Voice over WLAN Radio Frequency Design

The purpose of this chapter is to discuss, in general terms, the considerations in radio frequency (RF) planning and design for VoWLAN. Handset capabilities, local conditions, and regulations impose additional opportunities and constraints. This chapter illustrates the RF-related processes and considerations by presenting *typical* deployment scenarios.

General Voice AP Guidelines

The packet loss and jitter requirements of VoIP and the increased mobility of VoWLAN handset users place demands on connection quality, coverage, and user expectations that are beyond that a of a typical WLAN data deployment. While later generations of WLAN equipment and software might provide further VoWLAN improvements, RF planning, design, and implementation is the foundation of a successful VoWLAN deployment. A VoWLAN deployment without a solid RF foundation is the proverbial house built on sand. Correctly designing, planning, implementing, operating, and maintaining the WLAN RF environment is critical for a successful VoWLAN deployment. The processes, guides, heuristics, and tools used for a WLAN data deployment are unlikely to deliver a successful VoWLAN deployment. The general 7920 and 7921G VoWLAN guidelines are:

- The optimal VoWLAN network requires overlaps of 20 percent (2.4 GHz), and approximately 15 to 20 percent (5 GHz), where a WLAN Data design may use an AP cell overlap of 5 to 10 percent.

- The optimal VoWLAN cell boundary recommendation is -67 dBm

Note The RF characteristics of VoWLAN handsets do vary, and can greatly impact the WLAN design and capacity. If you are planning a deployment of a VoWLAN handset with RF deployment requirements that are at odds with those presented in this chapter, the handset guidelines should be followed. Although handset recommendations do vary, the general principles and issues discussed in this chapter still apply with some changes in cell sizes.

High Availability

One of the requirements of many systems—including VoWLAN—is for high availability (HA). In a VoWLAN deployment, the same HA strategies, as used in wired networks, can be applied to the wired components of the VoWLAN solution. One area unique to the VoWLAN availability is RF coverage HA—providing RF coverage that is not dependent upon a single WLAN radio. The primary mechanism for providing RF HA is *cell boundary overlap* as set out in the VoWLAN requirements. An overlap of 20 percent means that 80 percent of a given AP cell is also covered by other APs at the recommended

signal levels, while in the other 20 percent of the cell VoWLAN calls may have degraded quality, but would still be available. The RF HA coverage is augmented by the Cisco Unified Wireless Network Coverage Hole algorithm which detects if WLAN clients are experiencing poor signal-to-noise ratio (SNR) values and causes the power of APs to increase as needed in order to rectify SNR issues.

Note   In systems planning to rely on Coverage Hole algorithm, the planning needs to consider that if an AP is going to increase its power level to adjust for a hole, clients also need to increase their power to adjust for a hole. Therefore, the maximum power of the VoWLAN handset, which can be lower than the maximum power of an AP, needs to be considered in the AP power level used in the initial planning of the deployment. For example, if the VoWLAN handset has a maximum power of 40mW and the AP planning was based on an AP power of 40mW, increasing the AP power to cover an RF hole does not help a VoWLAN client in that hole. For the hole coverage to be effective, the RF planning needs to be based on an AP of 20mW or less.

Higher levels of overlap may be applied as required in order to increase the RF HA; however, increasing overlap requires that you consider the potential changes to your network operation due to the resulting increase in co-channel interference and the tuning of Auto-RF algorithms.

VoWLAN Call Capacity

An important parameter in VoWLAN planning is *call capacity*—the number of simultaneous VoWLAN calls that can be supported in an area. This value can vary depending upon the RF environment, the VoWLAN handset features, and the WLAN system features. For example, the VoWLAN maximum capacity for a Cisco Unified IP Phone 7921G using a WLAN that provides optimized WLAN services (such as the Cisco Unified Wireless Network), the capacity is expected to be 14 simultaneous VoWLAN calls per 2.4 GHz channel and 20 simultaneous VoWLAN calls per 5 GHz channel. These capacity values are based on assuming no competing high priority WLAN traffic and *normal* background noise. Note that because the 5 GHz spectrum generally features less noise and interference, there can be greater capacity with the higher carrier frequency implementation. The additional non-overlapping channels available in the 5 GHz spectrum also provides a great deal more call capacity for a given area.

Note   The call capacities are quoted per non-overlapping channel because the channel capacity is the limiting factor—not the number of access points (AP). This is explained in more detail in the following section. The purpose of providing these maximum call capacity figures is general planning purposes. The call capacity specified by the actual VoWLAN handset should be used for deployment since this is the supported capacity of that handset.

2.4 GHz Network Design

A total of 14 channels are defined in the IEEE 802.11b/g channel set. Each channel is 22 MHz wide, but the channel separation is only 5 MHz. This leads to channel overlap such that signals from neighboring channels can interfere with each other. In a 14-channel DS system (11 usable channels in the U.S.), there are only three non-overlapping (and thus, non-interfering) channels: 1, 6, and 11—each with 25 MHz of separation. This channel spacing governs the use and allocation of channels in a multi-AP environment, such as an office or campus. APs are usually deployed in a cellular fashion within an enterprise, where adjacent APs are allocated non-overlapping channels. See Figure 3-1.

Figure 3-1   2.4GHz Channel Allocations
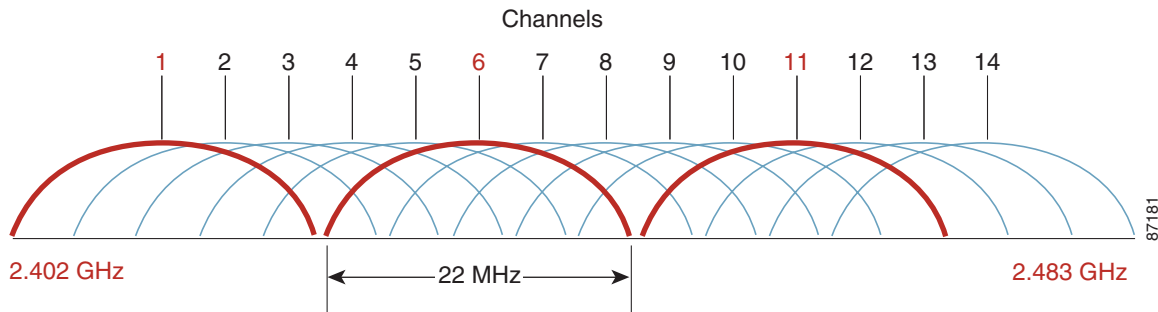
IEEE 802.11b provides rates of 1, 2, 5.5, and 11 Mbps. IEEE 802.11g provides data rates of 6, 9, 12, 18, 24, 36, 48, and 54 Mbps in the 2.4-GHz band, in the same spectrum as IEEE 802.11b. IEEE 802.11g is backward-compatible with IEEE 802.11b with a single AP providing WLAN access for both IEEE 802.11b and IEEE 802.11g clients.

Co-channel Interference Considerations

As mentioned in the preceding section, there are only three non-overlapping channels in U.S. 2.4 GHz spectrum. This presents a challenge when trying to deploy APs, and ensure that APs on the same channel cannot see the signal from an AP using the same channel. It is well known that the AP coverage radius changes with the client bit rates supported, and the boundary created by this RADIUS is often considered the AP's boundary.

The reality is somewhat more complicated because the AP influences the WLAN RF environment around it for a much greater distance than just the bit-rate boundary. This is because the RF energy from the AP, although too low to be demodulated in to a WLAN frame, is strong enough to cause an IEEE 802.11 radio to defer sending. In addition to the AP's influence of the RF environment, the clients associated with that AP extend the range of the RF energy associated with that AP's cell even further.

The IEEE 802.11 MAC is a Carrier Sense Multiple Access-Collision Avoidance (CSMA-CA) algorithm, and the Carrier Sense will perform a Clear Channel Assessment (CCA) before attempting to send an IEEE 802.11 Frame. If the CCA fails, it prevents the IEEE 802.11 radio to delay attempting transmission. The CCA mechanism is specified for each IEEE 802.11 physical layer; it is typically triggered either by a simple raw energy level, and physical layer convergence protocol (PLCP) header power levels, or carrier detection. The CCA of an IEEE 802.11 radio does not vary with the bit rates being used and is not, generally, user-configurable.

The impact of CCA deferrals on an AP WLAN from IEEE 802.11 radios that are not part of that AP WLAN is called *co-channel interference*. As co-channel interference results in delays in sending frames, it causes increased jitter and delay experienced by VoWLAN calls. Although WLAN QoS prioritizes WLAN traffic, this occurs after the CCA and therefore prioritization does not overcome the jitter and delay introduced by CCA.

The guidance for the Cisco Unified IP Phone 7921G VoWLAN handset is for a power level boundary of -67 dBm, and a separation between adjacent AP channels of -86 dBm. The -67 dBm requirement is to minimize packet loss, and the -86 dBm requirement is to minimize co-channel interference from other AP cells on the same channel. Figure 3-2 shows an example of the two boundaries created by the -67 dBm and -86 dBm requirements, based on standard RF loss formulas for an open office environment. This RF environment that would give an AP a client radius of 43 feet gives an AP co-channel interference radius of 150 feet using standard antenna gain (2 dB) and an AP output power of 16 dBm (40mW). Different RF environments, AP powers, and antennas will result in different client and co-channel interference radii, but the principles discussed in this chapter will generally hold.

Note The recommended cell boundary for the *Vocera* badge is at -65 dBm and therefore would yield slightly different results from those below.

