Optimizing your Wi-Fi for Home and Office

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For the best performance of your wireless (or “Wi-FI”) system, choose a channel at least five channels from nearby networks.

Both 802.11b and 802.11g devices are designed to share the airwaves with neighboring networks, however it is best to find a clear channel for several reasons, chief among these:

1. When your neighbors' networks are busy, there is less available bandwidth on those frequencies for your data, reducing your performance

2. Your Access Point (AP) and wireless devices may not fully hear your neighbor's weaker wireless signals (in order to compensate for them), thus causing degraded performance due to collisions

3. Nearby networks may not be entirely 802.11b or 802.11g compliant. Some "advanced" technologies are known to interfere with 802.11-compliant systems instead of sharing the airwaves with them.

In order to find a completely clear channel, you need to choose a channel that is five or more channel numbers away from your neighbors. This is not always possible, particularly in heavily populated areas.

There are some tools available that can detect and map wireless networks within range of a device’s Wi-Fi antenna:

- NetStumbler [Windows, so wireless laptop or desktop with a wireless adapter]
- iStumbler [Mac]
- inSSIDer [Windows]
- Wi-Viz [Linux, router-based such as DD-WRT and OpenWRT routers]
- WiFi Site Survey [Android, tablet-based]
- WiFi Mapper [Windows/Mac OS, browser-based]

You need to understand that the wireless channels translate to a radio frequency. Channel 6, for example, is 2.437 GHz (or 2437 MHz). Each channel up or down is 5 MHz away. However, and this is key, *Wi-Fi signals are 20 MHz wide!* So when you set your Wi-Fi device to channel 6, you actually are using the frequencies of channels 5, 6, 7, and half of 4 and 8.

```
                     -10 MHz    2437 MHz   +10 MHz
---------01---02---03---04---05---06---07---08---09---10---11---------
                         ~~~~~CHANNEL 06~~~~~
```

So consider the situation below when 3 wireless networks are on 3 different, but adjacent channels, 5, 6, and 7. They may be different channels, but they are using much of the same spectrum and, as a result, they will contend with each other.

```
---------01---02---03---04---05---06---07---08---09---10---11---------
                    ~~~~~CHANNEL 05~~~~~
                         ~~~~~CHANNEL 06~~~~~
                              ~~~~~CHANNEL 07~~~~~
```

