Multipath and Diversity

Document ID: 27147

Contents

Introduction

This document describes:

- Multipath distortion
- How multipath distortion degrades the performance of a wireless network
- Diversity
- How diversity helps improve performance in a multipath environment

Prerequisites

Requirements

There are no specific requirements for this document.

Components Used

The information in this document is based on these software and hardware versions:

- Cisco Aironet and Airespace wireless LAN equipment
- Cisco IOS®, VxWorks, and SOS (Cisco Aironet 340 Series and earlier) operating systems

The information in this document was created from the devices in a specific lab environment. All of the devices used in this document started with a cleared (default) configuration. If your network is live, make sure that you understand the potential impact of any command.

Conventions

Refer to the Cisco Technical Tips Conventions for more information on document conventions.

Multipath

In order to understand diversity, you must understand multipath distortion.

When a radio frequency (RF) signal is transmitted towards the receiver, the general behavior of the RF signal is to grow wider as it is transmitted further. On its way, the RF signal encounters objects that reflect, refract, diffract or interfere with the signal. When an RF signal is reflected off an object, multiple wavefronts are created. As a result of these new duplicate wavefronts, there are multiple wavefronts that reach the receiver.

Multipath propagation occurs when RF signals take different paths from a source to a destination. A part of the signal goes to the destination while another part bounces off an obstruction, then goes on to the destination. As a result, part of the signal encounters delay and travels a longer path to the destination.

Multipath can be defined as the combination of the original signal plus the duplicate wave fronts that result from reflection of the waves off obstacles between the transmitter and the receiver.

Multipath distortion is a form of RF interference that occurs when a radio signal has more than one path between the receiver and the transmitter. This occurs in cells with metallic or other RF−reflective surfaces, such as furniture, walls, or coated glass.

Common wireless LAN (WLAN) environments with a high probability of multipath interference include:

- Airport hangars
- Steel mills
- Manufacturing areas
- Distribution centers
- Other locations where the antenna of an RF device is exposed to metal structures, such as:
    - Walls
    - Ceilings
    - Racks
    - Shelving
    - Other metallic items

Effects of multipath distortion include:

- Data Corruption Occurs when multipath is so severe that the receiver is unable to detect the transmitted information.
- Signal Nulling Occurs when the reflected waves arrive exactly out of phase with the main signal and cancel the main signal completely.
- Increased Signal Amplitude Occurs when the reflected waves arrive in phase with the main signal and add on to the main signal thereby increasing the signal strength.
- Decreased Signal Amplitude Occurs when the reflected waves arrive out of phase to some extent with the main signal thereby reducing the signal amplitude.

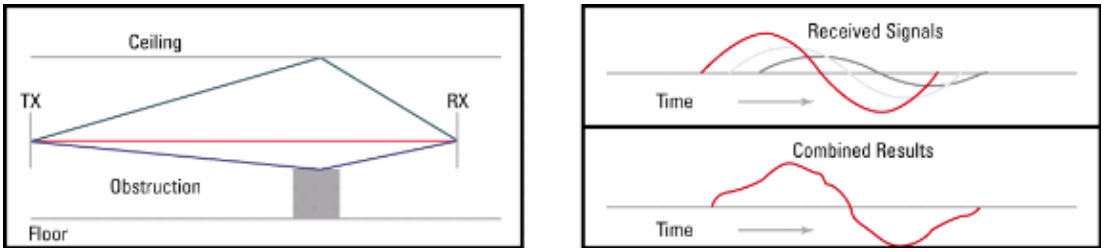
This section explains how multipath distortion occurs and how it affects WLAN.

A source antenna radiates RF energy in more than one definite direction. The RF moves between the source and destination antenna in the most direct path and bounces off RF−reflective surfaces (see Figure 1). The reflected RF waves cause these conditions to occur:

1. The reflected RF waves travel farther and arrive later in time than the direct RF wave.
2. The reflected signal loses more RF energy than the direct route signal, because of the longer transmission route.
3. The signal loses energy as a result of the reflection.
4. The desired wave is combined with many reflected waves in the receiver.
5. When the different waveforms combine, they cause distortion of the desired waveform and affect the decoding capability of the receiver. When the reflected signals are combined at the receiver, even

though the signal strength is high, the signal quality is poor.
6. The reflected wave is also positionally different from the unreflected wave.

