Cisco ClientLink: Optimized Device Performance with 802.11n

Overview

Over the next few years Wi-Fi networks will transition to 802.11n technology. During this time many networks will support a mix of 802.11a/g and 802.11n clients. Because they operate at lower data rates, the older clients can reduce the capacity of the entire network. ClientLink technology can help solve problems related to adoption of 802.11n in mixed-client networks by making sure that 802.11a/g clients operate at the best possible rates, especially when they are near cell boundaries.

Introduction

802.11n provides remarkable performance improvements in the areas of throughput, link reliability, and predictability. The transition to 802.11n provides significant benefits, but most organizations will take a phased approach to migration. Over the next few years, many installations can be expected to support a mix of older 802.11a/g clients and newer 802.11n clients. The reasons that older clients will continue to operate for some time is that it takes 3 to 5 years for a full refresh cycle of enterprise laptops. And certain industries such as manufacturing, retail, and healthcare can take even longer to replace their devices.

In mixed environments, older 802.11a/g clients delay communications for 802.11n clients and reduce system performance. Recognizing the need for businesses to protect their investment in these 802.11a/g devices, Cisco has developed a new technology that allows businesses to deliver the performance benefits of 802.11n to 802.11a/g devices, thereby increasing their useful life.

Most 802.11n solutions offer improvements in the uplink communication from client to access point. Cisco ClientLink technology is unique in that it offers uplink improvements as well as downlink communication from access point to client. This is significant because the majority of daily communication on the WLAN such as web browsing, email, and file downloads occur in the downlink direction. Improving the downlink throughput of the slowest clients improves the experience not only for the clients, but also for all other clients on the network. The result is a more reliable roaming experience and increased capacity of the network.

Cisco has added advanced signal processing into the Wi-Fi chipset. Multiple transmit antennas are used to focus transmissions in the direction of the 802.11a/g client, increasing the downlink signal-to-noise ratio and the data rate over range, thereby reducing coverage holes and enhancing the overall system performance. This technology essentially learns the optimum way to combine the signal received from a client, and then uses that information to send packets in an optimum way back to the client. This technique is also referred to as MIMO (multiple-input multiple-output) beamforming, transmit beamforming, or cophasing, and it is the only enterprise-class solution on the market that does not require expensive antenna arrays.

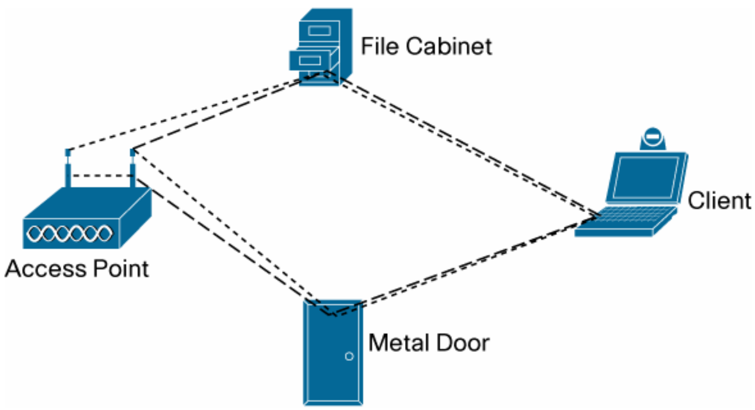
Basics of MIMO and 802.11n

MIMO, which refers to a radio system that has multiple separate receive and transmit paths, is at the heart of 802.11n. MIMO systems are described using the number of transmitters and receivers in the system. For example, 2x1 or "two by one" refers to a system with two transmitters and one receiver. 802.11n defines a number of different combinations from 2x1 to 4x4.

To understand the improvement brought by MIMO technology, it is important to understand some basic radio operating principles. In a radio system, the amount of information that can be carried by a signal depends on the signal-to-noise ratio, or SNR, typically expressed in decibels (dB). The greater the SNR the more information is carried on the signal and recovered by the receiver.

