



CMX Use Case Example—Upgrade VoWLAN Ready Network to Location/CMX Ready

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As an example, let us examine a Voice access point layout for the 275 x 159 foot facility. This space is a drywall office and indoor commercial office environment with a path loss exponent of 3.5. These access point locations were selected based on desired signal strength and overlap calculations that were performed by the original designer. In architecting this design, the designer's intention was to provide a solution that closely followed Cisco VoWLAN design best practices.

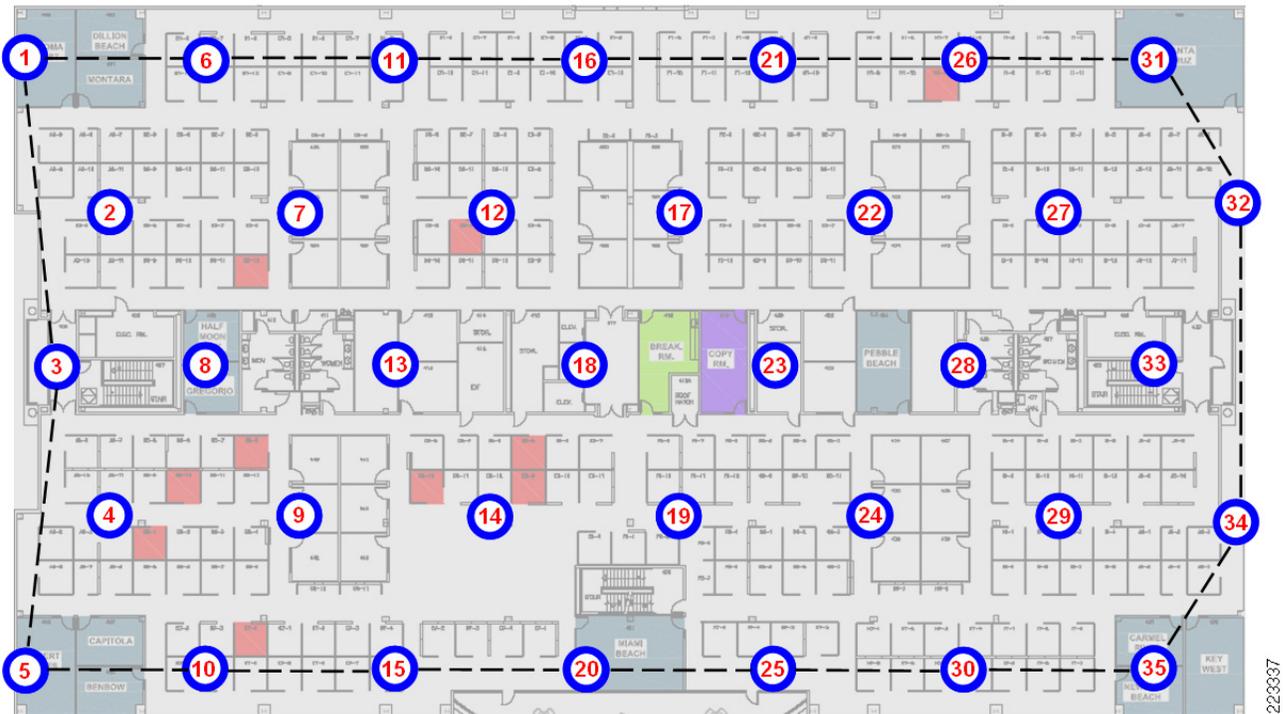
We opted for a dual band infrastructure, with an 802.11an/ac 5 GHz WLAN that is used by VoWLAN handsets and high-speed WLAN client devices. 802.11bgn 2.4 GHz operations is also supported, but due to the substantially reduced overall capacity on 802.11bgn brought about by the existence of only three non-interfering channels, its use is restricted to legacy data and voice devices. Legacy data devices would include devices that are unable to migrate to 802.11an/ac for reasons such as the client hardware device being no longer offered for sale, battery life concerns, and so on. Candidate legacy devices might include PDAs, older smartphones and tablets, and other devices with embedded wireless onboard that is not easily upgradeable. In the case of our example, we assume that there are still some users of 802.11bgn voice devices present in the environment that have not yet been addressed with 802.11an/ac replacements.



