Access Point Placement and Separation

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This chapter discusses AP placement and AP capacity planning, including core concepts regarding the distance between APs in a network and its impact on location, data, and voice.

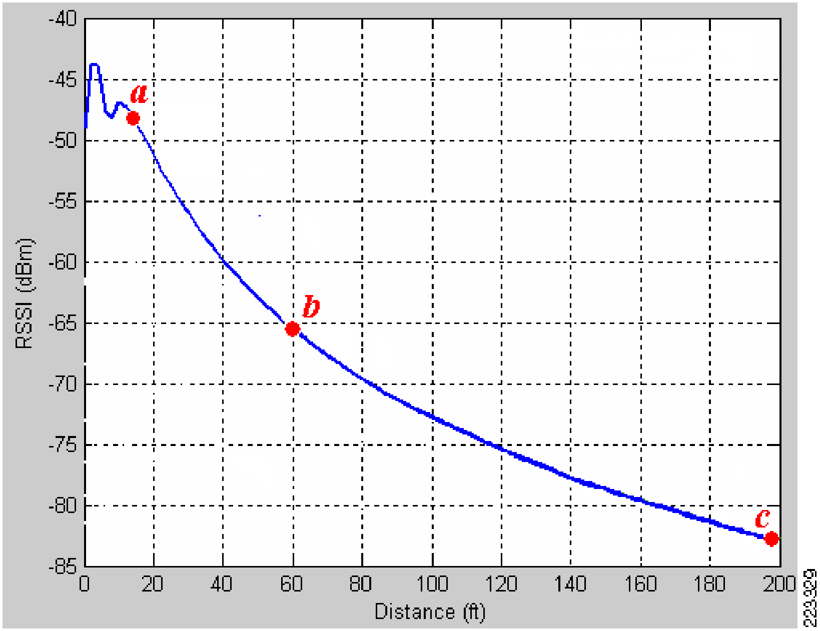
Access Point Separation

The distance between deployed access points can impact location performance, as well as the performance of co-resident voice and data applications. From a location perspective, while location tracking inter-access point spacing requirements tend to be relatively flexible and supportive of the coverage needs of underlying applications, very small or very large inter-access point separation distances are usually best avoided.

An excessive inter-access point distance can detract from good location accuracy by not providing sufficient signal strength differentiation at extended distance. Insufficient inter-access point distance can expose the system to short range antenna pattern anomalies, which may also be non-conducive to good location accuracy. From the perspective of co-resident voice and data applications, the inter-access point distance is one of the key factors determining whether required minimum signal level thresholds, data rate thresholds, signal to noise ratios (SNR), and required coverage overlap are met. From a location accuracy perspective, the range of acceptable inter-access point distance tends to be rather broad and can provide excellent location accuracy while accommodating the needs of most co-resident voice and data applications.

The techniques incorporated in the location-aware Cisco UWN to localize tracked devices operate most effectively when RSSI and distance are seen to possess a clearly monotonic relationship. To better understand what this means, we examine a simulated plot of a tracked device's detected RSSI as the distance between it and a detecting access point is increased. While the relationship between RSSI and distance varies depending on different combinations of antenna, antenna height, and environmental characteristics, the graph shown in Figure 15-1 is for an access point mounted at approximately twelve feet elevation can be used to better understand the concepts discussed here.

Figure 15-1 Relationship between RSSI and Distance



In Figure 15-1, we see that beginning at some point a fairly near the access point and ranging to another point c further in distance, the two variables exhibit a strict monotonically decreasing relationship (as distance between the tracked device and the access point increases, the RSSI at which the access point detects the device is shown to decrease). Between point a and another point b, the amount of change in RSSI (dBm) that occurs per-unit change in distance (feet) is highly consistent, approximately -5 dBm per 20-foot change in distance. This results in the slope of the graph between points a and b being fairly steep. As the distance continues to increase beyond point b, the slope of our graph begins to diminish and the level of RSSI differentiation decreases, providing increasingly less differentiation in received signal strength per-unit change in distance. Note that the slope of the graph between points b and c is not nearly as steep as it is between points a and b. As distance begins to significantly exceed point b in this example, the slope of the graph diminishes even further. This greatly reduced slope and steepness results in a decreased level of differentiation in signal level with increasing distance. When this occurs at extended distances, it becomes more difficult to accurately predict changes in distance based on detected changes in RSSI (lateration).

