Designing and Deploying 802.11n Wireless Networks

Gain a practical understanding of the underlying concepts of the 802.11n standard and the methodologies for completing a successful wireless network installation

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Jim Geier

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Introduction

The 802.11n amendment to the IEEE 802.11 wireless LAN (WLAN) standard was ratified in September 2009, and enables 802.11 systems to provide much higher performance and range than before. The majority of network equipment manufacturers now offer 802.11n-compliant equipment as their primary WLAN solution. WLANs based on earlier versions of the standard (802.11a, 802.11b, and 802.11g) are considered "legacy," and there is significant risk that these existing non-802.11n systems will become obsolete. As a result, organizations deploying new WLANs should definitely implement 802.11n-compliant equipment. In addition, organizations with existing non-802.11n WLANs should begin planning the migration to 802.11n-compliant networks.

This how-to book focuses on planning, designing, installing, testing, and supporting 802.11n wireless networks for a variety of applications. The methods, recommendations, and tips in this book are based on the author's many years of practical experience deploying WLANs. Organizations with no existing wireless network and those migrating from legacy wireless networks to 802.11n-compliant networks will find this book to be a valuable guide.

Goals and Methods

The overall goal of this book is to guide you through the steps of deploying an 802.l1n WLAN. To accomplish this, the book includes the following elements:

- **Step-by-step approaches:** The book breaks each phase of WLAN deployment into clearly defined steps that provide the basis for understanding and planning the details of the phase.
- **Case studies:** The book includes several case studies that provide explanations of concepts and methods as they are practiced in actual deployments.
- **Hands-on exercises:** The book includes exercises that make use of free and inexpensive tools that help you gain practical experience with concepts described in the chapter.
- **Tips:** Concise tips are distributed throughout the book and provide insightful information related to deploying WLANs.

Who Should Read This Book?

This book is intended for a variety of people, from someone with basic knowledge of networking to others who might have years of experience working with WLANs but have little if any experience implementing 802.11n networks.

How This Book Is Organized

Although this book can be read cover to cover, it is designed to be flexible and allow you to easily move between chapters and sections of chapters to learn just the information that you need.

This book covers the following topics:

- Part I, "Fundamental Concepts": This part of the book includes chapters that cover important underlying concepts that must be understood before deploying an 802.11n wireless network. Readers already familiar with WLANs may be able to skip one or more of the chapters in this part of the book.
  - Chapter 1, "Introduction to Wireless Networks": This chapter defines the markets and applications of WLANs and the wireless technologies that support them.
  - Chapter 2, "Radio Wave Fundamentals": This chapter explains radio wave fundamentals so that you have the basis for understanding the complexities of deploying WLANs.
  - Chapter 3, "Wireless LAN Types and Components": This chapter describes ad hoc, mesh, and infrastructure WLAN types and various components, such as access points, controllers, client radios, amplifiers, and others.
  - Chapter 4, "Wireless LAN Implications": This chapter explains the impacts of radio signal interference, security vulnerabilities, multipath propagation, roaming, and battery limitations on WLANs.
- Part II, "The 802.11 Standard": This part of the book includes chapters that contain in-depth coverage of the most current medium access and physical layers of the IEEE 802.11 standard (including 802.11n functionality). The focus here is on the elements of the standard that readers should know to be successful at deploying and supporting 802.11n wireless networks.
  - Chapter 5, "Introduction to IEEE 802.11 and Related Standards": This chapter provides a background and importance of 802.11 standards and an overview of the 802.11 standard and related standards, such as IEEE 802.2.
  - Chapter 6, "IEEE 802.11 Media Access Control (MAC) Layer": This chapter explains details of the 802.11 standard that you need to know to help you best configure and troubleshoot 802.11n WLANs.
  - Chapter 7, "IEEE 802.11 Physical (PHY) Layers": This chapter describes the modulation functions that are part of the 802.11n physical layer and legacy physical layers (802.11a, 802.11b, and 802.11g).

- Part III, "Wireless Network Design": This part of the book includes chapters that cover steps necessary to design an 802.11n wireless network for various scenarios.
  - Chapter 8, "Planning a Wireless LAN Deployment": This chapter provides an overview of the steps that you should complete when deploying a WLAN and details on defining the project scope, developing a work breakdown structure, identifying staffing, creating a schedule, developing a budget, evaluating risks, and analyzing feasibility.
  - Chapter 9, "Defining Requirements for a Wireless LAN": This chapter explains how to gather, analyze, and document requirements for an 802.11n WLAN.
  - Chapter 10, "System Architecture Considerations": This chapter explains what to consider when designing the access network and distribution system for an 802.11n WLAN.
  - Chapter 11, "Range, Performance, and Roaming Considerations": This chapter explains the various tradeoffs for enhancing the range, performance, and roaming capabilities of an 802.11n wireless LAN.
  - Chapter 12, "Radio Frequency Considerations": This chapter covers important radio frequency (RF) design considerations for 802.11n WLANs, such as frequency band selection, transmission channel settings, difficult-to-cover areas, and radio signal interference reduction techniques.
  - Chapter 13, "Security Considerations": This chapter explains important methods and techniques for securing a WLAN, including encryption, authentication, rogue access point detection, RF shielding, and security polices.
- Part IV, "Wireless Network Installation and Testing": This part of the book includes chapters that explain the steps necessary to install and test an 802.11n wireless network.
  - Chapter 14, "Test Tools": This chapter describes the tools that you need to effectively design and support an 802.11n WLAN.
  - Chapter 15, "Performing a Wireless Site Survey": This chapter explains the steps and techniques, such as inspecting the existing network, analyzing radio signal interference, and performing signal propagation testing, that you need to follow when determining the optimum installation locations for access points.
  - Chapter 16, "Installing and Configuring a Wireless LAN": This chapter explains how to plan the installation, stage the components, install the access points, and document the installation of a WLAN.
  - Chapter 17, "Testing a Wireless LAN": This chapter describes the steps and techniques necessary to test a wireless LAN, which includes signal coverage testing, performance testing, in-motion testing, security testing, acceptance testing, simulation testing, prototype testing, and pilot testing.

- Part V, "Operational Support Considerations": This part of the book includes chapters that explain what to consider when supporting an 802.11n wireless network. Readers will learn how to establish specialized support for wireless networks and perform help desk operations, network monitoring, and troubleshooting.
  - Chapter 18, "Managing a Wireless LAN": This chapter describes important operations and maintenance functions that you should consider when supporting a WLAN, including help desk, network monitoring, maintenance, engineering, configuration management, security management, trouble call coordination, operational support tools, and operational support transfer preparation.
  - Chapter 19, "Troubleshooting Wireless Networks": This chapter explains how to identify problems, such as connectivity and performance issues, and determine the underlying causes.
  - Chapter 20, "Preparing Support Staff": This chapter describes what you should consider when evaluating the experience and education of staff for supporting a wireless LAN.
- Glossary: The glossary describes terms that this book uses.

Hands-on Exercises

As mentioned in the "Goals and Methods" section, this book includes exercises that make use of free and inexpensive tools that help you gain practical experience with concepts described in the chapter. You can find these exercises on the following pages:

- Chapter 6:
  - Hands-on Exercise: Observing 802.11 Dynamic Rate Shifting—141
  - Hands-on Exercise: Observing 802.11 Active Scanning—150
  - Hands-on Exercise: Observing the 802.11 Connection Process—154
  - Hands-on Exercise: Observing 802.11 Beacons—169
  - Hands-on Exercise: Observing 802.11 Frames Resulting from Typical User Traffic—175
- Chapter 7:
  - Hands-on Exercise: Understanding Performance Impacts of Increasing 802.11n Spatial Streams—192
  - Hands-on Exercise: Understanding Performance Impacts of 802.11n Channel Bonding—193
- Chapter 11:
  - Hands-on Exercise: Analyzing Impacts on Range Using Different Data Rate Settings—305

Chapter 11

Range, Performance, and Roaming Considerations

This chapter will introduce you to:

- Range Versus Performance
- Range Considerations
- Performance Considerations
- Roaming Considerations

When designing a wireless LAN (WLAN), take care to ensure that the WLAN will satisfy requirements for signal coverage, performance, and roaming. Problems related to these items often crop up when supporting a WLAN, generally due to designers not considering all relevant elements of the design. This chapter provides insight and addresses important elements you should consider to avoid these problems.

Range Versus Performance

It would be great if WLANs had unlimited range and performance. If this were true, the job of designing a WLAN would be much easier. There would be no need to consider the multitude of design elements to ensure that there was enough signal coverage and capacity for supporting your applications. Unfortunately, due to the constraints of physics, definite range and performance limits apply.