This is why it is recommended to try to be at least 5 channels (25 MHz) away from your neighboring networks. By doing so, you avoid overlapping the frequency spectrum that their networks use. By moving the network 5 channels away (6 minus 5 equals 1, or 6 plus 5 equals 11), you avoid any overlap. As follows:

```
---------01---02---03---04---05---06---07---08---09---10---11---------
~~~~~CHANNEL 01~~~~~
                         ~~~~~CHANNEL 06~~~~~
                                                  ~~~~~CHANNEL 11~~~~~
```

Note: Channels available are governed by local regulations. You may have different channels available to you.

Note: Some tests have shown that the minor overlapping of channels does not degrade performance of Wi-Fi systems, allowing for four nearby networks to share the available spectrum. This 2004 article from Cisco® Systems discusses both three and 4-channel placement [requires Adobe® PDF compatible reader]:

http://www.stcllp.com/docs/stc_wifi_issues.pdf

Access Point Placement and Coverage Strategies

Often one of the biggest challenges in a high-density environment is access and aesthetics. A large meeting hall is impressive because of its size and a great deal goes into the aesthetics of the environment. The best approach to engineering a specific space is to do a qualified site survey. Once the APs are mounted, physical adjustments become a lot more complex, so it is best to test while installing and make certain that the coverage that has been defined in the design is what is installed.

APs have evolved rapidly in short period of time. If an AP with external antenna capabilities is to be used, it is essential that an antenna that was designed for that AP also be used. MIMO or 802.11n APs need MIMO antennas to perform properly. Even if HT rates are not being counted on, the antenna and the radios are a system and the system is designed to perform with all of these elements.

Multiple Wireless Access Points

In larger facilities, it is often necessary to have more than one wireless Access Point (AP). Generally, in many home and small business situations, the incoming, broadband modem will be adjacent to a router which will often, in turn, contain a wireless transceiver. The location of these "wireless routers" is not always optimal for coverage throughout a home or building. If positioned outside (such as in a garage) or in a distant corner of the building, it may be better to turn off the built-in wireless capability and install a separate wireless AP at a more central location.

Often, a second wireless router can be used and, in this case, the router/switch services would be turned off, but the wireless services used.

Do not purchase wireless routers in which both the wired router/switching service and the wireless access point service cannot be independently controlled. Look for an embedded, Linux-based router that can have its internal software replaced with DD-WRT or OpenWRT.

If two or three APs are needed, perhaps keeping the one in the main switch (wireless router) is allowed to remain on (and let it default to channel 1 or channel 6), but physical install a more central AP on the other channel (ch 6 if the main is on 1 or ch 1 if the main is on 6). Then, if desired, set up one more AP at the opposite end of the facility on channel 11. This allows multiple wireless networks within the same wired network (or LAN) and keeps interference to a minimum as each wireless Access Point has its own radio bandwidth on completely separate channels.

Another consideration would be if there are wireless camera, wireless music streaming or video streaming to be used. In the first case, set all wireless cameras to a single AP (on channel 11, for example) so that it is not shared with other wireless users. Or, three wireless cameras, for example, can be spread across three APs for "load leveling", thus no single AP's radio bandwidth is over-consumed by video streaming. If multiple users are going to stream music or video, have them manually select a specific AP of your choice (either the one you've dedicated to streaming or one you know is not currently streaming for other users or devices).

2.4 GHz Channel Reuse in High-Density Wireless Design

In 2.4 GHz there are three non-overlapping channels with which to work in achieving isolation. The RF properties of 2.4 GHz signals give it better range and less attenuation than signals in 5 GHz. In a high-density environment, there is often only one clean channel reuse within a 10,000 square foot area. Channel reuse in such an area is opportunistic at best and it is not possible to estimate without careful advanced survey techniques. Results will vary from no increase in bandwidth to modest gains and will differ from site to site. If faced with such a challenge, consult with a professional with experience in advanced engineering techniques specific to a high-density RF deployment. Adding more APs can reduce the number of users per cell and may appear to give more coverage when the space is empty. But once it fills up, the effect will be that of one large super cell covering the room with limited bandwidth and sporadic connections for all.

Note: Before considering a four-channel plan in 2.4 GHz, see the Cisco® document, "Channel Deployment Issues for 2.4-GHz 802.11 WLANs" for an excellent discussion on the issues. The conclusion is that it is better for two APs to share a channel than to have two channels overlapping on the edge. Two APs sharing a channel can demodulate each others' transmissions and share the bandwidth amicably. When two channels overlap at the edge, it is just noise to both and will result in collisions, retransmits, and SNR degradation.

