ALLEN & HEATH MIXING UNLEASHED

A GUIDE TO CONFIGURING AND OPTIMISING WiFi NETWORKS FOR WIRELESS MIXING

Background

With an ever-increasing amount of bandwidth and processing power it was inevitable that the pro audio industry would eventually embrace wireless networking as a reliable means of controlling performance critical audio systems. In this session, we are going to look at the evolving standards of IEEE 802.11 and the fundamental technologies which they are built upon. Finally, we will look at some of the practicalities when deploying a WLAN using A&H equipment.

802.11 is a set of Media Access Control (layer 2) and Physical (layer 1) specifications used for the implementation of wireless networking. Developed and maintained by the IEEE, the first draft standard was released in 1997 using products under the Wi-Fi brand. The specifications follow the standard lettering suffix used by the IEEE, ranging from .a to .az. For the purpose of this paper we will discuss those specifications which are widely in use today, being 802.11g/n/ac.

802.11g

Released in 2003, 802.11g operates in the 2.4GHz band with a maximum throughput of 54Mbps, depending on modulation type and coding rates. The band consists of 14 channels with each channel having a 22MHz bandwidth. However, the 2.4GHz range is extremely overcrowded and suffers from interference from devices such as cordless phones, microwaves, Bluetooth and neighbouring AP/routers. Channel separation is required to minimise this interference and the below images show the usable channels for both the U.S. and Europe. In figure 1 we can see that the U.S. stipulates that 3 channels are used (1,6 & 11) with 25MHz separation between channels. In figure 2 we can see that Europe has 4 usable channels (1, 5, 9 & 13) with only 20MHz separation.

Side-lobe interference can still be an issue when using the separated channels but to a much lesser extent than if using adjacent channels. The range for devices using 802.11g networks is approximately 40 metres indoors and 140 metres outdoors. However, this will depend on many environmental and physical factors, so should only be used as a guide.

802.11n

Released in 2009, 802.11n provided a significant increase in throughput with data rates up to 450Mbps (600Mbps is theoretically possible). 802.11n introduced dual band operation by adding 5GHz transceivers in addition to the 2.4GHz equipment used in 802.11g. The 5GHz frequency band offers 25 non-overlapping channels with a 20Mhz channel width.

