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# Location Based Services Design – Hyperlocation and vBLE

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BRKEWN-2650

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# Agenda

- Introduction to Indoor Positioning
- Hyperlocation
  - What it is
  - How it works
  - Design and Best Practice
- New Cisco Virtual Beacon Solution
  - What it is
  - How it works
  - How to use it


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# By The End of This Session

- You Should Understand
  - Where to get further information
  - How to evaluate that information and use it
  - Understand New tools and techniques available to solve specific issues
  - Use the information presented to create an action plan for change
  - Improve your networks capacity and your end users lives


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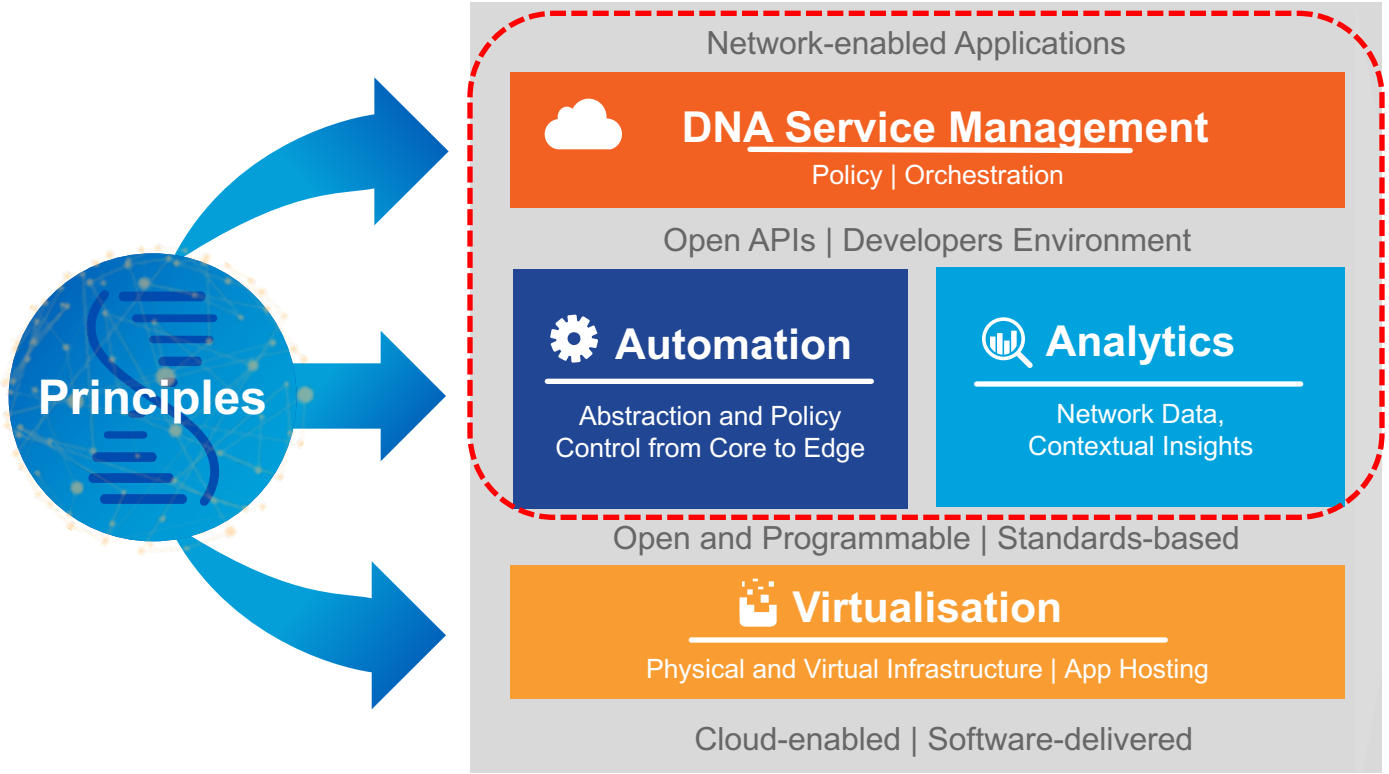
# Cisco Digital Network Architecture



Automation and Assurance

Security and Compliance

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# DNA in Mobility Solutions

## Faster Innovation

### Impactful Wireless

Use the intelligence in your wireless network to drive more business

**Innovative Solutions**
Hyperlocation Technology
Aironet 3800 Modules
Application Visibility and Control

## Reduce Cost and Complexity

### Adaptive Wireless

Keep pace with the more demanding needs of business and its users

**Adaptive Solutions**
WLAN Express
Apple Fast Lane
Flexible Radio Assignment

## Lower Risk and Meet Compliance

### Self-Protecting Wireless

Defend your sensitive assets on several fronts from device to application

**Secure Solutions**
ISE 2.2/CMX Connect
DNA Secure Access
High Density Experience (HDX)

Cisco is Transforming IT for the Digital Age

# Introduction to Indoor Positioning


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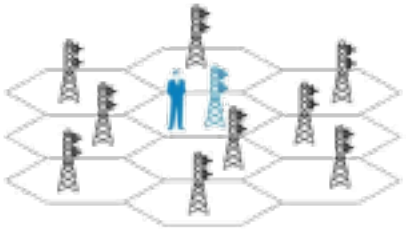
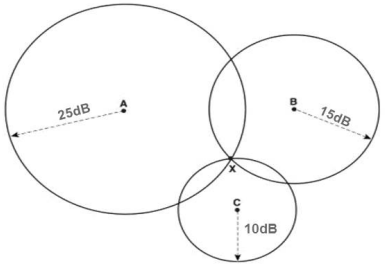
# Location Tracking Approaches

- Real-time location tracking and positioning systems can be classified by the measurement techniques they employ to determine mobile device location
- Approaches differ in terms of the specific technique used to sense and measure the position of the mobile device in the target environment
- Real-Time Location Systems (RTLS) can be grouped into four basic categories of systems that determine position on the basis of the following:

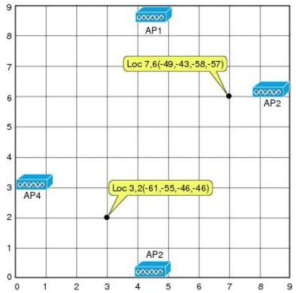


Cell of origin (nearest cell)




Distance based (lateration)

Angle based (Angulation)




Location patterning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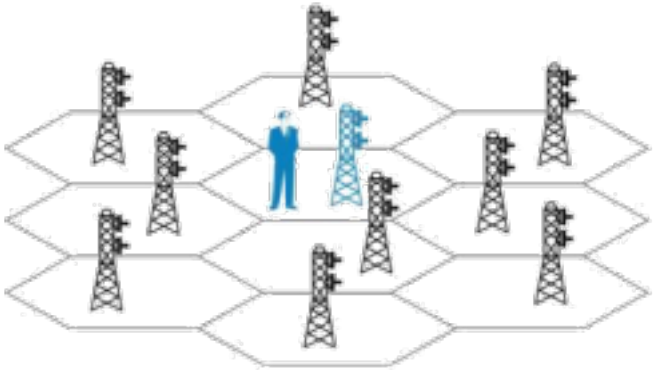
# Cell of Origin

- One of the simplest mechanisms of estimating approximate location in any system based on RF cells is the concept of ‘cell of origin’ (or ‘associated access point’ in Wi-Fi 802.11 systems)
- When receiving cells, provide received signal strength indication (RSSI) for mobile devices; the use of the highest signal strength technique can improve location granularity over the cell of origin.

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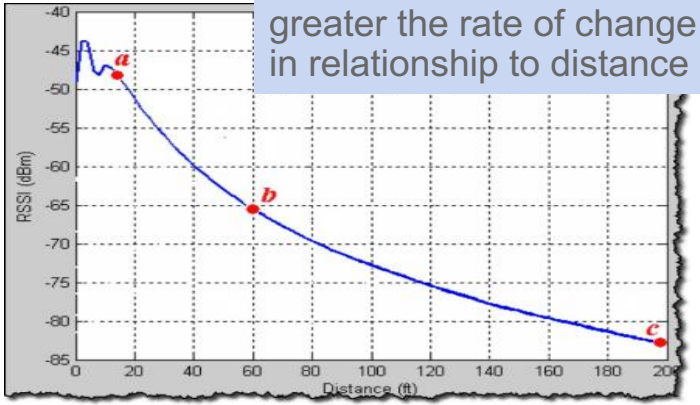
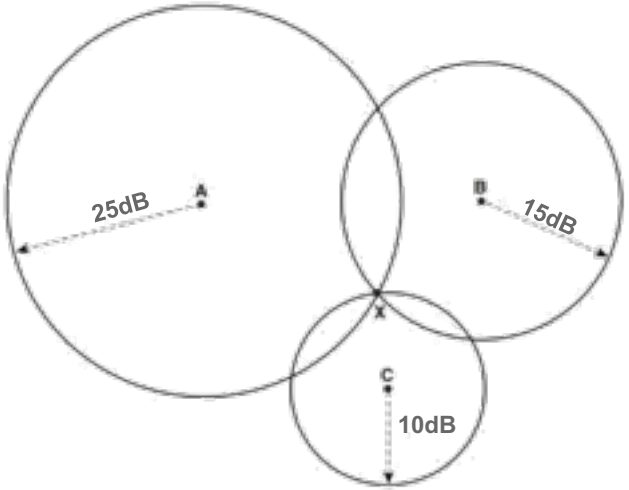
# Distance-Based (Trilateration) Techniques

- Trilateration can be performed by using received signal strength (RSS)
- Measured by either the mobile device or the receiving sensor

The closer the distance the greater the rate of change in RSS in relationship to distance




The change in RSS in relationship to distance flattens out at greater distances





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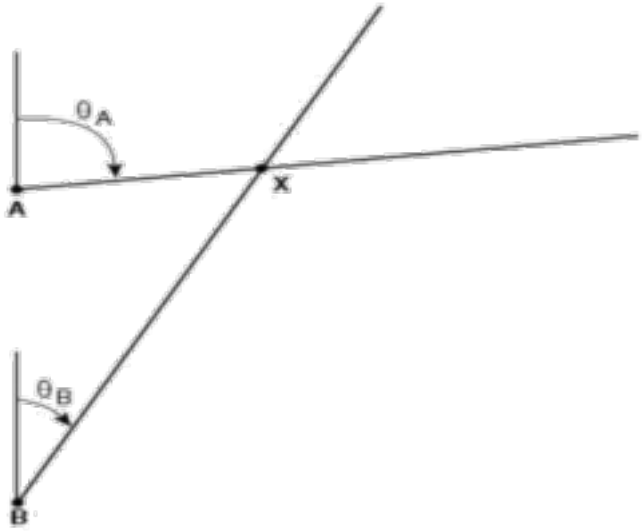
# Angle-Based (Angulation) Techniques

- The AoA locates the mobile station by determining the angle of incidence at which signals arrive at the receiving sensor
- Requires two receiving sensors for location estimation, with improved accuracy coming from at least three or more receiving sensors (triangulation)





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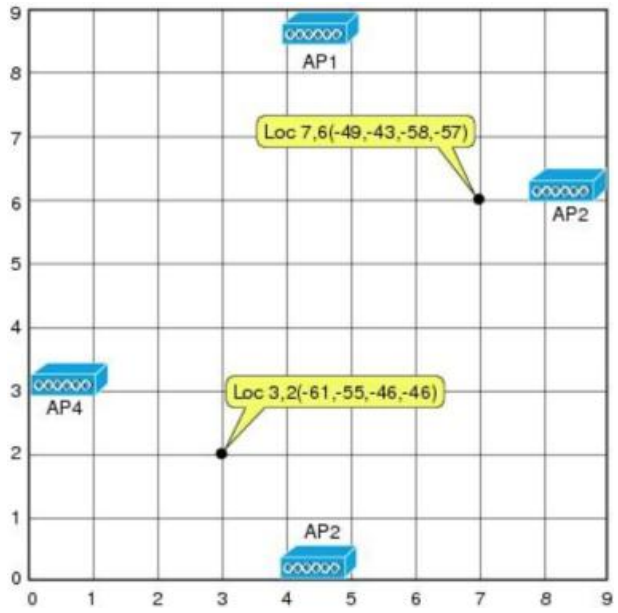
# Location Patterning (Fingerprinting)

- Location patterning is based on the sampling and recording of radio signal behaviour patterns in specific environments
- Each potential device location ideally possesses a distinctly unique RF "signature”