The risk of this lack of RSSI differentiation having a significant impact on location accuracy can be reduced if steps are taken to avoid areas of the RSSI versus distance curve where this phenomenon is known to exist most prominently. In general, for access points deployed indoors at antenna heights of 20 feet or less, this can be achieved if the range of any point on the floor to at least three detecting access points on that floor (one in each of at least three of the four quadrants surrounding it) is maintained within approximately 70 feet in an indoor environment. This is a general recommendation that is intended to assist designers in avoiding situations where excessive inter-access point distance may be a contributing factor to location inaccuracy. As shown in Figure 15-1, diminished RSSI differentiation with increasing distance is a gradually increasing phenomenon, therefore a degree of flexibility is implied in this recommendation.

In practice, in addition to being conducive to good location accuracy, this recommendation applies well to deployments where location tracking is deployed in conjunction with other WLAN applications (such as voice and high speed data) in accordance with current recommended best practices. This is especially true for environments where the expected path loss exponent is 3.5 (walled office environment) or higher, as the required inter-access point spacing tends to generally fall within this range. In addition to the potential effects of a lack of RSSI differentiation at distance extremes, inter-access point distances significantly greater than 70 to 80 feet can make it more challenging to satisfy the best practice signal strength and overlap requirements in environments with high path loss.

At ranges closer than point a in our example, propagation anomalies that are due to the elevation pattern of the chosen antenna, the antenna's installation height, and the current physical location of the tracked device can potentially combine to degrade monotonicity. As a result, RSSI cannot be depended on as a reliable predictor of distance in this part of the curve, since it may be possible that more than one equally likely value for distance exists at a particular detected RSSI level. Figure 15-2 illustrates an example of close-range non-monotonicity, depicting how a tracked device's RSSI reading of -40dBm can be associated with three different distances (5, 7, and 12 feet) from the access point antenna when operating in this close-range non-monotonic region of the RSSI versus distance graph. This behavior is typically the result of a variation in an overhead antenna's propagation pattern as a device approaches it begins to venture into the area almost directly beneath it. Obviously, these effects vary depending on the propagation pattern of the specific antennas used and their installation height above the area where tracked devices is located. However, the lesson to be learned from this is that although increased access point density can often be conducive to better location accuracy, the effect is not without its limits.

Figure 15-2 Close Range Non-Monotonicity

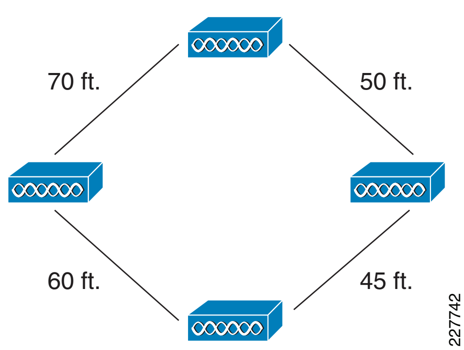
Clearly, such RSSI ambiguity can be confusing, especially when attempting to use RSSI to accurately laterate distance. Such ambiguous behavior is generally not conducive to good location fidelity. In tests conducted with access points at an installed height of 10 feet in with 2.2dBi omni-directional antennas in an environment with a path loss exponent of 3.4, this behavior could sporadically be observed out to a distance of almost 14 feet. In the specific case of this example, it would be best to maintain the inter-access point spacing above 28 feet (in other words, twice the distance at which such behavior would be expected) to reduce the potential of this phenomena occurring.

In some application designs, it may be desirable to deploy multiple access points on non-overlapping channels to potentially increase the amount of RF bandwidth available to users ("collocated non-overlapping access points"). This approach is often seen in classrooms and conference halls where there may be a large number of mobile users. If location tracking of WLAN clients and other devices is desirable in situations where some rooms may possess several collocated access points, it is suggested that the co-located access points not be deployed within very close proximity (i.e., a few feet) of each other. Rather, every attempt should be made to obtain as much separation as possible between these co-located access points so as to avoid any of the close-range effects that can be detrimental to good location fidelity. One way to accomplish this for co-located access points in a lecture hall, for example, would be to place the access points on different walls and perhaps the ceiling as well with appropriate inter-access point spacing.

