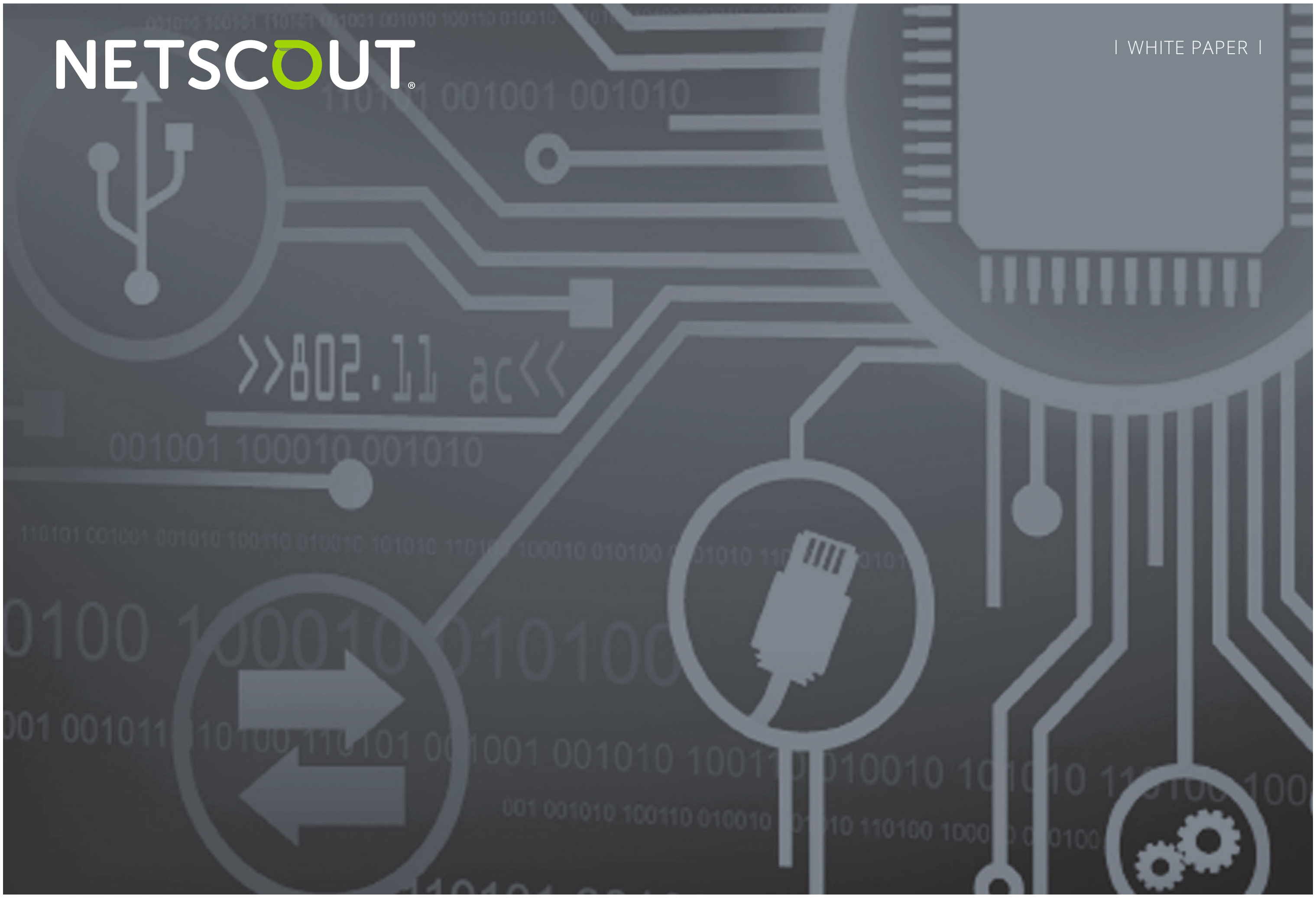


IMPLEMENTING 802.11 AC – REVOLUTION OR EVOLUTION?

These additional demands on the wireless LAN (WLAN) are creating increased pressure to redesign and upgrade wireless infrastructure to provide more bandwidth at higher rates. Networking professionals are often tasked with finding ways to make that happen.

The increasing demand for wireless bandwidth and growth of BYOD are driving the development of new standards to increase capacity and throughput and address congestion.