Because of fading and other phenomena, the observed signal strength of a mobile device at a particular location is not static but is seen to vary over time. As a result, calibration phase software typically records many samples of signal strength for a mobile device during the actual sampling process.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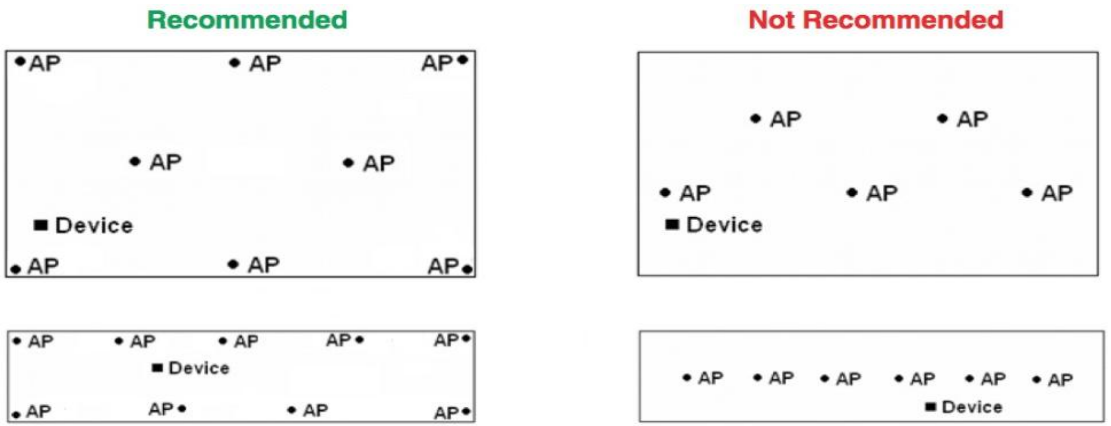
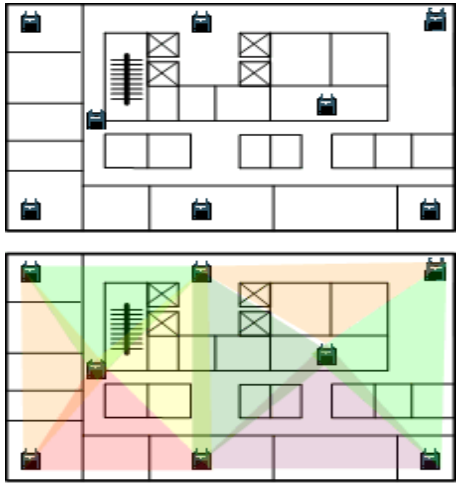
# Basic Example of Location-Aware AP Deployment

- APs may be installed along the perimeter walls as part of an effective LBS deployment
- Star or stager AP placement may be done based on physical architecture of building/Mall

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# Hyperlocation


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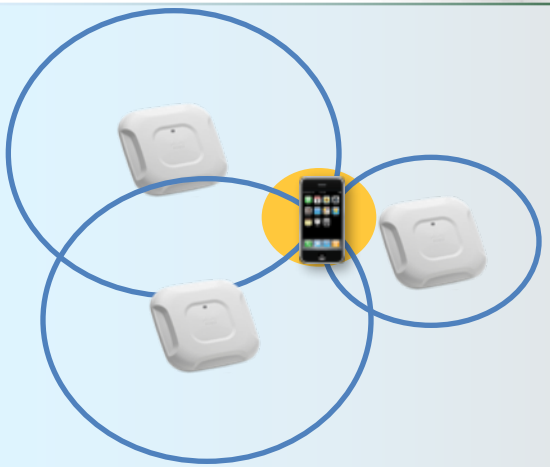
# Different Levels of Accuracy

| | | | | |
|---|---|---|---|---|
| **Location Accuracy** | 20m | 7-10m | 5-7m | 1-3m |
| **Location Type** | In-zone detection | X,Y coordinates | Optimised refresh | Highly accurate |
| **Use Cases** | Venue-level, Visitors, Dwell Time | Zone-level Correlation | Sub-zone-Level Navigation | Product Placement, Asset Management |
| **AP Requirements** | Minimum of one Cisco AP | Minimum 3 APs, Map Integration | Increased AP density FastLocate enabled | Modular APs with Hyperlocation module |

# Cisco Hyperlocation Technology & Solution

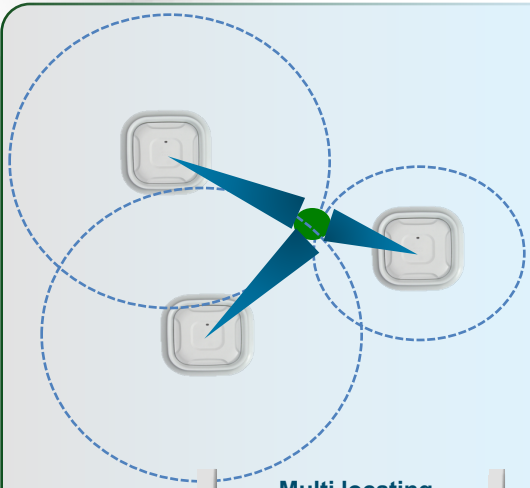
**Before:** Location approximated based on RSSI - ±5 to 10 meter accuracy

**After:** Determine direction (AoA) to client in addition to distance => up to 1 meter accuracy (50% CFD)



Room Level Accuracy | Range Inferred - Prone to errors | Only RSSI calculation

**Engage & Improve Guest Experience**



High Accuracy | Multi locating technology AoA, RSSI | Improved Calculation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# Hyperlocation Module

- Hyperlocation module wraps around AP
- 32 extra antennas to provide Angle of Arrival
  - 16 Dual-Band 2,4GHz & 5GHz
  - 16 5GHz
- The Advanced Security and Hyperlocation module includes Bluetooth capability as well


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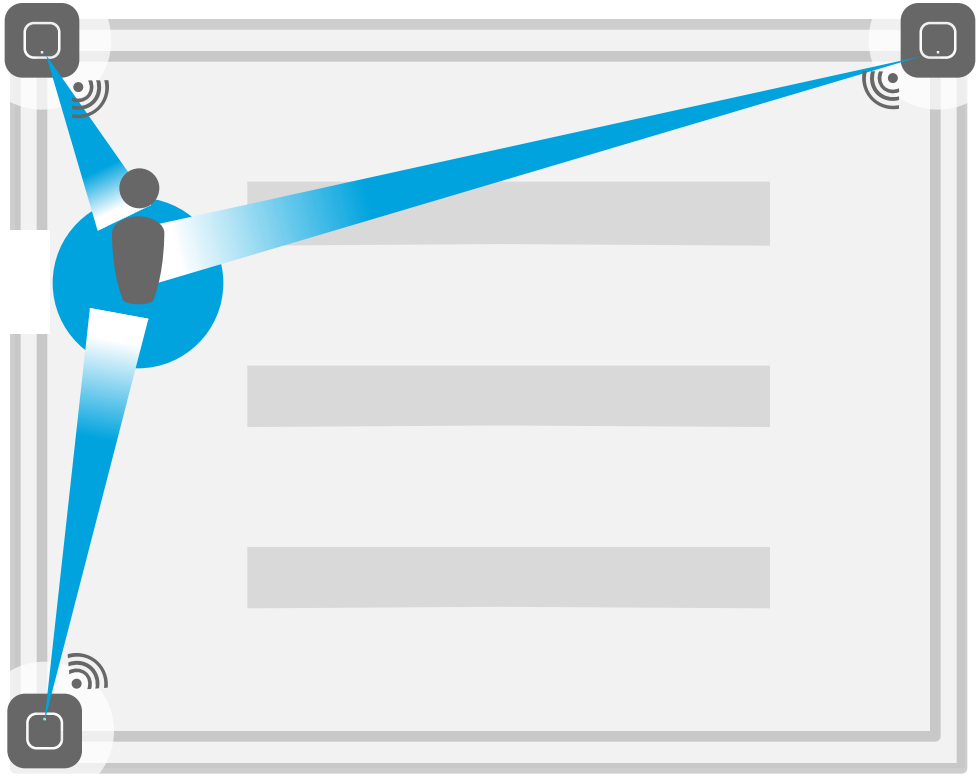
# Hyperlocation – One-Metre Location Solution

- Game changer – Indoor location
- Cisco's unique innovation
- Advanced military technology – Enterprise application
- 32 array antennas: RF, DSP, MAC

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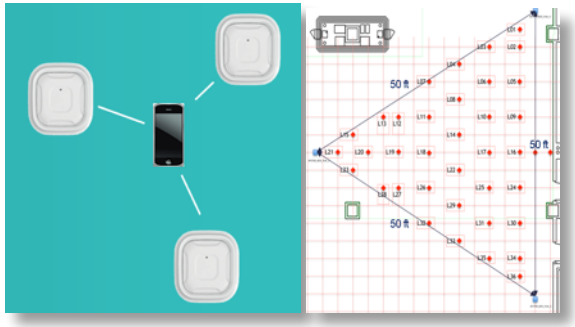
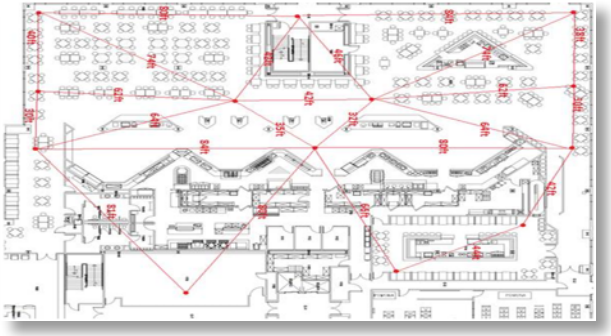
# Hyperlocation Performance




## Best Practices – 1m

- 3 APs (50 ft-triangle) or 5 APs (40x65ft-star)
- 10ft ceiling
- Client associated w/ AP, LOS to all APs
- 5 GHz @ 20 MHz, iPhone 6, S5
- Low interference, normal load
- 50% (CDF)



## Non-Standard – 2.5m

- Many APs, 1AP/2000-4000 sq ft
- 10-15 ft ceiling
- Client assoc. w/ AP, LOS to 3-5 APs
- 5 GHz @ 20 MHz, iPhone 6, S5
- Moderate interference, normal load
- 50% (CDF)

## Box Retail/ Mfg. – 2m

- 7 APs, 1AP/2800 sq ft (50 ft AP-AP)
- 15-20 ft ceiling
- 3-8 ft shelves
- Client associated with AP, LOS to 3 APs
- 5 GHz @ 20 MHz, iPhone 6, S5
- Moderate interference, normal load
- 50% (CDF); same measure of RSSI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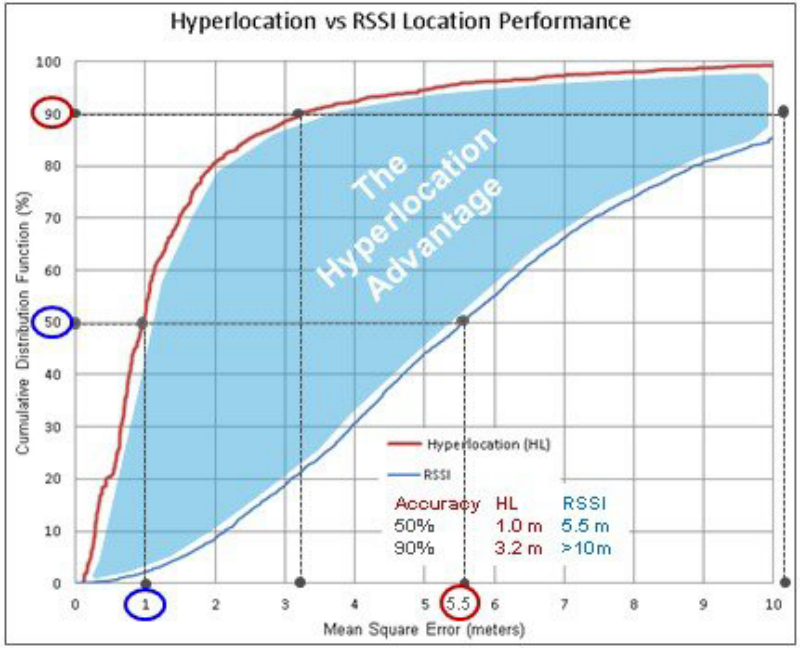
# Performance – The Hyperlocation Advantage

Example:

| | RSSI | Hyper-location |
|---|---|---|
| CDF: 50% | 5.5m | 1m |
| CDF: 90% | >10m | 3.2m |





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# Where is Data for Location Measured and Calculated?

| | Method | Data | Data Collection | Location Calculation |
|---|---|---|---|---|
| GPS | TDOA | TOA | Mobile Device | Mobile Device |
| Wi-Fi Presence | Proximity | RSSI of Probe Request | Infrastructure (AP) | Infrastructure (CMX) |
| Wi-Fi RSSI | Probe RSSI | RSSI of Probe Request | Infrastructure (AP) | Infrastructure (CMX) |
| Wi-Fi Hyperlocation | AoA | RSSI and AoA of Data Frames | Infrastructure (Hyperlocation AP) | Infrastructure (CMX) |
| Wi-Fi Location Patterning | Location Patterning | AP Beacon RSSI and MAC | Mobile Device (special chipset / driver) | Mobile Device or Infrastructure |
| BLE Beacon | Proximity | Beacon ID / RSSI | Mobile Device | Mobile Device or Infrastructure |
| BLE Beacons for Location | Multiple Proximities | Multiple Beacon IDs / RSSI | Mobile Device | Mobile Device or Infrastructure (Fingerprint) |


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# How Does Hyperlocation Work?