In a typical indoor WLAN deployment at an office, hospital, or warehouse the radio signal rarely takes the direct, shortest path from transmitter to receiver because walls, doors, or other structures obscure the line of sight. Luckily, most of these environments are full of surfaces that reflect a radio signal similarly to how a mirror reflects light. When a signal travels over different paths to a receiver, the signal traveling the shortest path arrives first, followed by copies or echoes of the signal slightly delayed by each of the longer paths. This situation is called **multipath** propagation (see Figure 1). Multipath conditions are constantly changing as clients, people, and objects move throughout the network of access points.

Figure 1. Multipath Propagation



802.11n systems take advantage of multipath by sending multiple radio signals at the same time. Each of these signals, called a **spatial stream**, is sent from its own antenna using its own transmitter. Because there is some space between these antennas, each signal follows a slightly different path to the receiver, a situation called **spatial diversity**. The receiver has multiple antennas as well, each with its own radio that independently decodes the arriving signals, and each signal is combined with the signals from the other receive radios. The result is that multiple data streams are received at the same time. This enables much higher throughput than previous 802.11a/g systems, but requires an 802.11n capable client to decipher the signal.

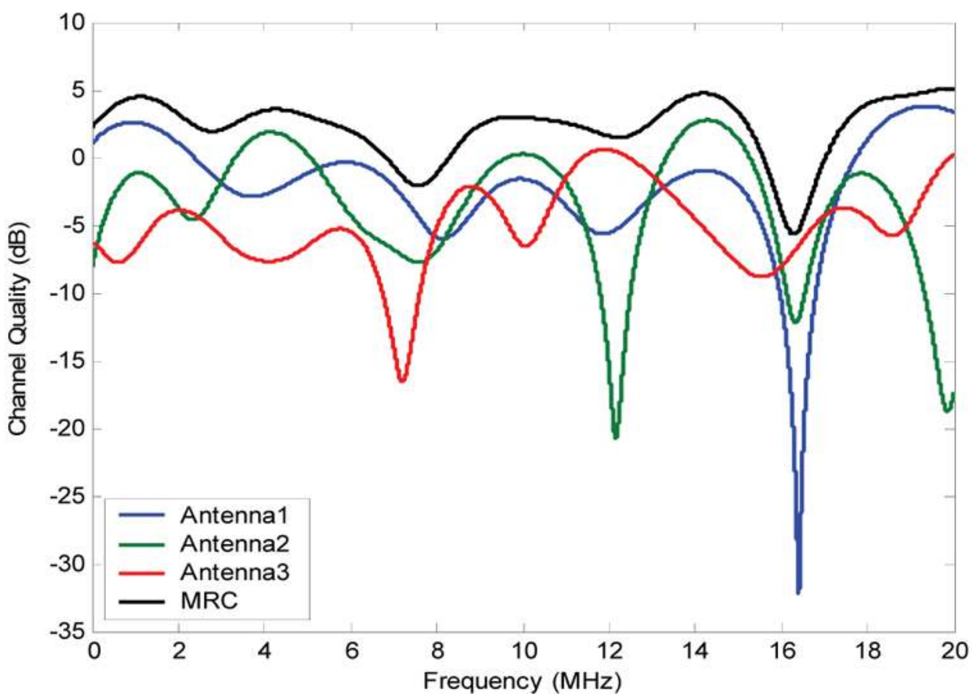
802.11n also specifies how MIMO technology can be used to improve SNR at the receiver by using **transmit beamforming**. With this technique, it is possible to coordinate the signal sent from each antenna so that the signal at the receiver is improved. In other words, in addition to sending multiple streams, multiple transmitters can also be used to achieve a higher SNR (and therefore data rate) on each stream. But there are two things to note: 1) The transmit beamforming specified in the 802.11n standard requires cooperation from the receiver to feed back training and/or channel information about the received signal to the transmitter—so **both** AP and client need to support this capability. 2) Due to the complexity issues, in the first generation of mainstream 802.11n chipsets, **neither** the AP nor client chipsets implemented 802.11n transmit beamforming. So, 802.11n standard transmit beamforming will come eventually, but not until the next generation of chipsets take hold in the market. Cisco intends to lead in this area going forward.