In addition, something that complicates the design is that range and performance are sometimes indirectly proportional. By increasing some design elements (for example, transmit frequency or data rate), the performance will increase but range will decrease (if all other design parameters, environment, and so on are constant). In other cases, changing design elements, such as transmit power and antenna gain, will increase performance and range. As a result, you must be familiar with how changing various design elements impacts range and performance to design an effective WLAN.

In addition, ensure that you have a solid understanding or the WLAN requirements dealing with performance, signal coverage, and the operating environment before getting started with the design. You will need to know this to determine which elements are most important and worthwhile to change.

Note The associated data rate between a client radio and an access point generally increases as the client radio becomes closer to the access point, which results in higher throughput closer to the access point.

Range Considerations

To satisfy signal coverage requirements, you will need to install access points in optimum locations based on the results of a wireless site survey, as explained in Chapter 15, "Performing a Wireless Site Survey." This involves completing propagation tests that determine the range of the access points based on specific minimum signal levels sufficient to support required client devices and applications. 802.11n systems provide much better range and performance than legacy 802.11b and 802.11g networks, but there is fine-tuning that you can do. To maximize range and reduce the total number of access points, carefully consider the following design elements:

- Signal coverage requirements
- Radio frequency bands
- Transmit power settings
- Transmission channel settings
- Data rate setting
- Antennas
- Amplifiers
- Repeaters
- Physical obstacles
- Radio signal interference

Signal Coverage Requirements

Review requirements that define the environment where the WLAN will operate and areas where signal coverage is needed. This will give you a feel for the importance of maximizing the range. If the WLAN must provide signal coverage over a large open area where it is not feasible to install access points, for example, the use of higher-gain antennas and possibly amplifiers may prove worthwhile.

Note For details explaining how to determine signal coverage requirements, see Chapter 9, "Defining Requirements for a Wireless LAN."

Radio Frequency Bands

As part of the design, you can choose to use 2.4-GHz or 5-GHz (or both) 802.11n bands. Communications theory explains that (with all other things constant), an increase in transmission frequency causes a decrease in range of the signal. As a result, the higher transmit frequencies of the 5-GHz band should provide shorter range than the lower 2.4-GHz band. In practice, the use of 5-GHz 802.11n, though, might or might not provide shorter range. In fact, sometimes a 5-GHz 802.11n system provides the same or even greater range as compared to a 2.4-GHz system. This might occur, for example, if the noise in the 2.4-GHz band is considerably higher than in the 5-GHz band (which is often the case). The resulting signal-to-noise ratio (SNR) values of the 5-GHz system, despite a decrease in signal strength due to higher operating frequencies, might be higher due to much less noise in the 5-GHz band.

Figure 11-1 illustrates a case where the range of a 2.4-GHz and 5-GHz access point are the same. At the client device (laptop) associated with the 2.4-GHz access point, the signal level is –70 dBm, and the noise is –85 dBm. This results in a SNR of 15 dB, which of course indicates a specific level of performance. Because of higher operating frequency, the signal at the client device associate with the 5-GHz access point is significantly lower at –80 dBm (an arbitrary number chosen for illustration purposes only). Because of the much lower noise level (–95 dBm) in the 5 GHz band, the SNR for the 5-GHz system is also 15 dB, which would likely provide similar performance as the 2.4-GHz system. This indicates that the 2.4-GHz and 5-GHz systems have the same range, which is a probable outcome depending on difference in noise levels between the 2.4-GHz and 5-GHz bands. Therefore, be certain to take into account the actual environment where the WLAN will operate choosing 2.4-GHz or 5-GHz bands based on range requirements and expectations.

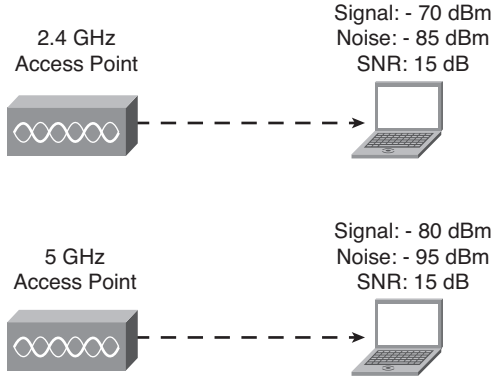

Figure 11-1 *A Case Where the Range Is the Same for a 2.4-GHz and 5-GHz System*

Transmit Power Settings

For a constant performance levels, increasing the transmit power of an 802.11 radio increases range. As the transmit power increases, communications at a particular data rate, such as 12 Mb/s, will be possible at greater ranges. The reason for this is that increasing transmit power improves the SNR at points farther away from the radio. The range expands to cover areas where increases in the transmit power causes the SNR at points farther away to be at or above the minimum signal values needed to for reliable operation. This higher SNR allows the end radios to receive communications at these farther points where they might not have been able to before.

Figure 11-2 illustrates this point. With the access point tuned to 10 dBm, the SNR at Location A is 15 dB, which for this example we will assume is the signal strength necessary for reliable communications at 12-Mb/s data rates. At Location B, the signal level is –76 dBm due to free space loss, attenuation, and so on, which results in a 9 dB SNR. Therefore, at Location B, the access point tuned to 10 dBm will support something less than 12 Mb/s. If you increase the access point transmit power to 16 dBm (a 6 dB increase), the signal level at Location B will increase by 6 dB to –70 dBm. This makes the SNR at Location B equal to 15 dB, which allows reliable 12-Mb/s operation. As a result, increasing the transmit power has made it possible to extend the range for a specific data rate.

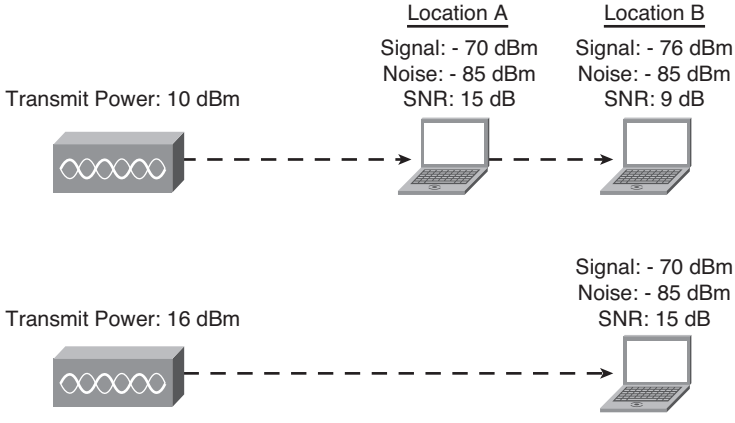

Figure 11-2 *Transmit Power Increases Provide Greater Range by Increasing Signal Strength*

This increase in range, however, only impacts the communications in one direction, which is the outward path relative to the radio with increased transmit power. The increase of transmit power of an access point, for example, only improves the range of the communications path from the access point to the client radios. To improve the overall communications of 802.11 signals, which occur in both directions between the access point and client radios, you will need to increase the transmit power of the client radios as well. In fact, it is usually not useful to increase the transmit power of the access points because the client radios are almost always operating at much lower transmit power. As a result, it

will likely only be worthwhile to increase the transmit power of the client radios. The signals going from the access points to the client radios are already relatively strong. The increase in client radio transmit power alone will improve the range of the overall communications in this case.

An advantage of using transmit power changes to improve range is that there are no expenses for additional hardware. A problem, however, is that it might not be possible to increase the transmit power on the client radios (the devices that would likely need a boost in power) because they might already be set by default to the highest power. Also, if you have little control over the client devices operating on the network, such as the case with public networks, you might not have the ability to change the transmit power of some or all the client radios.

Note Some WLAN vendors may have proprietary features where the client radios automatically change to a specific transmit power based on the data rate set in the access point.

Transmission Channel Settings

Within each of the 802.11 frequency bands, specific operating channels span from the lower-frequency end of the band to the higher-frequency end of the band. These channels use different transmission frequencies, but there negligible impact on range from using the lower-frequency channels versus the higher-frequency channels based on the theory that increases in frequency causes shorter range (and vice versa). For example, choosing channel 1 versus channel 11 in the 2.4-GHz band has no significant impact on range. There is not enough spread in the frequencies across the band to make a notable difference in range.

The choice of transmission channel settings does, however, make a difference on range if it is possible to choose a channel to avoid radio signal interference. An access point, for example, may be set to channel 11, but you might notice from a spectrum analyzer that there is significant interference in the upper part of the band (including channel 11). The lower part of the band, channels 1 through 3, may be relatively free from interference. By changing the access point to channel 1, it is possible to improve the SNR throughout the area, which improves range. For example, the noise levels relative to channel 1 might be 6 dB lower than what it had been for channel 11. As a result, the signal level can be 6 dB lower and still constitute acceptable SNR. Figure 11-3 illustrates this concept.