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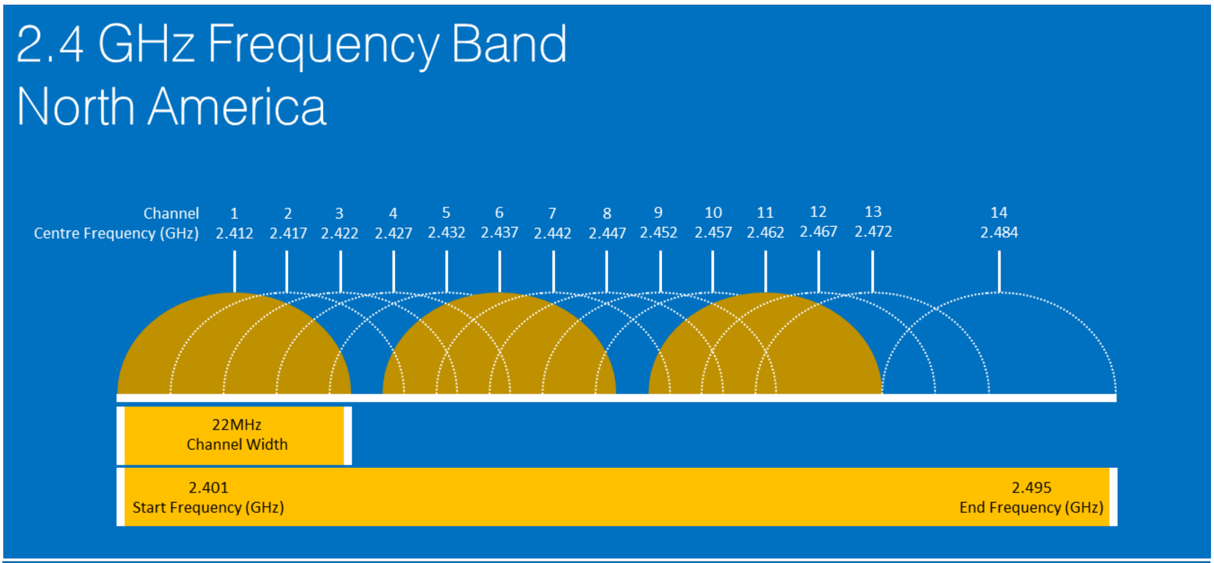
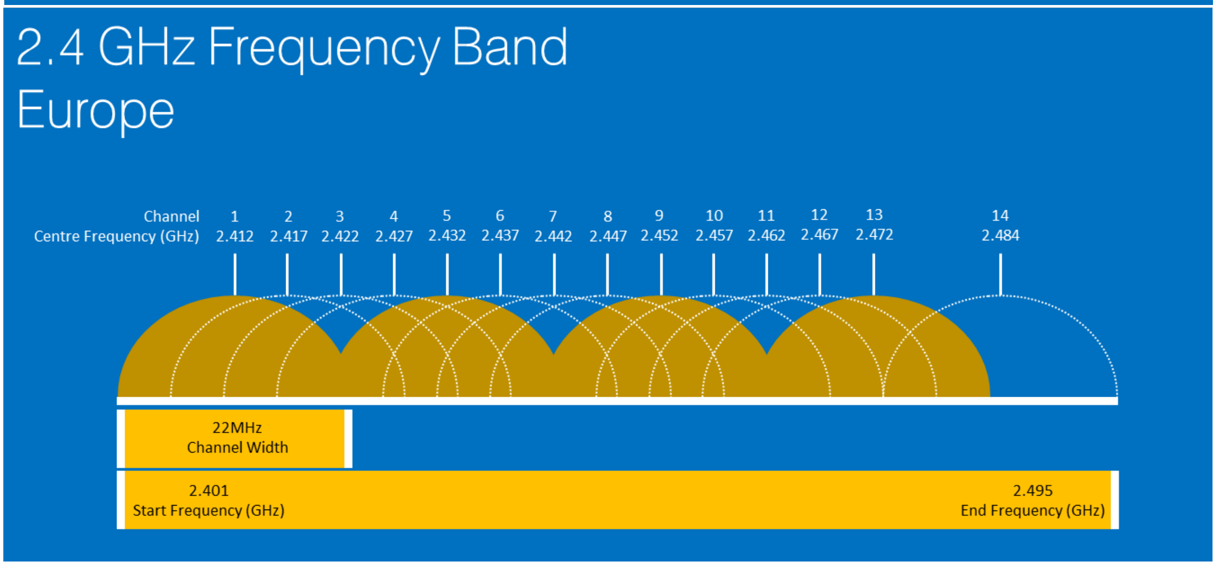
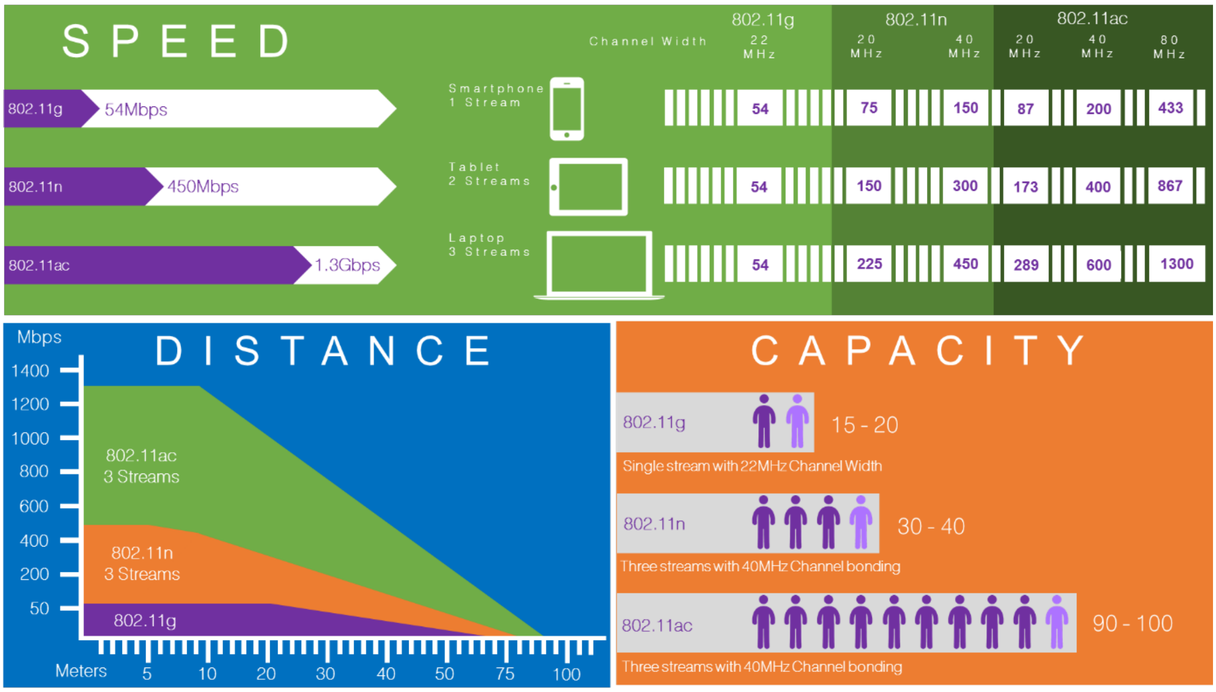
However, there are restrictions placed on many of the channels within the band and these restrictions differ from territory to territory (check local regulations prior to use). Many AP/routers utilise band-steering to direct clients to the appropriate frequency band, automatically forwarding dual-band clients to the 5GHz whilst directing legacy equipment to the 2.4GHz band. 802.11n also introduced MIMO (Multiple Input Multiple Output) with the theoretical possibility of four spatial streams, 40MHz channel bonding and additional security features, all of which we will cover in more detail later in this paper. 802.11n marginally increases device range but significantly increases throughput by 4-fold at a range of 20 metres.