ClientLink Technology

Cisco realized that for the current generation of 802.11n APs, while the second transmit path was being well utilized for 802.11n clients (to implement spatial diversity), it was not being fully used for 802.11 a/g clients. In other words, for 802.11 a/g clients, some of the capability of the extra transmit path was lying idle. In addition, Cisco realized that for many networks, the performance of the installed 802.11 a/g client base would be a limiting factor on the network. To take advantage of this fallow capacity and greatly enhance overall network capacity by bringing 802.11 a/g clients up to a higher performance level, Cisco created an innovation in transmit beamforming technology, called ClientLink. ClientLink uses advanced signal processing techniques and multiple transmit paths to optimize the signal received by 802.11 a/g clients in the downlink direction **without requiring feedback**. And because it doesn't require any special feedback, Cisco ClientLink works with **all existing 802.11a/g clients**.

To understand how this works, consider a single transmitter 802.11a/g client sending an uplink packet to an 802.11n access point with multiple transceivers. The access point receives the signal on each of its three receive antennas. Each received signal has a different phase and amplitude based on the characteristics of the space between the antenna and the client. The access point processes the three received signals into one reinforced signal by adjusting their phases and amplitudes to form the best possible signal. The algorithm it uses, called maximal ratio combining (MRC), is typically used on all 802.11n access points (see Figure 2). MRC only helps in the uplink direction, enabling the access point to "hear" the client better.

Figure 2. Reinforcement of received signal via MRC algorithm



Cisco ClientLink technology takes this one step further to improve performance in the downlink direction, making the client better able to hear the access point. The Wi-Fi channel is reciprocal, meaning that transmissions between access points and clients happen on the same frequency and use the same antennas. Thus the access point can use the adjustments calculated by MRC (referred to as "weights") to optimize the reciprocal signal transmitted back to that specific client using the APs two transmit antennas.

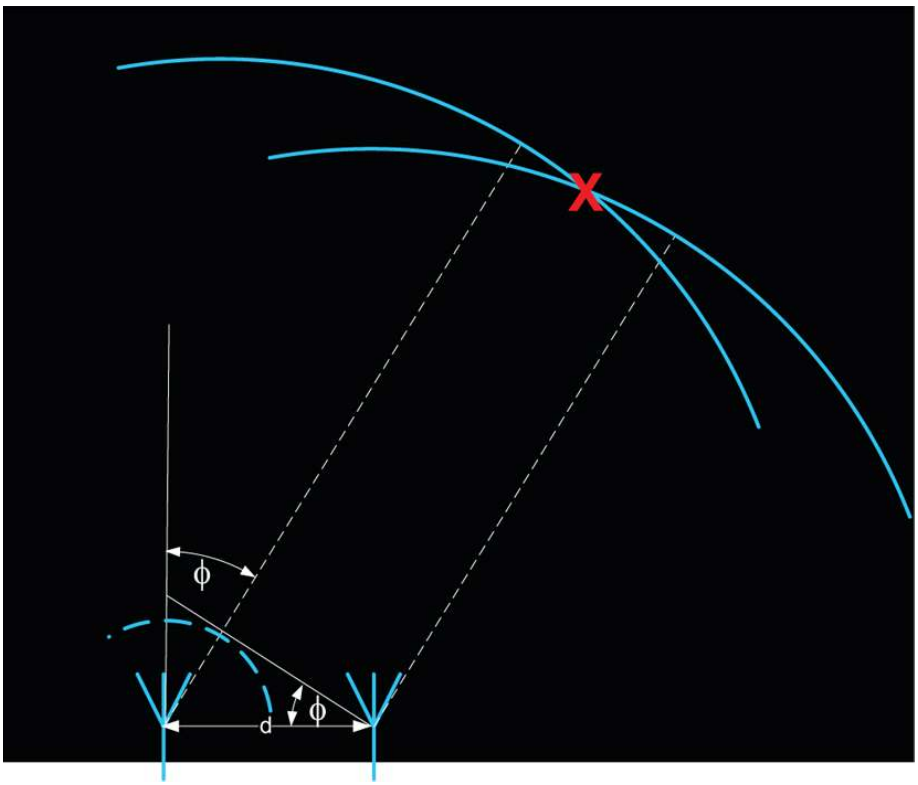
Enhancements to the Cisco Wi-Fi chipset that support ClientLink technology include hardware blocks that perform four tasks:

- Compute the weights on each received packet based on the MRC algorithm
- Store the weights for each client
- Look up the weights for the appropriate client prior to transmission
- Apply the weights to the transmitted signal, forming a radio beam

Because these enhancements are made in hardware, there is minimal additional overhead on the access point's platform and therefore no performance loss due to the signal processing.

The ClientLink algorithms deliver an optimum reinforced signal to the client on its one antenna (Figure 3). And because this technology does not depend on any client-side hardware or software capabilities, it works with all existing 802.11a/g clients. (Note that ClientLink interoperates seamlessly in mixed mode environments where 802.11n and 802.11a/g clients co-exist on the same access point. For 802.11a/g clients, transmit beam forming is used to increase the gain towards the client. For 802.11n clients, spatial multiplexing is used to deliver enhanced high throughput data rates upwards of 300 Mbps. In this manner the optimum MIMO technology is dynamically selected to deliver benefits to each client type.)

Figure 3. Example Alignment of Two transmitted phases to maximize signal at the client (X)



Cisco ClientLink technology effectively enables the access point to optimize the SNR exactly at the position where the client is placed. Improved SNR yields many benefits, such as a reduced number of retries and higher data rates. For example, a client at the edge of the cell that might previously have been capable of receiving packets at 12 Mbps could now receive them at 36 Mbps. Typical measurements of downlink performance with ClientLink show as much as 25 percent greater throughput for 802.11a/g clients. By allowing the Wi-Fi system to operate at higher data rates and with fewer retries, ClientLink increases the overall capacity of the system, which means more efficient use of spectrum resources.

In wireless networks, there are typically many coverage holes near the edges of cells where signal strength is too low for good Wi-Fi performance. Clients encounter these holes as they roam from cell to cell. By reducing the number and depth of coverage holes, Cisco ClientLink helps ensure more reliable, predictable, and homogeneous coverage throughout the floorspace. The performance maps in Figures 4 and 5 demonstrate how the maximum receive data rate at the client improves from the use of ClientLink technology. In this particular example, the signal improves by 5 dB and the data rate is increased from 24 Mbps to 36 Mbps. Note that typical indoor enterprise environments are considered Non-Line-of-Sight (NLOS) environments—meaning that the Wi-Fi signal typically bounces off one or more objects before reaching its destination. Based on both academic analysis[1] and empirical measurements, the expected range of improvement using transmit beamforming with two transmit antennas in an NLOS environment is from 4 to 6.5 dB.