Note

Smartphones like iOS or Android devices double up both as data and voice clients due to the inherent nature of devices and applications that can be loaded on them. For the purposes of this example, we shall treat smartphones as voice devices that can also do data and follow get a voice optimized design to be location ready as well.

Figure D-1 Layout for 5GHz Voice and High Speed Data—2.4GHz Legacy



In Figure D-1, we assume the use of 35 ceiling mounted AP3700 access points, each of which is equipped with a pair of 2.2dBi antennas for 802.11bgn and a pair of 3.5 dBi antennas for 802.11an/ac. The access points and the antennas are mounted at a height of 10 feet. The design is intended to provide a minimum of -67 dBm signal level and a data rate of at least 24 Mbps on 802.11an for VoWLAN and high speed data clients, and a minimum of -67 dBm signal level and data rate of at least 11 Mbps on 802.11bgn for legacy data and voice clients. 802.11an VoWLAN devices are assumed to be Cisco IP phones with integrated antenna. Legacy voice and data client devices are assumed to possess nominal antenna gain of 0 dBi. Inter-access point spacing is approximately 42.7 feet and was selected to allow for a uniform distribution of access points within the floor interior and also ensure that the access point power levels required to produce our desired cell-to-cell overlap would fall within the capabilities of our client devices.

Note the following:

With the exception of access points 1, 5, 32, and 34, access points are not located directly at the floor perimeter. This is not optimal for the support of good location accuracy in all areas of the floor.

The lack of perimeter access points in the right hand corners of Layout for 5GHz Voice and High Speed Data, 2.4GHz Legacy. Because of this, there are areas in the vicinity of access points 31, 32, 34, and 35 where the location requirement for each point to lie within 70 feet of three different access points in at least three different quadrants (with an access point present in the fourth quadrant at any range) will not be satisfied.

Transmit power for each access point has been configured to +5dBm for 802.11bgn and +11 dBm for 802.11an/ac. This results in a -67 dBm cell radius of approximately 28.72 feet with a cell-to-cell overlap of 15% for 802.11an/ac VoWLAN and high speed data clients. For 802.11bgn legacy clients, it results in a -67 dBm cell radius of approximately 31 feet with a 20% cell-to-cell overlap.

**Note**

The transmit power configured for access points should be within the range of the transmit power levels supported by clients to help avoid potential “one-way audio” telephony calls. When using Cisco’s Radio Resource Manager to manage access point power levels, it is further recommended that designers target achieving the required coverage radii and overlap at transmit-power levels that are less than the maximum supported transmit power level of the client device. This is recommended to allow the Radio Resource Manager some degree of power allocation “headroom” that can be used to address potential coverage hole situations while still using transmit power levels that are achievable by the client devices.

To facilitate optimal location tracking with this design, a few changes, additions, and adjustments will be necessary. Examining the current voice and data design and its associated parameters, the current access point spacing, antenna installation height, and placement pattern appear to be acceptable for location usage. However the lack of access points located at the actual floor perimeters and in the corners of the floor is a concern that should be addressed. This can be seen from the dashed line in [Figure D-1](#) that illustrates the convex hull established by the current perimeter of access points. Note that areas at each corner and along each upper and lower perimeter lie outside of this boundary. Although these areas may not prove to be a hindrance to some users, for the purposes of this example, our goal is to ensure optimal location accuracy in all areas of the floor, including the conference rooms in the corners of the floor and in all perimeter areas. Therefore establishing a proper floor perimeter will be our first order of business.

The first step is to implement top and bottom access point perimeters as close to the building perimeter as feasible, while attempting to maintain the uniform density of access points shown in [Figure D-1](#) to the highest degree possible. Maintaining a high degree of access point uniformity is especially beneficial to those users that depend on the Cisco Radio Resource Management (RRM) to maintain transmit power control and perform coverage hole remediation. RRM functions most effectively when the distribution of access points on a floor is as uniform as possible.

**Note**

While the recommendations show that Access Points are placed at absolute corners or touching the perimeters of an space, Access Points maybe placed a little away from the perimeter to avoid RF signal wastage outside of the perimeter. Designers are encouraged to have a RF Plan that also maximizes RF usage, as well as provide good perimeter coverage.