As with transmit power, changing the transmission channel to improve range does not cost anything in terms of new hardware. In addition, with infrastructure WLANs (ones with access points), there is no need to make changes to client radios. As a result, transmission channel changes can be made on networks where you may have little or no control over the client radio settings. Keep in mind, however, that there is a limit of nonoverlapping channels available (especially in the 2.4-GHz band) and radio signal interference may change over time. For example with larger WLANs, you might have significant inter–access point interference if you only set access points to lower-frequency channels to avoid the interference present in the higher-frequency channels.

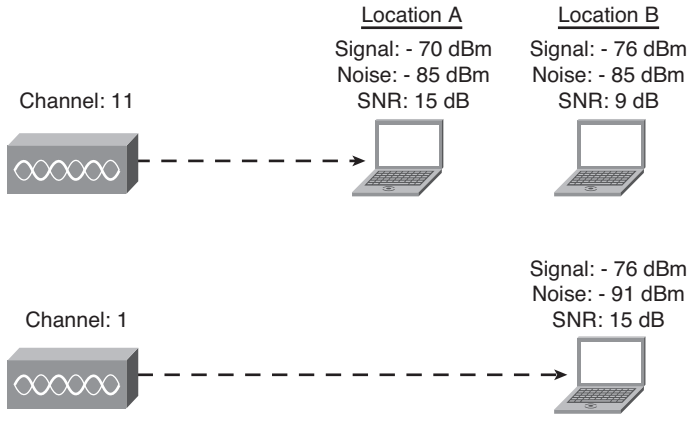

Figure 11-3 *Transmission Channel Changes Can Provide Greater Range by Lowering Noise Levels*

Data Rate Settings

At first, it may seem that data rate settings only impact the performance of a WLAN. The data rate settings, however, has an indirect impact on range. As a general rule (with everything else constant), an increase in data rate causes a decrease in range. Therefore, data rate and range are indirectly proportional. The reason for this is that higher data rates require higher received signal strength at the radio for the receiver to decode the 802.11 signal. Companies that make access points and client radios publish the received signal strength that supports various data rates.

As a result, be careful when adjusting the data rate in access points and client radios. By default, access points and client radios usually have their data rate setting configured as "auto" so that they will rate shift as needed to maintain associations with users. This is usually the best setting for general usage. Most access points also allow the data rate to be set to specific values, such as 12 Mb/s. If it is desirable to maximize range, consider setting all access points and client radios to low data rates. Just be sure that data rates are set high enough to provide adequate levels of performance.

Something to realize is that the setting in the access point only applies to the data rate that the access point uses, not the wireless clients. For example, setting the access point to 54 Mb/s causes the access point to transmit all data frames at 54 Mb/s. In this situation, wireless clients set to auto still continue to use higher data rates if possible. To extend range by forcing lower data rates, set both access points and user radio cards to the lower data rate configurations. That ensures that the data rates are the same in both directions.

Note Some WLAN vendors may have proprietary features where the client radios automatically change to a specific data rate based on the data rate set in the access point.

Hands-On Exercise: Analyzing Impacts on Range Using Different Data Rate Settings

This exercise allows you to experience the impacts that different date rate settings have on range between a client device and an access point. While observing the connection status of a wireless client device and an access point, you will determine the maximum range that provides a connection at different data rates.

Perform the following steps:

Step 1. Obtain test equipment. You will need a wireless client device and an access point to complete this exercise.

Step 2. Disable adaptive transmit power control on the access point if applicable.

Step 3. Associate the client device with the access point, with the access point and client radio configured for the maximum fixed data rate.

Step 4. Initiate a continuous TCP/IP ping between the client device and the access point to generate regular traffic between the client radio and the access point. This is necessary for the client radio to accurately monitor the connection state of the client radio.

Step 5. Position the client device close to the access point and begin walking away from the access point with the client device along a defined path until the connection is lost.

Step 6. Observe the connection state as you walk away from the access point until the connection is lost. You can observe this in the Windows (or vendor-specific) wireless client utility or by monitoring the continuous pings. If the pings continue successfully, the connection status is "connected." If the pings discontinue, the connection status is "disconnected."

Step 7. Note the location/range of where the connection was lost.

Step 8. Repeat Steps 5 and 6 multiple times with the access point and client radio configured to progressively lower fixed data rates. For example, after performing the test with the higher data rate setting, you might want to perform a second test by choosing a data rate somewhere in the middle between the lowest and highest data rate. As a third test, you could set the access point and client radio to the lowest fixed data rate. In each test at a different data rate, note the range along the predefined path where a connection is lost. What differences in range do you see for the various data rate settings?

As you lower the data rate settings, the range should increase where the connection is lost between the access point and the client device. The reason for this is that, as explained earlier, 802.11 radios have better receive sensitivity at lower data rates, which allows the radios in the client device and access point to be farther apart.

Antennas

The factory-default antennas that come with an access point usually have low gain (around 2dB). If the access point has removable antennas, replacing the default antennas with higher gain omnidirectional or directional antennas boosts range. For example, replacing a standard 2 dBi antenna with a 6 dBi omnidirectional antenna effectively adds 4 dB to the signal strength throughout the coverage area. As shown in Figure 11-4, the result of adding this gain improves the signal strength at Location B enough to maintain 15 dB SNR as compared to only 9 dB is using the standard 2 dBi antenna. Therefore, the increase in antenna gain has provided greater range for a specific data rate that corresponds to 15 dB SNR.

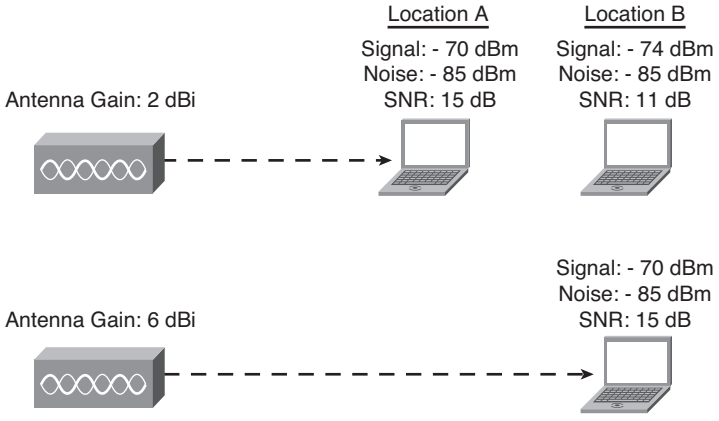

Figure 11-4 *Higher-Gain Antennas Boost Range by Increasing Signal Strength*

Note Keep in mind that some access points do not have removable antennas, which of course precludes you from using different antennas to increase range.

A higher-gain antenna, installed for instance on an access point, improves range from the access point to the client radio and from the client radios to the access point. This is different from increasing transmit power on only the access point, which would only increase range for the communications going from the access point to the client radios. The reason that a higher-gain antenna improves range in both directions is that the higher gain of the antenna improves both transmission and reception of radio waves. Therefore, the installation of higher-gain antennas can provide significant increases in range without making changes to the client radios.

In addition to using higher-gain antennas, antenna diversity can also help extend range in both directions because it minimizes multipath propagation. Diversity is an important part of 802.11n, and various vendors sell 802.11n access points and client radios that have

different levels of diversity. If your intent is to maximize range, choose components that have high levels of diversity.

An advantage of using higher-gain antennas or diversity is that it impacts range in both directions. As a result, you may be able to get by with changing the antenna configuration on only the access point, avoiding the need to alter each client radio. The cost of upgrading the antennas, however, might be considerable (possibly $50 to $100 or more per access point). Therefore, the cost might be prohibitive in larger networks.

Be sure to take into account different antenna gain and diversity with actual propagation testing in the target operating environment to determine the lowest overall cost of deploying the network. For example, you might find that the use of standard 2 dBi antennas may require the need for 100 access points, and the use of 6 dBi antennas may reduce the number of access points to 80. The addition costs for 6 dBi antennas in this example would probably be $4000 to $8000 ($50 to $100 each for 80 access points). This additional cost is likely much less than the 20 additional access points that you would need to purchase if going with the standard 2 dBi antennas. As a result, in this example, it would be worth the additional cost for the 6 dBi antennas. This assumes that the goal is to maximize range.