Additionally, if the WLAN is located in a regulatory domain where the bandwidth to deploy four channels is available (e.g., availability of channel 13 and 14) unless the WLAN is sufficiently isolated from every other network it is likely that someone will deploy using the standard 1, 6, 11 model and drastically increase the interference to the WLAN.

If it is necessary to maximize a 2.4 GHz connection, it is possible to increase the bandwidth and efficiency of cells by physically limiting the propagation through the use of antennas and creative placement options. This will require site specific engineering and careful measurement and design. This, however, is not always an option for budgetary or aesthetics reasons. [see section on placement above]

5 GHz Channel Reuse in a High-Density Design

In contrast to 2.4 GHz, 5 GHz has many more channels with which to work. As many as 20 channels can be received in the United States and between 5 and 21 in the rest of the world. Most regions have between 19 and 21 channels. But all 5 GHz channels are not created equally. Limitations on maximum power for parts of the band are not of concern, but Dynamic Frequency Selection (DFS) channels represent some challenges that must be addressed.

Dynamic Frequency Selection and High-Density Design

DFS was implemented so that APs and clients can share the band with radar devices. DFS details how radar is detected and what should be done in the event of detection. APs operating on DFS channels must first listen to a channel for 60 seconds to determine if there is a radar present before transmitting any energy. If an AP is operating on a DFS channel and detects a radar (real or false) it must shut down operations on that channel and abandon it for 30 minutes before that channel can be evaluated again for use.

Client support for DFS channels has been inconsistent, however. Client devices do not have the ability to detect radar and rely on the infrastructure established by a DFS certified AP. Most clients today support channels 52-64. Client support for channels 100-140 has been slow in coming. Often it is a matter of not only the hardware but the version of the driver for the client that determines its operating channel range.

Client support has been steadily increasing and to-date Intel 5100 a/g/n, 5300 a/g/n, and 6300 a/g/n all operate on channels 52-64 and 100-140. The Cisco Cius and the Apple iPad and the Cisco 7925 IP phone also support the full range of DFS channels.

The effect of using channels that are not supported by all clients can result in coverage holes for those clients. Channels 100-140 are disabled by default on a some routers and switches, but can be enabled easily in the DCA channel selections by choosing the extended UNII-2 channels. Before doing so, it is highly advisable to inventory the clients and drivers that must be supported.

If DFS channels have been used in a WLAN installation, their suitability within the WLAN will be established. If they have not been enabled previously, it is advisable that the DFS channels are surveyed using Cisco equipment and that monitoring for radar detection is done before enabling the channels. In public and other venues within higher education environments, it is often recommended to avoid using these extended UNII-2 channels due to their current lack of client support. The base UNII-2 channel availability in clients is more pervasive and these are channels that could be considered but ongoing monitoring of client capabilities should not be overlooked.

802.11n - 20 MHz or 40 MHz Channels?

802.11n can operate in a 40 MHz channel by bonding two 20 MHz channels together and this significantly increases throughput. However, this is reserved for burst mode transfers only. It is only practical to do this in 5 GHz because 2.4 GHz is already limited by the number of channels available. If there are enough 5 GHz channels to achieve the WLAN goals using a bonded channel plan (9 in the U.S. if using available DFS channels) to meet throughput goals, consider it. If forced to reuse 5 GHz channels, more consistent results will be delivered using strictly 20 MHz channels and avoiding loss of efficiency due to CCI.

Evaluating Requirements for 2.4 GHz and 5 GHz Connection Support

The essential question for a high-density design is how many channels for each band will be needed to match the client base? This can be a tricky question since even dual band capable clients do not always select the faster 5 GHz band. Since bandwidth in 2.4 GHz is going to be limited, 5 GHz must be relied on to reach the goal.

Dual band adapters have been shipping with most laptops for some time. This does not mean that every laptop is a dual band client, but many are. Simply having a dual band client does not guarantee that it will choose 5 GHz over 2.4 GHz. The Microsoft Windows operating system defaults to a Wi-Fi channel search that starts with the 5 GHz channel 36 and continues searching through all of the 5 GHz channels that the client is capable of. If no 5 GHz AP is found then it will continue the search in 2.4 GHz starting at channel 1. Unless the Windows default is changed or the user has chosen a third party Wi-Fi utility to set spectrum preference to 2.4 GHz, the client radio will first try to associate to a 5 GHz AP. Apple Computer's latest release for Atheros and Broadcom chipsets also searches 5 GHz first.