In general then, most indoor location tracking deployments with access point antennas installed at heights of between ten and twenty feet can be well served with an inter-access point spacing of between 40 and 70 feet, especially when combined with the signal threshold and access point placement recommendations suggested in the preceding sections of this document. In some cases however, inter-access point spacing below 40 feet may be necessary to satisfy the requirements of some applications for high signal strength thresholds, especially in environments where high path loss is present. An example of this might be a voice application deployed in such an environment (for example, a path loss exponent of 4.0 where a high degree of environmental clutter is present). Best practices for Location Aware deployments for CMX suggest a minimum signal level of -67dBm, 20% inter-cell overlap, and signal to noise ratio of 25 dB for 802.11n in this type of situation. Applying these requirements mathematically, we calculate an estimated cell size of 24 feet and an inter-access point spacing of 33 feet. In this case, to deploy our voice application in accordance with recommended best practices, the inter-access point spacing should be reduced below the general guideline of 40 feet. Note that good location accuracy is achievable at inter-access point ranges below 40 feet, provided that the access point spacing is not decreased so much that the negative effects of close range non-monotonicity come into play. Generally, this should not be an issue if the inter-access point distances are above 25 to 28 feet when using low gain, omni-directional antennas mounted at an installation height of approximately 10 feet in an indoor environment.

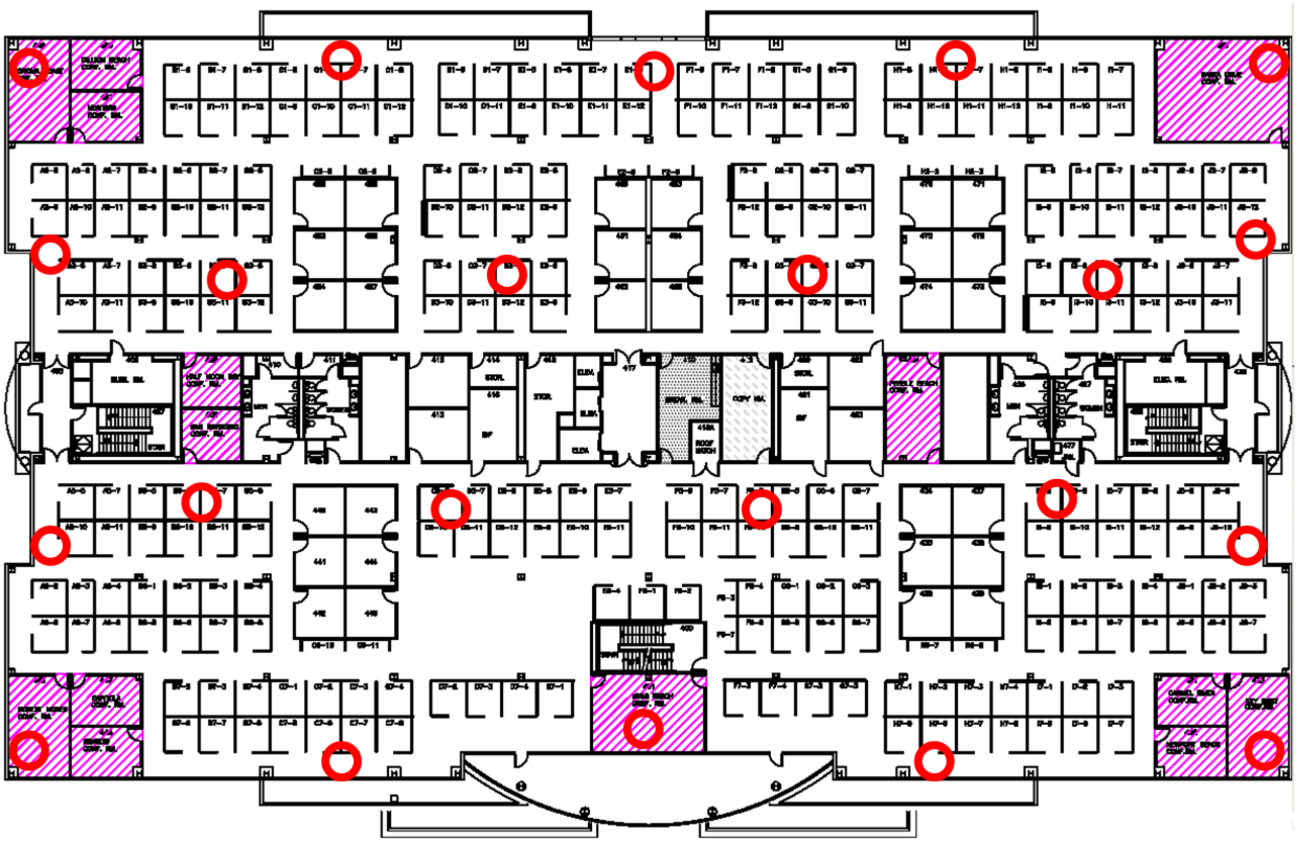
Figure 15-4 shows an example of location aware AP placement that illustrates access point placement and inter-access point spacing, offering a foundation for a location-aware design. The environment in Figure 15-4 consists of drywall offices and cubicle office spaces with a total space of approximately 275 feet by 159 feet. Taking into consideration the location tracking requirement for illustrative purposes only, our inter-access point linear-spacing recommendations of 40 to 70 feet suggests approximately 22 location-aware access points as an initial estimate. Incorporating the placement strategies made in preceding sections, interior, perimeter, and corner access points are placed to facilitate multi-lateration and establish a clearly delineated convex hull around the floor.