The trouble with increasing antenna gain for purposes of extending range is that you will likely place the access points farther apart (of course to reduce the number of access points and reduce costs). This results in a larger 802.11 collision domain, which limits the capacity of the WLAN. More client devices end up connecting to fewer access points.

Note For more details on antennas, see Chapter 3, "Wireless LAN Types and Components."

Amplifiers

The use of an amplifier is a way of increasing range. Similar to increasing the transmit power on the access point (or client radio) an amplifier boosts the signal strength throughout the coverage area, as illustrated in Figure 11-5. In addition, amplifiers have receive gain, which amplifies the incoming signals coming from the client devices. Therefore, the signal strength increasing behavior of an amplifier is similar to that of an antenna.

Note When using amplifiers, be certain to follow your country's regulatory rules that define the usage of radio frequency (RF) amplifiers.

Most WLAN amplifiers are rated at a specific transmit power, such as 200 mW, and a specific receive gain, such as 15 dB. Amplifiers with higher transmit power produce greater range for communications going from the access point to the client radios. The receive gain will increase the range for communications going from the client radios to the access point. Therefore, be sure to take both transmit power and receive gain of the

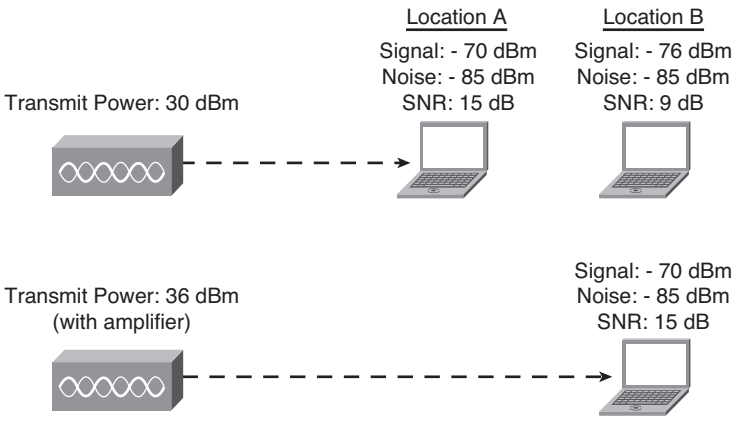

Figure 11-5 *Amplifiers Improve Range by Increasing Signal Strength*

amplifier into account when determining which one to use. Of course, as with anything else, it is always a good idea to do some propagation testing with amplifiers to realize their actual impact on range.

Companies such as Hyperlink and RF Linx sell amplifiers for WLANs. These amplifiers are designed to install between the antenna and the access point. As a result, you can use an amplifier only if it is possible to remove the access point antenna.

Note For more details on amplifiers, see Chapter 3.

Repeaters

A WLAN repeater is meant to reside between access points and client radios and regenerate signals it receives. As a result, a repeater increases range between access points and client radios (see Figure 11-6). A repeater might double the range, but it can significantly reduce the capacity of the WLAN because the repeater retransmits data frames it receives. This causes a duplication of data traffic, which reduces the overall capacity by up to 50 percent. This could be a problem if performance is important. Also, a repeater requires electrical power, which might be costly to install. Because a repeater does not connect to the distribution system, Power over Ethernet (PoE) is not an option.

Note For more details on repeaters, see Chapter 3.

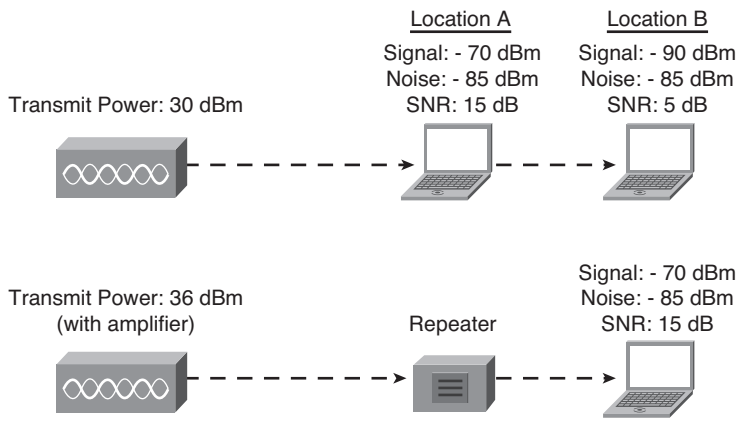

Figure 11-6 *Repeaters Extend Range Between Access Points and Client Radios*

Physical Obstacles

Certainly physical obstacles may be present within the operating environment of the WLAN, and these obstacles offer varying amounts of attenuation. To improve range in some areas, consider installing access points in locations that avoids obstacles. If possible, even consider moving some obstacles if it is advantageous (and feasible) to improve range. This effectively improves the signal strength throughout the applicable areas.

For example, signal coverage may be needed in an office where there are ceiling high filing cabinets along one of the walls in the office. These cabinets will likely highly attenuate RF signals. As a result, it would be wise to position one or more access points to cover the office so that the signals do not travel through the cabinets.

Note For more details on obstacles and RF signal propagation, see Chapter 2, "Radio Wave Fundamentals."

Radio Signal Interference

As discussed earlier in this chapter, a way of avoiding existing interference is to use frequencies where interference is less, such as using the 5-GHz frequency band or turning the access point to channels having lower interference levels. By reducing radio signal interference, you can increase range between access points and client radios, as illustrated in Figure 11-7. Another similar way of improving range is to remove the source of interference. For example, it might be possible to decrease the noise levels by 6 dB in the 2.4-GHz band by stopping the use of 2.4-GHz cordless phones (and possibly switching to 5-GHz or 6-GHz phones instead). Also you could use RF shielding to reduce noise. Special RF shielding paint and wallpaper is available that offers high degrees of attenuation (80

dB). Of course the elimination of interference sources may not be feasible, but it is at least something to consider.

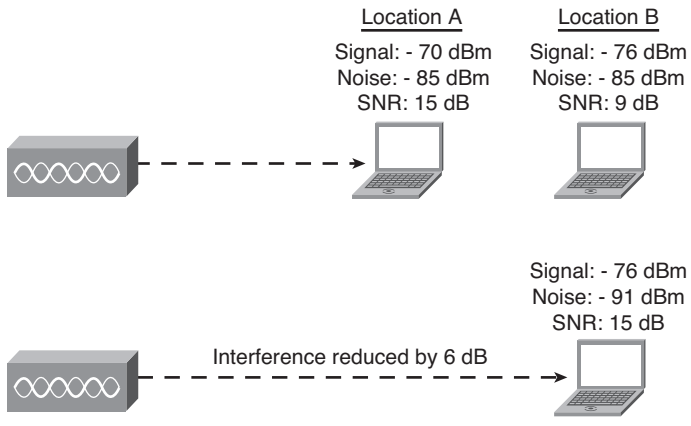

Figure 11-7 *Lowering Radio Signal Interference Increases Range*

Note For more details on radio signal interference, see Chapter 4, "Wireless LAN Implications."

Extending Municipal Wi-Fi Mesh Indoors

Most municipalities require Wi-Fi signal coverage in 90 percent of outdoor areas and 70 percent inside homes and businesses. For indoor places, the coverage is generally required just inside the exterior wall the facility on the first and second floors. To meet overall coverage requirements, the trend is to install Wi-Fi mesh nodes on city-owned assets, such as streetlamp poles and traffic lights. This generally offers good coverage outside throughout the city, but indoor coverage is generally not sufficient without careful planning.

Indoor signal propagation suffers because the exterior walls of the facilities offer significant attenuation. In addition, the transmit power of user devices operating inside the buildings is usually relatively weak. The transmit power of the mesh nodes is much higher, but this only affects the downlink communications path, from the mesh node to the user device. This does not do much good when the user devices have much lower transmit power. In this case, the ability for the communications link to operate is based on the weaker uplink signal, which causes limited range.

Because of varying wall attenuation and relatively weak transmit power of user devices operating inside the facilities, signal propagation indoors is not reliable and difficult to verify. You cannot depend on getting inside an appropriate sample of these facilities to test signal propagation and tweak the positioning of the mesh nodes to improve coverage.

Most of the indoor locations are private homes and businesses, and a large number of them are not likely going to let you in to do testing.

As a result, when designing a municipal Wi-Fi network, it is highly recommended to specify the use of indoor customer premises equipment (CPE), which offers a stronger uplink signal to compensate for the attenuation of the walls. The use of indoor CPE will make signal coverage inside buildings much more reliable and satisfy requirements. I have found that about 50 percent of the homes and businesses in cities actually require CPE to provide acceptable indoor coverage, but a blanket requirement for all indoor locations to use CPE may be beneficial.