802.11ac

The latest Wi-Fi iteration from the IEEE is 802.11ac. Released in 2013, it builds upon 802.11n in terms of speed and efficiency and hence is also known as VHT (Very High Throughput) or Gigabit Wi-Fi. 802.11ac operates solely in the 5GHz frequency band and is subject to the same restrictions as mentioned previously. Improvements to the previous standard include the addition of 80 and 160MHz







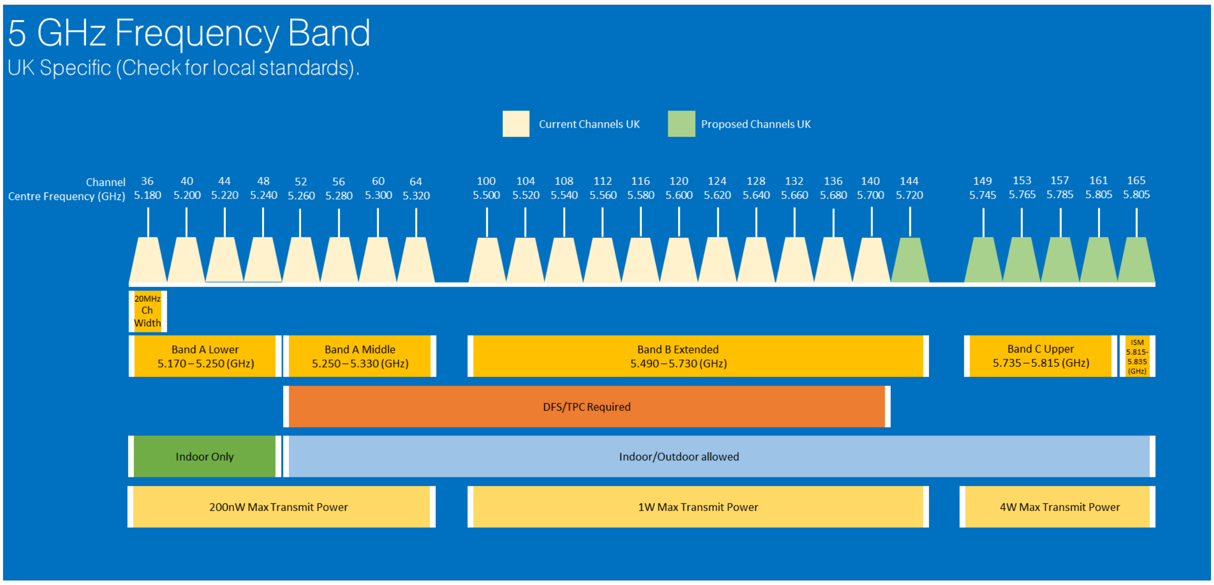
channel bonding, eight spatial streams, 256-QAM and the inclusion of MU-MIMO (Multiple User – Multiple Input Multiple Output), giving a theoretical throughput of around 7Gbps.

However, practical limitations in terms of maximum streams (three) and channel bonding (80MHz) place a maximum throughput of 1.3Mbps. 802.11ac marginally increases device range but significantly increases throughput by 3-fold at a range of 20 metres over 802.11n.