Note The output power chosen for the AP must align with the VoWLAN handset capabilities and deployment requirements. For example the Cisco Unified Wireless IP Phone 7921G has a maximum output power of 40 mW. An AP power greater than 40 mW should not be used for a Cisco Unified Wireless IP Phone 7921G deployment. In circumstances where the Cisco Unified Wireless Network Hole Coverage mechanism is expected to provide VoWLAN coverage in event of an AP outage, an AP power of less than 40 mW (using the Cisco Unified Wireless IP Phone 7921G as an example) should be used for AP planning to allow the APs covering an RF hole to be operating in a range suitable for the VoWLAN handset. One additional advantage of using a lower AP transmit power is a proportional decrease in the co-channel interference radii. Our example of 40 mW transmit power gives a co-channel radius of the 150 feet and a client radius of 43 feet. Decreasing the power to 20 mW reduces the co-channel radius to 130 feet and the client radius to 38 feet, and also reduces the co-channel interference proportional to the co-channel interference generated by an AP.
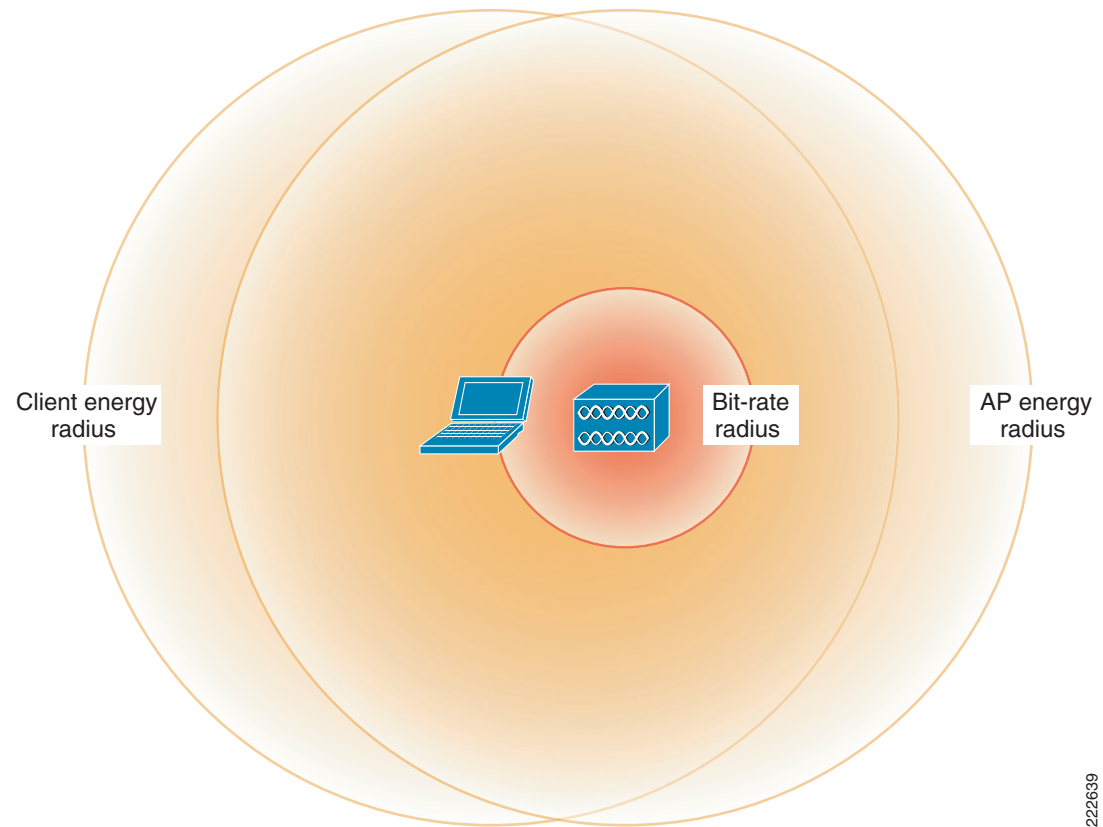
Figure 3-2   *Bit Rate and Co-channel Interference Boundaries of an AP*
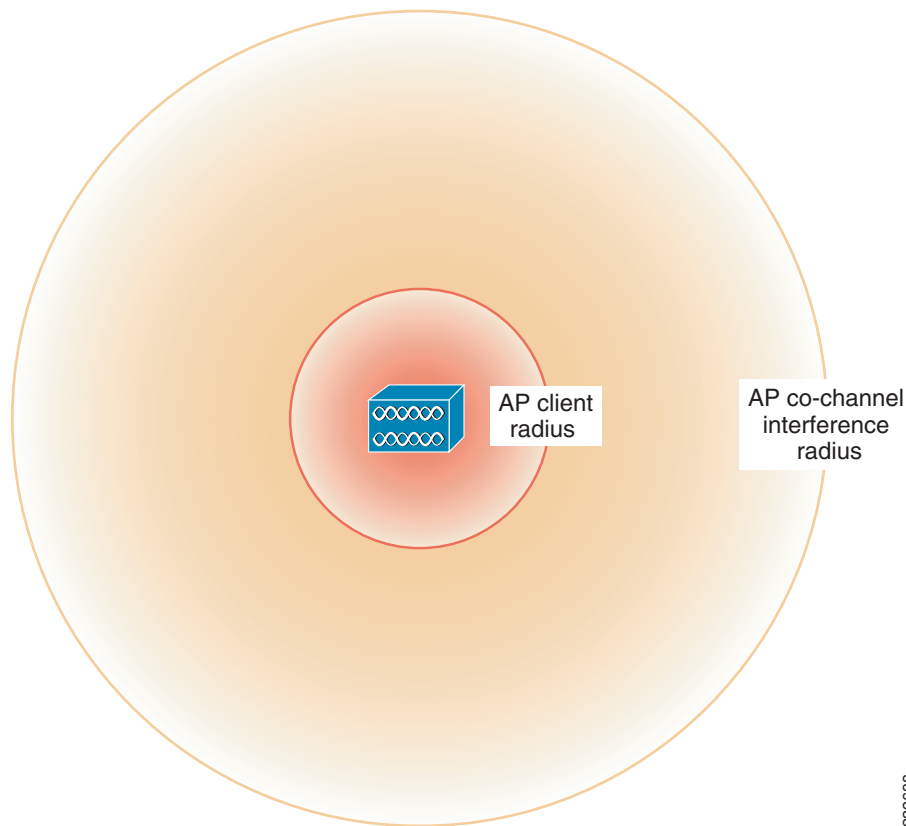
The RF co-channel interference radius of an AP is not the whole picture because a WLAN client is just as capable as an AP of producing co-channel interference as illustrated in Figure 3-3.

Figure 3-3   Single Client Co-channel Interference Radius

Given that a client or clients might be anywhere on the bit-rate radius perimeter, the client co-channel interference radius is better illustrated by Figure 3-4. Given the 43 foot bit-rate radius and 150 foot AP co-channel interference radius of the previous calculations the new client co-channel interference radius is 193 feet.

Note   The 193 feet would represent close to a worst case because the WLAN client is not normally in an equivalent location to an AP and would likely suffer greater signal attenuation due to obstacles.

Figure 3-4   *Complete Client Co-channel Interference Radius*
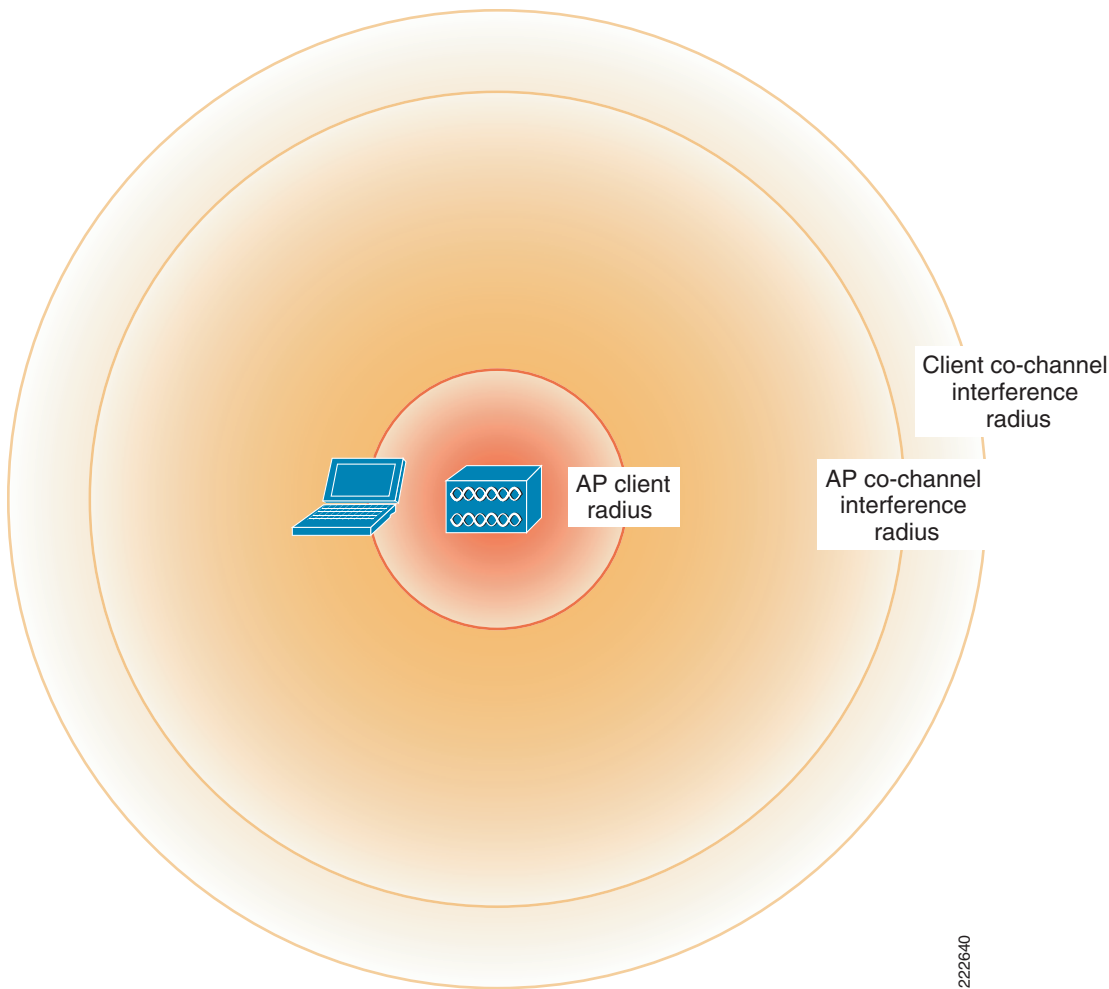
Bit Rate Impact on Co-channel Interference