CPE installs inside the facility, near one of the exterior walls, and associates via Wi-Fi to the nearest mesh node. CPE also provides a separate Wi-Fi or Ethernet connection inside the facility. If it is Wi-Fi, users will likely have much greater indoor Wi-Fi coverage than what the municipal network requirements specify. Each indoor location will have the equivalent of a Wi-Fi router installed inside the building. If it is Ethernet, users will need to connect a laptop or PC directly to the CPE device or plug in an external Wi-Fi router or access point.

Something to keep in mind is to properly set user expectations regarding indoor coverage of a wireless municipal network and the need for CPE. Many potential users are accustomed to using Wi-Fi hotspots where signal coverage is good without CPE devices. A municipality can circumvent frustrated users by educating users early on during the deployment of the network. Users need to realize that without indoor CPE, they will not have reliable Wi-Fi signal coverage.

Performance Considerations

When WLANs first became available in the early 1990s, primary applications were wireless bar code solutions for needs like inventory control and retail price marking. Data transfers for these types of applications do not demand very high performance. In fact, 1 Mb/s data rates are generally sufficient to handle the transfer of relatively small bar codes for a limited number of users.

Today, enterprises are deploying WLANs for larger numbers of users with needs for corporate applications that involve large file transfers and wireless telephony. In addition, there are often needs for supporting a high density of users in a smaller area, such as a conference room. The need for higher data rates and techniques to improve performance of WLANs is becoming crucial to support these types of applications. To get that extra performance when designing a WLAN, consider the following elements:

- Throughput versus data rate
- Radio frequency bands
- Transmit power settings
- Transmission channel settings

- Data rate settings
- Antennas
- Amplifiers
- Obstacles
- Radio signal interference
- Channel width settings
- Signal coverage
- Fragmentation settings
- Request-to-send / clear-to-send (RTS/CTS) settings
- Multicasting mechanisms
- Microcell deployment strategies

Throughput Versus Data Rate

The data rate of a signal is based on the time it takes to send information and overhead data bits when transmitting. Therefore, the aggregate data rate (throughput) is actually much lower because of delays between transmissions. Data rate mostly affects the delay performance of a WLAN. The higher the data rate, the lower the delay when sending data from one point to another. As a result, higher data rates can increase the capability to support a larger number of users. Data rate alone is not a good measure for the performance of the system, though. You also need to consider the effect of overhead bits, waiting times to access the medium, and the format of the data being sent.

Actual throughput is a much better indicator of the performance of a WLAN because it provides an indication of the time it takes to send information. Throughput is the flow of information over time. It is important to not confuse throughput with 802.11 data rate, which is the speed that the data bits in individual 802.11 data frames are sent. Because there is idle time between 802.11 data frames and retransmission due to noise, the throughput is always less than the data rate. Throughput, however, provides a more accurate representation of the delays that users experience because they are concerned with how fast information is sent, not 802.11 frames. It is possible to have a very high 802.11 data rate and still have throughput that is relatively low. This can occur, for example, when the user is close to an access point but there are many other users actively accessing the WLAN from the same access point or if there is substantial radio signal interference present. In these cases, the WLAN carries the information at a much slower rate. As a result, be sure to focus on specifying throughput, not 802.11 data rates as the basis for performance.

Note When laptops are unplugged from an electrical outlet and running on batteries, the client device operating system will likely cause an 802.11n client radio to enter power-saving mode. As a result, throughput may drop by as much as 50 percent. To ensure throughput is not affected when running on batteries, configure the operating system to not invoke client radio power management.

Radio Frequency Bands

As mentioned earlier in this chapter, you can choose to use 2.4-GHz or 5-GHz (or both) 802.11n bands. In addition to the impact this selection has on range, the choice of frequency band also affects performance. The 5-GHz band includes much more spectrum (and corresponding channels) as compared to the 2.4-GHz band. There are many more overlapping channels in the 5-GHz band as compared to the 2.4-GHz band. In addition, the 5-GHz band is usually relatively free from RF interference sources. As a result, the 5-GHz band offers much greater capacity. Keep in mind, however, that the 5-GHz band, as explained earlier, might provide less range as 2.4-GHz deployments.

Transmit Power Settings

For a constant range, increasing the transmit power of an 802.11 radio increases performance in the outward direction. As the transmit power increases, communications at a particular location will be possible at greater data rates. The basis for this is that increasing of transmit power improves the SNR at a particular location, which allows the receiving radio to decode signals at higher data rates.

For example, as shown in Figure 11-8, increasing the transmit power of the access point by 6 dB causes a 6 dB increase in the signal strength and corresponding SNR throughout the coverage area. In the case shown in Figure 11-8, the client device associated with the access point set to higher transmit power has a SNR of 21 dB, which is significantly higher than it would be if the transmit power of the access point were set to a lower level. The higher signal level (and SNR) allows the client device to receive 802.11 signals at higher data rates.

This increase in data rate applies to the communications in only one direction, which is the outward path relative to the radio with increased transmit power. The increase of transmit power of an access point, for example, only improves the data rate of the 802.11 data frames being sent from the access point to the client radios. To improve the overall communications of 802.11 signals, you may need to increase the data rate settings on the access points and the client radios. As discussed previously in this chapter, client radios may have considerably less transmit power as the access points. Therefore, you will likely need to increase the transmit power on the client radios to see any improvement in data rates.

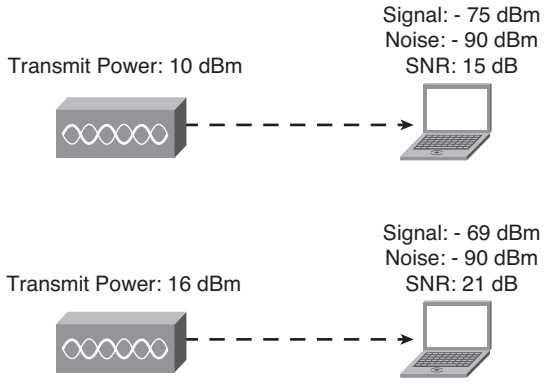

Figure 11-8 *Transmit Power Increases Provide Higher Data Rates at Specific Points Due to Corresponding Increases in SNR*

Transmission Channel Settings

As with range improvements, transmission channel settings can impact performance as well if it is possible to select a channel that avoids radio signal interference. Figure 11-9 illustrates an example of this concept, where testing has shown that the noise level for channel 1 is 5 dB lower than the noise level for channel 11. Because of the lower radio frequency interference corresponding to channel 1, the resulting SNR for channels at the client device is 15 dB, which enables the applicable client radio to process 802.11 signals at a higher data rate.

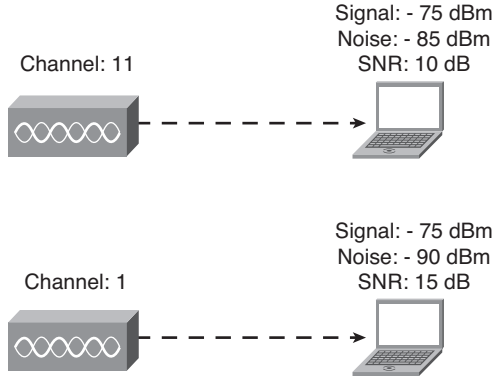

Figure 11-9 *Transmission Channel Changes Can Provide Greater Performance by Lowering Noise Levels*

Data Rate Settings

If you need to deploy a high-performance WLAN, consider configuring data rate settings to higher fixed values. This forces operation at a higher specific data rate and avoids transmissions at lower data rates, which would negatively impact overall performance. Just keep in mind, however, that using higher data rate settings will significantly reduce range. Also, as explained earlier in this chapter, data rate settings impact communications in only one direction. For example, setting the access point to 54 Mb/s causes the access point to transmit all data frames at 54 Mb/s, but the client radios may be transmit at different data rates depending on their data rate settings. As a result, you must configure the data rate settings in client radios (which might not be feasible) to realize benefits of using higher fixed data rate settings to improve performance.

Note Check administration logs to verify that client devices are connecting to the network at desired 802.11n rates.

Antennas

The use of higher-gain antennas increases communications performance in both directions between access points and client radios. For example, as Figure 11-10 illustrates, if you replace a standard 2 dBi antenna with one having 6 dBi, the signal level and corresponding SNR at the client radio at a specific location will increase. The higher signal level and SNR allows the radio in the access point and client radio to decode signals at higher data rates. A higher degree of antennas diversity has a similar affect on performance. Similar to using higher-gain antennas or diversity to improve range, be sure to take into account different antenna gain and diversity with actual propagation testing in the target operating environment to determine the lowest overall cost of deploying the network.