Figure 15-3 Inter-AP Distance



In an actual installation involving WLAN applications deployed in conjunction with location tracking, interior access point design should be conducted prior to instituting design modifications in support of location tracking modifications to ensure that best practice recommendations for signal strength, overlap, and signal to noise ratio requirements of data and voice applications are met.

Figure 15-4 Example of Location Aware AP Placement



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The Cisco Prime Infrastructure includes a planning tool that allows designers to model "what-if" design scenarios. This is a predictive modeling tool that is used on a per-floor basis to provide initial guidance on access point placement, as well as an interactive representation of predicted access point signal strength and data rate information. It can be safely used without impacting any actual deployment of access points that may already be in service. It is however possible that Cisco Prime Infrastructure may not be available at a location when the deployment is being designed. Other RF planning tools like Ekahau can also be used to plan for RF in advance with scenarios in mind.

Note The Cisco Prime Infrastructure RF Planning tool and Ekahau RF Survey planning tools are both discussed in more detail in Chapter 16, "Predictive Radio Frequency Planning."

AP Placement

Proper placement of access points is one of several best practices that should be adhered to in order to unleash the full performance potential of the location-aware Cisco Unified Wireless Network. In many existing enterprise LANs, access points are distributed mainly throughout interior spaces, providing service to the surrounding work areas. These access point locations have been selected traditionally on the basis of coverage, WLAN bandwidth, channel reuse, cell-to-cell overlap, security, aesthetics, and deployment feasibility. In a location-aware WLAN design, the requirements of underlying data and voice applications should be combined with the requirements for good location fidelity. Depending on the particular site, the requirements of the location-aware Cisco UWN are flexible enough such that the addition of location tracking to voice installations already designed in accordance with Cisco best practices, for example, may not require extensive reworking. Rather, infrastructure already deployed in accordance with accepted voice best practices can often be augmented such that location tracking best practice requirements are met as well (such as perimeter and corner access point placement, for example) depending on the characteristics of the areas involved.

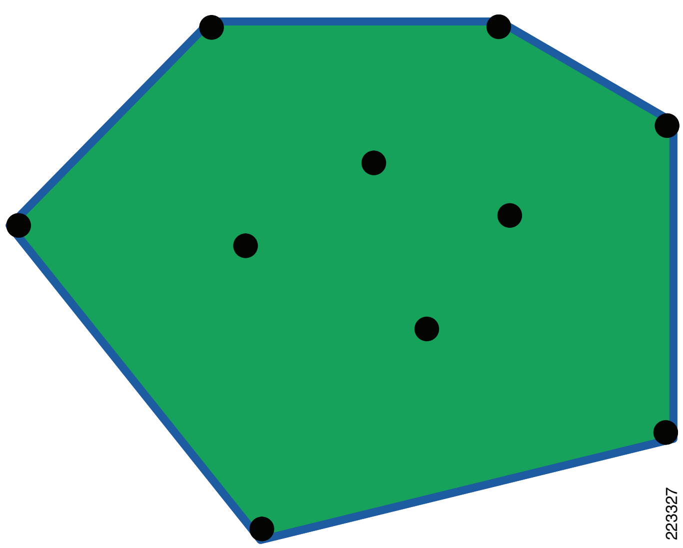
In a location-ready design, it is important to ensure that access points are not solely clustered in the interior and toward the center of floors. Rather, perimeter access points should complement access points located within floor interior areas. In addition, access points should be placed in each of the four corners of the floor and at any other corners that are encountered along the floor perimeter. These perimeter access points play a vital role in ensuring good location fidelity within the areas they encircle and in some cases may participate in the provisioning of general voice or data coverage as well.