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# Location Calculations with Hyperlocation Module

- Hyperlocation Module and Antenna are programmed with which MAC addresses they should report for, this is based on the associated clients of “surrounding” AP’s
- Surrounding AP are based on which AP can hear a packets from the serving radio that has the Hyperlocation AP (L1 List)
- When clients are “quiet” the serving radio is interrupted to send a BAR packets to radio to awake it up.
- Location is a “*FUSION*” of the RSSI calculated location and AoA calculated location if both are available.

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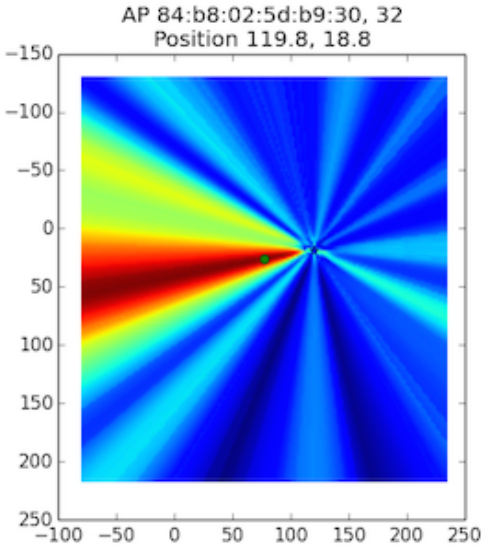
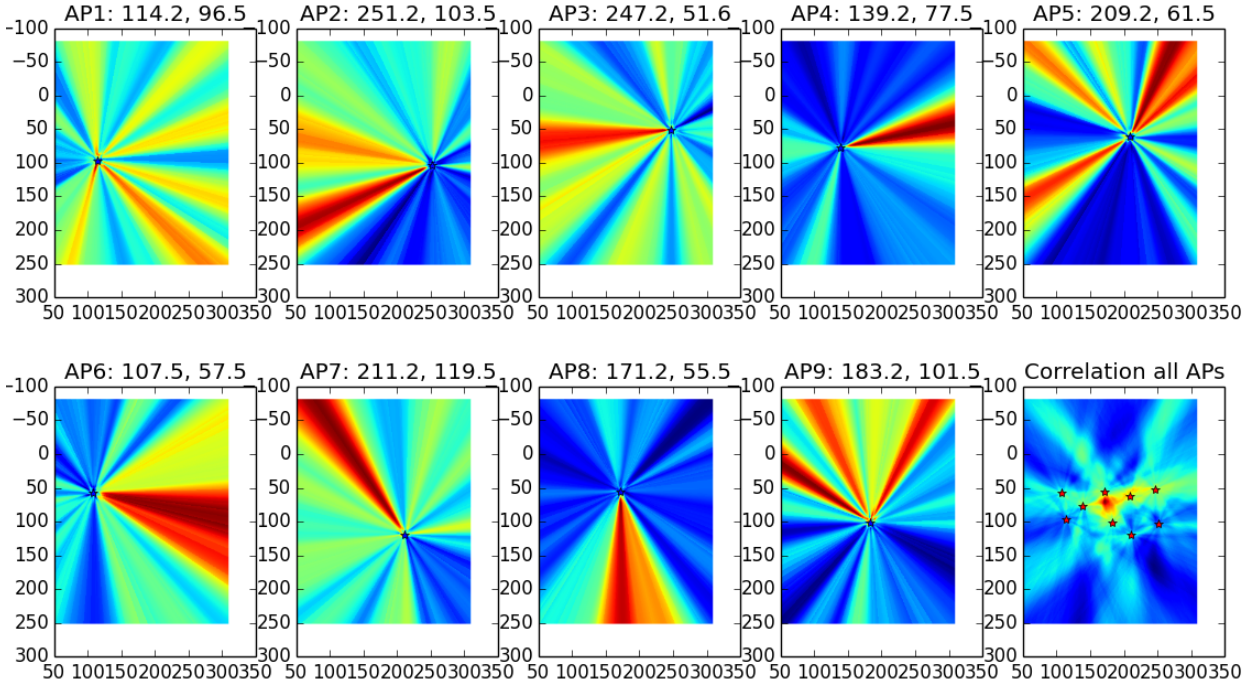
# How Does Hyperlocation Work:

## Good Signal:





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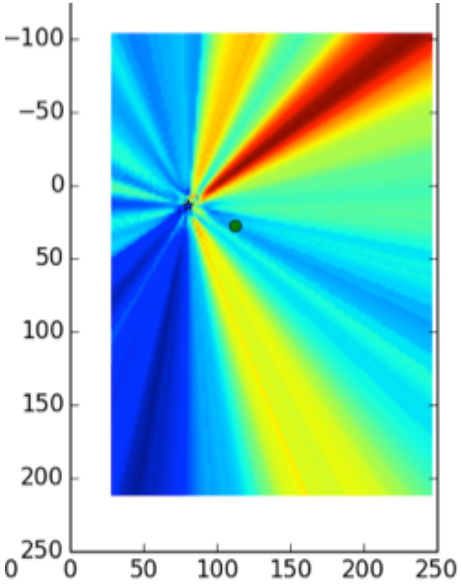
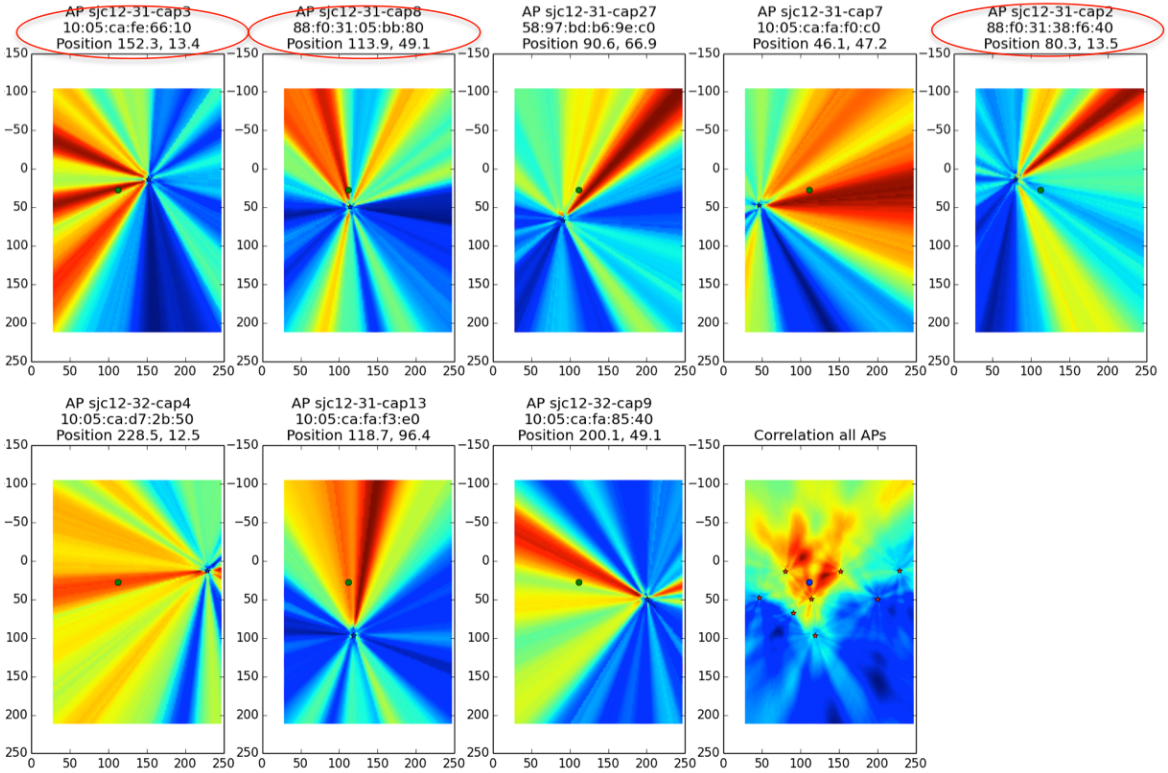
# How Does Reflection Affect Hyperlocation?

Bad Signal with

Strong Reflection





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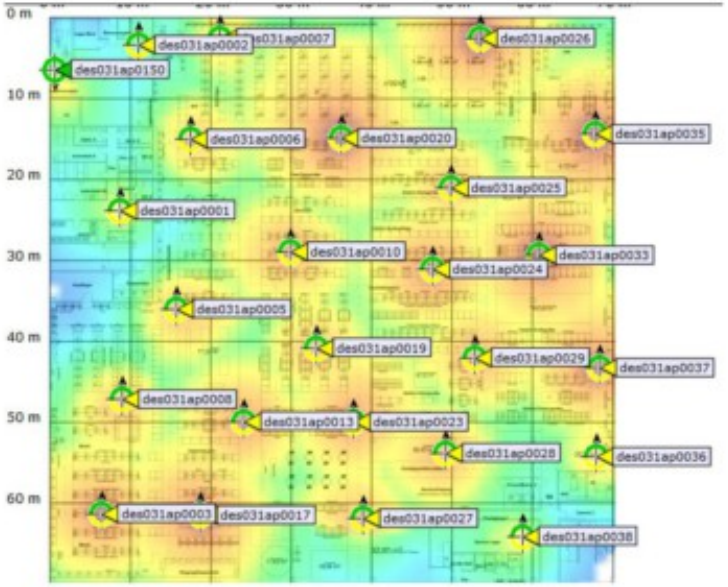
# Hyperlocation - Retail Store

- Size: 70m x 70m (4900 m2)
- 25 APs (196 m2 per AP / 16m Cell Size)

| Location Computation Frequency (s) | 10m Accuracy (%) | Average Error Distance (m) | 90% Accuracy Error Distance (m) | 75% Accuracy Error Distance (m) | 50% Accuracy Error Distance (m) |
|---|---|---|---|---|---|
| 2.7 | 100.0 | 0.71 | 1.33 | 0.68 | 0.54 |
| 2.8 | 100.0 | 0.91 | 1.72 | 1.20 | 0.77 |
| 5.1 | 100.0 | 1.68 | 2.13 | 1.47 | 1.46 |
| 3.4 | 100.0 | 1.33 | 1.69 | 1.64 | 1.45 |





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# Hyperlocation - Retail US

## AP to AP: 50’ (15m)

| Client | Location Computation Freq | Average Error Distance (m) | 90% Accuracy Error Distance (m) | 75% Accurac Error Distanc (m) | Nam |
|---|---|---|---|---|---|
| ke's iPhone 6 us | 4.90 | 0.20 | 0.33 | 0.24 | st0101-t12-s5-5 |
| ke's iPhone 6 us | 5.30 | 1.08 | 1.63 | 1.31 | st0101-t11-s5-5-2 0.99 |
| ke's iPhone 6 us | 5.60 | 1.44 | 2.17 | 1.79 | st0101-t11-s5-5 1.18 |
| ke's iPhone 6 us | 5.40 | 1.60 | 2.26 | 1.97 | st0101-t10-s5-5 |
| ke's iPhone 6 us | 4.70 | 0.87 | 1.29 | 1.16 | st0101-t9-s5-5 0.77 |
| ke's iPhone 6 us | 3.70 | 2.94 | 5.18 | 3.97 | st0101-t8-s5-5 |
| ke's iPhone 6 us | 4.40 | 1.16 | 2.24 | 1.45 | st0101-t7-s5-5 0.89 |
| ke's iPhone 6 us | 4.70 | 0.33 | 0.50 | 0.45 | st0101-t6-s5-5 0.28 |
| ke's iPhone 6 us | 5.60 | 0.92 | 1.55 | 1.03 | st0101-t5-s5-5 |
| ke's iPhone 6 us | 5.60 | 1.21 | 1.90 | 1.45 | st0101-t4-s5-5 1.13 |
| | 4.99 | 1.18 | 1.91 | 1.48 | st0101-t3-s5-5 Average 1.01 |
| | | | | | st0101-t2-s5-5 |
| | | | | | st0101-t1-s5-5 |

