No Strings Attached Show

Cisco Hyperlocation
Preface

The No Strings Attached Show was recently invited to the Cisco real world labs in Richfield, Ohio to get a behind the scene look at some new and exciting technology. Our primary discussions were focused on the Cisco Hyperlocation product portfolio.

We ensured that throughout the testing there were no ‘hidden commands’ or pre-production hardware or software components being used. In short, we wanted to make sure that what we saw, you, the reader, could go get your hands on. We did not perform a write erase on the configuration nor retain it for publishing with this paper and the WLC configuration is fairly basic when enabling Hyperlocation and the intent of this paper is not to show how to configure Hyperlocation, but to show how it works.

In order to maintain testing integrity, the hosts of the No Strings Attached show were not financially compensated in any fashion for the authoring of this white-paper. Our travel and accommodations were covered by Cisco, and the No Strings Attached Show received 4x 3702i Access Points with Hyperlocation modules and antenna arrays to continue to do further testing with. These were divided equally between show hosts.
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Introduction
Testing Goals

The goal of this testing exercise wasn’t to show how to configure Cisco Hyperlocation or to provide best practices for configuration, the goal was to show the increase in accuracy that Hyperlocation gives you over traditional Wireless based location services.

During the testing we used a mix of Cisco provided laptops & phones as well as NSA Show provided phones & tablets. While the positions used during testing were predetermined, NSA Show did request a few random locations be tested as well. The predetermined locations were not picked as the most optimal locations for highest accuracy, they were picked to represent the best and worst case scenarios.
When a new product comes to market it’s rare that you get to fully understand the history behind it ultimately leading to the final product. When Cisco asked us to the Ohio Center for RF Excellence to write this paper one of the first things we wanted to know about was the history behind the product. As we started talking about the history all of the iterations of the product starting piling up on the floor. When you stepped back one could see the difficulty behind developing a product and bringing it to market. Seeing the products very early stages where it was a 4 Access Points with antennas chained together shrunk down to a module on the back of the 3600/3700 was amazing. Listening to the engineers talk about the iterative process of the various shapes and designs showed us the commitment to excellence when developing products. Ultimately knowing where a product came from gives you a better understanding and respect for what was created.
In order to understand how Hyperlocation works we feel it is necessary to take a look at the different types of methods that are used for location based services. Each method has pros and cons providing different levels of accuracy for different deployment scenarios. Hyperlocation uses Angle of Arrival, while the traditional location based services used lateration.
Two other methods exist as well: cell of origin and location patterning.

**Cell of Origin**

When using cell of origin to determine the location of a device no distance estimation is performed. By using the Access Point that the device is connected to we make an assumption of where the device is located according to that RF cell area. For some use cases this is all that is required. If you simply want to know if a device is in a certain department of a clothing store this might work. The problem with cell of origin is that it is highly dependent upon the device making a smart decision during association or roaming. If the device chooses to associate to an Access Point on the floor above/below or in a completely different area because it has the strongest received signal strength your location accuracy is lost. This is where distance based techniques provide value.

**Distance Based (Lateration) Techniques**

When we talk about distance based techniques we typically summarize them into two different methods: time based and RSSI based. With time based location services it is crucial that all devices synchronize with a common clock source. This is a requirement because the device sends a signal with an exact start time that multiple receivers pick up using the start time to determine the distance from transmitter to receiver. The most common form of time of arrival system is the Global Positioning System (GPS). There is a variation of Time of Arrival called Time Difference of Arrival that doesn’t require a synchronized clock source. It replaces absolute time measurements with relative time measurements simplifying the deployment. A good example of TDoA systems would be radar systems in use by airplanes and traffic control towers. Finally, the third type of distance based techniques is RSSI Lateration. This is the most commonly deployed method of location services in use by many vendor systems currently. This method doesn’t require the use of any synchronized clocks or relative time measurements. For each receiver that can detect the signal generated by the device the distance is determined based off of the strength the signal was received at. This method requires a well thought out design specifically for use with RSSI Lateration. Access Point locations are driven by providing a fairly consistent grid type layout working from the outside perimeter in allowing for a minimum of typically 3 Access Points at -75dBm or better. You may recognize this as the foundation for
‘best practices’ location based survey or design.

**Location Patterning**

Location patterning isn’t necessarily a methodology by itself, it’s more of an enhancement to distance based solutions. We commonly refer to this as the calibration process. By taking readings at known points on a floor plan we can create a radio map that influences the RSSI Lateration algorithms to more accurately locate a device. This step is commonly skipped but typically greatly improves location accuracy.

**Angle of Arrival**

Finally, we have Angle of Arrival (AoA). AoA locates the device by calculating the angle of incidence at which the signals arrive at the receiver. The algorithms can use the geometric relationships using intersecting lines. We require at least two receiving sensors for this location methodology to work. This is the methodology used by Hyperlocation to determine location of a device. Most solutions use an array of receiving elements to sample the signal in a single placement point eliminating the need for complex antenna systems. AoA is more commonly referred to as triangulation, not to be confused with trilateration from before. The two are different and triangulation is only done with AoA algorithms. One example of an AoA system the VHF Omnidirectional Range (VOR) which is used by aircraft for navigation systems. VOR transmitters send multiple VHR radials at different angles of incidences. Another example is cellphone location services using cellular towers for triangulation and determining the location of a device.
Integrating Hyperlocation
Requirements

If you already have a Cisco Unified Wireless Network deployed chances are you are ready for Hyperlocation. In order for Hyperlocation to be deployed you need either Cisco 3600 or 3700 Series Access Points, a Wireless Lan Controller like the 5508/5520, Prime Infrastructure, and a Mobility Services Engine (MSE) running CMX 10.2. All of these components work together to build the framework needed for Hyperlocation. The Access Point requirement is set because of the need for the module slot which is only available on the 3600 or 3700 series Access Points.