At this point, we must decide on one of the following options:

1. Expand the equilateral formations composing our existing access point constellation to accommodate rearranging the top and bottom rows of access points to form the upper and lower portions of the floor perimeter. With this option and our example environment, a minimal number of additional access points would be required, as their primary use is to fill-in any missing areas on the left and right side perimeters. Since it requires expanding the separation between access points, this option is considered more aggressive when compared to option 2 below. Caution must be exercised to avoid modifying the design beyond the limits imposed on access point transmit power (see below).
2. Contract the equilateral formations composing our existing access point constellation to accommodate shifting upward the current top row of access points and subsequently introducing a sixth row of access points at the bottom to form a new lower perimeter. This option requires a greater number of additional access points when compared to option 1 above. However since we are reducing the inter-access point distances, this option typically does not possess the risk of increasing access point transmit power levels beyond that of the original design and is considered the more conservative option of the two.

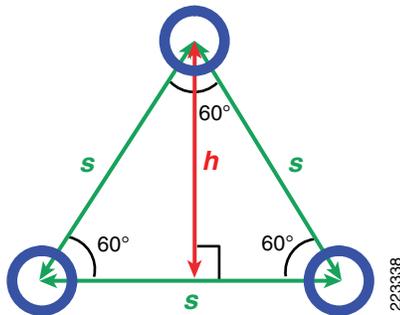
When considering the first option, it is necessary to examine the current inter-access point spacing and transmit power levels and estimate the increase that will be required to the inter-access point separation to place the existing outer rows of access points at the actual floor perimeters. If current access point transmit power levels are already at high levels relative to the power capabilities of our client devices, and the estimated increase to inter-access point separation appears to be large, then expanding the constellation of existing access points to accommodate perimeter placement may not be the best option. This is mainly because it may require the use of higher than desirable access point transmit power levels. In such cases, it is recommended to pursue the second option, which contracts the equilateral formations and results in shorter inter-access point separation, typically with the same or reduced access point transmit power levels.

Recall from our discussion that our transmit power levels are configured at +5dBm for 802.11bgn and +11 dBm for 802.11an/ac. To determine the new inter-access point separation that would be in effect if we were to uniformly expand the current formations (seen as equilateral triangles in Layout for 5GHz Voice and High Speed Data, 2.4GHz Legacy), we need to perform some basic geometrical calculations. We determine the new inter-access point separation required by assuming that the current top and bottom rows of access points are relocated such that they are positioned at the actual top and bottom floor perimeter. For the 275 x 159 floor in [Figure D-1](#), this is performed by dividing the top-to-bottom width of the floor (159 feet) by the number of desired rows of equilateral triangular formations (4), thereby yielding a projected formation height of 39.75 feet.

From the premise that in an equilateral triangle each angle is equal to 60° (shown in [Figure D-2](#)), we calculate the length of any side s from the height h of our equilateral triangle formations as follows:

$$h = s(\sin 60^{\circ})$$

Figure D-2 Equilateral Access Point Formation



Solving for s , we calculate:

$$s = \frac{h}{\sin 60^{\circ}}$$

Or:

$$\frac{39.75}{.866}$$

= 45.9 feet. Thus we would need to expand our current inter-access point spacing from 42.7 feet to 45.9 feet to move both the top and bottom rows of outermost access points to the actual building perimeter. As this represents a relatively minor increase in inter-access point spacing, it should be easily

accommodated by a correspondingly minor increase in transmit power, if any at all. In our next step, we determine the new cell size that would be required to support the recommended levels of overlap, given our newly calculated inter-access point spacing.

Using this new value for inter-access point spacing, we first calculate the -67dBm cell signal boundary with a 15% cell-to-cell overlap for 802.11an/ac. We then calculate the -67dBm cell signal boundary with a 20% cell-to-cell overlap for our legacy data and voice devices that will be using 802.11bgn. With the assumption that the radii of any two adjacent access point cells are equal (that is $R_1=R_2=R$), we can use the equation for the area of a circle-circle intersection as the basis for this calculation. To determine the cell radius given that the inter-access point separation and the percentage of overlap are known, we proceed as follows:

$$O\pi R^2 = 2R^2 \arccos\left(\frac{d}{2R}\right) - \frac{1}{2}d\sqrt{4R^2 - d^2}$$

Where:

- O = the desired overlap percentage divided by 100

$$\arccos\left(\frac{d}{2R}\right)$$

is expressed in radians

- d = the inter-access point distance in feet
- R = the cell radius in feet

We substitute either 15 (for 802.11an/ac) or 10 (for 802.11bgn) as the percentage of overlap O and 45.9 feet for the inter-access point distance d . Solving for R as an approximate root of the function shown above, we determine that the cell radii should be equal to 30.88 feet for a 15% cell-to-cell overlap using 802.11an/ac and 33.4 feet for a 20% cell-to-cell overlap using 802.11bgn.