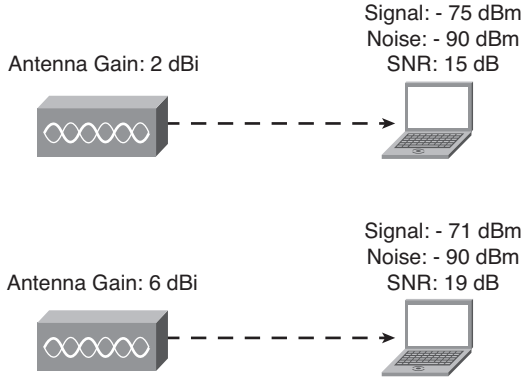

Figure 11-10 *Higher-Gain Antennas Boost Performance Throughout the Coverage Area*

Amplifiers

In addition to improving range, an amplifier can also increase performance. Because an amplifier increases the signal strength and corresponding SNR throughout the coverage area, a client radio at a specific point is able to decode the 802.11 signals at a higher data rate. For example, as shown in Figure 11-11, without an amplifier at the access point, the signal strength and SNR at the client device is -75 dBm and 15 dB, respectively. After installing an amplifier on the access point, the signal strength and SNR at the client device increase to –69 dBm and 21 dB, respectively. As a result, in this example, the client radio is able to support reception of data frames at a higher rate than without the amplifier because of the higher signal level and SNR. Also for similar reasons, because the amplifier's receive gain, the access point will also be able to receive 802.11 signals from the client radio at a higher data rate.

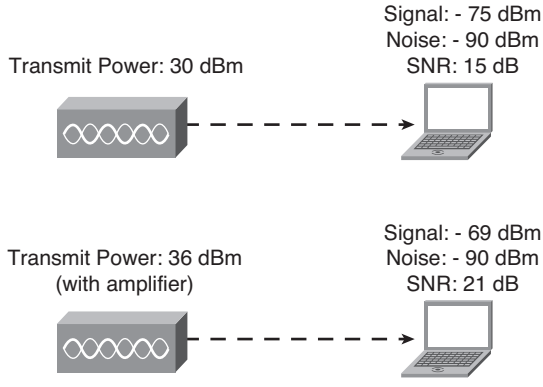

Figure 11-11 *Amplifiers Improve Performance Throughout the Coverage Area*

Radio Signal Interference

By reducing radio signal interference, it is possible to increase performance at specific points within the coverage area. For example (see Figure 11-12), a reduction of noise levels by 6 dB (possibly by eliminating the operation of other radio equipment) will raise the SNR at points throughout the coverage area by 6 dB. This enables the access points and client radios to successfully decode 802.11 signals at higher data rates.

Channel Width Settings

The 802.11n standard provides two different channel width settings, 20 MHz and 40 MHz. The wider 40-MHz channels support much higher performance as compared to 20-MHz channels. For 2.4-GHz implementation, however, it is not wise to configure 40-MHz channels. As discussed in other parts of this book, there is not enough spectrum in the 2.4-GHz band to support multiple 40-MHz channels without significant inter–access

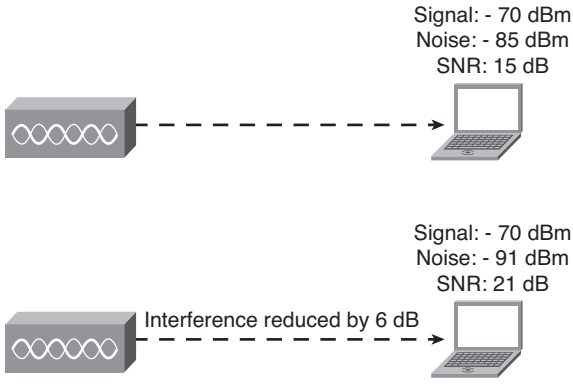

Figure 11-12 *Lowering Radio Signal Interference Increases Performance at Specific Locations*

point interference. As a result, if you choose to implement the 2.4-GHz band, the only practical option is 20-MHz channels.

The 5-GHz band, however, has a much greater amount of spectrum, with plenty of room for 40-MHz channels. Therefore, seriously consider configuring the network for 40-MHz channels. To accommodate 40-MHz channels, the client radios must be 802.11n-compliant. As a result, it might not be possible to implement 40-MHz channels if the network must accommodate legacy (802.11b and 802.11g) client devices. A way of still taking advantage of 40-MHZ channels in this case, as expressed in other parts of this book, is to configure legacy radios to connect to the WLAN over 2.4 GHz (with 20-MHz channels) and have only 802.11n devices connect via 5 GHz (with 40-MHz channels).

Signal Coverage

As the basis for providing good performance, it is important to have adequate signal coverage throughout the required coverage areas. In areas that have weak signal coverage, the signal level and corresponding SNR will be relatively low. The 802.11 radios might still be able to decode the signals and successfully communicate, but the data rate may be fairly low. To ensure that signal coverage is good enough, perform a proper wireless site survey as described in Chapter 15.

Fragmentation Settings

The use of 802.11 fragmentation can increase the reliability of 802.11 data frame transmissions in the presence of radio frequency interference, which improves the throughput of the network. Because of sending smaller frames, corrupted bits in the frame due to radio frequency interference are much less likely to occur. If a frame does receive corrupted bits, the source station can retransmit the frame quickly.

The fragment size value can typically be set manually on access points and client radios between 256 and 2048 bytes. This value is user controllable. In fact, you activate fragmentation by setting a particular frame size threshold (in bytes). If the frame that the access point is transmitting is larger than the threshold, it will trigger the fragmentation function. If the packet size is equal to or less than the threshold, the access point will not use fragmentation. Of course, setting the threshold to the largest value effectively disables fragmentation.

A good method to find out whether you should activate fragmentation is to monitor the WLAN for retransmissions. If very few retransmissions are occurring, do not bother implementing fragmentation. The additional headers applied to each fragment will likely dramatically increase the overhead on the network, which will actually reduce throughput. If you find a relatively high percentage of retransmissions (greater than 5 percent) and the presence of radio signal interference or weak signal levels is likely causing the retransmissions, try using fragmentation. This can improve throughput if the fragmentation threshold is set to the optimum value, which is where the throughput is maximum.

If the retransmission rate is relatively high, start by setting the fragmentation threshold to around 1000 bytes, and then tweak it until you find the best results. After invoking fragmentation, follow up with testing to determine whether the number of collisions is less and that the resulting throughput is better. You should try a different setting or discontinue using it altogether if the throughput drops (even if you have fewer retransmissions).

The issues with using fragmentation to improve performance is that interference driving the retransmission rate may change over time or as users roam throughout different portions of the signal coverage area. On one day, for example, the presence of significant radio signal interference may cause the retransmission rate to be around 20 percent. In this case, you may find that a fragmentation threshold of around 800 bytes maximizes throughput. On another day, the interference may go away, resulting in a drop in the retransmission rate to only 1 percent or 2 percent. Without changing the fragmentation threshold, throughput may actually drop because the cost of additional overhead resulting from the fragmentation mechanism is not providing much benefit of reducing the retransmission rate.

Note For more details on the 802.11 fragmentation mechanism, see Chapter 6, "IEEE 802.11 Medium Access Control (MAC) Layer."

RTS/CTS Settings

The use of 802.11 RTS/CTS can increase the reliability of 802.11 data frame transmissions in the presence of hidden nodes, which improves the throughput of the network. Similar to analyzing the need for fragmentation, a way to gauge whether RTS/CTS will help throughput is to monitor the WLAN for retransmissions. If the retransmission rate is low (under 5 percent), do not implement RTS/CTS. The additional frame transmissions need to implement RTS/CTS will likely dramatically increase the overhead on the network, which will actually reduce throughput.

If the retransmission rate is high, and you find a large number of collisions with users that are relatively far apart and likely out of range of each other (that is, hidden nodes are present), try enabling RTS/CTS on the applicable client radios. After activating RTS/CTS, test to determine whether the number of retransmissions is less and the resulting throughput is better. Because RTS/CTS introduces overhead, disable it if you find a drop in throughput, even if you have fewer collisions. After all, the goal is to improve performance.

Of course, keep in mind that user mobility can change the results. A highly mobile user may be hidden for a short period of time, perhaps when you perform the testing, then be closer to other stations most of the time. If retransmissions are occurring between users within range of each other, the problem may be the result of radio signal interference. In that case, fragmentation might help.