5GHz Band

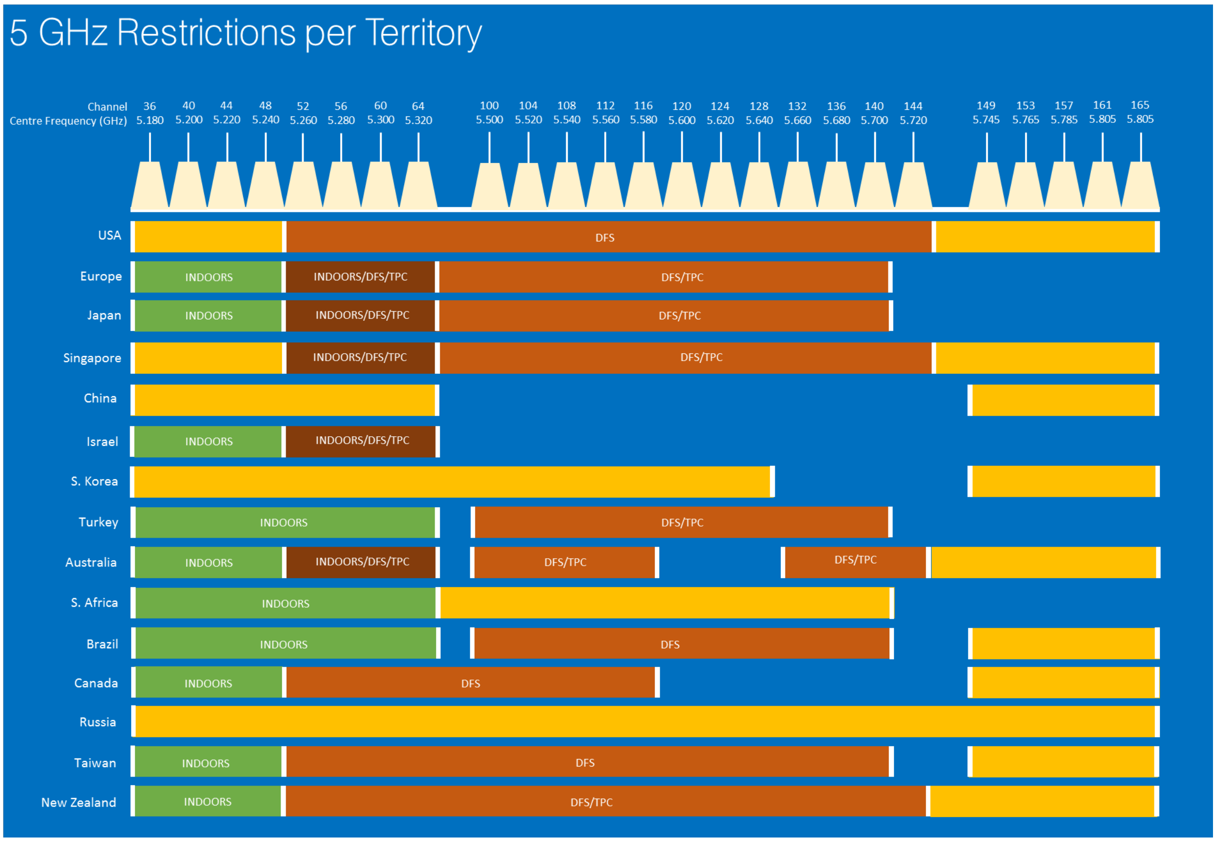
As mentioned previously the 5GHz band is made up of 25 non-overlapping channels. However, not all channels are available in every territory and certain considerations should be considered, especially when used in touring applications. As can be seen in the below graphic not all channels are available in the UK, although Ofcom is currently proposing (April 2017) that these channels are to be freed for use with 5GHz wireless networking.

In addition, there are also regulatory considerations including the use of equipment indoors/outdoors, licensing, DFS and TPC. DFS (Dynamic Frequency Selection) is a mechanism which allows unlicensed devices to operate in the channels which are allocated to both civilian and military radar systems. With DFS enabled, the AP will automatically scan for such signals and if found to be over a certain power level, will vacate and select another channel. When moving between territories be sure to change the Regulatory Domain of the AP to ensure it complies with the local regulations.



TPC (Transmit Power Control) is an automatic function of 802.11 whereby two devices operating within the spectrum will negotiate with each other to implement a mutual power level to ensure they do not interfere with other.

The below graphic gives an indication of the various regulatory domains. Although the above functions should be automatic be sure to check the domain and ensure any additional licensing is required in the territory (especially when using channels within the Band C/ISM bands).



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Wireless Technologies

Channel Bonding

The process of Channel Bonding is the mechanism by which two adjacent channels are "bonded" together to create a larger channel. For instance, in the 2.4GHz band we have three usable channels, each having 20MHz of bandwidth. Channel bonding allows for two of these channels to be aggregated to create a single channel of 40MHz and therefore slightly doubling the throughput of a single channel. However, channel bonding in the 2.4GHz band creates additional problems in the form of reduced channelization and therefore should only ever be considered if used in a single AP deployment with little to no possibility of crosstalk from neighbouring AP's.

Where channel bonding does become beneficial is within the 5GHz band where we have a total of 25 non-overlapping channels to choose from. 802.11ac took channel bonding further by adding the ability to bond channels of 40, 80 and 160MHz.