The AP client radius in our example results in a nominal bit rate for the Cisco Unified IP Wireless IP Phone 7921G of approximately 24 Mbps or greater, depending upon noise. The AP client radius can be extended further by decreasing by supporting lower bit rates. This is not recommended for the following reasons:

- Lowering the bit rate extends the AP client radius, but also increases the client co-channel interference radius, increasing the area that only has the VoWLAN call capacity of a single AP.

- The lower bit rates reduce the overall call cell capacity, as lower bit rate packets consume more time, and transmit less packets.

VoWLAN call quality is sensitive to data-rate shifting. The decision to a data-rate shift is normally the result of being unable to send at the date rate previously used which is determined by sending multiple times without receiving an acknowledgement for that frame. This increases the delay and jitter experienced by a VoWLAN call.

20 Percent Cell Overlap

The recommended AP cell overlap for VoWLAN deployments at 2.4GHz, is 20 percent. The purpose of the 20 percent overlap is to ensure that a VoWLAN handset can detect and connect to alternative APs, when it is close to the cell boundary. This should allow a VoWLAN client to change AP associations with a minimum of interruption to a call, by minimizing the amount of data rate shifting and retransmission at a cell boundary for a given VoWLAN client. This 20 percent overlap requirement means that APs are spaced closer together than the two-times-70 feet distance suggested by the cell boundary. The area of overlap between two circles of radius equals 1 is given by:

This calculation is taken from http://mathworld.wolfram.com/Circle-CircleIntersection.html

In this equation, *d* is the distance between the centers of each circle. Solving for an area of 20 percent gives a *d* value of 1.374 for a standard radius of 1, or 59 feet between APs for our 67 dBm boundary.
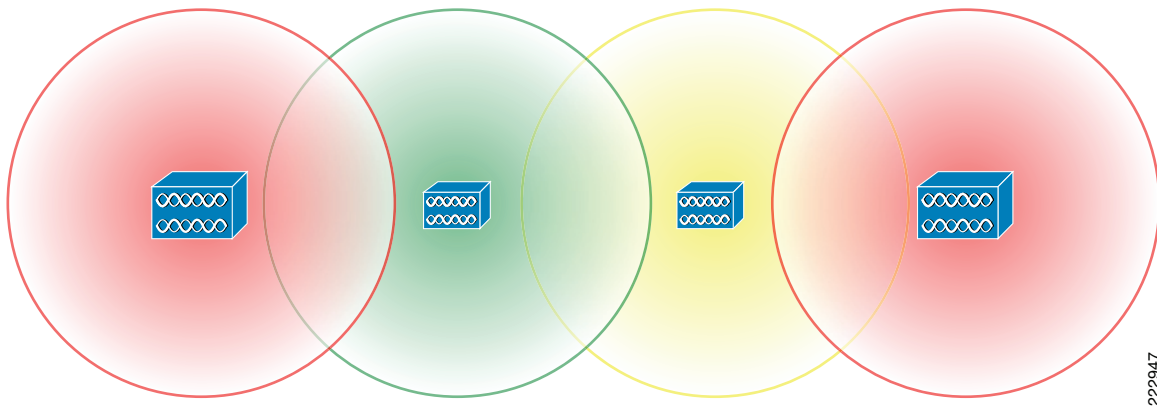
Note   Other common *d* values are 10 percent (1.611), 15 percent (1.486), 25 percent (1.269), and 30 percent (1.198)

Figure 3-5 illustrates this AP overlap, where the colors, red, green, and yellow represent channels 1, 6, and 11 respectively.

Figure 3-5   *APs with 20 Percent Overlap*

Co-channel Interference and 20 Percent AP Cell Overlap

Figure 3-6 shows the APs with 20 percent overlap and their co-channel interference boundaries. The co-channel interference boundary for one of the APs using channel 1 (red) overlaps with an AP using the same channel. In this situation, co-channel interference will occur in a 2.4 GHz VoWLAN deployment.

Figure 3-6   **AP with 20 Percent Overlap and Co-channel Interference Boundaries**
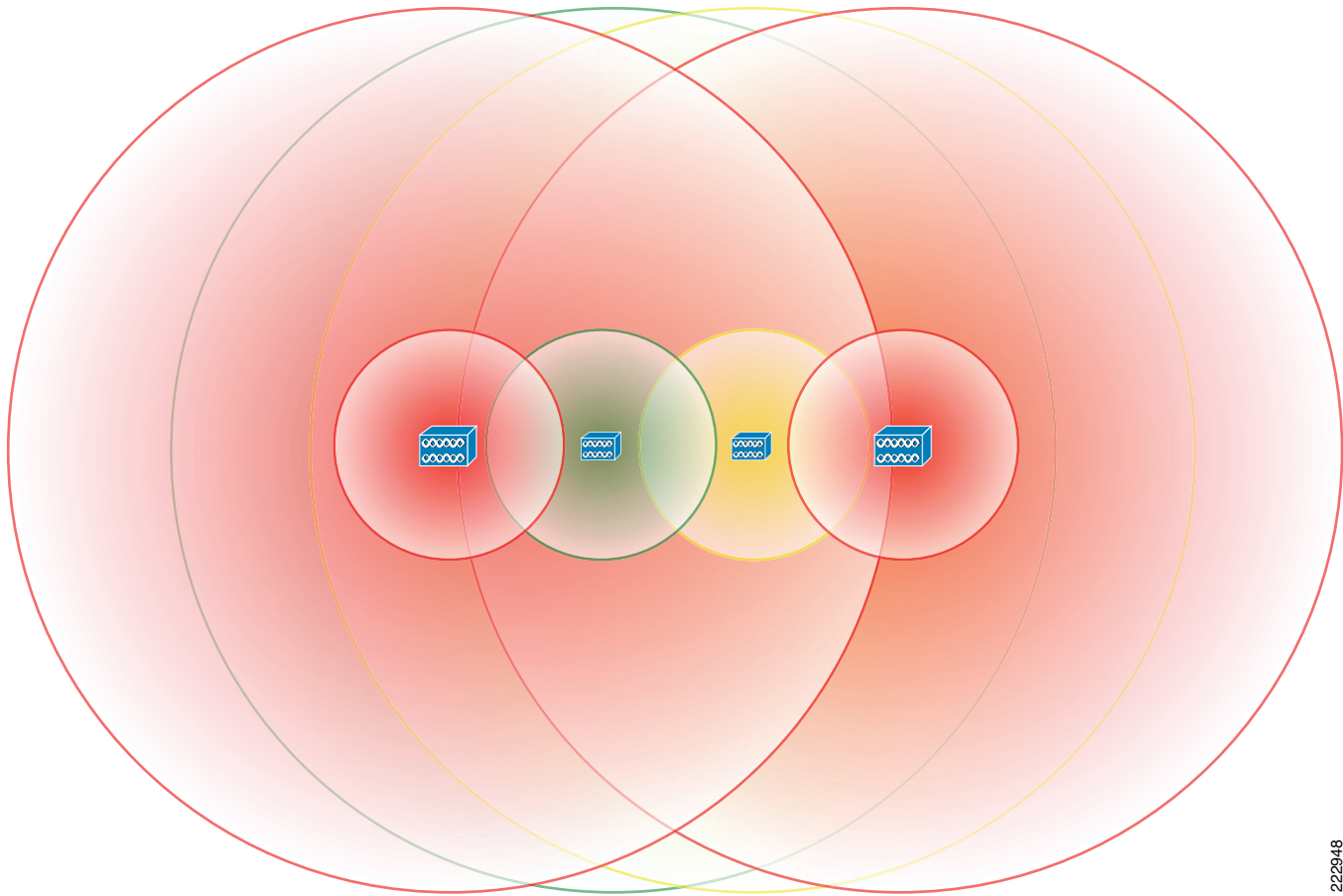
It should be noted that the combined effect of the 20 percent overlap requirement for reliable roaming between AP cells and the impact of co-channel interference is a reduced per VoWLAN call capacity over a given area.

Note   It is not an effective strategy to reduce the overlap in order to reduce co-channel interference. As users satisfaction can be greatly affected by poor roaming performance. In contrast, call capacity can be addressed in planning and design.