In most cases, initiating RTS/CTS in the access point is fruitless because the hidden station problem does not exist from the perspective of the access point. All stations having valid associations are within range and not hidden from the access point. Forcing the access point to implement the RTS/CTS handshake will significantly increase the overhead and reduce throughput. Focus on using RTS/CTS in the client radios to improve performance.

Note For more details on the 802.11 RTS/CTS mechanism, see Chapter 6.

Bandwidth Control Mechanisms

To provide consistent performance for all users, it might be necessary to implement bandwidth control mechanisms, which divides the total capacity of the network into smaller sizes made available to each user. For example, as shown in Figure 11-13 (case without bandwidth control), a single user (client device A) may download a very large file that requires a few minutes (or even hours), consuming nearly all the capacity of the network. As a result other users, such as client B and C may have very little if no throughput. This uncontrolled use of the network can aggravate users and significantly reduce the effectiveness of the network. A solution to this is to use bandwidth control and configure the access points (or other applicable components) to provide each user a throughput limit, such as 250 kbps each. This level of performance, based on the total users and utilization of the network, forces users to share the total capacity of the WLAN in a manner that ensures sufficient performance for everyone.

Microcell Deployment Strategies

If WLAN requirements call for extremely high performance, consider using a high density of access points. This calls for turning down the transmit power of all access points and client radios, which forces access points to be much closer together (and avoid interfering with each other). This “microcell” architecture makes the physical area collision domains smaller than with conventional access point density. The microcell architecture leads to much higher performance because there are fewer client devices connecting to

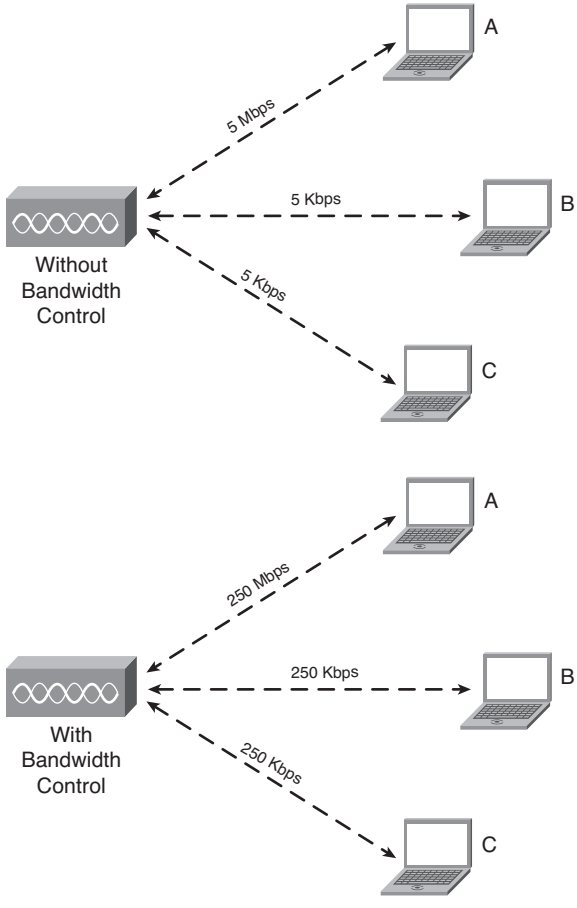

Figure 11-13 *Bandwidth Control Provides Consistent Performance for All Users*

each access point. This allows each client device radio to consume a greater percentage of the access point's capacity and avoid collisions with other radios. Therefore, performance can be much greater.

An issue with using higher access point density to improve performance is that it leads to a great number of access points. Of course this means that the deployment will cost more, possibly considerably more. To reduce the need for increasing the density of access points, first consider all other less-expensive options covered previously in this chapter.

Note Your organization will likely not realize the true potential of 802.11n until you are able to migrate away from legacy (802.11b and 802.11g) devices and implement a pure 802.11n network. Of course, this requires that all wireless client devices must implement 5-GHz frequencies.

Determining Wireless LAN Capacity

One way of sizing up a WLAN is to install the access points and see what happens. This approach does not require much investment in time and brainpower; however, you may never really know the maximum capacity until users start to complain. For example, you may install a WLAN to enable users in an office to access Internet services. After first commissioning the system, only a handful of users may be active at any given time. Within 6 months, the number of active users may increase to 50, and you start to observe users complaining about slow performance. This is an indirect sign that access points are operating at capacity. Of course, this result assumes that there are no other bottlenecks, such as sluggish servers or slow Internet service provider (ISP) connections.

Another method of sizing a WLAN is to gather up a bunch of people armed with wireless client devices and have them hammer on the network. Just keep adding more and more active users until performance starts to decline to a level that is not acceptable. The maximum capacity could be the point at which users experience more than five seconds delay when loading a particular web page, for example. This approach will provide fairly accurate results, but it is often not feasible. The difficulty is finding enough people and client devices to perform the testing. In most cases, this type of testing is just too expensive.

Simulation programs, such as OPNET, run on a computer and imitate a WLAN under different situations. With simulation, you can artificially characterize WLAN components, such as access points, client radios, and users. A simulation calculates resulting throughput, which gives you a good idea of how many users can be active on the network. By adjusting the number of users, you can estimate how many users that access points can handle and the resulting per user performance. A strong advantage of simulation is that it can be done before purchasing and installing the WLAN. Simulation tools are rather costly, however, with prices in the tens of thousands of dollars. In addition, you will probably have a steep learning curve before being proficient at developing the simulation models. This can make the simulation option out of reach for most companies. Results are also only as good as the utilization level estimates.

Roaming Considerations

WLAN requirements generally call the ability of users to roam with wireless client devices throughout the coverage area. Each client radio will roam differently, depending on proprietary protocols that the vendor has incorporated into the radio. The type of wireless application that the client device is using also impacts the ability to roam. As a result, it is crucial that you test the roaming capability of all client device before finalizing the design of the WLAN.

When designing a WLAN, consider the following elements that impact roaming:

- Roaming levels
- Wireless IP phone roaming
- Mobility settings

Roaming Levels

As a basis for designing a WLAN that provides effective roaming, it is important to first understand basic roaming concepts. For WLANs, roaming takes place at several levels. As shown in Figure 11-14, roaming can take place at Layer 2 or Layer 3. As a user moves about the coverage area, the client radio automatically hands off from one access point to another as needed to support communications. This is Layer 2 roaming, sometimes referred to as access point roaming. In addition, the client device might need to roam from one subnet to another, which is Layer 3 roaming.

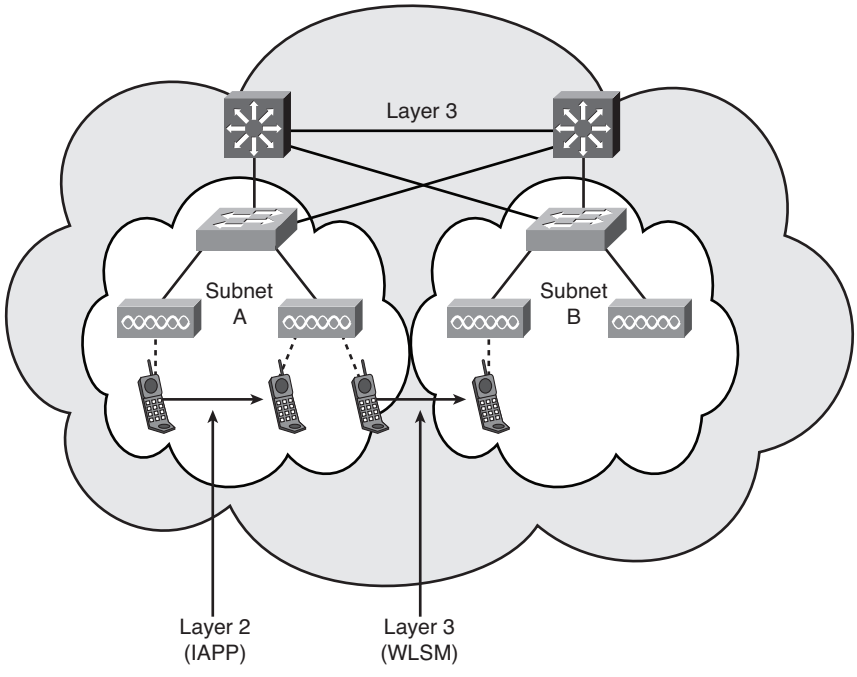

Figure 11-14 *Layer 2 Versus Layer 3 Roaming*

Access Point Roaming

Through the collaboration of WLAN vendors, the Inter–Access Point Protocol (IAPP) specification provides a common roaming protocol enabling users (client radios) to move throughout a facility while maintaining a connection to the network via multivendor access points. Interoperability tests and demonstrations show that IAPP works with a variety of access points. The Wi-Fi Alliance includes interoperable roaming as a requirement to receiving Wi-Fi certification.