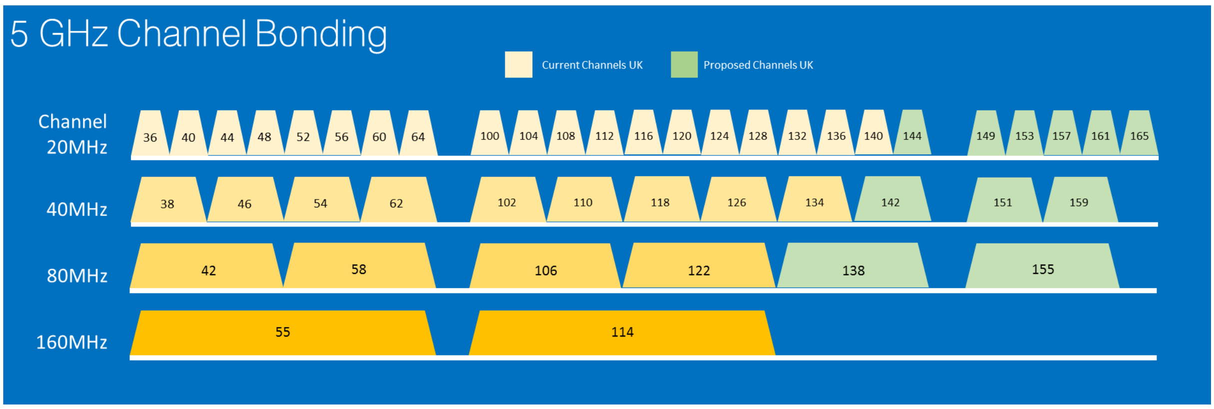
Again, channelization becomes an issue and 160MHz channel bonding is impractical to use except for single AP applications with no neighbours. When devising a Channel Plan for wireless networks there are a few points to consider to eliminate co-channel interference, and careful selection of operating channels and primary 20MHz channels is key to achieving this.

The first consideration is to determine whether DFS channels can be used. 802.11ac mandates that clients support DFS channels and the AP will actively scan the spectrum for radar detection prior to operating on any DFS channel.

The second consideration is to determine the guaranteed channel width which will be free of co-channel interference. This will be based on the density of the AP deployment as well as the client device capabilities. The main objective here is to try and ensure that each AP has fewer neighbouring APs within radio range than non-overlapping channels available.

As a rule of thumb use the below chart when channel planning (assuming DFS channels are permitted for use).

In addition to channelization, wider channels result in an increased noise floor whereby the receiver finds it more difficult



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to distinguish between the signal and background noise. With each doubling of channel width, the noise floor is raised by 3dB from -101dBm at 20MHz to -98dBm at 40MHz. As most client devices have weak transmitters (i.e. smartphones and tablets) compared to access points, it is imperative to achieve a greater signal strength to maintain a higher SNR. The simplest way to achieve this is to minimise the distance between AP and client, which usually entails deployment of additional AP's (densification). However, as discussed previously this can have a detrimental effect of reducing capacity due to channelization issues.

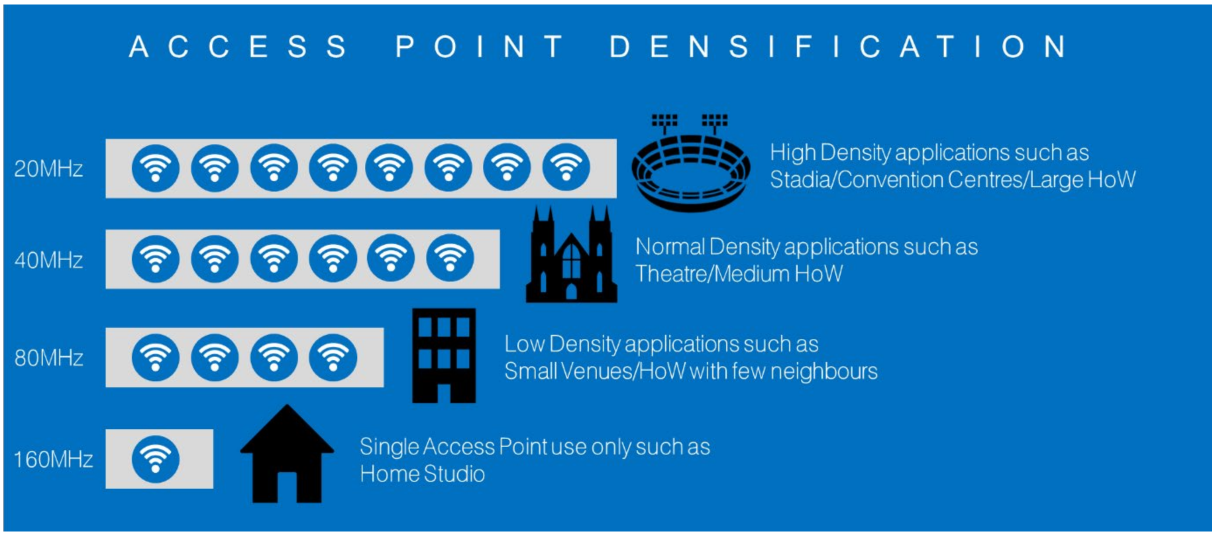
Beamforming

Beamforming is a transmission method by which a transmitter focuses energy in the direction of the receiver. Historically, AP's would have used single omni-directional antennas, meaning its energy would radiate in all directions from the transmitting antenna. However, if the AP had the information required to 'focus' its radio energy in a certain direction, it would allow for an extended range and increased throughput via an increase in power and SNR. With the introduction of MIMO antennas, beamforming was introduced and became part of the 802.11n specification. However, due to the lack of standardisation there was little guarantee of cross manufacturer compatibility. This standardisation was finally addressed and introduced with 802.11ac which ensured that each manufacturer complied to a set of standards to allow cross compatibility. It should also be noted that beamforming will only increase throughput in the medium range. At short and long distances, there is no advantage of beamformed signals over its omnidirectional counterpart.