Existing WLAN data deployments (initially using lower-power cell-boundaries and less overlap) that are changed to match recommended power boundaries and overlap for VoWLAN or Location might experience application issues for timing-sensitive applications. It is difficult to predict which applications might be affected by the WLAN changes, because the actual effect depends on the application implementation. Generally, custom applications (requiring keepalive timeouts) are most likely to be affected and should be validated in the new environment to ensure that their timers require no adjustment.

For the sake of comparison, a WLAN data deployment is illustrated in Figure 3-7. This example features an AP client radius of 110 feet, -a 75 dBm client power boundary-, and a 10 percent overlap. The increased client radius and reduced overlap is possible because WLAN data clients are generally more tolerant of packet loss and jitter.

Figure 3-7   *WLAN Data Single Floor Data Example*
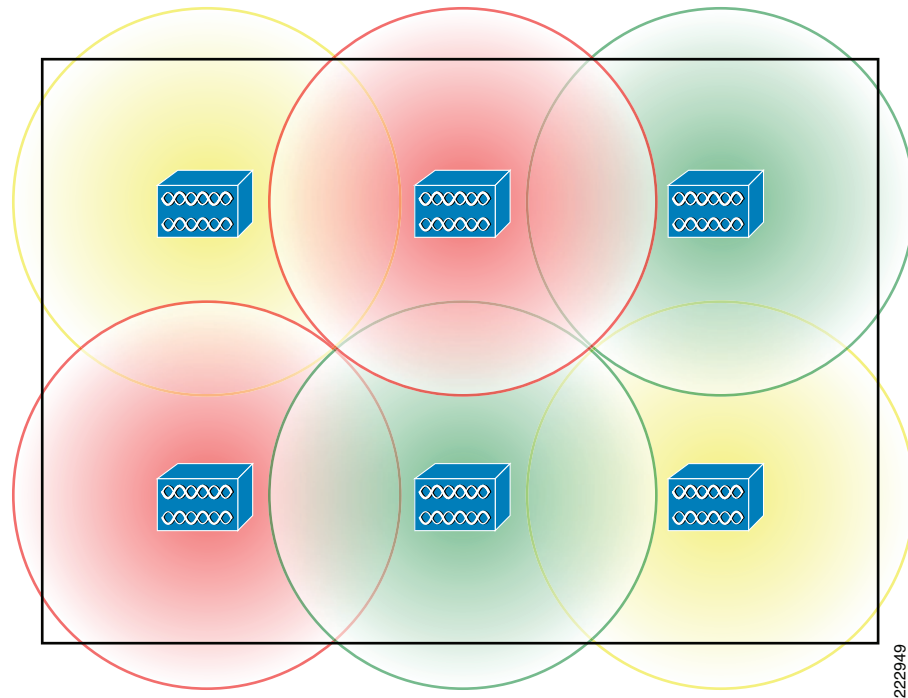
> **Note**   The co-channel radius is larger for the WLAN Data example. See Figure 3-8. The energy detect levels are the same, but the AP client radius 67 feet larger. This means that the capacity of the single floor will still be the equivalent of three channels, even though 6 APs are used.

Figure 3-8   *Single Floor WLAN Data with Co-channel Radius*
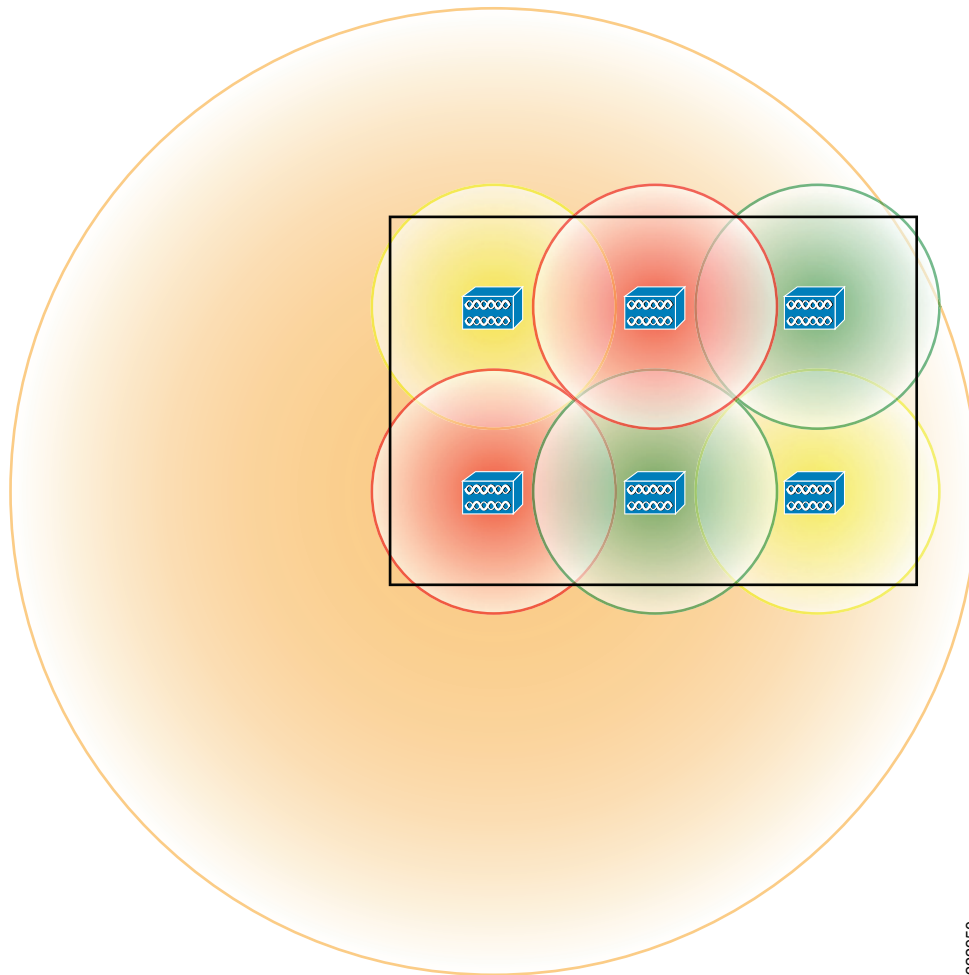
Example Deployments

The AP layout within a building depends greatly upon the building construction and shape, as well as the WLAN coverage requirements in that building. Due to differing effects of implementation-specific variables, there is not a single recommended deployment for the number of APs that should be deployed nor a single solution for determining the effect of co-channel interference. Therefore, we illustrate the design process with examples to illustrate deployment options. In the subsequent descriptions, we focus upon the following examples:

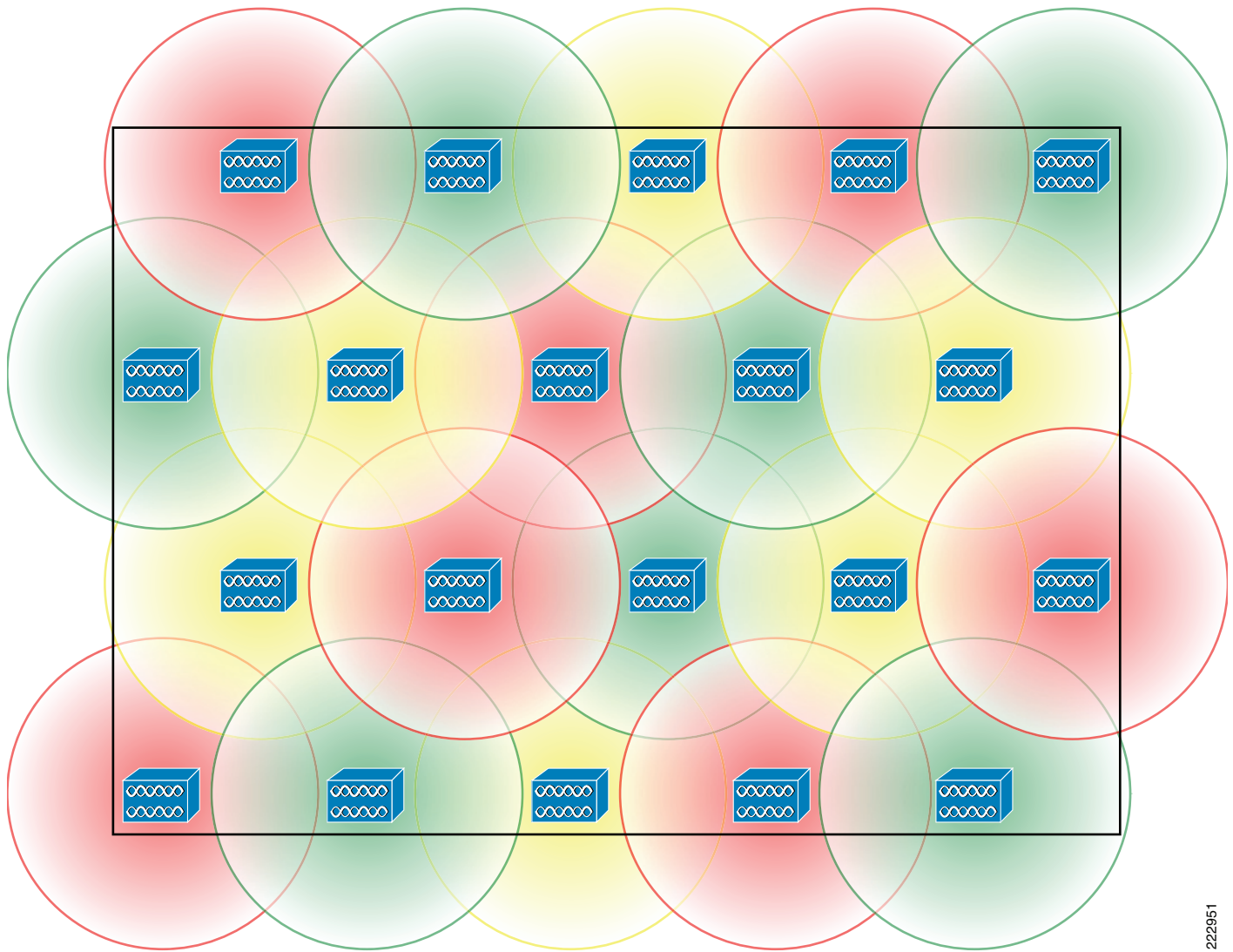- Example Single Floor Building Deployment
- Example Multi-Floor Building