At this point, we have the information necessary to calculate the access point transmission power settings that will be necessary to achieve our desired cell signal boundaries. This can be performed using a form of the equation presented earlier to calculate receive signal strength (TX_{POWER}) from knowledge of our reference path loss, path loss exponent, transmit power and various miscellaneous receive and transmit gains and losses. This was discussed in Received Signal Strength (RSS), page 2-7. As it is the transmit power (TX_{POWER}) of our access points that we wish to calculate and not the receive signal strength, we shall use a modified form of the equation as follows:

$$TX_{POWER} = RX_{POWER} + Loss_{TX} - Gain_{TX} + PL_{REFERENCE} + 10 \log D^N + s - Gain_{RX} + Loss_{RX}$$

For the purposes of this example, we have assumed:

- That transmission losses due to cables, connectors, etc. ($Loss_{TX}$ and $Loss_{RX}$) are equal to 0 dB.
- 0 dB shadow fading standard deviation.
- Receive antenna gain for our legacy 2.4 GHz data client devices of 0 dBi.

Substituting the appropriate values along with our expectation of a -67 dBm minimum receive signal strength (RX_{POWER}) for both 802.11an/ac 802.11bgn, as well as the appropriate antenna gains, our cell radius in meters (30.88 feet = 9.41 meters, 33.4 feet = 10.18 meters), an estimated path loss exponent n of 3.5 and our reference path losses, we obtain the following results:

802.11bgn:

$$\begin{aligned} TX_{POWER} &= -67 \text{ dBm} + 0 - 2.2 \text{ dBi} + 40 \text{ dB} + 10\log(10.183.5) - 0 + 0 \\ &= -29.2 + (10 * 3.527) \end{aligned}$$

$$TX_{POWER} = +6.07 \text{ dBm, or approximately } +8 \text{ dBm}$$

802.11an/ac:

$$\begin{aligned} TX_{POWER} &= -67 \text{ dBm} + 0 - 3.5 \text{ dBi} + 46 \text{ dB} + 10\log(9.413.5) - (-3.0) + 0 \\ &= -24.5 + (10 * 3.408) + 3 \end{aligned}$$

$$TX_{POWER} = +12.58 \text{ dBm, or approximately } +14 \text{ dBm}$$

Note that these power levels have been rounded upward to the next available transmit power increment available on the AP3700 access point. Since this is +1.93 dBm higher than the required transmit power to achieve our recommended 20% overlap goal at a cell signal boundary of -67 dBm, we can expect that the overlap will exceed the 20% target. This is acceptable, as the 20% overlap is a minimum target. Similarly, for 802.11an/ac the access point transmit power level of +14 dBm is +1.42 dBm higher than what is required to achieve the recommended 15% overlap, once again resulting in more overlap between cells than expected.

In this particular case, the option to expand our inter-access point separation is an acceptable alternative. Due to the increase in the inter-access point separation (from 42.7 feet to 45.9 feet), a +3 dBm increase is required to both our 802.11an/ac and 802.11bgn access point transmit power settings to remain in strict compliance with our calculated requirements. Despite the increase in access point transmit power level, additional transmit power is left in reserve on both bands to address potential coverage holes or other anomalies that could occur due to changes in the environment. If this had not been the case, we would have proceeded with our second option which entails contracting our inter-access point spacing and introducing a sixth row of access points. The main differences in our calculations would be to divide the size of floor by five (instead of four) rows of equilateral triangular formations. This would have resulted in a smaller formation height, a smaller inter-access point separation, and therefore, smaller cell-to-cell radii and lower transmit powers.

**Note**

The signal level measurements and the calculations described in this appendix, while based on generally accepted RF theory, are intended for planning purposes only. It is reasonable to expect some level of signal level variation from these theoretical calculations in different environments.