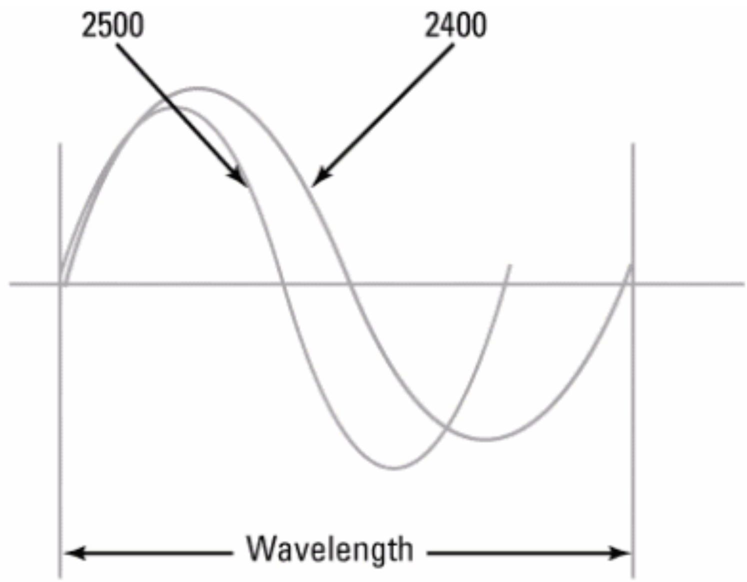
Figure 1 Receiver Hears Multiple Multipath Signals from the Reflected Surfaces

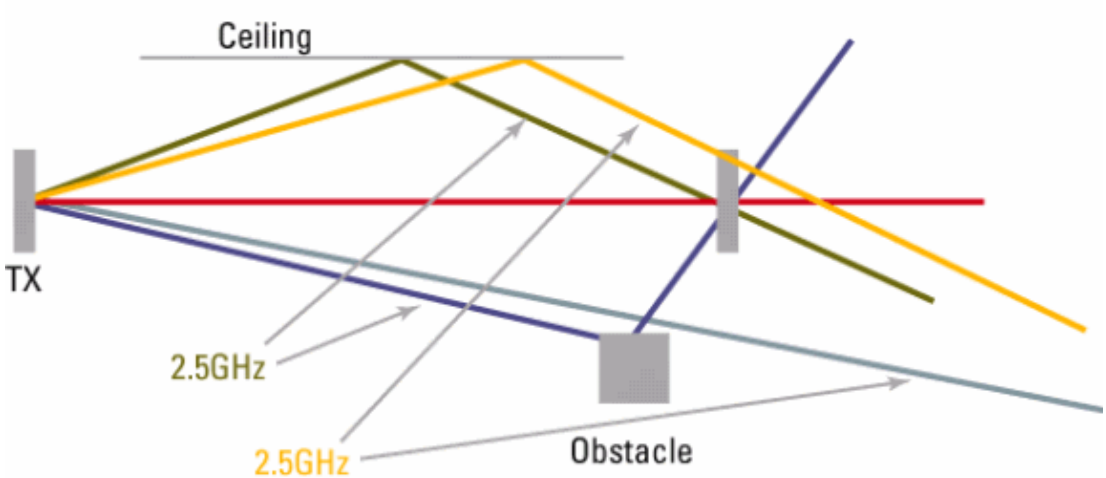


Multipath delay causes the information symbols represented in 802.11 signals to overlap, which confuses the receiver. If the delays are great enough, bit errors in the packet occur. The receiver cannot distinguish the symbols and interpret the corresponding bits correctly. The destination station detects the problem through the error−checking process of 802.11. The cyclic redundancy check (CRC, the checksum) does not compute correctly, which indicates that there is an error in the packet. In response to the bit errors, the destination station does not send an 802.11 acknowledgment to the source station. The sender eventually retransmits the signal after it regains access to the medium. Because of the retransmissions, users encounter lower throughput when multipath interference is significant. If the location of the antenna is changed, the reflections are also changed, which diminishes the chance and effects of multipath interference.

In a multipath environment, signal null points are located throughout the area. The distance an RF wave travels, how it bounces, and where the multipath null occurs are based on the wavelength of the frequency. As frequency changes, so does the length of the wave. Therefore, as frequency changes, so does the location of the multipath null (see Figure 2). The length of the 2.4 GHz wave is approximately 4.92 inches (12.5 cm). The length of the 5 GHz wave is approximately 2.36 inches (6 cm).

Figure 2 Position of the Multipath Null Point Based on the Frequency of the Transmission





Delay spread is a parameter used to signify multipath. Delay Spread is defined as the delay between the instant the main signal arrives to the instant that the last reflected signal arrives. The delay of reflected signal is measured in nanoseconds (ns). The amount of delay spread varies for indoor home, office, and manufacturing environments.