Spatial Multiplexing/Streaming

Spatial Multiplexing is a technique by which data throughput is increased by transmitting multiple data streams simultaneously. Each stream is transmitted on the same channel by all antenna and is demultiplexed at the receiving device. The benefits of spatial multiplexing are either faster data rates or higher reliability using diversification.

802.11n mandated the use of spatial multiplexing with a theoretical maximum of 4

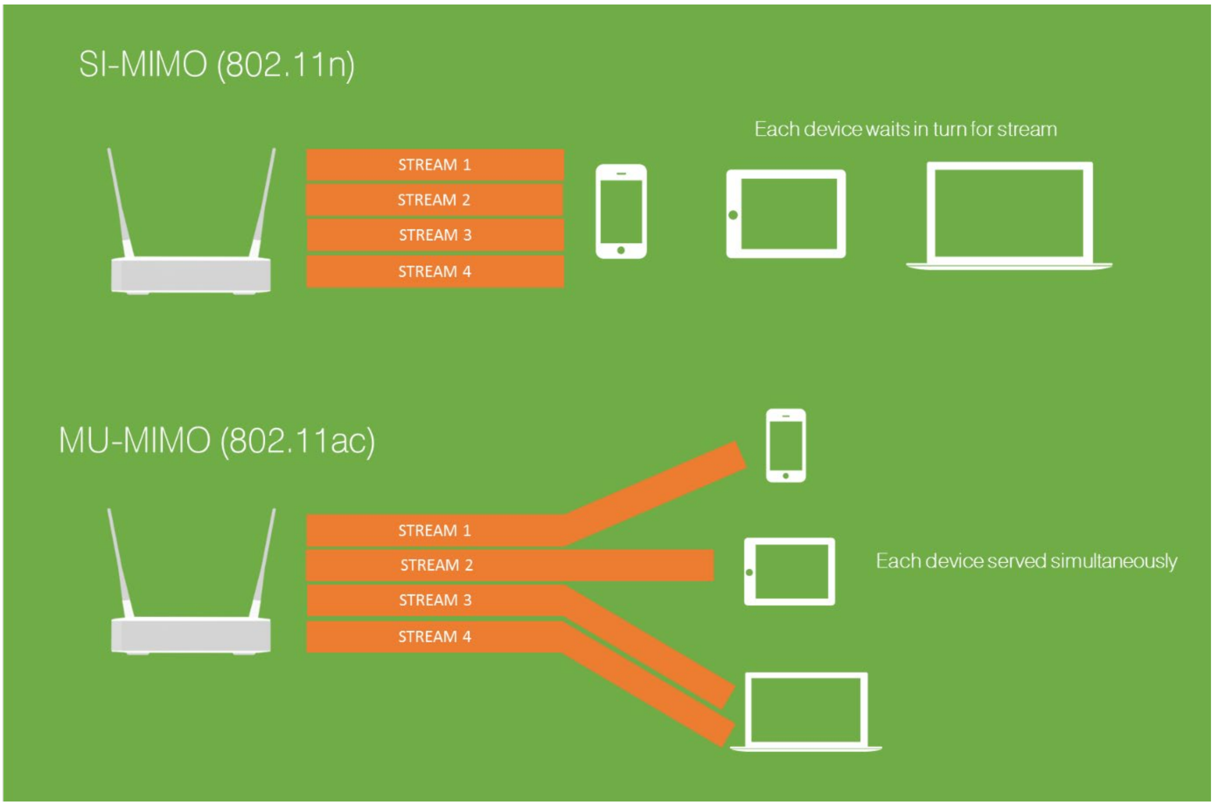


spatial streams and 802.11ac builds upon this with the possibility of 8 streams. However, in both cases current products are limited to a maximum of 4 spatial streams. When choosing equipment and deploying a system, the AP specification will usually show how many antennas and streams are supported by the product. This is represented in the form of 4x4:3, which translates as 4 (transmitting antenna) x4 (receiving antenna) :3 (spatial streams).

MIMO

MIMO, or Multiple-Input Multiple-Output, is a wireless technology which utilises multiple transmitters and receivers. Introduced in the 802.11n specification it utilises RF multipath propagation where transmitted signals bounce off walls, ceilings and objects, reaching the receiver at different times. In previous wireless specifications, this multipath effect caused interference. However, MIMO technology allows the use of multiple antennas which can capture multiple spatial streams arriving from different propagation paths. When antennas outnumber spatial streams, it results in an increase in range via receiver diversity. MIMO can be implemented if either the receiver or transmitting device support the technology. However, to achieve optimal performance both devices must support MIMO.