Example Single Floor Building Deployment

Figure 3-9 shows a simple rectangular building example, based upon a standard size building floor at the Cisco San Jose Campus (285 feet x 185 feet). As we can see from Figure 3-9, 20 APs are required to give complete coverage. A WLAN data deployment with the same AP boundary and plan may have been able to use only 15 APs, as shown in Figure 3-10, but this has small coverage gaps. One of the

characteristics of VoWLAN deployments is that users are more mobile and find coverage gaps that were not found by WLAN data clients. As a result, a 20 AP deployment is needed. A detail that has not been shown in Figure 3-9 and Figure 3-10 is the location of building exits. It is critical to have coverage around the building exits, if not between buildings. Employees will step outside for many reasons and expect VoWLAN calls to be maintained. One of the issues of Figure 3-10 is that the coverage gaps would occur at building exits.

Figure 3-9   Single Floor Deployment with 20 APs

Figure 3-10   *Single Floor Deployment with 15 APs*
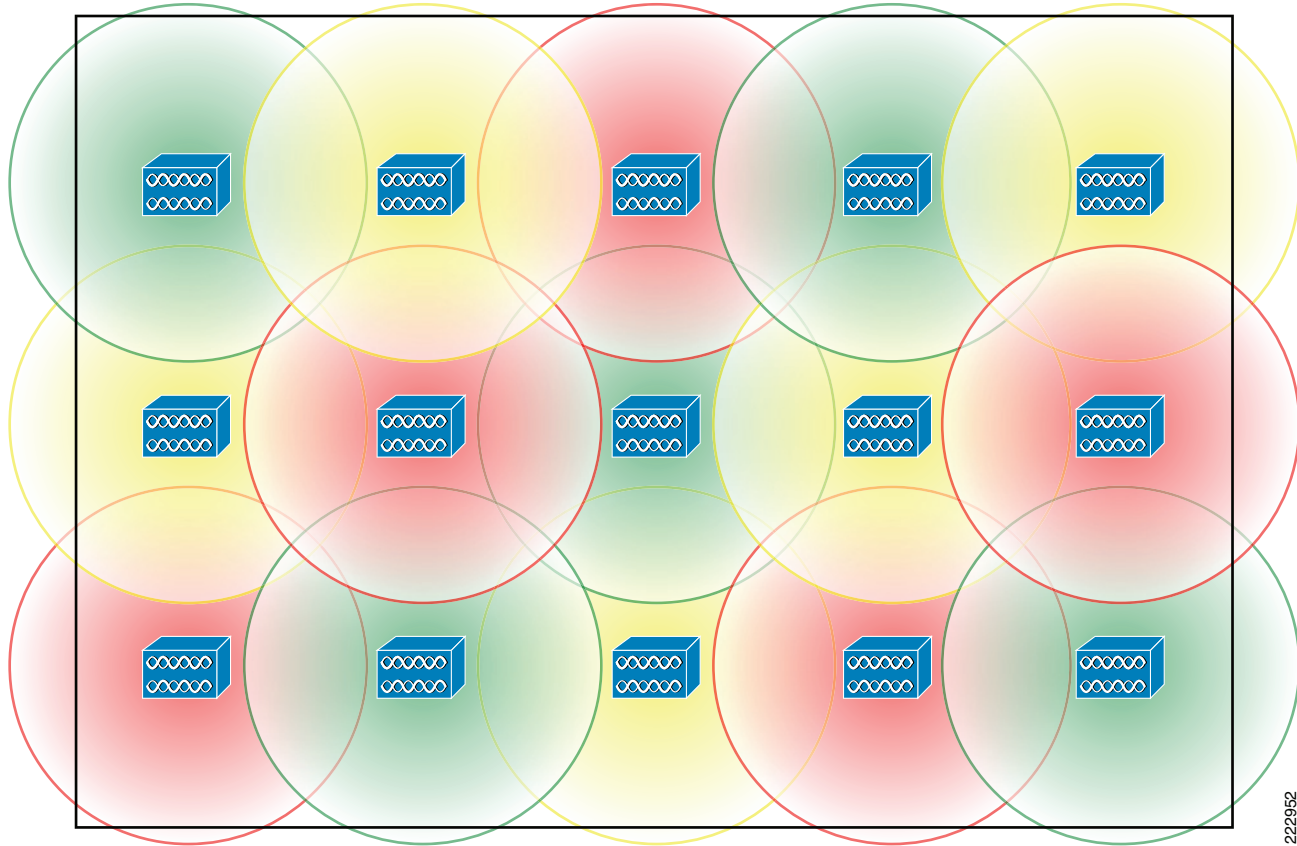
222952

Figure 3-11 shows the co-channel interference radius of an example AP. As can be seen from the figure, the co-channel interference radius extends for the entire building. This means that the APs using channel 1 (red) are effectively sharing some channel capacity. The seven channel 1 APs have increased the coverage over single AP by seven times, but has not increased the capacity by the same ratio and might not increase the capacity significantly in comparison with single AP. The same is true for the APs on other channels. Due to co-channel interference the call capacity of the floor is equivalent to something above the capacity of 3 independent APs, but not approaching the capacity of 20 APs. This is the primary reason for addressing VoWLAN call capacity in terms on the number of calls per channel, rather than the number of calls per AP. Channel capacity is the limiting factor.

Figure 3-11   Single Floor Co-channel Interference
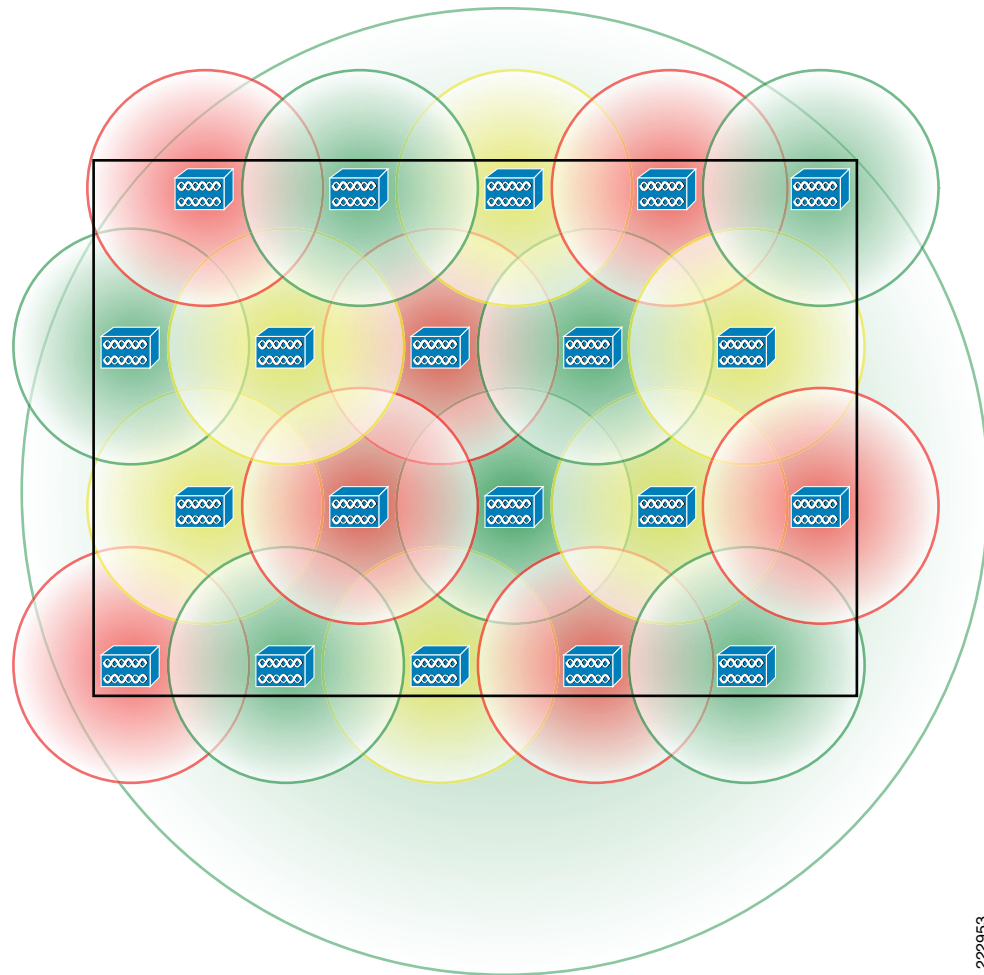

Example Multi-Floor Building

In a multi-floor building, RF energy can travel between floors and, as part of RF planning, the channels are staggered from floor-to-floor to minimize the co-channel interference between floors, as show in Figure 3-12.