## AP to AP: 70’ (21m)

| Location Computation Frequency (s) | 10m Accuracy (%) | Average Error Distance (m) | 90% Accuracy Error Distance (m) | 75% Accuracy Error Distance (m) | 50% Accuracy Error Distance (m) |
|---|---|---|---|---|---|
| 4.2 | 100 | 2.07 | 3.06 | 2.77 | 2.23 |
| 3.3 | 100 | 2.16 | 2.57 | 2.51 | 2.51 |
| 2.5 | 100 | 2.47 | 4.41 | 2.64 | 2 |
| 3.5 | 100 | 1.36 | 1.61 | 1.59 | 1.35 |
| 4.6 | 100 | 1.68 | 1.82 | 1.78 | 1.72 |
| 3.7 | 100 | 0.45 | 0.71 | 0.62 | 0.4 |
| 4.5 | 100 | 1.91 | 3.21 | 1.85 | 1.66 |
| 4.2 | 84.4 | 7.56 | 11.01 | 9.15 | 6.7 |
| 5 | 100 | 0.81 | 1.14 | 1 | 0.73 |
| 4.1 | 100 | 1.19 | 1.64 | 1.55 | 1.24 |
| 4 | 100 | 0.98 | 1.33 | 1.11 | 0.71 |
| 3.6 | 100 | 2.06 | 2.91 | 2.39 | 1.9 |
| 4.4 | 100 | 2.27 | 2.62 | 2.33 | 2.14 |
| 3.97 | 98.80 | 2.07 | 2.93 | 2.41 | 1.95 |

[redacted]


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# Production Retail Store

- Approx. 95,000 sq-ft.
- 13 ft ceiling, AP-AP distance 50ft

| 5GHz - iPhone 6 Plus | | | | | |
|---|---|---|---|---|---|
| Location | Location Computation Freq | Average Error Distance (m) | 90% Accuracy Error Distance (m) | 75% Accuracy Error Distance (m) | 50% Accuracy Error Distance (m) |
| L1 | 4.90 | 0.20 | 0.33 | 0.24 | 0.11 |
| L2 | 5.30 | 1.08 | 1.63 | 1.31 | 0.99 |
| L3 | 5.60 | 1.44 | 2.17 | 1.79 | 1.18 |
| L4 | 5.40 | 1.60 | 2.26 | 1.97 | 1.49 |
| L5 | 4.70 | 0.87 | 1.29 | 1.16 | 0.77 |
| L6 | 3.70 | 2.94 | 5.18 | 3.97 | 2.48 |
| L7 | 4.40 | 1.16 | 2.24 | 1.45 | 0.89 |
| L8 | 4.70 | 0.33 | 0.50 | 0.45 | 0.28 |
| L9 | 5.60 | 0.92 | 1.55 | 1.03 | 0.74 |
| L10 | 5.60 | 1.21 | 1.90 | 1.45 | 1.13 |
| | 4.99 | 1.18 | 1.91 | 1.48 | 1.01 |

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# Average Testing Summary Compare

- The table below represents the average testing results of stores with the same AP separation. The summary results are representative of 5Ghz only and exclude a couple outlier results where Cisco recommended a physical AP location change.

| Accuracy % | 50’ Store | 70’ Store | Delta 50’ vs 70’ |
|---|---|---|---|
| 90% | 2.65m | 3.22m | ↑ 0.57m |
| 75% | 1.88m | 2.70m | ↑ 0.82m |
| 50% | 1.27m | 2.14m | ↑ 0.87m |


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# Hyperlocation-Specific RF Design


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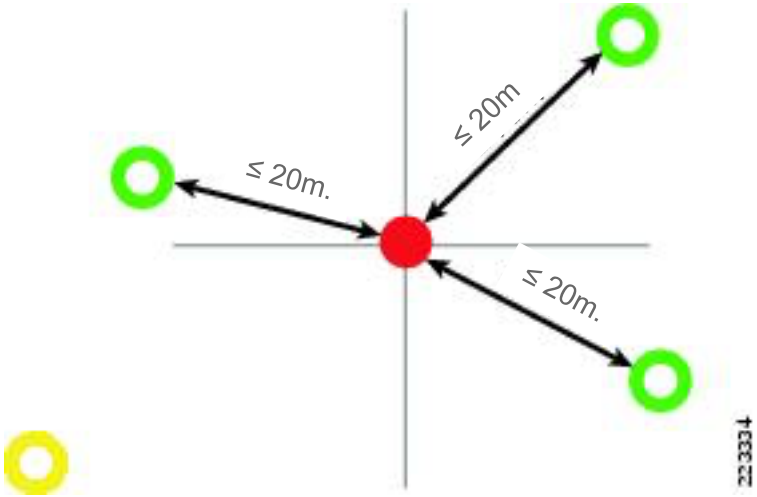
# Line of Sight to Minimum 3 APs

- 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 like a pillar, column, advertisement boards.
- Distance 12 – 20m.
- -75 dBm Client RSSI on 3 APs
- In some cases however, inter-access point spacing below 12m may be necessary to satisfy the requirements of some applications for high signal strength thresholds, especially in environments where high path loss is present.





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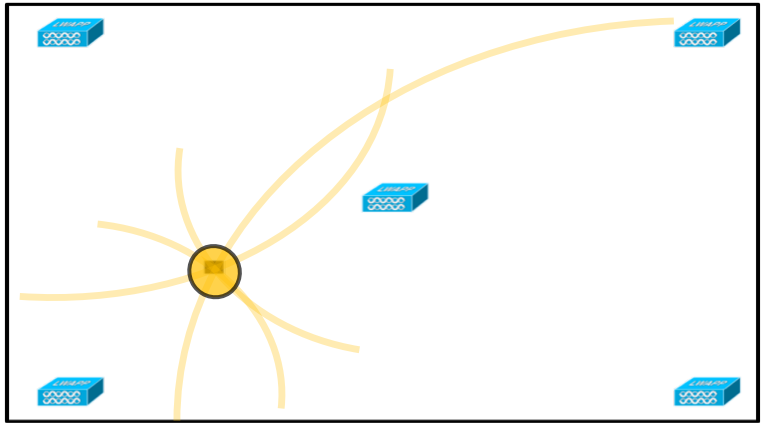
# Factors Affecting Location Accuracy and Frequency

## RF uncertainty

- AP Placement and RF environment
- Noise present in the RF environment
- Short-term physical obstructions between the AP and client

## Client behaviour

- Probing occurs when a client is discovering the network and, once connected, at regular intervals
- Frequency at which the client transmits probe requests

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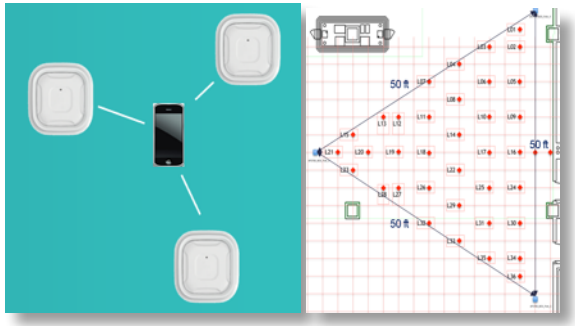
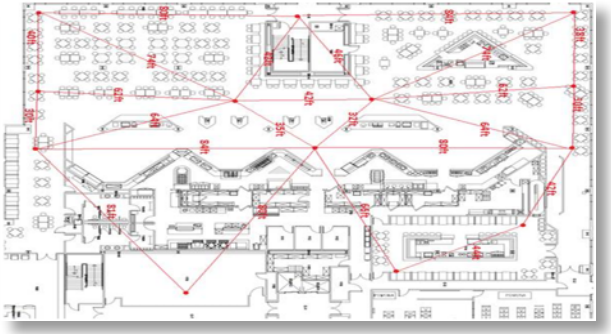
# Hyperlocation Performance




## Best Practices – 1m

- 3 APs (15m-triangle) or 5 APs (12x20m-star)
- 3m ceiling
- Client associated w/ AP, LOS to all APs
- 5 GHz @ 20 MHz, iPhone 6, S5
- Low interference, normal load
- 50% (CDF)



## Non-Standard – 2.5m

- Many APs, 1AP/185-370 sqm
- 3 – 4.5 m ceiling
- Client assoc. w/ AP, LOS to 3-5 APs
- 5 GHz @ 20 MHz, iPhone 6, S5
- Moderate interference, normal load
- 50% (CDF)

## Box Retail/ Mfg. – 2m

- 7 APs, 1AP/230 sqm (15m AP-AP)
- 4.5 - 6 m ceiling
- 1 - 2.5 m shelves
- Client associated with AP, LOS to 3 APs
- 5 GHz @ 20 MHz, iPhone 6, S5
- Moderate interference, normal load
- 50% (CDF); same measure of RSSI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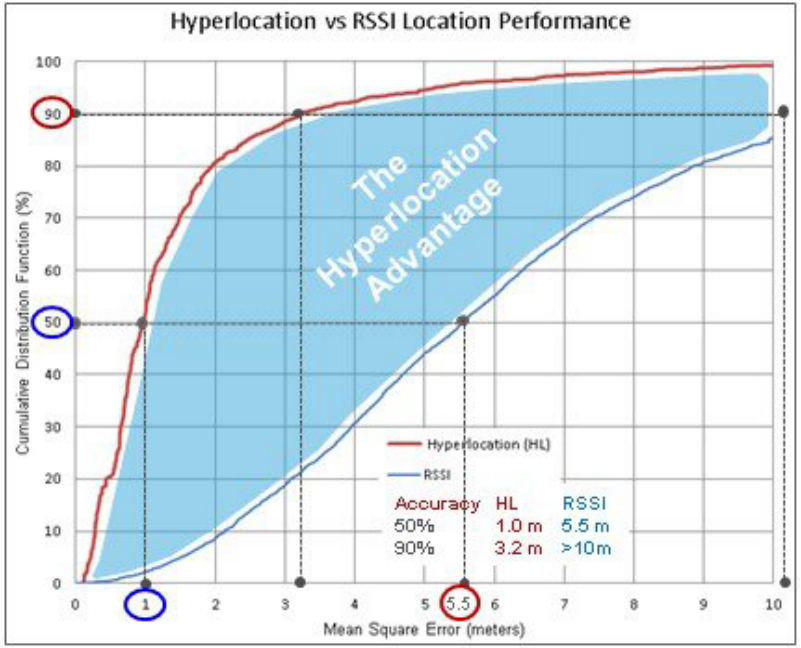
# Performance – The Hyperlocation Advantage

Example:

| | RSSI | Hyper-location |
|---|---|---|
| CDF: 50% | 5.5m | 1m |
| CDF: 90% | >10m | 3.2m |





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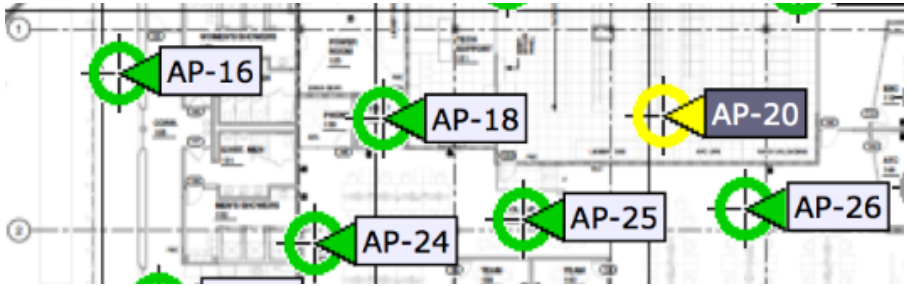
# Hyperlocation AP Map Placements in Prime

Install the APs on the ceiling grid, if possible try to align Hyperlocation arrow on AP so they all are pointing in the same orientation



In this release all APs be in the same map need to be Hyperlocation capable.