The access points that form the perimeter and corners of the floor can be thought of as outlining the convex hull or set of possible device locations where the best potential for high accuracy and precision exists. By definition, the convex hull of a set S of points, denoted hull(S), can be regarded as the smallest polygon P for which each point of S is located either on the boundary or within the interior of P.

Figure 15-5 illustrates the concept of a convex hull. Assume the set of access point locations is denoted by the black dots, which we refer to as set S. The convex hull of set S, or Hull(S), is figuratively represented as an elastic band (shown by the blue line) that is stretched and allowed to snap over the outermost members of the set (which in this case represents perimeter and corner access points).

The interior area encompassed by this band (depicted in green) can be considered as possessing high potential for good location accuracy. As tracked devices stray into the area outside the convex hull (outside the green area in Convex Hull set of points), accuracy can begin to deteriorate. Although it may vary given the number of access points deployed and their inter-access point spacing, generally speaking, the rate of this accuracy degradation has been seen to be almost linear as the tracked device moves further and further outside the convex hull. For example, a device that experiences less than or equal to 10m/90% accuracy within the convex hull may deteriorate to 18m/90% by the time the device moves to a point 20 feet outside it.

Figure 15-5 Convex Hull Set of Points

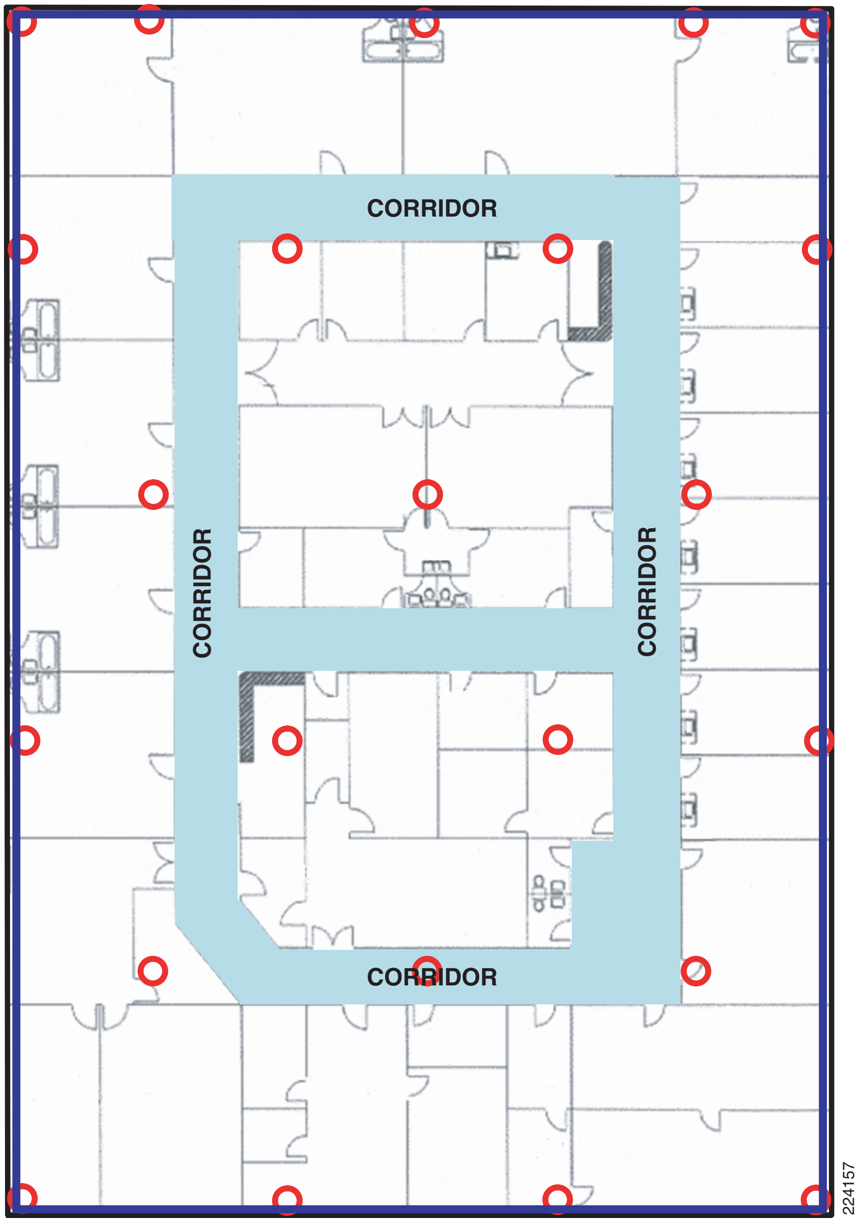