Note   Figure 3-12 and Figure 3-13 do not represent a recommended channel implementation and are provided only to illustrate this description.

Figure 3-12   *Multi-floor Channel Assignments*

Floor 3

Floor 2

Floor 1

222954
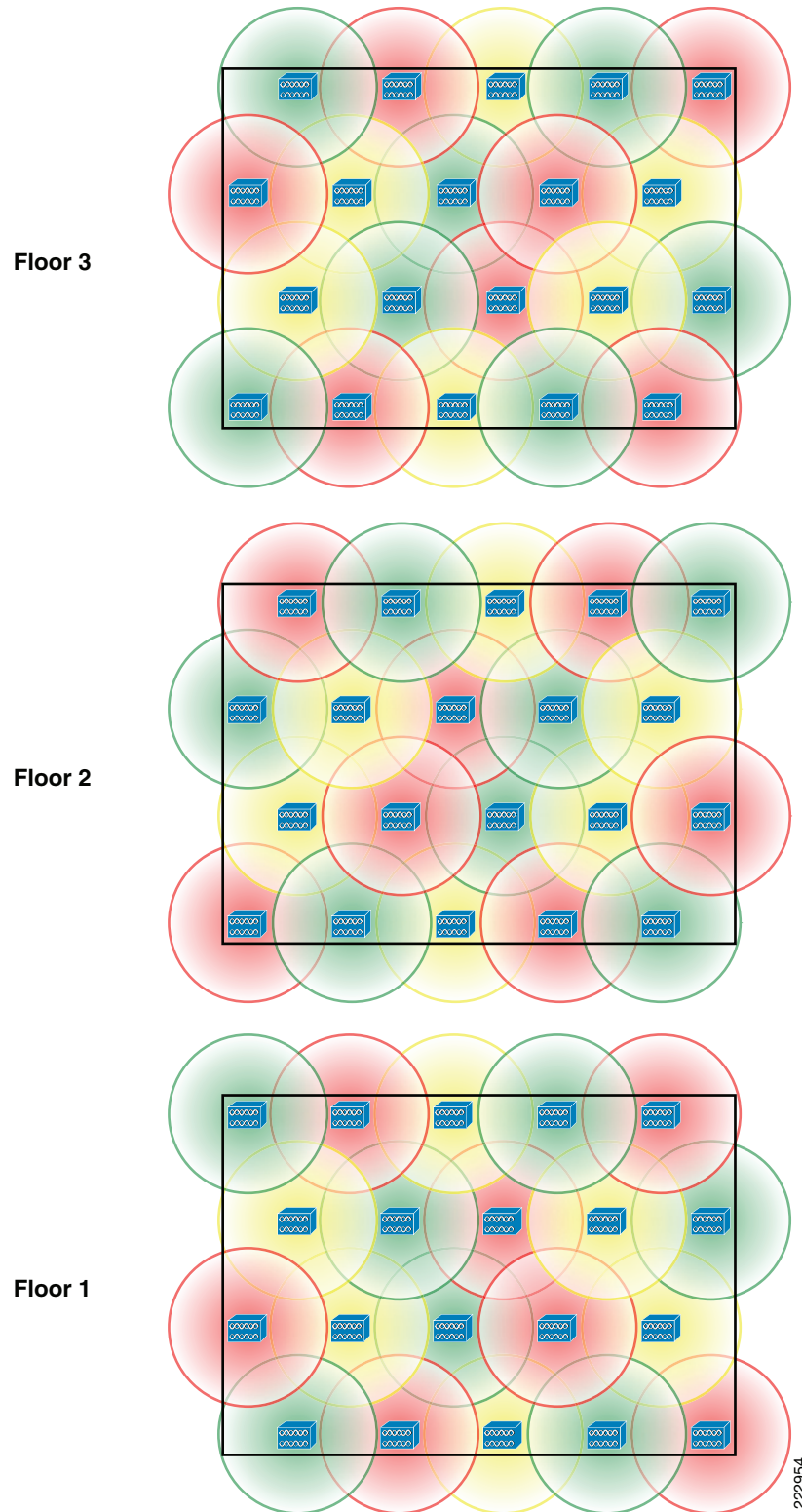
As the signal path between the floors is different from that on the same floor (there is often a piece of reinforced concrete in the between floor path), this must be taken into account when considering the co-channel interference radius of an AP. If we use a typical between floor loss of 7 dB, the co-channel interference radius of an AP between floors is reduced to 120 feet. Figure 3-13 shows an example of the co-channel interference radius of APs on different floors. Where floor 2 is the same layout as our single floor example earlier, and floor 1 and floor 3 shows the co-channel interference radius on the floors above and below. As can be seen from Figure 3-13, the co-channel interference between floors is still significant and it is reasonable to assume that the capacity across the three floors may be the equivalent of six or seven APs, but is not close to that of the 60 APs that have been deployed.

Figure 3-13   *Multi-floor Building Showing Co-channel Interference*

Floor 3

Floor 2

Floor 1

222955
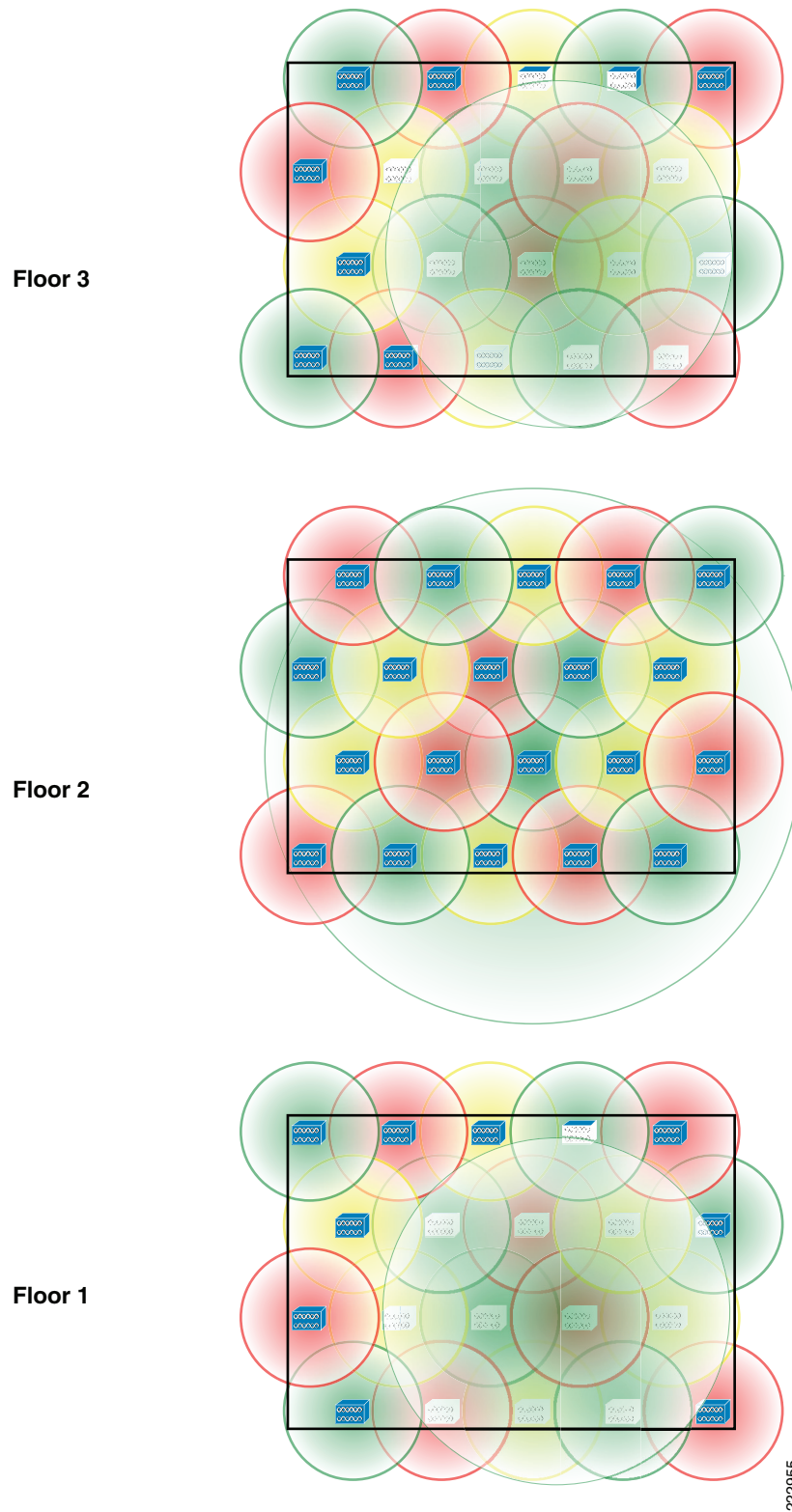
Location-based Services Design Considerations

The signal level requirements of IEEE 802.11 location-based services are similar to those on VoWLAN, but the AP placement requirements are different. For example, our AP placements shown in Figure 3-9 illustrate APs positioned close to what would be required in a Location-based Service (LBS) deployment. In this environment, there are many APs deployed on the perimeter—as well as at the core of the building. An additional column of APs (four) might be required. The VoWLAN AP count and the Location AP count may not always be this similar. The AP placement requirements of LBS may result in the addition of more APs—depending on the shape and size of the building. The addition of more APs for LBS will introduce an additional level of co-channel interference due to the additional IEEE 802.11 management traffic associated with additional AP; however, given the existing co-channel interference, the difference is not likely to be significant. The key point, as with the VoWLAN deployment, is that the addition of extra APs does not contribute to additional capacity in the 2.4GHz band due to co-channel interference.