Best Practice: Mount APs in Default Orientation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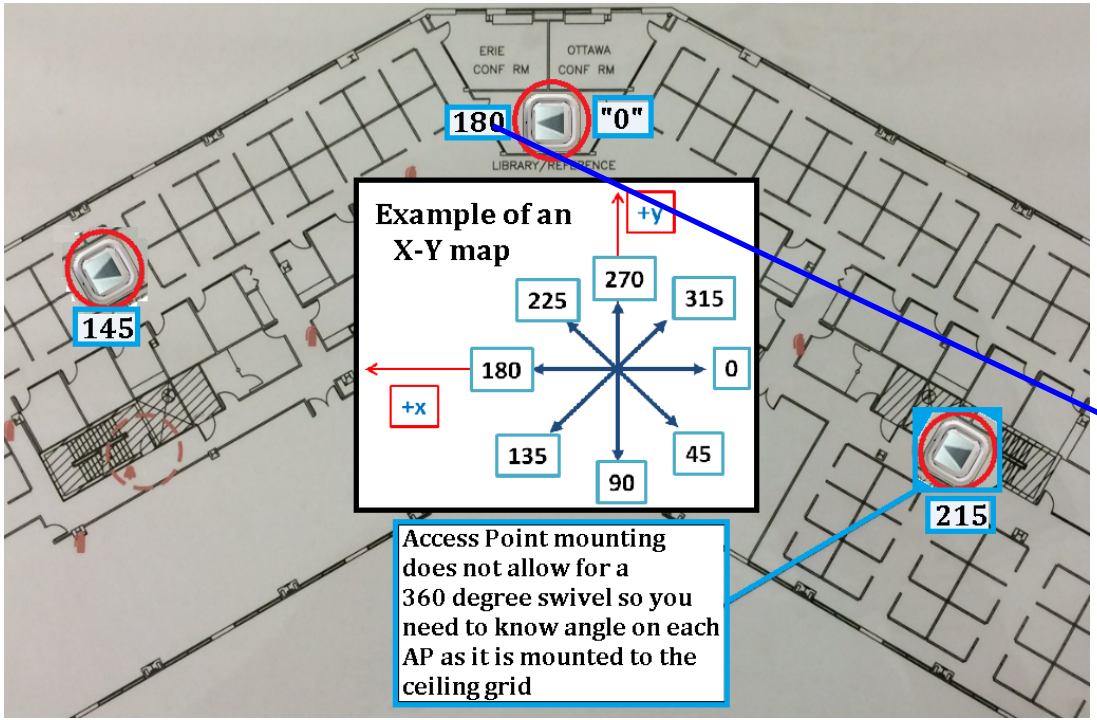
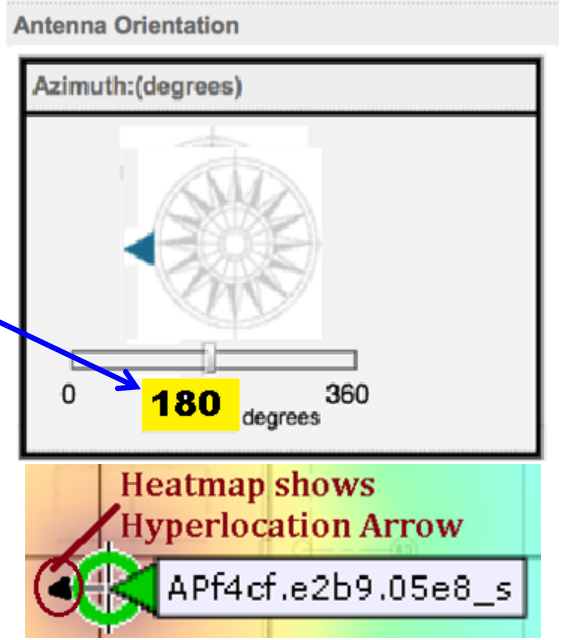
# When the Building Isn't a Perfect Square…




This building has three different angles so each AP has its own azimuth on the map 145, 180 and 215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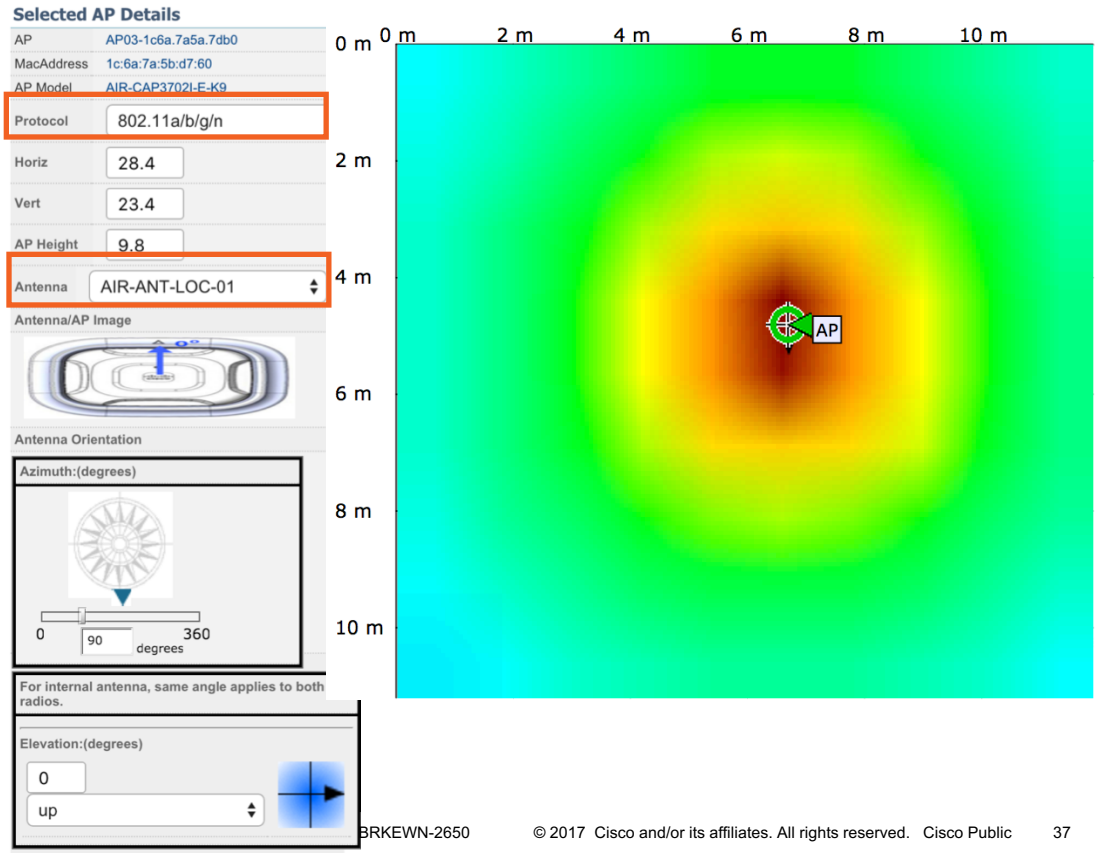
# Hyperlocation – AIR-ANT-LOC

- Default: Ceiling Mount
  - Logo facing DOWN
  - Ethernet Ports pointing SOUTH
  - Arrow on ANT pointing SOUTH
  - Arrow on Map pointing SOUTH

  - Azimuth: 90°
  - Elevation: 0° up

- AP height defaults to ceiling height





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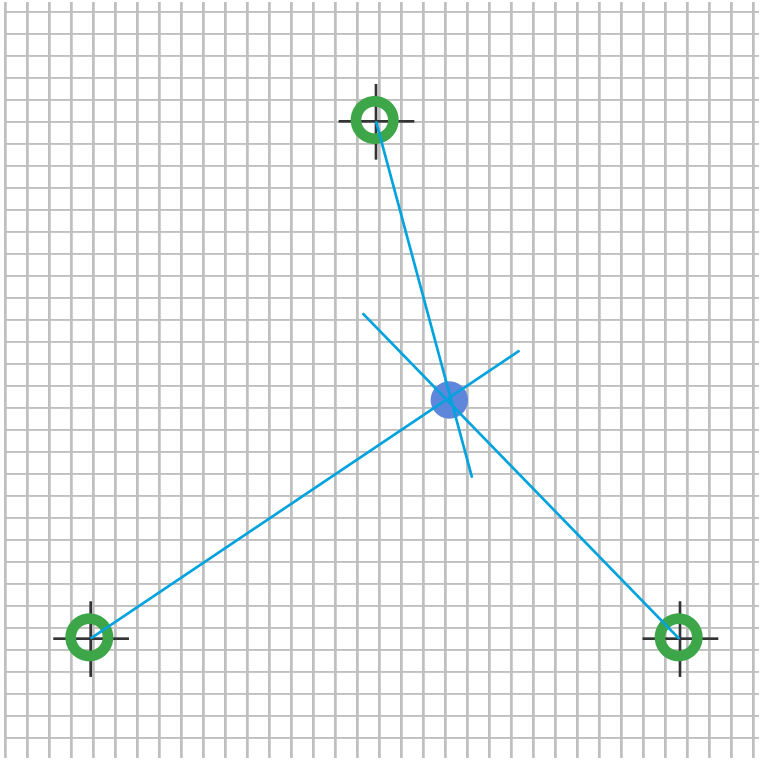
# AP Positioning Errors are Affecting Accuracy

- How good are your floor plans?
- Do you know your exact AP Positions?
  - Often about 1-2 m off
- Do you know your AP Orientation?
  - Did not matter before Hyperlocation

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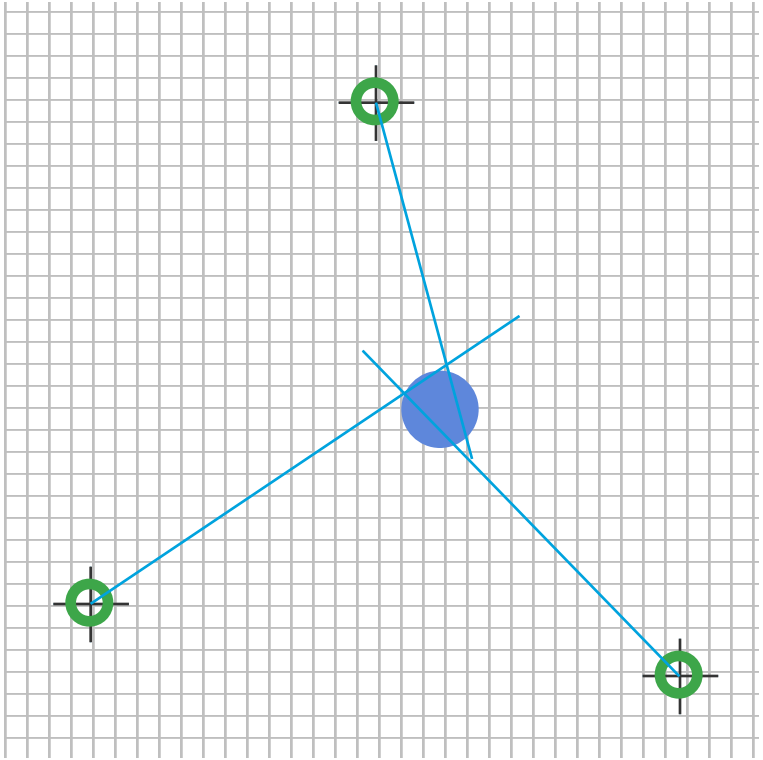
# Inaccurate AP Position