To ensure proper convex hull establishment around the set of location data points possessing high potential for good accuracy, access points should be placed in each corner of the floor as well as along the floor perimeter between corners. Inter-access point separation along the perimeter should be in accordance with the general access point separation guidelines (described in Chapter 16, "Predictive Radio Frequency Planning"). The designer may reduce this spacing if necessary in order for these access points to participate in the provisioning of voice or data service to the floor.

Proper Access Point Placement

Figure 15-6 shows an example in which these concepts are applied to a type of floor plan found in many enterprises (that of rooms or offices contained by and surrounding an interior corridor). In this case, the area in which we desire to locate clients is the entire floor. In Figure 15-6, note that the access points located towards the center of the floor are complemented by those that have been placed along the perimeter, but slightly inside. As is the case in most proper location-aware designs, the set of location data points possessing the highest potential for good location accuracy is contained within the convex hull, which in Figure 15-6 is represented by the blue rectangle and encompasses the entire floor.

Figure 15-6 Proper Access Point Perimeter Placement



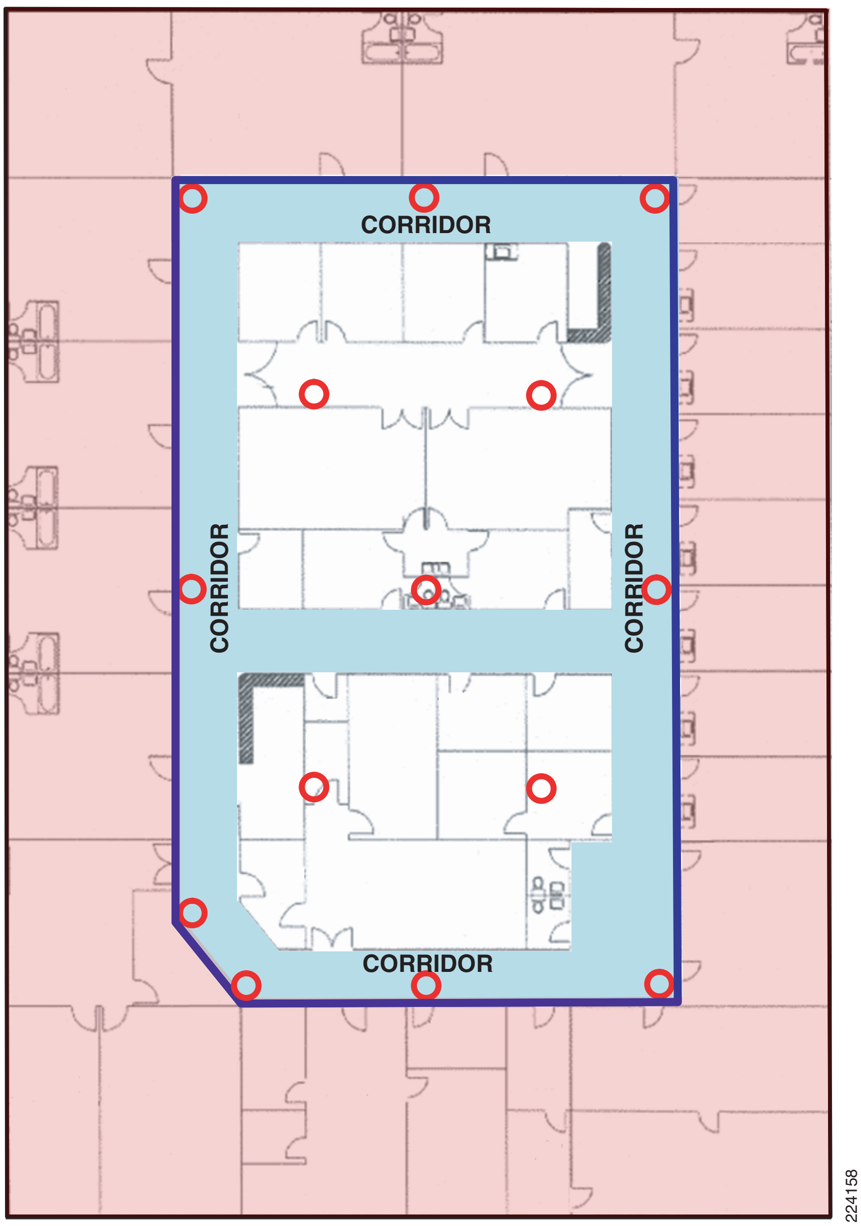
In some cases, customer preferences or deployment restrictions may factor into the access point placement decision and the placement of access points at the floor perimeter may be restricted in one way or another.