Delay Spread	Nanoseconds
Homes	< 50 ns
Offices	~100 ns
Manufacturing Floors	~200›00 ns

A multipath signal can have a high RF signal strength yet have poor signal quality level.

Note: Low RF signal strength does not indicate poor communication. Low signal quality, however, does indicate poor communication.

Diversity

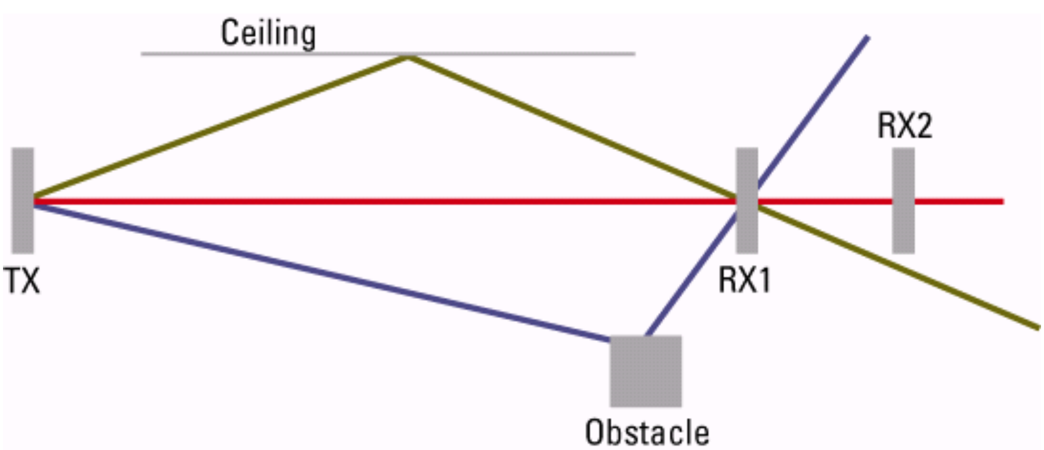
Diversity is the use of two antennas for each radio, to increase the odds that you receive a better signal on either of the antennas. The antennas used to provide a diversity solution can be in the same physical housing or must be two separate but equal antennas in the same location. Diversity provides relief to a wireless network in a multipath scenario. Diversity antennas are physically separated from the radio and each other, to ensure that one encounters less multipath propagation effects than the other. Dual antennas typically ensure that if one antenna is in an RF null then the other is not, which provides better performance in multipath environments (see Figure 3). You can move the antenna to get it out of the null point and provide a way to receive the signal correctly.

Cisco Systems enables antenna diversity by default on its Aironet access point products. The access point samples the radio signal from two integrated antenna ports and chooses a preferred antenna. This diversity creates robustness where there is multipath distortion.

Diversity antennas are not designed to extend the coverage range of a radio cell, but to enhance the coverage of a cell. The enhanced coverage is an effort to overcome issues that arise from multipath distortion and signal nulls. Attempts to use the two antennas on an access point to cover two different radio cells can result in connectivity issues.

One caution with diversity, it is not designed for using two antennas covering two different coverage cells. The problem in using it this way is that, if antenna number 1 communicates to device number 1 while device number 2 (which is in the antenna umber 2 cell) tries to communicate, antenna number 2 is not connected (due to the position of the switch), and the communication fails. Diversity antennas should cover the same area from only a slightly different location.

Figure 3   How Dual Antennas Help Ensure That One Antenna is not in a Null Point



With a diversity antenna solution that has two antennas in the same physical housing, there are two receiving and transmitting elements in that type of antenna. Because there are two elements, there are two antenna cables; both of those cables must be connected to the antenna ports of the access point.

The radio in the access point cannot physically move the antenna. Compare the diversity feature to a switch that selects one antenna at a time. It cannot listen to both antennas simultaneously, because that creates a multipath condition as the radio signal hits each antenna at different times. Because each antenna is selected by itself, both antennas must have the same radiation characteristics and be positioned to provide similar cell coverage (see Figure 4). Two antennas connected to the same access point must not be used to cover two different cells.

In order to increase coverage, conduct a site survey to determine the RF coverage of the antennas. Place access points in the appropriate areas of the installation site. The purpose of diversity is to overcome multipath reflections. Diversity antennas that share the same physical housing are placed at an optimum distance apart. The maker of the particular antenna determines that distance based on the characteristics of the antenna. When you use a pair of antennas with matching characteristics to provide diversity for cell coverage in your facility, the guideline is to put those matched antennas at a distance apart from each other that is equal to a multiple of the wavelength of the frequency that is being transmitted. The 2.4 GHz wavelength is approximately 4.92 inches. Therefore, to support diversity on a 2.4 GHz radio with two separate antennas, the antennas should be spaced approximately 5 inches apart. The antenna pair could also be spaced at multiples of 5 inches, but the distance between should not exceed 4 multiples: reflected waves farther apart than that are likely to be so distorted and different in delay spread that the radio could not work with them.