- AP Position on Map wrong by 1m

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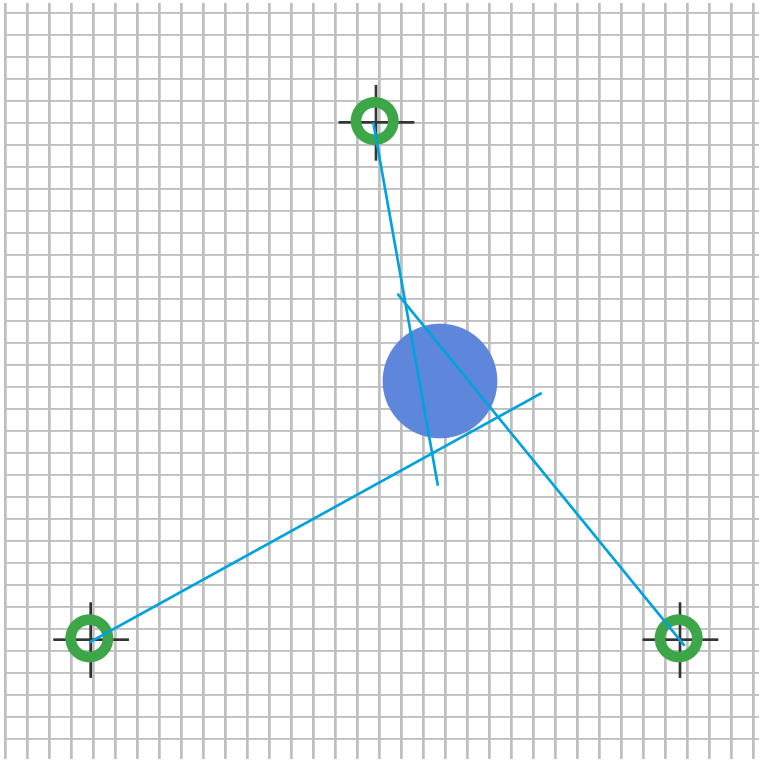
# Inaccurate AP Orientation

- AP orientation on Map wrong by 5°
- at 10 m about 1 m divergence

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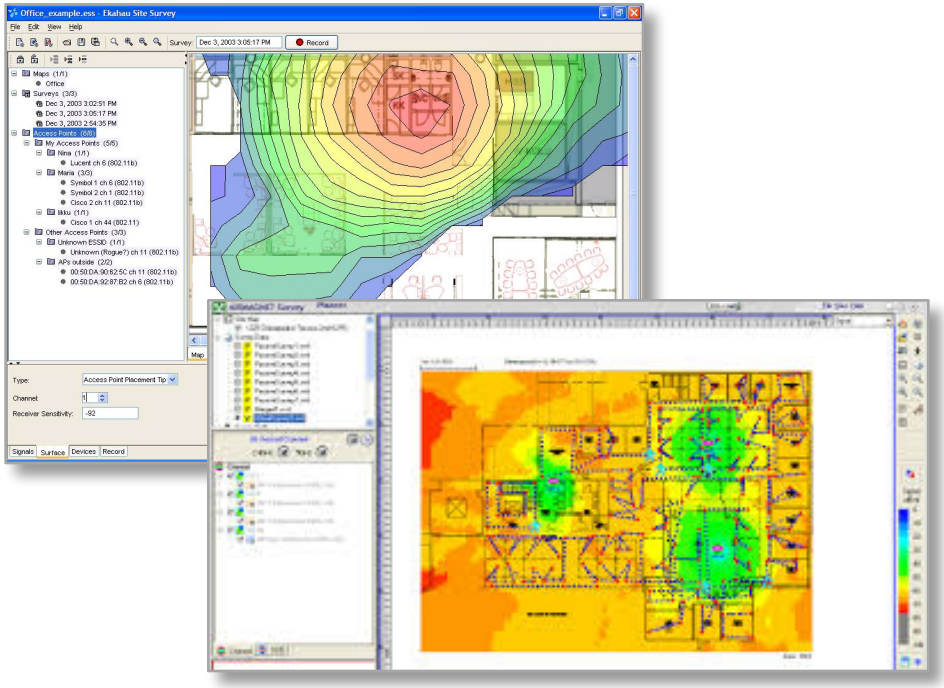
# Rule of Thumb for Site Survey

- Example for Predictive Site Survey with Ekahau or AirMagnet Planner
  - Design for 5 GHz
  - Signal Strength >= -67 dBm
  - SNR >= 20 dB
  - Number of APs = 3
  - Packet Loss = 10%
  - Transmit Power 10mW
- Rule of thumb is 1 AP per:
  - 460 m2 (5000 sq ft) for Data
  - 230 m2 (2500 sq ft) for Voice / Location
- **Line of Sight? – so be careful**





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# Verify Hyperlocation


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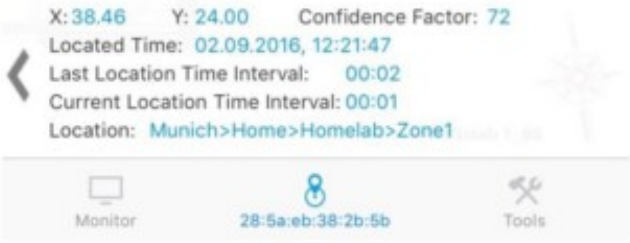
# Verify Installation

- Connect a client
- Verify Location Metrics
  - Hyperlocation Rate should not be 0
- Use iPhone with CMX Admin App





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# Check Hyperlocation Grouping

AP01#show capwap rm hyperlocation level1-list

```
AP01-7db0#show capwap rm hyperlocation level1-list
Level-1 List for 2.4GHz Band
-----------------------------
Channel   Width    Serving MAC     Max Clients
-------   -----   ---------------  -----------
      1       0   1c6a.7a68.8ce0            18
     11       0   1c6a.7a5b.d760            18
      1       0   1c6a.7a68.8d00            18

Level-1 List for 5GHz Band
-----------------------------
Channel   Width    Serving MAC     Max Clients
-------   -----   ---------------  -----------
     44       1   1c6a.7a68.8d00            18
    100       1   1c6a.7a5b.d760            18
    132       1   1c6a.7a68.8ce0            18
```


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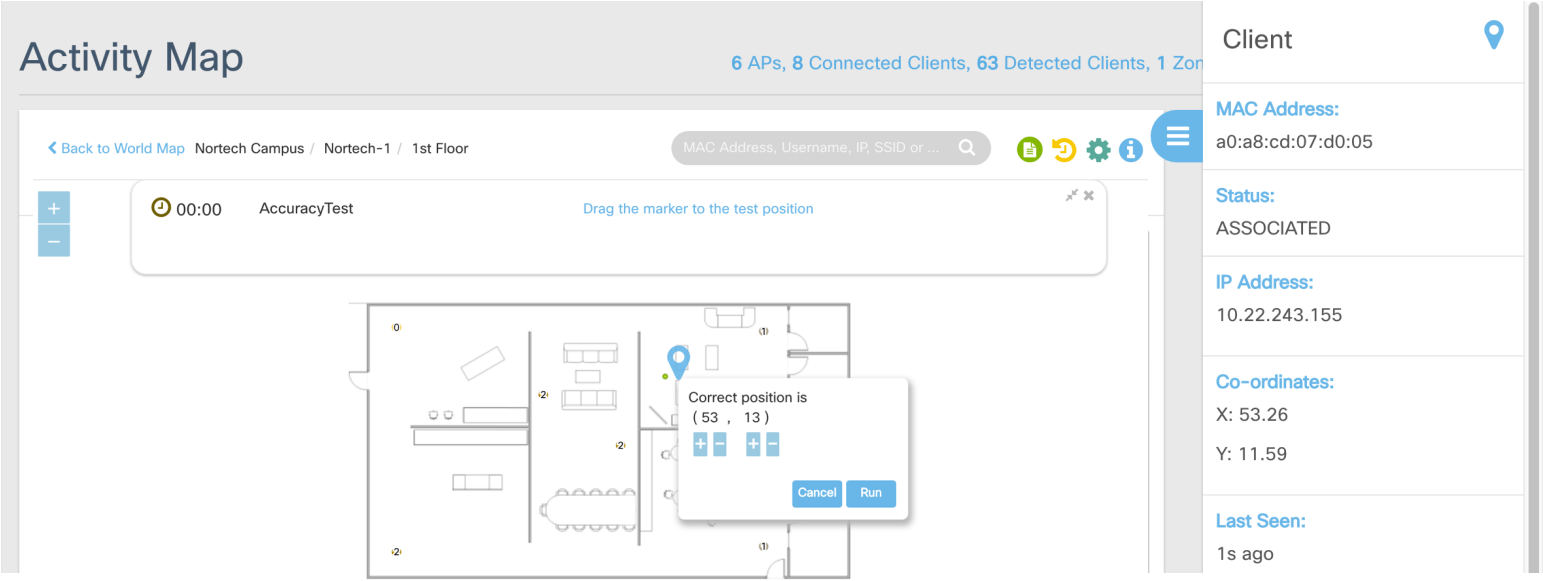
# How to Test Accuracy?

- Use the build in tool





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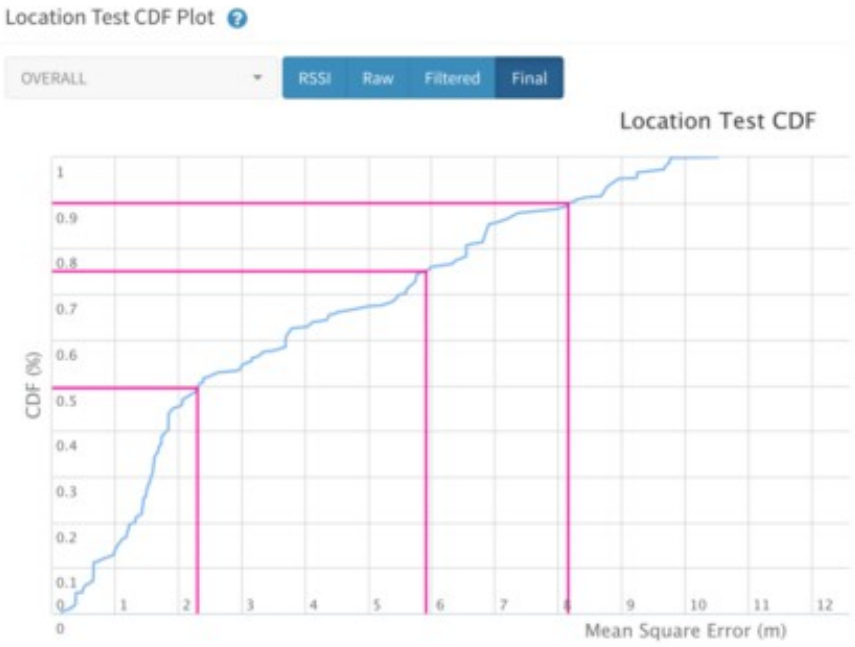
# Accuracy Reports

| Avg Err Dist (m) | 50% Acc | 90% Acc |
|---|---|---|
| 2.71 | 2.29 | 5.44 |
| 4.51 | 4.35 | 8.74 |
| 3.63 | 1.83 | 6.54 |
| 1.75 | 1.59 | 3 |
| 5.72 | 5.75 | 9.66 |





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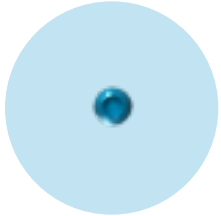
# Confidence Factor

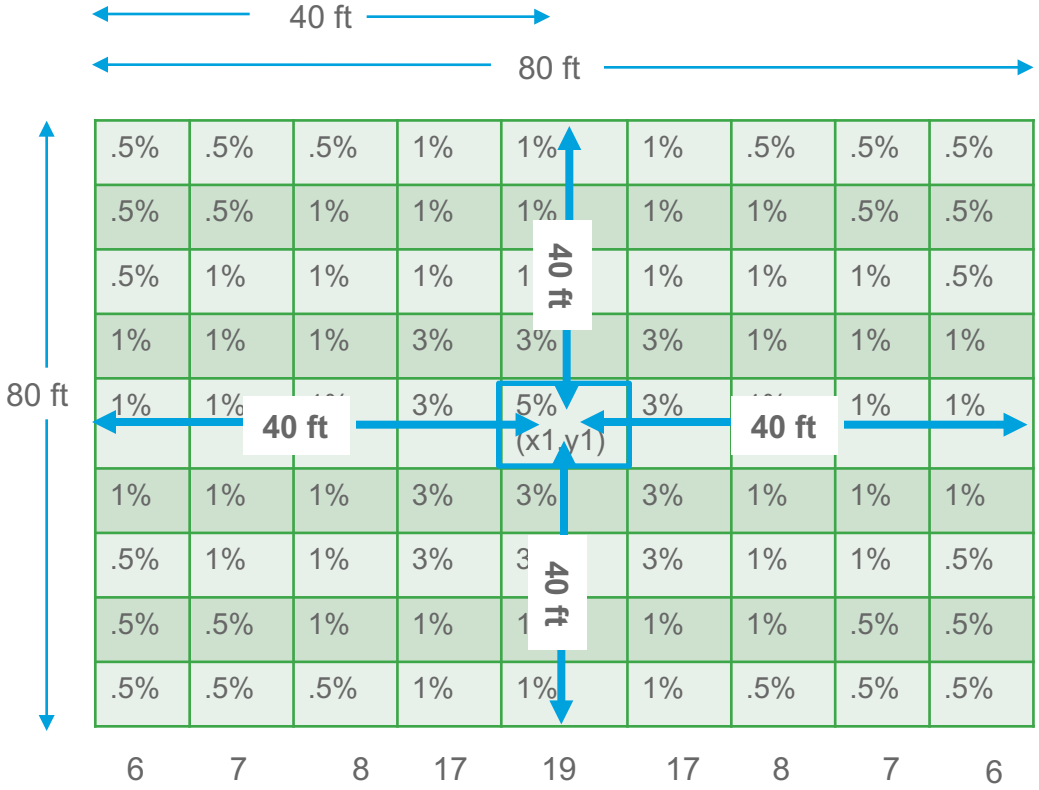
- 95% Confidence Square



```
- mapCoordinate: {
      x: 40.836765,
      y: 19.507086,
      z: 0,
      unit: "FEET"
  },
  currently Tracked: true,
  confidenceFactor: 40.
```