There are different variations of MIMO technology. The above deployment, as set out in 802.11n is SU-MIMO or Single User MIMO. 802.11ac introduced MU-MIMO or Multiple User MIMO. Although SU-MIMO can utilise multiple streams with multiple antennas, an AP still serves each client independently. MU-MIMO changes this by allowing multiple clients to be served simultaneously by the AP. Again, to gain maximum benefit both AP and receiv-



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ing device should support MU-MIMO, although clients will still have minimal benefits when only the AP supports MU-MIMO.

Quadrature Amplitude Modulation

Quadrature Amplitude Modulation or QAM is a modulation technique whereby two carrier frequencies are modulated and shifted in phase by 90º. The resultant waveform therefore consists of phase and amplitude variations which represent a predetermined data sequence. 802.11n supports 64 QAM which has a 6-bit data byte per constellation point, whereas 802.11ac has an 8-bit byte per point. This results in a higher data throughput for 802.11ac but can also lead to a higher risk of corrupted data as constellation points are closer together and more susceptible to noise.

Guard Interval

The guard interval is used to avoid signal loss due to the multipath effect. RF transmission within wireless networks can reach the receiving antenna by two or more paths via multipath propagation. This can include a direct path but may also diffract, scatter or reflect off obstacles which alter the original signal or create new signals, resulting in possible signal degradation. In earlier implementations of 802.11, an 800ns was required but 802.11n introduced a 400ns option. This short guard interval can improve throughput by up to 10% but must be used with caution to minimise the multipath effect. If the environment does not contain too many reflecting or metal materials, then a short GI can be used. Additionally, a short GI should only be used if using 802.11n or 802.11ac exclusively. If deployed within a mixed mode network, ensure that the GI is set to the longer interval or it may cause issues.

Deploying a VLAN

Deployment Considerations

When designing a wireless LAN there are many considerations to take account of in terms of AP deployment. In principle, there are two models to consider.

Coverage – here the main design consideration is to provide a good quality of service in as much of the area as possible with a single or multiple access points. Examples of coverage-based deployments include sites where there is a relatively large area with few Wi-Fi devices per user, such as:

- Small School Classrooms
- Warehouses
- Nursing Homes, Hospitals and Clinics
- Hotels
- Huddle Rooms

In the above applications, the number of AP's required is typically determined by the AP signal strength, which is a combination of AP output power and antenna gain. Additional considerations to take account are floor coverage and ceiling height, internal construction, number of floors and exclusion areas.

Capacity – the second type of deployment is based on network capacity. Here the goal is to provide a good quality service to a concentrated set of simultaneous users in a confined area. Examples of capacity-based deployments include;

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- Larger School Classrooms
- Lecture Halls
- Auditoriums
- Libraries
- Stadiums
- Office Conference Rooms

Additional considerations when designing capacity-based networks are such things as number of users covered by a single AP, percentage of active users, number of devices per person, type of applications and type of clients (2.4GHz or 5GHz).

For both the above models, or when using a mix of the two, it is advisable to carry out the necessary evaluation of the area which you intend to cover and to determine the amount of throughput required. Doing so will enable the designer to correctly choose a suitable AP and determine the best placement for the device.

Install Best Practice

When installing an AP there are no hard rules but there are some best practices which may result in optimised coverage and capacity.

Firstly, always try to mount the AP to the ceiling. This allows for maximum coverage and usually a direct line of sight to the client devices. Try to avoid installing too high as this can lead to problems when maintaining the unit. When using AP's with internal antenna, mounting too high can also cause issues with coverage due the radiation pattern of these AP's.

Secondly, avoid placing AP's above a false ceiling as this environment can be particularly hostile to an AP. Many false ceilings hide a myriad of objects such as metal pipework, ducting and containment. It can also be the home to unshielded cabling and contain a lot of dust from previous building work.

Thirdly, avoid wall mounting an AP flush against the wall. This will result in the RF output being radiated away from its intended recipients. If there is no alternative but to wall mount a device, use a suitable corner bracket to maximise coverage.

With the introduction of 802.11ac, conventional hallway placement can be changed to an 'in the room' philosophy. With the enhancements that 802.11ac adds, direct room placement will benefit the user by avoiding co-channel interference and adjacent channel interference. It also allows greater proximity to lower powered devices such as smartphones and iPads which are much more prevalent in today's professional environments.

Draft a Channel Plan

Eliminating co-channel interference is one of the main objectives when designing a wireless network. As mentioned previously, correct placement of the AP can help minimise this issue but implementing a carefully considered channel plan will help reduce interference to a minimum. Refer to the section on 'Channel Bonding' for an overview of plan basics, such as DFS considerations and channel width allocation. For optimum results, there are various software programmes available which will actively scan the RF spectrum. From here a detailed 'map' of channel allocation can be derived.