When the antennas are seperated either more or less than the 2.4 Ghz wavelength (5 inches), the radio coverage cell for each antenna becomes different. If the coverage cells become too different, the client or end node can experience signal loss and poor performance. An example of different coverage cells would be a directional antenna on one antenna port with an omnidirectional or higher−gain antenna on the other port.

The purpose of diversity is to provide the best possible throughput by reducing the number of packets that are missed or retried.

For information on the different types of antennas that Cisco offers, refer to the Cisco Aironet Antenna Reference Guide.

Figure 4   Cisco Aironet 350 Series Wireless Devices with Two 6.0 dBi Patch Antennas for Diversity

Case Study

A golf course with an electronic scoring application uses an access point with an outdoor antenna to cover an area of the golf course. One antenna is used to cover the left side of the course. Because there is little multipath, one antenna is sufficient. The course uses a directional Yagi antenna for its distance capability and ease of installation.

When the golf course wants to add coverage to the right side of the course, the staff does not add another new access point to acheive this. Instead, it attaches a directional Yagi antenna to the other antenna connector, and points it in another direction. The staff drives around the golf course and performs a site survey to test the network. There are no issues with coverage. However, when tournament play starts and more users are added to the wireless network, they start to encounter difficulty and loss of connectivity.

When the client on the left side of the course associates to the access point, it has very low signal strength, because the access point picks up the signal from the client on the right−pointing antenna. As a result, the client is out−of−range of the right antenna and drops its connection. However, the access point radio detects a problem and samples the left antenna port, under the assumption that it has encountered a multipath problem. The antenna switches over and the client increases coverage. As the client moves to the other side, retries begin and the access point radio switches over, uses the other antenna port, and preserves connectivity.

Thus, when the access point cannot receive the client signal, it switches. The access point evaluates and uses the best antenna to receive client data. The access point then uses that same antenna when it transmits data back to the client. If the client does not respond on that antenna, the access point tries to send the data out the other antenna.

In this scenario, the initial configuration was one client and two separate coverage cells; this works until additional clients are added. As the access point communicates to clients on the left side of the course, it does not switch to the right antenna port if no retries occur, because it does not detect any errors. However, it causes difficulties for users that are not on the left antenna.

Note: The two antenna ports on the access point are designed for spatial diversity, and the radio only checks the other antenna when it encounters errors.

The clients on the right side of the course have difficulty with connections. Only when a client with a weak signal reaches the left antenna does the access point recognize those clients and switch over to pick them up. This makes the right antenna active, so the left side of the course starts to receive errors until the antenna on the right hears a client from the left and switches over again.

In the case of this golf course, two methods can resolve the problem:

- Replace the directional Yagi antennas with omnidirectional antennas.

  Although the omnidirectional antennas have a slightly lower gain than the Yagi antennas, the access point radio can work in all directions instead of only in the 30 degree directional pattern of the Yagi antenna. Because the gain for the omnidirectional antenna is only 1 dBi less than the Yagi antenna, this substitution works.
- Add an additional access point to cover the other radio cell.

  Both access points can handle the RF traffic and each access point can use the higher−gain Yagi antenna to cover its area. This requires you to configure each access point to use frequencies that do not overlap, to reduce radio congestion. Throughput is increased as the number of users per access point is reduced.

Summary

- Diversity is an automatic process with no required user intervention or configuration.
- Diversity is a method to overcome or minimize multipath distortion.
- Multipath distortion causes radio nulls and radio reflections (also called echoes), which result in data retries.
- Radio waves reflect off of metal surfaces such as filing cabinets, shelves, ceilings, and walls.
- Diversity antennas should be of the same type and gain.
- Antennas should be placed close enough to each other so that the RF coverage area is nearly identical. Try not to place two antennas far enough away that they cover two different radio cells.
- Cisco Aironet access points use spatial diversity.
- Antennas should be deployed close to the intended coverage area, to avoid long cable runs.
- You should always perform a site survey first, to properly evaluate the coverage area.

Related Information

- **WLAN Radio Coverage Area Extension Methods**
- **Wireless Site Survey FAQ**
- **Troubleshooting Connectivity in a Wireless LAN Network**
- **Cisco Aironet Access Point FAQ**
- **Wireless Support Page**
- **Technical Support & Documentation − Cisco Systems**

Updated: Jan 21, 2008 Document ID: 27147