The IAPP specification builds upon the capabilities of the IEEE 802.11 standard, using the distribution system interfaces of the access point that 802.11 provides. IAPP operates between access points, using the User Datagram Protocol (UDP) and the Internet Protocol (IP) as a basis for communications. IAPP defines two basic protocols: the

Announce Protocol and the Handover Protocol. The Announce Protocol provides coordination between access points by performing the following functions:

- Informs other access points about a new active access point
- Informs the access points of networkwide configuration information

The Handover Protocol informs an access point that one of its stations has reassociated with a different access point. The old access point forwards buffered frames for the station to the new access point. The new access point then updates filter tables to ensure that MAC-level filtering (bridging) will forward frames appropriately.

The finalization and proliferation of IEEE 802.11r and 802.11k amendments to the 802.11 standard have positive impacts on access point roaming. 802.11r provides seamless roaming between access points. The main application for 802.11r is for providing effective roaming for VoIP and security mechanisms. 802.11r provides functions for determining QoS and performing security protocol handshakes before handoffs occur to avoid delays after handoff. 802.11k works in conjunction with 802.11r by providing information to discover the best available access point for handoff purposes. Consider incorporating 802.11r and 802.11k into VoIP and security applications.

Subnet Roaming

As a wireless client device roams from one IP subnet to another, the client device might need to obtain a valid IP address for the new subnet. The client device can make use of DHCP to obtain the IP address, but this is not always effective when supporting mobility. DHCP is not designed to renew addresses when crossing subnet boundaries. As a result, it might be necessary to configure a WLAN to operate on a single subnet.

This might work in a private network, but the subnet roaming issue resurfaces when the client device needs to roam to another network. Consider the use of wireless middleware for applications that are affected by subnet roaming issues.

Some companies, however, might want to implement multiple IP subnets across a common WLAN for various reasons, such as to make network management easier, facilitate location-based services, and decrease the spread of broadcast packets throughout the network. For instance, a company might want to deliver specific information to users based on their location in a specific building. By designating different subnets throughout the WLAN, the location of the user can be found and content delivered to the user based on their location. The location of the user in an airport, for example, could deliver a map of the applicable concourse or terminal, indicating flight information and the location of coffee shops and ticket counters. The system could also deliver advertisements from concessions located within the general area.

With multiple subnets mobile users must be able to seamlessly roam from one subnet to another while traversing a facility. As users roam across subnets, though, there must be a mechanism at Layer 3 to ensure that the user device configured with a specific IP address can continue communications with applications. Some controller-based WLAN implementations, such as Cisco using Layer 3 services, however, can solve this via a feature

called Proxy ARP, where a wireless client device can roam from an initial *anchor* controller to another *foreign* controller while maintaining the IP address originally assigned via the anchor controller. This is possible even though the foreign controller is operating on a different subnet than the anchor controller.

If the wireless solution you choose does not implement Proxy ARP, consider Mobile IP, which solves Layer 3 roaming by allowing the mobile user to use two IP addresses. One address, the home address, is static. The second address, the "care-of" address, changes at each new point of network attachment and can be thought of as the user's position-specific address.

The home address enables the mobile node to continually receive data relative to its home network, through the use of a network node called the home agent. Whenever the user is not attached to the home network, the home agent receives all the packets sent to the mobile user and arranges to deliver them to the mobile user's current point of attachment, which is its care-of address. Whenever a Mobile IP user moves, it registers its new care-of address with its home agent. This makes it possible for the home agent to keep up with the whereabouts of the mobile user. The home agent then sends any packets it receives for that user to the applicable care-of address.

To implement Mobile IP, you need two major components: a Mobile IP server and Mobile IP client software. The Mobile IP server will fully implement the Mobile IP home agent functionality, providing mobility management for the mobile users. The Mobile IP server can generally also keep track of where, when, and how long users use the roaming service. That data can then provide the basis for accounting and billing purposes.

The requirement for client-side software makes Mobile IP impractical for some applications. For example, public networks demand open connectivity for users, which makes it difficult to deploy solutions that require client software. Of course, the task of installing software on user devices before enabling roaming is too cumbersome. Another problem with Mobile IP is that it is somewhat vendor specific. To ensure interoperability among multivendor Mobile IP clients and servers, definitely do some upfront testing.

Wireless ISP Roaming

With Wi-Fi hotspots, there is very limited roaming among wireless ISPs. The Wi-Fi Alliance had tried developing standards several years ago to make wireless ISP roaming seamless, but the group later disbanded due to significant incompatibility among differing access controllers. In general, standards for roaming from one Wi-Fi wireless ISP to another are nonexistent. As a result, you must negotiate teaming agreements with other ISPs when deploying widespread Wi-Fi hotspots and create a custom access control system that is common among all applicable ISPs.

Wireless IP Phone Roaming

One the applications that roaming impacts a great deal are wireless telephony. If you plan to have wireless IP phones operating on the WLAN, ensure that the WLAN you design supports effective roaming. The voice user must be able to move about the facility, and

the system will need to allow roaming at both Layer 2 and Layer 3. Without smooth roaming, users will experience dropped calls.

Layer 2 roaming takes place when a wireless IP phone moves out of range of an access point and reassociates with a different access point. Because this type of roaming will occur frequently as users move about a facility, such as a warehouse or hospital, be certain that Layer 2 roaming is fast (ideally less than 100 milliseconds). This mid-call roam time is the amount of time that elapses after the last RTP packet is seen from the current access point and the first RTP packet seen from the access point that the wireless IP phone associates with.

When selecting wireless IP phones, be certain that they support fast roaming. The Cisco 7920 wireless IP phones, for instance, are specially designed to make Layer 2 roaming fast enough to avoid dropped calls. For example, a Cisco 7925 phone will initiate a reassociation process with a different access point if the phone does not receive three consecutive beacons from the existing access point and its unicast frame to the access point is not acknowledged. The 7920 also periodically scans for better access points and maintains a list of potential access points. A decision to roam is made on signal strength and signal quality metrics. The quality metric makes use of information provided by each access point in its beacon regarding the utilization of the access point. As a result, the phone can avoid attempting to reassociate with access points that have high utilization and may not be able to effectively support voice traffic. With these mechanisms, the 7925 is generally able to complete Layer 2 roaming within 100 milliseconds.

The addition of Layer 3 roaming might cause substantial delays that may drop voice calls. This will depend on the wireless solution that you implement, especially those that do not implement enhanced features for voice roaming. As a result, you might need to consider avoiding having wireless IP phones perform mid-call Layer 3 roaming. In this case, if possible, define a single subnet for the entire WLAN. This will completely avoid Layer 3 roaming. If this is not possible or feasible, at least minimize the possibility of Layer 3 mid-call roaming. For example, you may have a different subnet on each floor of a hospital. When performing the wireless site survey, ensure that signals from one floor do not overlap at such an extent that the wireless IP phones will roam to the floor above (or below) while the user is walking through a particular area.

Mobility Settings

Many WLAN product vendors enable you to indicate the degree of mobility of each station so that the access point can optimize roaming algorithms. If you set up the station as being “mobile,” the roaming protocols will enable the station to reassociate as it moves from one access point to another. If set to “mobile” mode, stationary devices, such as wireless desktops, might experience a short episode of radio signal interference and falsely reassociate with a different access point. As a result, stationary roaming modes usually take this into consideration.

Note Avoid the use of automatic/adaptive channel control on access points when implementing wireless IP phones. Frequently changing channels will cause the phones to roam frequently, which generally results in a higher and undesirable call drop rate.

Summary

It is important to pay close attention to aspects of the WLAN design that impact range, performance, and roaming. Bear in mind that sometimes range and performance indirectly proportional. As a result, have a good idea of whether range or performance is more essential before getting too far with the design. If focusing on maximizing range, consider signal coverage requirements, radio frequency bands, transmit power settings, transmission channel settings, data rate, antennas, amplifiers, repeaters, physical obstacles, and radio signal interference. If performance is important, consider radio frequency bands, transmit power settings, transmission channel settings, data rate settings, antennas, amplifiers, physical obstacles, radio signal interference, channel width settings, signal coverage, fragmentation settings, RTS/CTS settings, multicasting mechanisms, and microcell deployment strategies. To optimize roaming in cases where mobility is imperative, think about the various levels of roaming, special considerations for wireless IP phones, and mobility settings.

Index

A

B

C

D

E

F

G

H

I–J

K–L

M

N

O

P

Q

R

S

T

U

V

W

X–Z