The latest standard to the market is the Very High Throughput (VHT) standard, 802.11ac, which was ratified in December, 2013. Many products supporting the new standard are already available, with differing aspects of the standard supported depending on device type and product release date.

Enterprises need to decide when to implement 802.11ac and how to plan and implement the transition at the appropriate time. The decision will vary from one organization to another and will depend on both their immediate needs and their long term vision.

To enable their organization to make the right decision at the right time, network engineers need to understand what the technology offers and the various options available for implementation. This White Paper explains the technology behind the 802.11ac standard, the potential benefits it offers and the factors that should be considered when planning the future development of their wireless network.

The Need For Greater Wireless Capacity

Increasing user demands for mobility and connectionless protocols have led to tremendous growth in requirements for wireless capacity within the enterprise. Whether using a company supplied laptop or tablet or their own devices (BYOD), users expect the performance of mobile applications to keep pace with their wired counterparts. They want to use any device to access any application, anywhere, without experiencing any lag or delay in performance.

Recent equipment sales paint a picture that looks rosy at first glance. According to ABI Research, mobile devices; including smartphones, tablets and e-readers, accounted for 64% of Wi-Fi device sales. In addition, 5 GHz support is available in 68% of Wi-Fi devices sold in 2015, also according to ABI Research. Conventional wisdom is that those two developments are easing the bandwidth crunch. In theory, mobile devices consume less data and the 5 GHz band offers more spectrum.

In reality, Wi-Fi device trends are adding to the capacity crunch. More mobile devices means more opportunities for users to bring more than one device on to the wireless network. Mobile devices also have the drawback of supporting lower maximum data rates, which reduces wireless capacity for all nearby devices. While the fact that 68% of new devices offer 5 GHz support alleviates some concerns, that still leaves 32% of devices with a requirement for high quality 2.4 GHz Wi-Fi access. In addition, many newer device segments such as smart watches and single-function “Internet of Things” (IoT) support only the already crowded 2.4 GHz band.

It is instructive to view 802.11ac implementation decisions on two levels. Level one is understanding the technological advantages of 802.11ac compared to its predecessor, 802.11n, and deciding whether an upgrade is necessary. Level two is understanding which 802.11ac technologies are appropriate for the enterprise and disabling technologies that are designed for low-density, residential environments.

Introducing a new standard: 802.11ac

802.11ac is the newest standard for high speed wireless local area networks (WLANs). The IEEE created the new standard as a way to take advantage of both technological advancements and unused capabilities for WLAN technology. The IEEE also made sure to make 802.11ac backwards compatible with all previous 5 GHz standards, including 802.11n and 802.11a.

There are two primary reasons why the IEEE 802.11 Working Group created 802.11ac for the 5 GHz band only, which includes Wi-Fi channels 36 through 165. One reason was to push Wi-Fi deployments towards the 5 GHz band. The 2.4 GHz band, which includes Wi-Fi channel 1 through 14, is crowded in many environments where Wi-Fi access is desired. The second reason was because the improvements specified in the 802.11ac standard would rarely be available over the 2.4 GHz band because of the band's limited frequency spectrum.

The good news, as it relates to the 2.4 GHz band, is that the vast majority of 5 GHz Wi-Fi devices also support 2.4 GHz Wi-Fi. When a modern Wi'Fi device connects to a 2.4 GHz channel, it uses 802.11n. When that same device connects over 5 GHz, it uses 802.11ac.

802.11ac is an especially delicate technology to implement because some of its technological advancements are inappropriate for enterprise wireless networks. The engineers who created 802.11ac were well aware that Wi-Fi is a popular technology for both residential and commercial use. Rather than making unique 802.11 amendments for each use case, the IEEE chose to make a single 802.11ac amendment and make it as fast as possible.

Wi-Fi Certified ac Products: Key Benefits

- Higher data rate – Delivering data rates up to 1.3 Gbps – more than double that of a typical Wi-Fi CERTIFIED n network.
- Higher capacity – More devices can be simultaneously connected to a Wi-Fi CERTIFIED ac network without reducing performance to address congestion challenges.
- Lower latency – Wi-Fi CERTIFIED ac products can deliver a higher-quality user experience with applications such as gaming or streaming music, where even the slightest delay can have a detrimental impact.