0

- Error = 40 ft (12,2 m)





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# CMX Zone Design Best Practice


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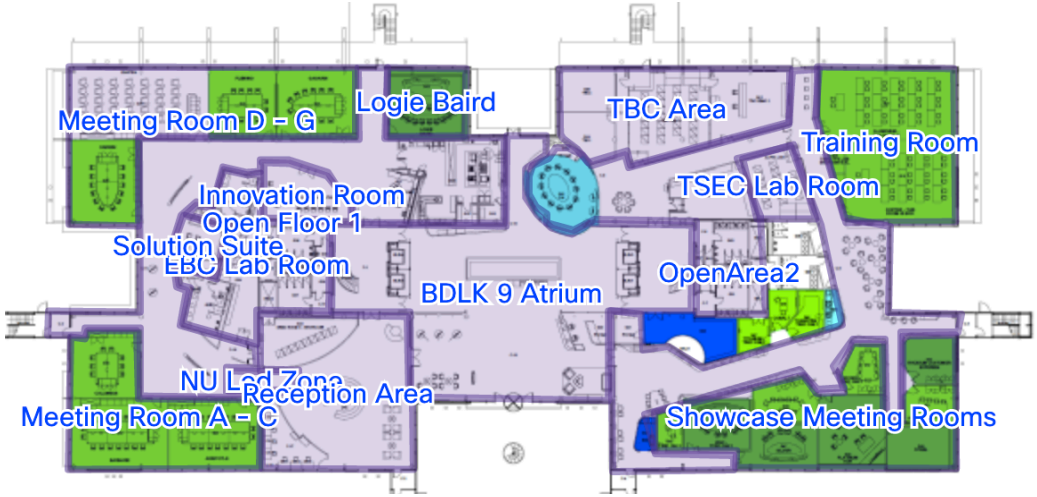
# What is a Zone?

- Area (Polygon) on the map to subdivide a floor to
  - generate notifications
  - count devices
  - measure fill levels
  - calculate dwell times





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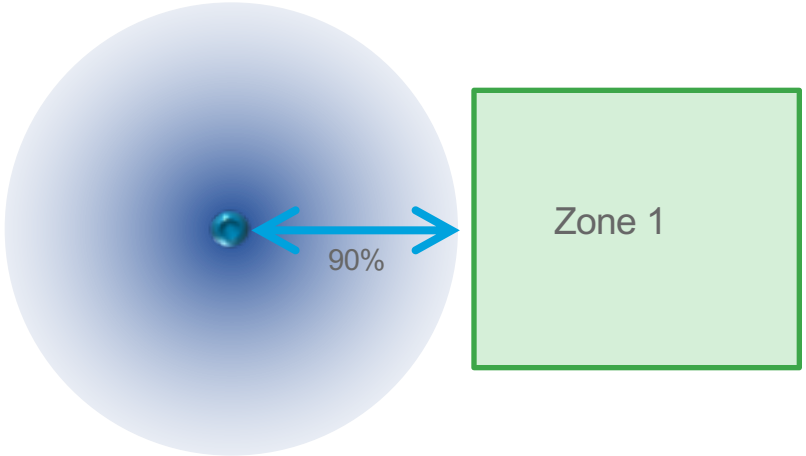
# Zone Design

- Size and Separation should match accuracy (90% accuracy distance)
- Not possible to suggest absolute sizes and distances
- Absolute numbers depend on achieved location accuracy





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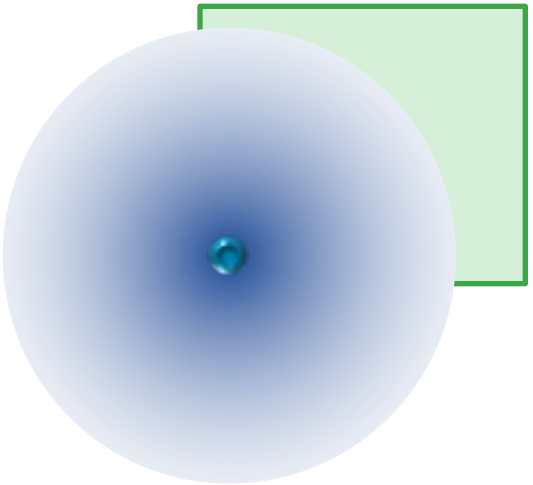
# Zone Design

- Size and Separation should match accuracy
- Much larger than “90% accuracy” distance



Problem: **Zone too small**
Device in Zone 1
but only ¼ of the 90% in the Zone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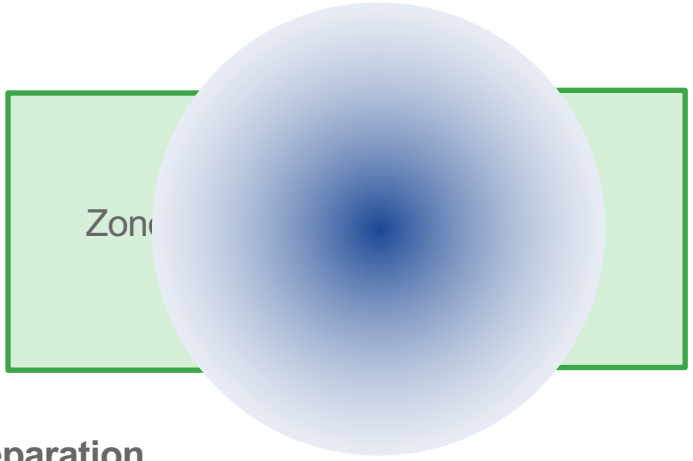
# Zone Design

- Size and Separation should match accuracy
- Much larger than “90% accuracy” distance
- About “90% accuracy” apart from each other




Problem: **Not enough separation**
Device in Zone 1
but high probability to be located in Zone 2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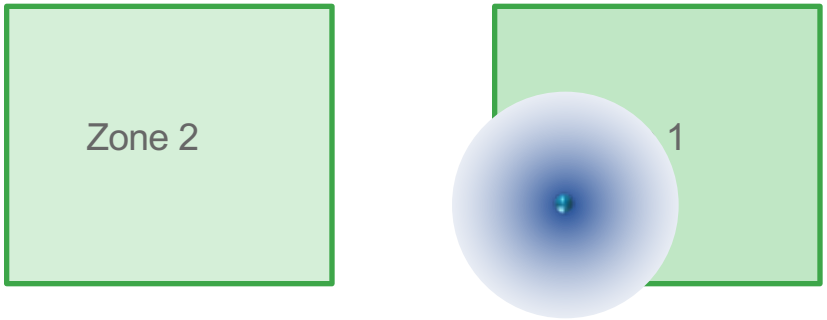
# Zone Design – Better Accuracy

- Better Accuracy allows smaller zones and less separation




Good Separation and Zone Size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# Virtual Bluetooth Beacons


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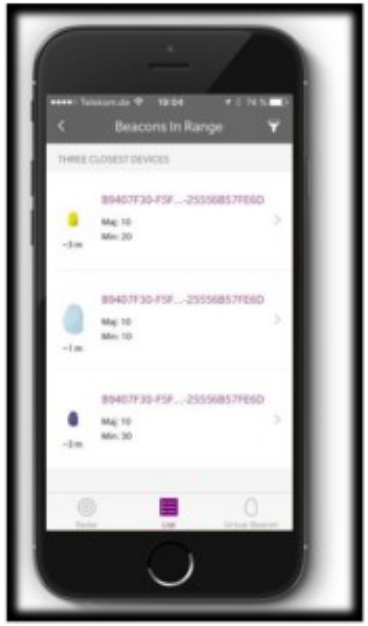
# BLE Beacon for Proximity Messaging and Location

- What is transmitted?
  - Company
    **UUID**: b9407f30-f5f8-466e-aff9-25556b57fe6d
  - Building / Store
    **Major**: 0 - 65535
  - Location / Item
    **Minor**: 0 - 65535

  - Eddystone-URL and Eddystone-TLM



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# Beacon Point

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# BEACON POINT - Cisco Virtual Beacon

## Virtual Beacons

Scalable → Sustainable → Enterprise Grade


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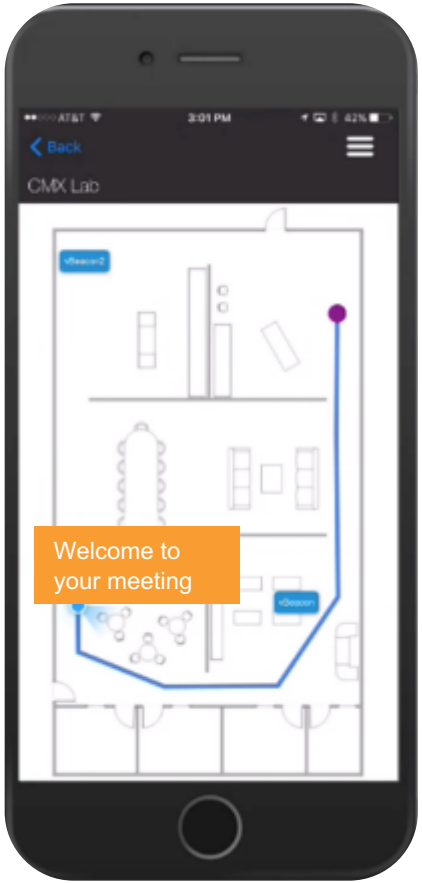
# Hand & Glove Use Cases




**Wayfinding/ Navigation**

Enable an accurate Blue dot on a map

**Proximity Messaging/Alerts**

Location Aware notifications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# PHYSICAL VS VIRTUAL BEACON: HOW TO MOVE A BEACON

1. Drive to a location
2. Find the beacon
3. Move the beacon, replace batter, replace, …

1. Click on a beacon & Move it.

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# Beacons @ San Francisco Terminal 3 – Operational Nightmare

*Multiple Beacons within feet of each other*

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# Virtual Beacon – Why is it Better?