Omnidirectional Antennas

Use of an AP with attached low gain omnidirectional MIMO antenna is recommended if mounting is to be done on the ceiling of a modest-sized auditorium (averaging 20 feet or lower) with no channel reuse required in 2.4 GHz or 5 GHz. Omnidirectional antennas provide better ceiling-to-floor coverage, thereby reducing the likelihood that a packet traveling to or from the client has bounced off some object (usually a wall or the ceiling) before reaching the receiving antenna. This reduces the opportunity for multipath interference.

A related consideration is high-gain versus low-gain omnidirectional antennas:

- **Use of a high gain omnidirectional antenna should be avoided.** This type of antenna will increase the size of the cell and the number of users that will be sharing the bandwidth. Higher gain in an omnidirectional antenna design generally means increased horizontal beam-width with a decrease in vertical beam-width. This effect will be more pronounced as the ceiling height increases.

- **The low-gain omnidirectional antenna has less horizontal coverage** and in an auditorium will have less floor coverage than a high-gain antenna. This supports the goal of small channel and small floor size and it will serve to limit the number of users in the coverage area, effectively managing client-based co-channel interference. The low-gain antenna will also provide a better quality signal.

Actual real-life speed of wireless networks

There are many wireless standards in use today, and newer technologies can bond multiple channels/frequencies together to achieve higher throughput. First, keep in mind that in data communications, speed is measured in kilobits (or megabits) per second, designated as kbps, or Mbps. Check Speedguide.net bits/bytes conversion calculator for reference:

http://www.speedguide.net/conversion.php

Below is a breakdown of the various 802.11 WiFi standards and their corresponding maximum speeds. Theoretical wireless speeds (combined upstream and downstream) are as follows:

802.11b - 11 Mbps (2.4GHz)

802.11a - 54 Mbps (5 GHz)

802.11g - 54 Mbps (2.4GHz)

802.11n - 600 Mbps (2.4GHz and 5 GHz) - 150Mbps typical for network adapters, 300Mbps, 450Mbps, and 600Mbps speeds when bonding channels with some routers

802.11ac - 1300+Mbps (5 GHz) - newer standard that uses wider channels, QAM and spatial streams for higher throughput

The performance of Wi-Fi networks practically never approach these theoretical maximums. 802.11b networks, for example, generally operate no faster than about 50% of theoretical peak, around 5.5 Mbps. Likewise, 802.11a and 802.11g networks generally run no faster than 20 Mbps. And even though 802.11n rates at 300 Mbps compared to wired Fast Ethernet at 100 Mbps, the Ethernet connection can often outperform 802.11n in real world usage. Wi-Fi performance continues to be improved with future generations of the technology, though.

Real world wireless speeds vary significantly from the above theoretical maximum speeds due to:

distance - distance from the access point, as well as any physical obstructions, such as walls, signal-blocking or reflecting materials affect signal propagation and reduce speed

interference - other wireless networks and devices in the same frequency in the same area affect performance shared

bandwidth - available bandwidth is shared between all users on the same wireless network.

The disparity between theoretical and practical Wi-Fi performance comes from network protocol overhead, radio interference, physical obstructions on the line of sight between devices, and distance between devices. In addition, as more devices communicate on the network simultaneously, its performance will also decrease.

A Wi-Fi network connection operates at the highest possible speed that both devices (endpoints) can support. In addition, net IP layer throughput of WiFi is typically 60% of the air link rate due to WiFi being half-duplex with ACKs, and being CSMA/CA. The number of simultaneous connections – and even the type of wireless security – can affect and slow down some older routers with inadequate processors/memory.

An 802.11g laptop connected to an 802.11n router, for example, will network at the lower speeds of 'g'.

On home networks, the performance of an Internet connection is often the limiting factor in end-to-end network speed. Even though most residential networks support sharing files within the home at speeds of 20 Mbps or more, Wi-Fi clients will still connect to the Internet at the usually lower speeds supported by Internet providers.

Below is a breakdown of actual real-life average speeds you can expect from wireless routers within a reasonable distance, with low interference and small number of simultaneous clients:

802.11b - 2-3 Mbps downstream, up to 5-6 Mbps with some vendor-specific extensions.

802.11g - ~20 Mbps downstream

802.11n - 40-50 Mbps typical, varying greatly depending on configuration, whether it is mixed or N-only network, the number of bonded channels, etc. Specifying a channel, and using 40MHz channels can help achieve 70-80Mbps with some newer routers. Up to 100 Mbps achievable with more expensive commercial equipment with 8x8 arrays, gigabit ports, etc.

802.11ac - 70-100+ Mbps typical, higher speeds possible over short distances without many obstacles, with newer generation 802.11ac routers, and client adapters capable of multiple streams.