- Efficient power usage – Enhancements in Wi-Fi CERTIFIED ac mean less power consumption when transmitting data.

Figure 1: the benefits of 802.11ac. Image courtesy of the Wi-Fi Alliance.

802.11ac IMPROVEMENTS

There are six technological improvements that are designed to boost 802.11ac performance, and five of those are expected to be available for real world Wi-Fi deployments:

Wider Channels

802.11ac uses orthogonal frequency division multiplexing (OFDM) technology for wireless data communication. OFDM has been part of the IEEE 802.11 family of standards since 1999, when it was introduced as part of the first amendment to the 802.11 standard, 802.11a.

From the time it was introduced to the 802.11 family of standards, OFDM has always been a technology that uses a 20 MHz wide channel. A 20 MHz channel width was chosen because it was considered wide enough to reach adequate speeds while mitigating interference issues, but not so wide that would make deployment difficult in large, multi-channel environments.

The current 802.11n wireless protocol introduced 40MHz channels, which offers a significant improvement in single-channel speed over the 20MHz channels in earlier standards. While 40 MHz wide channels are not recommended for 2.4 GHz 802.11n deployments, 5 GHz 802.11n deployments have enough unique 40 MHz wide channels — twelve, if part of a careful Wi-Fi design — that the per-channel speed benefits of wider channels can be accessed in low density environments.

802.11ac ups the ante on channel bandwidth by supporting channel widths of 80 MHz and 160 MHz. While legacy channel bandwidths of 20 MHz and 40 MHz continue to be supported, 80 MHz and 160 MHz channels allow for the achieving of higher data rates than 802.11n devices and APs are capable of reaching.

The use of wider channels, however, comes at a cost. In fact, several costs. Fewer channels are available. Fewer devices have support for all channels. Higher signal strengths are required for successful data communication.

It is only natural that wider channel widths would mean that fewer unique channels are available, but the international nature of Wi-Fi adds additional complexity. There are a wide variety of rules on how the 5GHz frequency band can be used, depending on the country in which Wi-Fi is being deployed (see Table 1).

The United States has relatively liberal rules for the 5 GHz band. 802.11ac has six available 80 MHz channel selections; two in universally available bands and four in bands that require the use of dynamic frequency selection (DFS), which comes from the IEEE 802.11h amendment. 802.11ac Wave 2 adds 160 MHz channel selections for some devices, though as of this writing those numbers are a distinct minority. If 160 MHz channels are used, only one will be available for non-DFS devices, while devices with DFS support will be able to use up to three.In Europe, 802.11ac has four available 80 MHz channels, and will have two available 160 MHz channels in the second wave. By comparison, there are 19 non-overlapping 20 MHz channels available.

	INCLUDING DFS*		EXCLUDING DFS	
Channel size	US	EUROPE	US	EUROPE
40 MHz	6	9	4	2
80 MHz	3	4	2	1
160 MHz	1	2	—	—

*** DFS = Dynamic Frequency Selection – for avoiding interference with weather radar**

Table 1 - Available 802.11ac channels.

Note that without using DFS, in Europe the available 80 MHz channels drops to 1 and in the US it drops to 2 so DFS support in APs and clients is going to be a necessity to deploy 80 MHz or 160 MHz 802.11ac effectively.

For many enterprises, there is a problem with 80 MHz and 160 MHz channels that goes beyond DFS limitations: wider channels require higher signal strengths. Using 80 MHz or 160 MHz channels introduces a far higher likelihood that Wi-Fi data transmissions will fail due to insufficient signal strength or excessive interference. The problem is especially acute for mobile devices like smartphones because users often hold devices in unpredictable orientations and move in unpredictable patterns. The use of narrower channels mitigates some of that unpredictability by making data transmissions more resilient to fluctuations in signal strength and interference levels.

Given the potential issues related to channel volume, device compatibility and data resilience, most enterprise Wi-Fi works better when 20 MHz wide channels are used for day-to-day network access. It is a fact that neutralizes one of the most prominently touted features of 802.11ac.

Higher Modulation and Coding Schema

If reading that 80 MHz and 160 MHz wide channels offer more hype than help for enterprise WLAN deployments is a downer, never fear. There are real-world benefits derived from an 802.11ac upgrade, and one of them is the fact that more data can be squeezed onto each radio wave. 802.11ac introduces a higher order modulation called 256-QAM. 256-QAM increases the number of bits that can be encoded in a single OFDM symbol to eight. The order highest modulation of 802.11n was 64-QAM, which only allowed for six bits per symbol. That is a 33 per cent improvement in bit rates.