**Guidance**
- Overlay
- PoE power/Daisy Chain
- Height ≤ 15 ft
- 40-60 ft separation
- Phone: App & BLE on

**Proximity Engagement**

**Turn-by-Turn Navigation**

- Create multiple Virtual Beacons
- Network Based & Managed
- Remotely Reconfigurable; Add or move beacons with a click
- Eliminate batteries
- Eliminates site surveys with advanced machine learning
- Operational simplicity
- Accuracy (< 3m)
  Latency (< 3 s)


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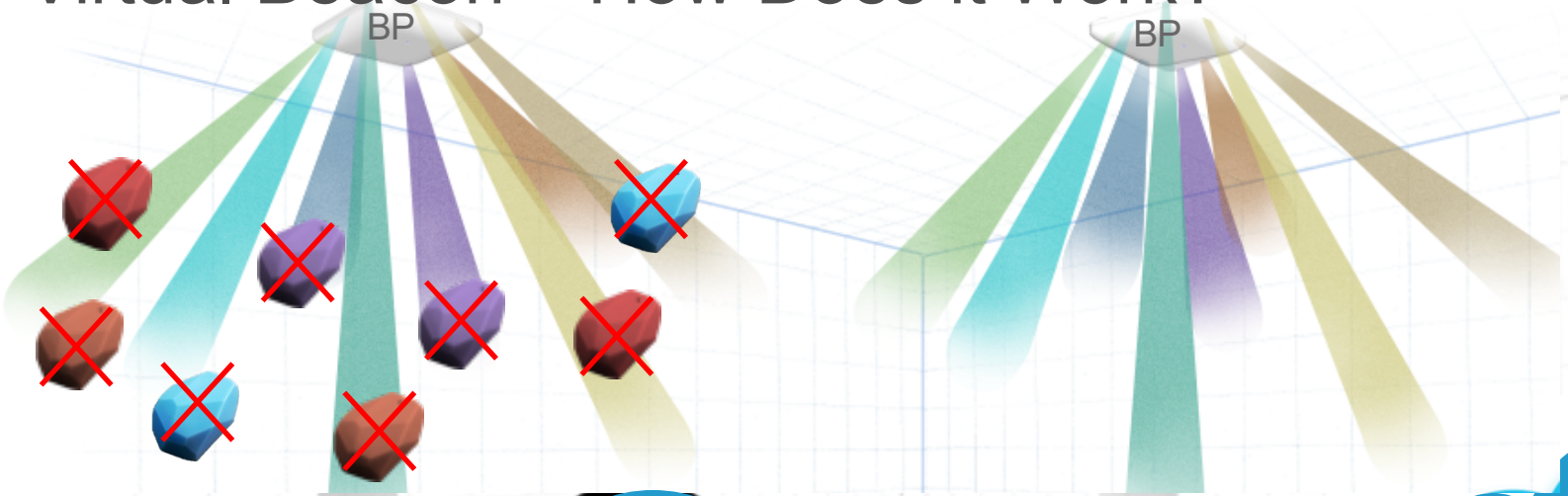
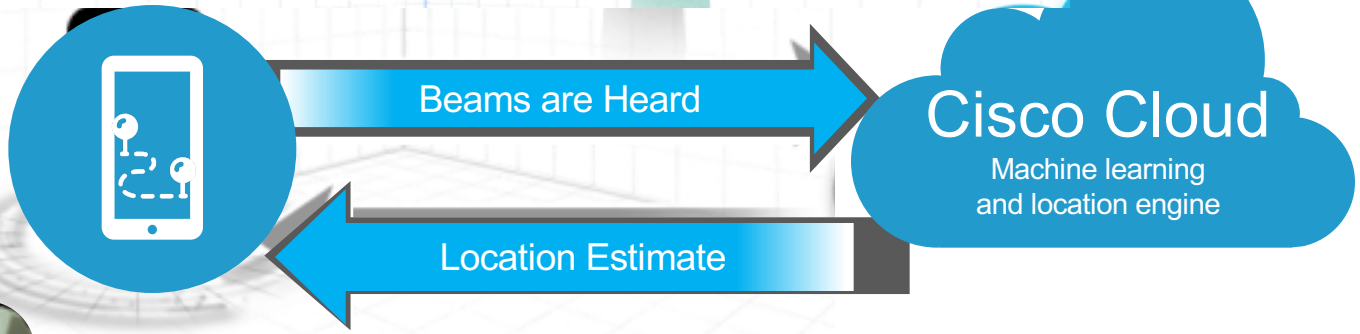
# Virtual Beacon – How Does it Work?



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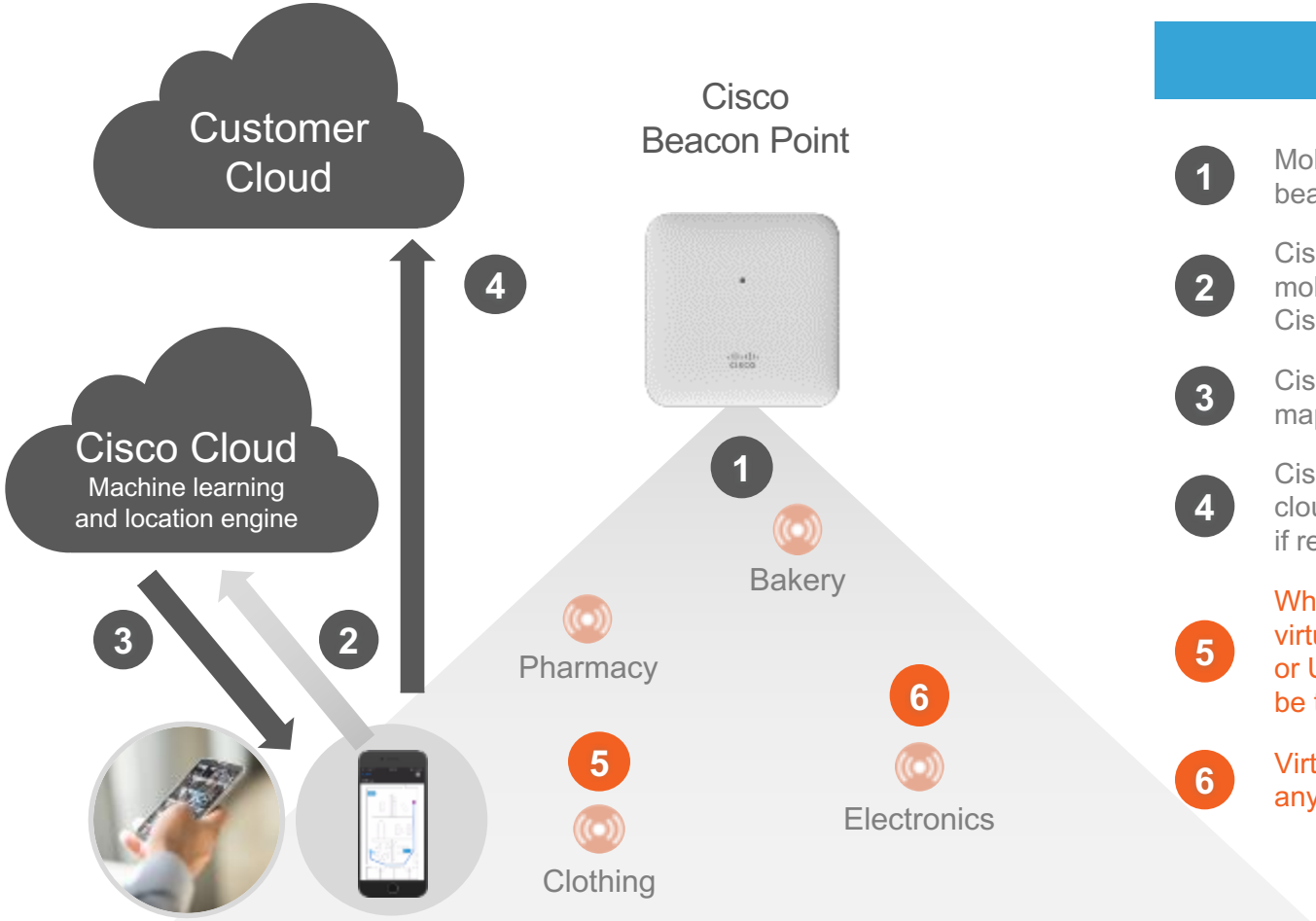


Mobile app with Cisco SDK

# How It Works

1. Mobile device listens to the BLE beacons from 2-3 Beacon Points
2. Cisco SDK (integrated into the mobile app) sends information to the Cisco cloud (via WiFi or 3/4G)
3. Cisco Cloud sends location & map information to the mobile app.
4. Cisco cloud interacts with customer cloud for user, location and content if required
5. When users are in proximity of a virtual beacon, custom notifications or URLs can be sent or actions can be taken
6. Virtual Beacons can be created anywhere in the coverage area


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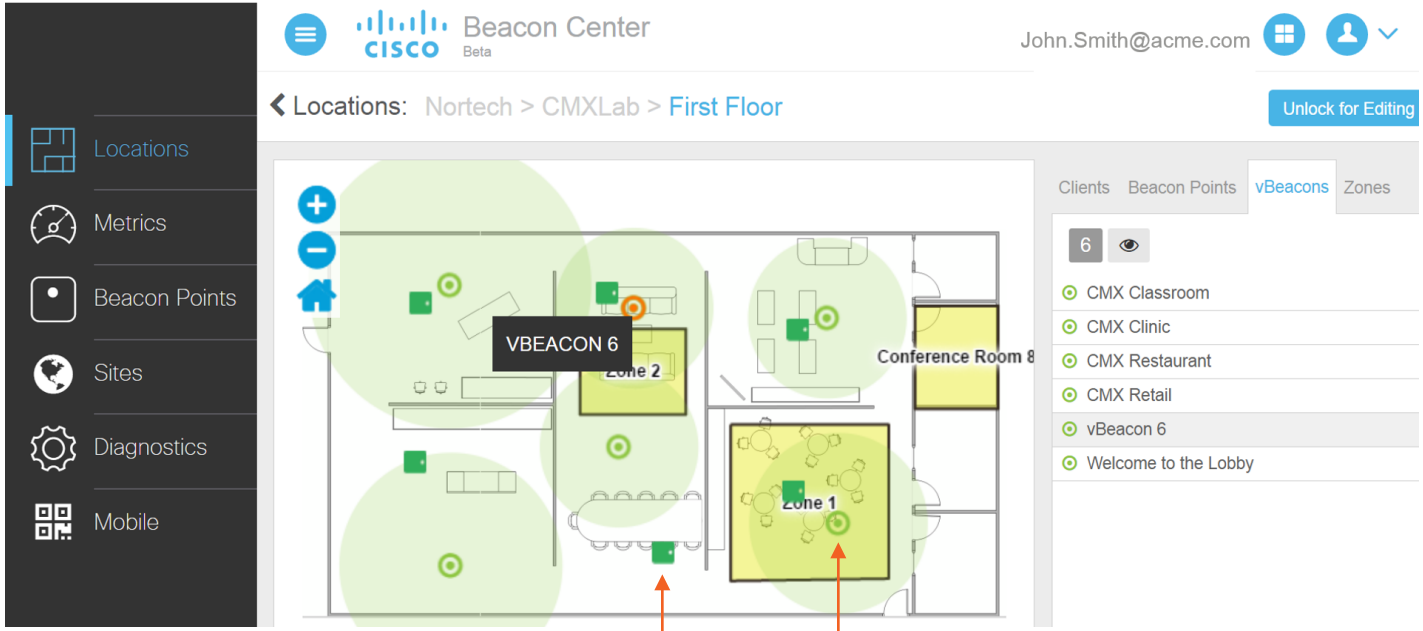
# Simplify Beacons – CMX Cloud Beacon Centre




Beacon Point

Virtual Equivalent of a physical BLE Beacon

Drag and Drop Virtual Beacons

Create Proximity Message

Engagement Metrics

Manage Beacon Points

Machine Learning Across Device Types

http://www.cisco.com/go/cmx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# Cisco Point of View - Wi-Fi and BLE

| Use Cases | Wi-Fi | | BLE | |
|---|---|---|---|---|
| | Triangulation | Hyperlocation | Physical | Virtual |
| Presence Analytics - Passer-by, Conversion, Dwell Times | ✓ | | | |
| Geofence - Alerts | ✓ | ✓ | | |
| Location Analytics - Zone Based Position, Footfall, Traffic Heatmap, Path and Correlation | ✓ | ✓ | | |
| Location Analytics - Wait/Queue times | | ✓ | | |
| Proximity - Messaging, Engagement | | | ✓ | ✓ |
| Indoor Wayfinding/Navigation (“Turn by Turn”) | | | | ✓ |

*Some use cases can be achieved using multiple technologies. Proximity Messaging, Engagement and Indoor wayfinding/navigation use cases require a mobile app


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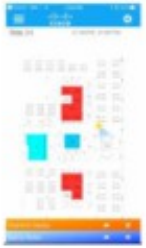
# Building an Indoor Navigation Application

Features

- Where am I now ?
- 10 M accuracy
- Update every 30 seconds

Use API

GOOD



- GUI system for creating beacons
- Accuracy to +/-5M
- Update every 2 seconds

Use base BP SDK

BETTER

- GUI system for Offline notification
- Uses phone sensors to improve accuracy
- Accuracy to +/- 3M or less
- Real time updates
- Point of Interest Editor

Use Phunware SDK for HL or BP

BEST

There are multiple methods for creating an indoor navigation solution. Cisco can provide the infrastructure for each type of solution.

HL = HyperLocation
BP = Beacon Point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# Q & A


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