Rather than statically administering access point transmission power levels, the Cisco Radio Resource Manager (RRM) can be used instead. RRM can be used to dynamically control access point transmit power based on real-time WLAN conditions. Under normal circumstances, transmit power is maintained across all access points to maintain capacity and reduce interference. If a failed access point is detected, transmit power can be automatically increased on surrounding access points to fill the gap created by the loss in coverage. Should a coverage hole occur, RRM can use any remaining transmit power reserve on surrounding access points to raise the adjacent coverage levels and address the coverage hole until it can be investigated and resolved.

In either case, it is recommended that a verification of access point transmit power settings be performed periodically. If you opt to manually administer access point transmit power settings, you should examine the overall performance of your system to ensure that your original design assumptions are still valid and that there have not been significant changes in your environment that might warrant reconsideration of those assumptions. When using RRM, it will monitor your system for changes that might warrant an increase or decrease in access point transmit power settings for you. After your system has been installed, various adjustments can be made to RRM to bring its selection of access point transmit power levels and other parameters within your expectations for the environment at hand.

Keep in mind that immediately after installation and for a period of time after, it is reasonable to see a fair degree of RRM activity, as the system settles in and final parameter selections are made. At the conclusion of this “settling in” period, the system designer should ensure that the choices made by RRM are inline with the overall expectations of the design. Once the system has settled there should be little to no change in RRM managed parameters over time, as barring any significant environmental or equipment changes, the selections made for access point transmit power levels should remain fairly static. Any indication of constant fluctuation in assigned access point transmit power levels or channels should be regarded by the system administrator as potential indication of other anomalies that may be developing within the environment. The root causes behind such frequent fluctuations should be investigated and addressed promptly.

Figure D-3 illustrates the updated access point layout using the information from the calculations above along with perimeter access point placement which is discussed next.

Figure D-3 Layout for 5GHz Voice and High Speed Data—2.4GHz Legacy with Location



In Figure D-3 we can see the effects of the increase in inter-access point distance:

- The top row (access points 1, 6, 11, 16, 21, 26, and 31) and bottom row (access points 5, 10, 15, 20, 25, 30, and 35) of access points are now located at the actual top and bottom floor perimeter.
- On the right side of the floor perimeter, access points 31 and 35 have been moved into the right hand corners of the floor. Access point 33 has been moved to the right side of the floor perimeter. As a group, access points 31 through 35 now comprise the right side of the floor perimeter.
- On the left side of the floor perimeter, access points 1 and 5 have been moved into the left hand corners of the floor. In addition, two new access points (36 and 37, indicated by adjacent yellow stars) have been added to the design to complete the formation of the left side of the floor perimeter.

The two new access points added in [Figure D-3](#) bring the total access point count for the integrated voice, data, and location design to 37 access points. The primary source of voice and data coverage in this design still emanates from the access points participating in the equilateral formations seen across the floor (i.e., this can be seen in [Figure D-3](#) as the set of access points depicted in red). Access points 32, 34, 36, and 37 are necessary to establish a location perimeter, but based on the assumptions and calculations presented here, may not be required to participate in providing voice or data coverage in either band. That being the case, these access points can be statically configured to operate at significantly reduced transmit power (such as -1 dBm, for example), which also minimizes the co-channel interference contribution of these access points as well.

When using Cisco RRM to manage power levels, access points that are placed into the design solely for location purposes should not be included in either the Radio Resource Management transmit power control or coverage hole remediation processes. Configuring a custom access point transmit power level (using the “custom” TX power option on Cisco Prime Infrastructure or the controller GUI) will automatically exclude these access points from transmit power and coverage hole remediation algorithms.

Based on our planning output and our calculations, our original voice and data design shown in [Figure D-1](#) can be migrated to a location-ready design. The result is a combined design that is well suited to support VoWLAN, high speed data and location tracking on 5 GHz, as well as legacy data and voice support with location tracking on 2.4 GHz.

The techniques and principles described in this appendix illustrate how a design performed in accordance with VoWLAN and data best practices can be upgraded to being “location-ready”. The key concepts behind how inter-access point separation, cell radius, and transmit power are inter-related and how these factors can be used to determine coverage overlap, can be applied to designs of various different sizes and shapes, as well as environments with varying path loss characteristics and shadowing.