The Importance of Auto-RF

As developed in the preceding sections, the VoWLAN call capacity is constrained by the effect of co-channel interference in the 2.4GHz band. This constraint should be considered in the planning, design and operation of the VoWLAN network. In our examples we determined that the call capacity of our deployment is the equivalent of three times the capacity of a single AP. These estimates assume that Auto-RF in being used, and that an AP will change channels to minimize interference and provide an optimal channel plan. Unfortunately, there is only so much Auto-RF can do to address the effects of co-channel interference in the 2.4 GHz channel because the limiting factor in the 2.4 GHz band is the three, non-overlapping channels. Auto-RF can tune AP power levels that might reduce co-channel interference by reducing power levels, but this power level adjustment must be balanced against the signal-level and coverage requirements of the VoWLAN deployment. Auto-RF is discussed further in a subsequent chapter of this document. The best mechanism to achieve greater capacity and a greater return on the investment of deployed APs is to use the 5 GHz band of IEEE 802.11a.

5 GHz Network Design

This section describes the following considerations for implementing a 5 GHz VoWLAN deployment:

IEEE 802.11a Physical Layer

IEEE 802.11a defines requirements for the physical layer (of the OSI model), operating in the 5 GHz UNII frequency band, with data rates ranging from 6 Mbps to 54 Mbps. It uses Orthogonal Frequency Division Multiplexing (OFDM), which is a multi-carrier system (52 sub-carriers are used, modulated with BPSK, QPSK, QAM or 64-QAM to provide different data rates). OFDM allows sub-carrier channels to overlap, providing a high spectral efficiency. The modulation technique used by OFDM is more efficient than spread spectrum techniques used with IEEE 802.11b; it is the same as is used in 802.11g.

IEEE 802.11a Channels

The basic IEEE 802.11a channels are shown in Figure 3-14. This shows the center frequency of the channels. The spectrum of each channel is 10 MHz on either side of the dotted line (20 MHz total), with 5 MHz of separation between channels spectrum.

Figure 3-14   5 GHz Channel Set
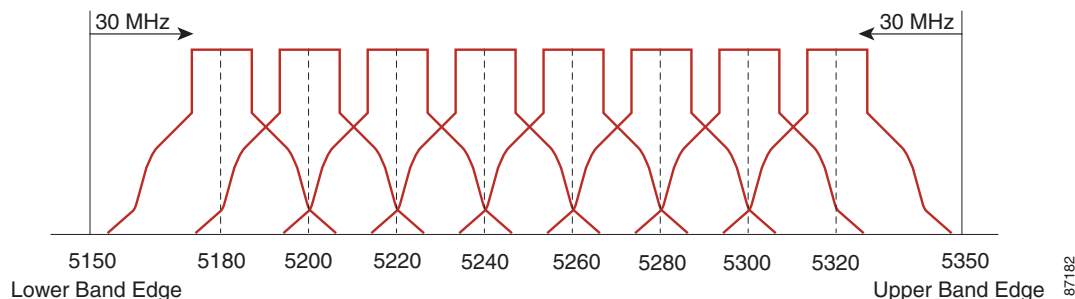
For the U.S.-based IEEE 802.11a standard, the 5 GHz unlicensed band covers 300 MHz of spectrum and supports 23 channels. As a result, the 5 GHz band is actually a conglomeration of three bands in the U.S.: 5.150-to-5.250 GHz (UNII 1), 5.250-to-5.350 GHz (UNII 2), and 5.725-to-5.875 GHz (UNII 3).

IEEE 802.11a Operating Frequencies and Data Rates

Operating in the unlicensed portion of the 5 GHz radio band, IEEE 802.11a is immune to interference from devices that operate in the 2.4 GHz band, such as microwave ovens, many cordless phones, and Bluetooth (a short-range, low-speed, point-to-point, personal-area-network wireless standard). Because the IEEE 802.11a standard operates in a different frequency range, it is not compatible with existing IEEE 802.11b or IEEE 802.11g-compliant wireless devices, but it does mean that 2.4-GHz and 5-GHz equipment can operate in the same physical environment without interference.

IEEE 802.11a provides data rates of 6, 9, 12, 18, 24, 36, 48, with a maximum data rate of 54 Mbps, though generally at shorter ranges compared to 2.4GHz network, for a given power and gain. However it has up to 23 non-overlapping frequency channels (depending on the geographic area) as compared to the three non-overlapping channels for the 2.4GHz band, which results in increased network capacity, improved scalability, and the ability to create microcellular deployments without interference from adjacent cells.

The 5 GHz band in which IEEE 802.11a operates is divided into several sub-bands. Each of the Unlicensed National Information Infrastructure (UNII) bands presented in Table 3-1 were originally intended for different uses, but all can now be used for indoor IEEE 802.11a deployments with applicable power restrictions. Originally, the FCC defined what is known as the UNII-1, UNII-2, and UNII-3 bands, each consisting of four channels. The channels are spaced 20 MHz apart with an RF spectrum bandwidth of 20 MHz, thereby providing four non-overlapping channels.

Table 3-1   Operating Frequency Range for IEEE 802.11a

Band	Channel ID	Center Frequency (MHz)
UNII-1	36	5180
	40	5200
	44	5220
	48	5240
UNII-2	52	5260
	56	5280
	60	5300
	64	5320
	100	5500
	104	5520
	108	5540
	112	5560
	116	5580
	120	5600
	124	5620
	128	5640
	132	5660
	136	5680
	140	5700
UNNII-3	149	5745
	153	5765
	157	5785
	161	5805

There are different limitations imposed on each of the UNII bands. Depending on the band, restrictions include transmit power, antenna gain, antenna styles, and usage. The UNII-1 band is designated for indoor operation, and initially required devices to use permanently attached antennas. The UNII-2 band was designated for indoor or outdoor operation, and permitted the use of external antennas. The UNII-3 band, originally intended for outdoor bridge products that use external antennas, can now be used for indoor or outdoor IEEE 802.11a WLANs as well. The channels in UNII-1 (5.150 to 5.250 GHz) are 36, 40, 44, and 48. The channels in UNII-2 (5.250-5.350 GHz) are 52, 56, 60, 64 and require Dynamic Frequency Selection (DFS) and Transmitter Power Control (TPC). The channels in the new frequency range (5.470-5.725 GHz) are 100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140 and require DFS and TPC. The channels in UNII-3 are 149, 153, 157, 161, 165 (5.725-5.825) and do not require DFS and TPC. Not all channels in a given range can be used in all of the regulatory domains. Table 3-1 shows the various channels in the UNII-1, -2, and -3 bands, along with the additional 11 new channels.

Note   The 1100 AP does not have an 802.11A radio and the 1000 series AP does not support DFS channels.

IEEE 802.11a and VoWLAN Deployments

Although there are 23 non-overlapping channels in the 5 GHz band, it is generally recommended to use the lower four channels and upper four channels of the 5 GHz spectrum as the base for VoWLAN, as they do not have a DFS and TPC requirements. Then add to the base of eight channels by determining which other channels are unlikely to be affected by DFS and TPC. The timing requirements of DFS and

TPC can adversely affect VoWLAN call quality. If your region or location is such that you are certain DFS and TPC will not be triggered, then the use of specific channels should not be an issue. If you are not certain, you should investigate. The Cisco Spectrum Expert analyzer is a good tool for starting this assessment to determine whether there are any 5 GHz signals in the area that would trigger DFS and TCP. Note that these channels must also be supported by the WLAN clients (data and VoWLAN). It is simpler to stay with the eight non-DFS channels, but every additional channel that can be safely deployed increases the capacity of the design. In addition to avoiding the DFS and TPC channels, it is also recommended that adjacent channels be avoided in the AP channel lay out—to avoid interference from the sidebands in each channel. The channel spacing and channel mask characteristics are such that the sidebands produced by an IEEE 802.11a client might interfere with the adjacent channels. It is best to avoid this potential issue in the AP layout. The general power levels and AP separation recommendations use in this guide for VoWLAN in the 5 GHz implementation are the same as the 2.4 GHz implementation: a power level boundary of ~67 dBm and a separation between adjacent AP channels of -86 dBm. Given the lower noise floor in the 5 GHz bands, the overlap recommendation may be reduced to 15 percent. A 20 percent or higher overlap can still be used if desired. It provides a higher availability design and takes into account that the use of the 5GHz spectrum is increasing; therefore, the noise floor can be expected to rise.

The range in the 5 GHz band is different to that in the 2.4 GHz band. However, when using the recommended power levels and typical antennas in our example, we obtained distances similar to those used in the 2.4 GHz example. Therefore, the same AP locations and overlap have been used for both the 2.4 GHz and 5 GHz bands. The primary difference between the two deployments is the additional capacity available due to the additional non-overlapping channels. This difference is sufficient for the 5 GHz band to be recommended for VoWLAN deployments.

Note   The TPC mechanism discussed above is different from the TPC algorithm that is part of Auto-RF.