Also it is not entirely necessary to place the APs right at the perimeter. In fact the APs can be slight staggered inside the building to provide better RF coverage as well as minimize RF wastage outside the building or necessary area.

Improper Access Point Placement

Figure 15-7 illustrates an example of a less-than-desirable situation where the placement of access points has been restricted to hallway corridors and administrative/storage facilities located within the areas encircled by the corridors. For aesthetic reasons, facilities management has decided that access points will not be placed within any of the executive offices or conference rooms located between the hallway corridors and the physical perimeter. Because of these restrictions, our convex hull now lies at the outside edge of the corridor (indicated by the blue rectangle) and not at the true physical perimeter of the floor.

Figure 15-7 Improper Access Point Perimeter Placement



Given what we know about the distribution of location errors when operating outside the convex hull, it is logical to expect that location accuracy will not be as good in the offices and rooms located there. These areas of potentially lower accuracy are highlighted in red in Figure 15-7.

With our recommendation of establishing the convex hull at the true floor physical perimeter notwithstanding, in practice the difference in location error rate between points located within the convex hull and outside it may be tolerable in some situations. These might include situations where such areas extend beyond the office perimeter for only a short distance (for example, small 10x10 foot rooms lining the walls of a corridor). For example, looking at the areas highlighted in red in Figure 15-7, the potential increase in location error would be less in the smaller offices located at the right side of the floor plan than in any other affected area. Depending on magnitude, the effect of operation outside the convex hull will likely be the least. In contrast, the areas at the bottom of the floor plan, with larger offices and multiple wall partitions, would be potentially effected to a significantly higher degree.

In cases where access point placement in perimeter offices and conference rooms is restricted due to aesthetic concerns, a potential compromise may be possible using a very low profile antenna along with access point mounting in a plenum-rated enclosure (where permitted by local codes). This would offer the ability to mount access points at the proper perimeter and corner locations (thereby avoiding the quandary described in Figure 15-7, but with a minimal visible footprint to the casual observer.

Getting Around Placement

As mentioned earlier, the floor plans shown in Figure 15-6 and Figure 15-7 are commonplace, but by no means exclusive. For example, some modern building designs may possess hallway corridors that are located directly alongside the actual floor and building perimeter, typically allowing a panoramic view of campus environs as visitors move about between offices and conference rooms. In this case, all offices and conference facilities are located within the area between the corridors and the center of the floor. Figure 15-8 provides an illustration of such a floor plan. Note that with this floor layout, placement along the outer edge of the hallway corridor places the access points along the actual physical perimeter, by default.