The down side of 256-QAM is that is makes RF design so challenging that it is often unavailable in enterprise Wi-Fi deployments. 256-QAM requires that extremely high signal-to-noise ratios are maintained for data to be transmitted and received successfully. In low-density, low-mobility residential environments, this is often just fine. In environments with more mobility and user density, the theoretical benefits of 256-QAM are often not realized.

A new, non-standard modulation and coding scheme is being developed as well, and it will be even more narrowly targeted towards low-density, non-mobile environments. 1024-QAM improves upon 256-QAM by allowing for ten bits of data to be transmitting with every OFDM symbol. As of this writing, it is unclear whether 1024-QAM will be widely adopted, or if it will become a speciality technology for home gamers and others seeking high speed Wi-Fi connections to stationary devices.

The remaining three 802.11ac improvements are designed to improve throughput capacity while not affecting data rate capabilities.

Beamforming

Transmit beamforming (TxBF) is a technology that is designed to allow 802.11ac APs to deliver a more directionalized wireless signal. The theoretical benefit of beamforming is that the intended receiving device would hear a strong signal, while the rest of the area surrounding the AP would not. This theoretically serves two purposes: allowing for the intended device to receive higher rate data and reducing the interference levels for nearby wireless LANs that may be occupying the same channel.

Although 802.11ac requires APs to support TxBF, the real world impact of beamforming has been minimal. TxBF is optional for 802.11ac devices, just as it is for both 802.11n APs and devices. Modern 802.11ac devices do not support TxBF when transmitting and do not support the negotiation process that APs would have to use to optimize TxBF's effectiveness. For those reasons, TxBF support in 802.11ac APs has yielded disappointing results for many Wi-Fi deployments.

A non-standard offshoot of TxBF has been found to improve Wi-Fi performance in some environments. The use of adaptive antennas — arrays of 60 degree antennas designed to directionalize data transmission from APs to devices — has proven beneficial in environments where a majority of data is downlink to devices and devices are usually stationary while in use. Adaptive antennas use the same principal as TxBF — that Wi-Fi works best when AP-to-device data is directionalized — while executing better. Very few vendors support adaptive antennas in 802.11ac APs and wireless routers.

Multi-user MIMO + More Spatial Streams

The final two real world 802.11ac improvements — multi-user MIMO (MU-MIMO) and increased numbers of spatial streams — can be grouped together.

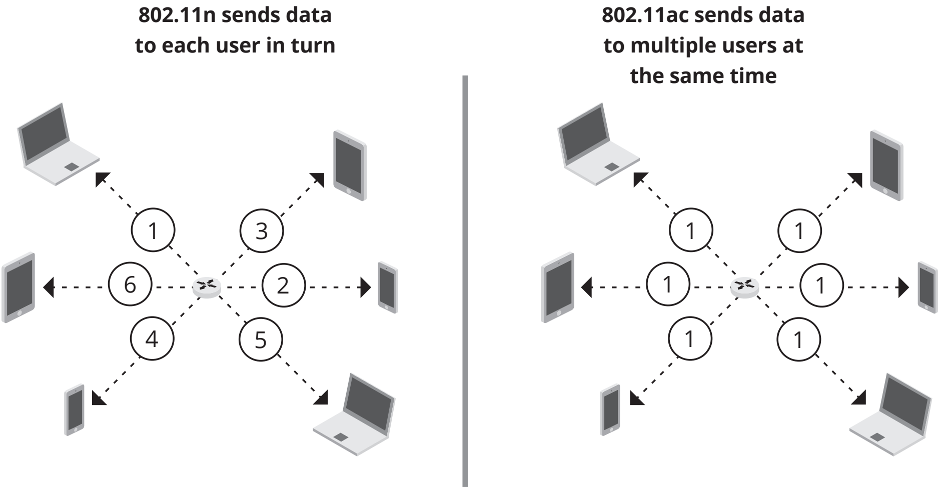
MIMO, or Multiple Input Multiple Output, means sending and receiving more than one data stream at a time over a single channel. MIMO was supported in 802.11n and is supported in 802.11ac, though it is optional for devices.

