRF to generate a basic foundation for planning. But then you should visit the site to perform a walk-through, verifying AP location and signal coverage.

Make adjustments to the VisualRF plan (if applicable)

If a physical site survey was conducted, the RF propagation assessment affects the best choice of actual AP locations. Aside from the general environment, specific physical obstructions such as poles, lights, ventilation, and cable runs all should be considered. Change the floor plan to adjust for these findings.

Install the selected APs and external antennas (if applicable)

Installation guides are available with the products and on the Aruba support site.

Configure the APs

Perform AP configurations following the best practices outline in the Aruba validated reference design guide.

Note: This guide describes the first seven steps in the process. Mounting instructions for APs and antennas are available with the product and on the Aruba support site. Information about the configuration of APs is available in the validated reference design guide on the Aruba web site.

Required actions to implement 802.11ac

- Ensure minimum 1-Gbps uplink ports available per AP. If redundant cabling is already in place, or if costs permit pulling additional cabling, consider using multiple 1 Gbps Ethernet ports for uplink.
- Select uplink ports that support 802.3at PoE+ for best performance (802.3af can be used)
- Evaluate the bandwidth capacity upstream from the APs to ensure that sufficient bandwidth is available between the edge switch and the core/distribution switch. 10 Gbps should be used.
- Conduct a virtual RF plan or site survey
 - Compare minimum receive sensitivity requirements to Figure 4 below.

Security and rogue AP detection

With the advent of 802.11ac, monitoring the 5-GHz spectrum for rogue access points becomes a necessity. While an 802.11n-only environment would operate in the 5-GHz band and be able to detect 802.11n and 802.11ac rogues, it cannot mitigate 802.11ac rogue devices.

An 802.11n AP cannot see the 802.11ac data frames that are sent due to the new 256-QAM modulation as well as the wider channels. 802.11ac without monitoring capabilities is unable to perform advanced rogue detection, advanced IDS analysis or device containment.

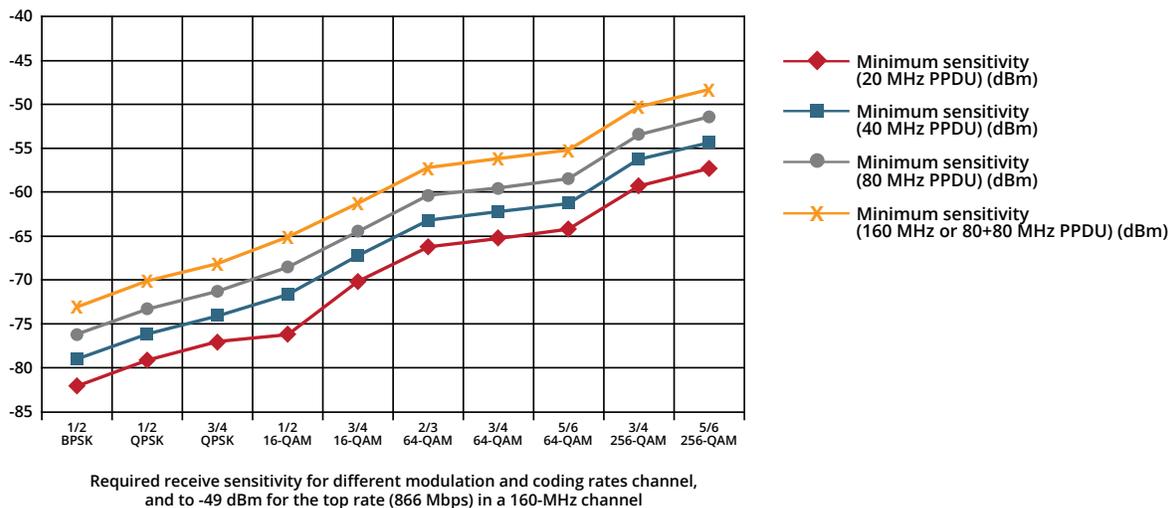


Figure 4

Consequently, it is important to consider deploying 802.11ac APs at various points throughout your 802.11n network to mitigate any 802.11ac APs and contain clients operating in the 5-GHz spectrum.

RF coverage considerations and questionnaire

Answers to these questions help you to determine the proper Aruba AP type, prepare for the site survey, and plan appropriately for the deployment.

- Which RF bands will be used? 2.4 GHz, 5 GHz?
Use both bands so you can support legacy 802.11n devices on the 2-4 GHz radio as well as maximize the RF spectrum to support increased in client densities.
- What channel width – 20 MHz vs. 40 MHz vs. 80 MHz – will be used in each band?
Typically, 20-MHz channels are used in 2.4 GHz, and 40- and 80-MHz channels are used in the 5-GHz band. In dense deployments, speed may be traded for capacity in the 5-GHz band by reducing to a 20- or 40-MHz channel.
- Will voice-over-Wi-Fi be used?
The answer will affect how you plan for roaming and calculate AP signal strength. For example, signal strength and quality of service are key factors for voice-over-Wi-Fi, but no nearly as important for data.
- Will multicast video-over-Wi-Fi be used?
The requirements for video-over-Wi-Fi are similar to voice. Video requires consistent bandwidth and low latency. For example, typical streaming HD video requires a bit rate from 1.5 to 6 Mbps per user.
- Will real-time location services (RTLS) be used?
Consider deploying air monitors around the building perimeter to help with location accuracy. This deployment ensures that all clients are within the triangulation zone.
- How many devices will each user have?
Plan for at least three devices per user: A laptop, a tablet, and a smartphone. The number of devices per user also impacts VLAN and subnet design. AP density must also be considered if all devices are active simultaneously.
- What is the maximum number of devices on each AP?
On average, plan for 40-60 active devices per AP but be able to support as many as 255 per radio, depending on device bandwidth requirements for high-density environments.
- What applications will be used, now and in the future?
The amount of bandwidth you will need can help determine coverage vs. capacity requirements.

- Are floor plan images available?
The Aruba VisualRF planner supports direct importation of JPEG, GIF, PNG, PDF, and CAD (.dwg and .dxf) files for floor plan formats.
- Are DFS channels are being considered?
If so, ensure that the most commonly used devices in the network support DFS.

SUMMARY

The final 802.11ac standard was ratified in December 2013 and the Wave 1 products have been undergoing Wi-Fi Alliance certification for interoperability since June 2013. You can be confident in adopting today's 802.11ac Access Point and client products.

802.11ac takes all the techniques the Wi-Fi industry has learned up to 802.11n, and extends them. It is relatively uncontroversial to say that in a few years, Wi-Fi will be synonymous with 802.11ac.

The significant improvements attained by migrating to 802.11ac today are:

- Three-times faster throughput, delivering higher client capacity. For smartphones, there is a five-times performance improvement.
- Two-times wider channels.
- Lower latency.
- 33% higher-rate modulation.
- 30% better battery life.

REFERENCES

For more information as you consider a migration to 802.11ac, the following resources are recommended reading:

- [Creating the all-wireless workplace with 802.11ac](#)
- [802.11ac resource center](#)
- [802.11ac access points](#)

ABOUT ARUBA NETWORKS, INC.

Aruba Networks is a leading provider of next-generation network access solutions for the mobile enterprise. The company's Mobile Virtual Enterprise (MOVE) architecture unifies wired and wireless network infrastructures into one seamless access solution for corporate headquarters, mobile business professionals, remote workers and guests. This unified approach to access networks enables IT organizations and users to securely address the Bring Your Own Device (BYOD) phenomenon, dramatically improving productivity and lowering capital and operational costs.

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