Figure 15-8 Perimeter Corridor Placement Plan

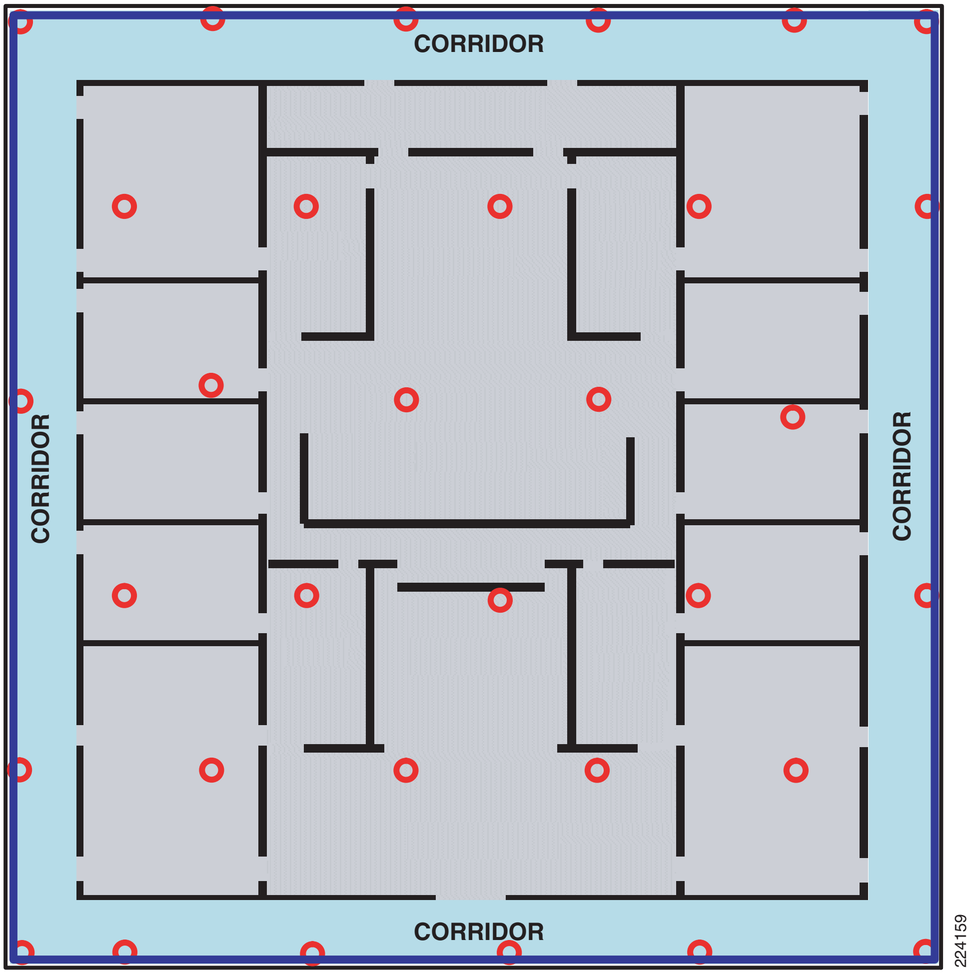
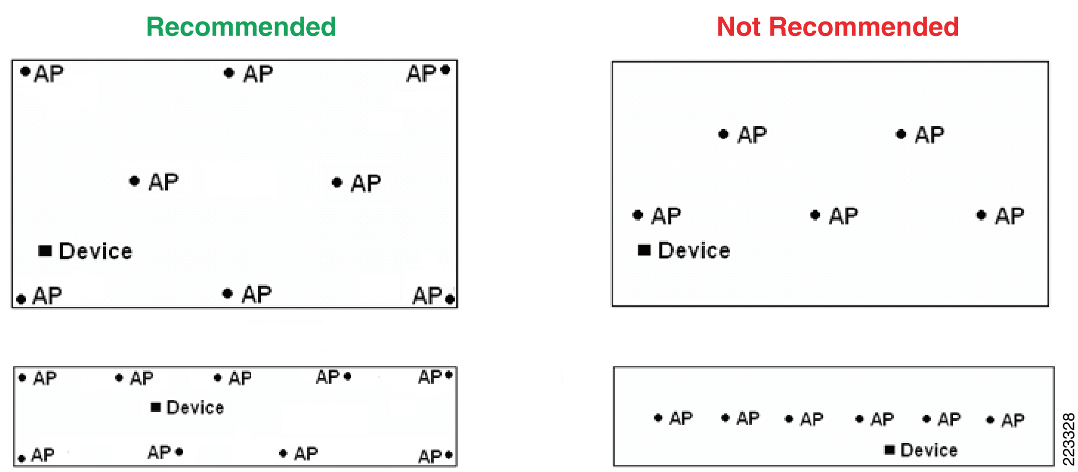


Figure 15-8 provides simple illustrations summarizing the access point placement concepts discussed in this section so far. Note that designs that make use of only clustered or straight-line access point placement should be augmented or redesigned in favor of those that combine center access point placement with perimeter and corner placement.

Recommend Access Point Placement

Figure 15-9 Recommended Access Point Placement



If possible, mount antennas such that they have an unencumbered 360º view of all areas around them without being blocked at close range by large objects. For example, if possible, avoid placing access point antennas directly against large objects such as steel columns, as illustrated in Figure 15-10. One option is to mount the access point along with its antennas to a ceiling location (provided that this allows an acceptable mounting height). Another option is to use short, low loss cable extension to allow separation between antennas and such obstructions.

Figure 15-10 AP Mounted Directly to Steel Column