An Example Single Floor Building

Figure 3-15. shows an AP layout using the eight different channels and designed to maximize the distance between re-used channels. However, in most cases, more channels should be available. Because the 2.4GHz and 5 GHz AP client radius and co-channel interference radii are fundamentally the same in this example, the multiple floor examples need not be repeated here. The major difference between the two bands is the increase in capacity that is made available by the added channels associated with the 5 GHz band. The more channels that can be found for use in the 5 GHz band, the closer the capacity of the system can correlate to the number of APs deployed.

Figure 3-15   5 GHz Single Floor Layout
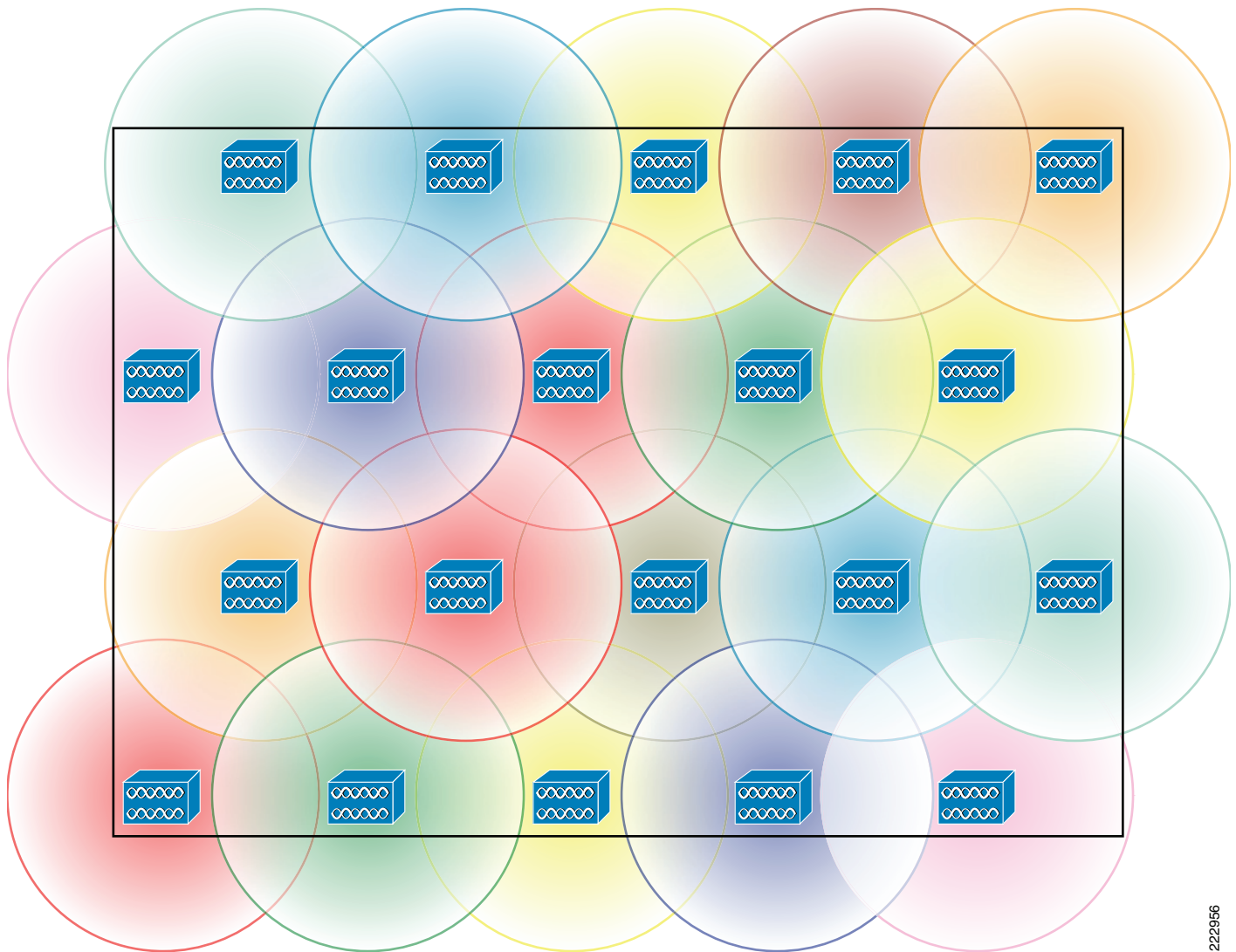
Figure 3-16 illustrates an example of the same AP layout as Figure 3-15 combined with the co-channel interference radius of a single AP. This illustrates that even though the co-channel interference is smaller, and the number of channels available is greater, co-channel interference is sufficiently large to affect overall call capacity on the floor. It would be very difficult to attempt to calculate the amount of co-channel interference across the entire floor, given that there are 20 APs and eight channels in use. It is safe to say, given that there are eight channels in use, that the VoWLAN call capacity of the floor would be equivalent eight times the call capacity of a single AP.

Figure 3-16   *5 GHz Single Floor Layout with Co-channel Radius*
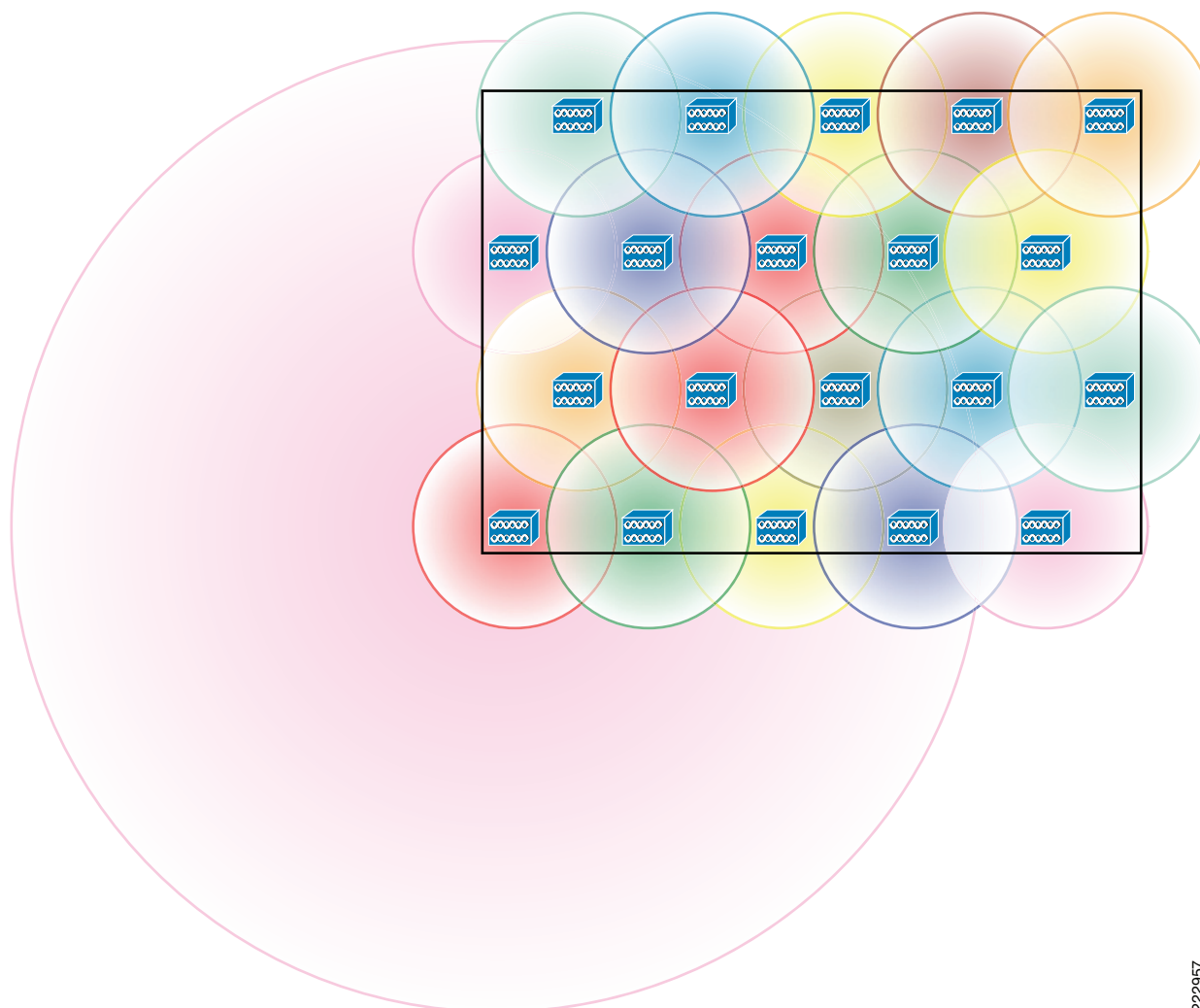
Planning Tools

The examples shown in this chapter use simple drawing tools and do not address the complex physical construction and building layout that must be considered in WLAN planning. We recommend that WLAN planning tools be used to plan the WLAN layout. These tools will assist in both ordering and placing equipment in an optimum. As with any project, the cost of fixing errors increases by orders of magnitude in a project. An error missed in planning can be 10 times more costly to fix in the implementation stage and 100 times more costly to fix in the operation stage. Investments in planning and planning tools generally pay for themselves many times over.

The Cisco Unified Wireless Network Wireless Control System (WCS) provides a WLAN planning tool, as do third-party vendors such as *AirMagnet*. Figure 3-17 depicts an example of the WCS planning page that uses the same floor plans that would be later used by the WCS to automatically lay out APs based on common WLAN deployment models.

Figure 3-17   Example WCS Planning Page

Planning Tools