Securing the Network

As wireless signals propagate beyond physical wall and buildings, securing a network should be a top priority of any engineer working with networked technologies. We all know the importance of securing our home networks with authentication and encryption to mitigate any malicious snooping or 'piggy-backing'. However, in corporate or venue networks we may have a fluid workforce which will require management to limit access. All our digital products offer comprehensive management of access restrictions in terms of admin, advanced user and basic user. Similarly, a wireless network should be divided into domains which can be used for employees, contractors and guests. BYOD is a classic example of the challenges faced when securing such networks, whether it be from employees using personal smartphones to guest speakers using a laptop or tablet for presentation purposes.

In each scenario, the network administrator should manage these devices or face a potential threat to services and/or data residing on the network.

When securing a network, the following should be used as guide:

Separate internal users from guest users to ensure they only have access to the internet and no internal resources.

Use WPA2 authentication. There are two types, Personal and Enterprise and if possible, always use WPA2 Enterprise as it requires unique authentication per client.

Ensure that your AP is physically secured and that any local access requires a unique password.

Limit the Wi-Fi signal to only the areas where you require it. If working in an auditorium for example, you could limit the propagation so that the seating areas or breakout rooms are not covered by the FoH Wi-Fi signal.

Monitor the network for any possible malicious rouge AP's that have been installed within a secure network and use a wireless intrusion prevention system to detect specific WLAN attacks such as AP spoofing, malicious broadcasts and packet floods.

Use mobile device management to manage BYOD devices. This can aid security and will quarantine devices which do meet set security standards, limit application installations and data loss through geofencing techniques.

Finally, legacy Wi-Fi devices which do not support the latest security technologies should be managed appropriately. For these devices, it is advised to segment these devices into their own virtual network with a unique SSID.

Wireless Mixing

Allen & Heath offers a wealth of wireless mixing solutions, from stand-alone tablet-based mixing to the ability to set-up and mix the show from tablets, smartphones and Windows/Mac devices:

AHM-64

- System Manager (Windows, Mac)
- Custom Control (Windows, Mac, iOS, Android)

dLive

- Director (Windows, Mac)
- dLive MixPad / OneMix (iPad)

- Custom Control (Windows, Mac, iOS, Android)

Avantis

- Avantis MixPad / OneMix (iPad)
- Custom Control (Windows, Mac, iOS, Android)

SQ

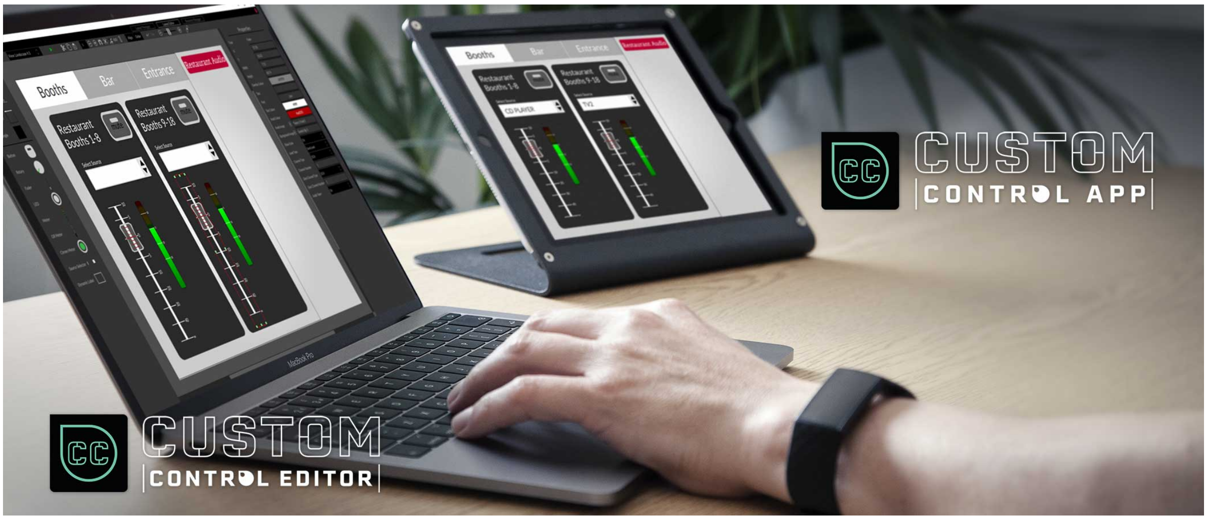
- SQ4You (iOS, Android)
- SQ MixPad (Windows, Mac, iOS, Android)

Qu

- Qu-Control (iOS)
- Qu-Pad (iPad)
- Qu-You (iOS, Android)

Conclusion

Each venue will present itself with unique challenges in terms of wireless networking. When touring, each venue will present a different problem to the night before and with each install you will encounter new materials and competing IT network infrastructure. Hopefully this document will shed some light on some of the decisions you should consider when designing and deploying such systems.



For further information, application guides, and recommended products please visit:
https://www.allen-heath.com/installation/

Don't hesitate to contact our Install team at installedsolutions@allen-heath.com if you need assistance on which products to specify or if you have questions about an application.

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