802.11ac will theoretically use multi-user MIMO to support simultaneous transmissions to multiple clients. This improves utilization of the channel by allowing more of the APs antennas to be used. 802.11ac Wave 1 does not support MU-MIMO, while 802.11ac Wave 2 does. As of this writing, Wave 1 APs and devices are widely available, while Wave 2 support is limited to APs, with no devices supporting MU-MIMO.

802.11ac also supports increased numbers of spatial streams as part of MU-MIMO. While 802.11n supports up to four spatial streams using single-user MIMO, 802.11ac supports up to eight spatial streams using MU-MIMO.

Since MU-MIMO is a technology that has yet to debut in real world environments, there are natural questions as to whether it will improve performance and, if so, to what degree. If MU-MIMO does end up working as advertised, it would lead to dramatic Wi-Fi performance improvements, especially in environments where a majority of data communication is downlink to devices. MU-MIMO will require TxBF in order to work, so the questions posed previously about TxBF apply to MU-MIMO as well.

802.11n sends data to each user in turn, 802.11ac sends data to multiple users at the same time.



	802.11n	802.11ac
Frequency band	2.4GHz and 5GHz	5GHz
Channel width	20 and 40MHz	20, 40, 60, 80MHz (option 160MHz)
Spatial streams	1 to 4	1 to 8 (up to 4 per client)
Multiple user MIMO	No	Yes
Single stream max. client data rate	150Mb/s	433MB/s (if 80MHz channel)

Table 2: Comparison of 802.11n and 802.11ac protocols.

GCMP Security Protocol

Galois mode cipher block chaining, message authentication code protocol (GCMP) is an encryption method that could improve Wi-Fi performance, but is currently not supported by Wi-Fi AP and device vendors.

The security protocols used with 802.11ac will in most respects be the same as those used with 802.11n. 802.11ac data rates, called VHT rates, are unavailable when using WEP or TKIP, which also applies to the HT rates of 802.11n. For that reason, Wi-Fi networks using 802.11n or 802.11ac should be configured to use AES-CCMP, which is the encryption method required for WPA2 certification.

802.11ac also permits use of GCMP – the Galois/Counter Mode Protocol, but the future of GCMP is cloudy. Like CCMP, GCMP provides encryption and data integrity. Unlike CCMP, GGMP uses a technique called Galois Field Multiplication to authenticate each block of data individually. GCMP's use of Galois Field Multiplications allows data blocks to be encrypted in parallel instead of in sequence, thus speeding up the encyrption process. Unfortunately, no companies that make Wi-Fi APs or devices have signaled that GCMP will be adopted in the near future, if ever.

NETSCOUT offers the ability to detect, analyze and troubleshoot 802.11ac APs using currently supported 802.11n adapters. This provides key metrics such as the number of 802.11n and 802.11a clients present in the network, the APs these clients are connected to and network channel utilization by 802.11n and 802.11a clients. By decoding 802.11ac management frames in real time, engineers can detect VHT capabilities of the AP and thus troubleshoot performance issues in 802.11ac networks resulting from the presence of legacy clients.

Phased Introduction

802.11ac has been introduced to the market in two phases, with a third, non-standard phase possibly yet to come.

Most current 802.11ac access points and devices support 802.11ac Wave 1. 802.11ac Wave 1 requires APs to support channel widths up to 80 MHz, 256-QAM and single user MIMO, using up to four spatial streams with beamforming..

The next phase, 802.11ac Wave 2, is currently supported by some APs and by no devices. 802.11ac Wave 2 allows for channel widths up to 160 MHz (either a contiguous 160 MHz channel or split channels as part of the "80+80" channel configuration) and MU-MIMO using up to eight spatial streams.

Choosing When to Implement the New Standard

802.11ac introduces a double-decker question: is an 802.11ac upgrade needed and, if so, when?

Both 802.11ac and 802.11n provide significant performance boosts when compared to legacy Wi-Fi technologies like 802.11a, 802.11b and 802.11g. If one of those latter three amendments is currently the most modern deployed Wi-Fi technology, then an upgrade is almost always recommended.

If 802.11n is the currently deployed Wi-Fi technology, then the decision to upgrade becomes situational.

Questions that network professionals can ask themselves include:

- Are my users mobile?