Figure 4. Initial Coverage Map Without ClientLink

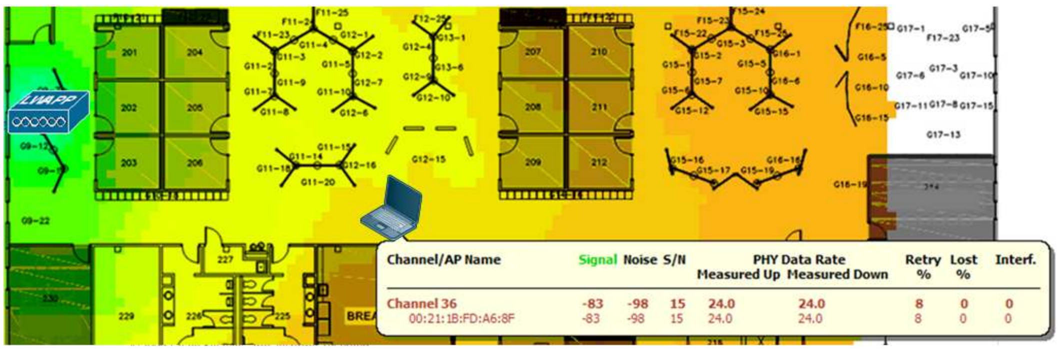
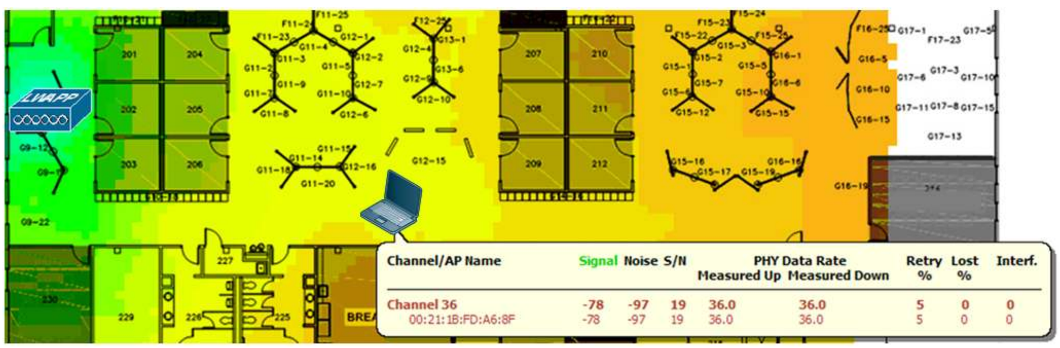


Figure 5. Improved Coverage Map With ClientLink



Deployment Guidelines

The following are some guidelines to consider when deploying systems with Cisco ClientLink technology:

- Although ClientLink increases the SNR and data rates of clients at the edges of the cell, it does not extend the maximum range of a cell. This is because certain packets that must be heard by all clients (such as beacons) are sent as broadcasts, which ClientLink cannot optimize. These broadcast packets effectively become the limiting factor on the cell size. Therefore cell spacing should not be increased when using ClientLink. In fact, to be conservative, the ClientLink feature can be turned off during a site survey.
- Because the absolute size of the cell has not been extended, ClientLink presents no issues with an increased number of hidden nodes. When a packet is sent via ClientLink to a specific client, although the signal is improved for that client, the signal heard by all other clients is not in general degraded.

[1] Perahia and Stacey, Cambridge University Press, "Next Generation Wireless LANs", p. 338

- Use of ClientLink does not result in any changes to the output power of the access point. In general, it is not a good idea to increase output power either due to FCC limits, or due to issues with co-channel interference on neighboring cells. Although it might seem possible to decrease output power because of improved SNR at the clients, this would reduce the range of broadcast packets, which do not experience the gain.
- In addition to providing gain in an indoor multipath environment, ClientLink also provides increased SNR at the client in line-of-sight environments such as outdoors or large open indoor spaces.
- ClientLink interoperates seamlessly in mixed mode environments where 802.11n and 802.11a/g clients co-exist on the same access point. For 802.11a/g clients, transmit beam forming is used to increase the gain towards the client. For 802.11n clients, spatial multiplexing is used to deliver enhanced high throughput data rates upwards of 300 Mbps. In this manner the optimum MIMO technology is dynamically selected to deliver benefits to each client type.

Summary

In the next few years, it will be common for Wi-Fi networks to support a mix of 802.11a/g and 802.11n clients. Cisco ClientLink technology helps solve the problems of mixed-client networks by making sure that older 802.11a/g clients operate at the best possible rates, especially when they are near cell boundaries. Unlike most 802.11n access points, which only improve the uplink performance, Cisco ClientLink technology improves performance on both the uplink and downlink providing a better user experience during web browsing, email, and file downloads. Similarly, the improved robustness of the link benefits connectivity-oriented applications such as voice and SAP database on handheld appliances. Finally, ClientLink technology is based on signal processing enhancements to the access point chipset and does not require changes to network parameters. The Cisco M-Drive solution and Cisco ClientLink technology help solve one of the key challenges associated with 802.11n adoption. It extends the useful life of existing 802.11a/g devices and is beneficial for organizations that want to ensure that all clients on the network, regardless of type, are guaranteed the bandwidth and throughput they need.

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