If users are mobile, then 802.11ac often provides little in the way of a performance upgrade. In fact, performance may remain virtually identical. Mobile devices usually work best over narrower channels because narrow channels allow for successful data reception at lower signal levels. Both 802.11n and 802.11ac support 20 MHz as the narrowest channel bandwidth.

- Is my environment high density?

If the environment is high density, then 802.11n and 802.11ac often provide similar performance levels; sometimes identical. High density environments work best when large numbers of APs are available and when data errors are rare. Using 20 MHz wide channels allows for the largest number of APs to be deployed without causing co-channel or adjacent-channel coverage overlap. Data errors also tend to be minimized when 20 MHz wide channels are used because data can be received successfully at lower signal levels than when 40 MHz, 80 Mhz or 160 MHz channels are used.

- Is consistency more important than high throughput?

If consistency is the number one objective, then 802.11n and 802.11ac often provide similar results. Throughput tends to increase as channel widths gets wider because fewer APs cover more frequency spectrum. Low density, high throughput applications like HD video streaming, large file transfers and gaming thrive when 802.11ac is used over wide channels. On the other hand, wider channels tend to reduce consistency because coverage overlap becomes more likely and successful data reception requires higher signal levels.

- Am I alone (in the Wi-Fi sense)?

If Wi-Fi is being deployed in an environment where the 5 GHz channels can be controlled, then 802.11ac often provides higher throughput than 802.11n. Without neighbors, 802.11ac APs are often able to find unused frequency spectrum over which to use 80 MHz wide channels. If neighbors are present, then 20 MHz wide channels often work best, because narrower channels allow Wi-Fi devices to receive data more consistently amidst neighboring channel activity.

Planning for 802.11ac Implementation

If the decision has been made to upgrade to 802.11ac, then additional factors should be considered. Some of these factors include:

- network upgrades
- channel alocation
- impact of using DFS channels
- impact of older standards

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Network Upgrades

Organizations planning to upgrade to 802.11ac should also consider upgrading the capacity of their Ethernet access and uplink networks. For example, if the AP links are currently 100MB, they should be upgraded to 1GB; if 1GB, consider upgrading them to 2GB Aggregation links may need to be sized to allow for all the 802.11ac APs that they will have to accommodate.

Using a network performance planning tool that supports both existing and new protocols also helps engineers to assess whether there is sufficient capacity in the WLAN. By using a planning tool which provides visualizations of key performance factors such as channel width, channel overlap and MCS coverage, network engineers can quickly determine areas where high throughput can be achieved and hence high client density can be supported.

Channel Allocation

It is important to develop a channel application plan when planning for 802.11ac. Decisions must be made on whether 20 MHz channels will be required, or whether the wider 40 MHz, 80 MHz and 160 MHz wide channel should be considered. A planning tool should show where APs are expected to cover the same spaces. If overlapping APs end up on the same channel, then they will interfere with each other. Such situations require engineers to adjust channel allocations and AP locations to avoid potentially debilitating channel congestion.

Assessing the Impact of DFS Channels

The 5GHz band used by 802.11ac contains channels that require Dynamic Frequency Selection (DFS) capabilities to avoid using the same frequency range as radar. Network administrators have a choice in whether those channels are made available in their network. Wi-Fi channels 52 through 144 require DFS and enabling those channels provides the potential for extra bandwidth. The downside is that APs using DFS channels must vacate the channel when radar is detected. In some situations, making DFS channels available has resulted in frequent channel changes which negatively impacts performance.

A planning tool incorporating spectrum analysis will enable the network engineer to detect and measure RF signals on each channel and determine if DFS channels are available for use or occupied. A spectrum analyzer may also help measure RF signals – radar and other non-Wi-Fi interference sources - that could result in low performing DFS and non-DFS channels. Using an spectrum analyzer to ensure a clean environment for 802.11ac deployments will potentially prevent expensive network redesigns.

Impact of Slower Transmission Rates

An unfortunate side effect of 802.11 backwards compatibility is that low transmission rates can retard performance for modern technologies like 802.11ac. Engineers may want to gauge whether 802.11ac performance is likely to be negatively impacted by the slower transmission rates of 802.11a and 802.11n devices. The throughput visualization features of Wi-Fi network analyzers and planning tools can be helpful in determining whether the WLAN can provide the required user performance.

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