The Hyperlocation setup requires both the module (Figure 4.1) as well as the antenna array ring that circles the Access Point (Figure 4.2).

The module contains a 2.4GHz and 5GHz monitor mode radio for RSSI based location measurements as well as security monitoring. In addition to the wireless radios the module also has 5 Bluetooth low energy (BLE) beacons that can be individually configured for UUID and power levels. As an enhancement for the RSSI based location measurements Cisco has introduced their FastLocate capability which provides more frequent location updates than using a standard Access Point for RSSI location.
Once you pair the AIR-ANT-LOC-01 Hyperlocation antenna with the AIR-RM3010L you introduce AoA to the solution. This is where the 5-10m accuracy is brought down to 1-3m accuracy. The Hyperlocation antenna connects via Cisco’s new DART antenna connector which passes both analog and digital signal from the antenna to the module as seen in Figures 4.3 and 4.4.

The software component of the solution requires the use of Prime Infrastructure to manage the WLC and MSE integration as well as to setup the maps to be used. When you are configuring the Access Point in Prime Infrastructure you’ll see the new antenna option, AIR-ANT-LOC-01, allowing you to set the appropriate orientation which we’ll talk about in the next section and is shown in Figure 4.5.
Deployment Guidelines

Wireless designs have evolved significantly from deploying Access Points at the highest power covering the largest area possible. Today’s networks are based off of smaller coverage areas and lower power. As we introduce location services into the mix that design then changes to be grid like to ensure maximum location accuracy. Hyperlocation because it uses AoA allows us to move away from grid-like designs but still requires a well thought out design. For instance, you want to have all of your Access Points orientated correctly in CMX 10.2, this doesn’t mean they all need to be pointing North for example but all the arrows on the antenna array should be correctly reflected in the software.

Figure 4.6 shows the arrow. As we showed in Figure 4.5 when configuring the access point in Prime Infrastructure we change the orientation to match the direction the access point is facing. This is a requirement because of the AoA operation being performed for location estimation.

Another design consideration is how many Hyperlocation arrays do you need in relationship to your Access Points? Do you need to deploy this as a 1 for 1 deployment? The short answer is yes. Because of how Hyperlocation works you should be deploying a module and antenna array into every access point. When the location algorithm is performed the concept of master and slave nodes are introduced. The master is the access point that you are associated to and transmitting data with, the slaves are other nearby Access Points that will be used in the calculation of the device location. Hyperlocation, as of the date this paper was published, only works on associated clients that are connected to a wireless network. It does not work with passive unassociated clients. The downside to this
is similar to the Cell of Origin method for locating a device: if the client chooses poorly with its association or roaming process your location data could be skewed; we’ll talk about this more in the real world testing chapter. Does Hyperlocation work with just a single module and antenna? Yes it does, but fidelity does suffer slightly and it is not a supported deployment. Let’s take a look at how multiple antenna arrays see the device compared to a single antenna array. When you have a single antenna array AoA certainly works well to figure out from which “side” of the antenna array the client but adding multiple antenna arrays as seen in Figure 4.8 improves the likelihood of locating the device.

It is important to note from a deployment consideration that for best results Hyperlocation requires the clients to be HT/VHT OFDM (802.11n) capable. The reason for this is that Hyperlocation sends BlockAckRequests to the client devices which causes the clients to send BlockAcks back which are used by the Hyperlocation antenna array for AoA calculation. If the client is not HT/VHT OFDM capable, Hyperlocation is still possible but it requires the client to be sending data. Using BlockAckRequest is a simple way to trigger the client to send data without causing too much overhead on the network. Figure 4.9 shows a sample packet capture from our testing. You can see the BlockAckReq being sent to the client ad the BlockAck being returned to the Access Point.
Figure 4.9 BlockAckReq & BlockAck Packet Capture
Troubleshooting Hyperlocation
While the Hyperlocation system is straightforward, you will invariably be tasked with ensuring that you’re actually seeing the location fidelity that you were expecting prior to deploying the solution. Fortunately, the Hyperlocation system includes several tools for validating accuracy measurements both pre- and post deployment. These primarily center around several features in the CMX product that are used to perform accuracy fidelity testing. These features will take points on a map that you’ve uploaded, and compare them to where the Hyperlocation system believes it is. It will then give you a delta between where you thought it was and where it actually was and represent it accurate to a specific measurement (typically in meters).

Once you have a client selected on your CMX map, you then select the location accuracy test from within the client details pane on the right hand side of the screen. After naming the test and pressing enter, you are faced with, arguably the most complicated component of the Hyperlocation system - a ‘to the pixel’ representation of where your client is actually at on the map as shown in Figure 5.1. We’ll talk more on the X&Y in the next chapter as we explain the testing scenario.

This is not an area that you want to guess at since a minor deviation here (one pixel in any direction) will likely throw off your CMX’s ability to calculate the location fidelity. After you let the test run for a period of time (say, a minute), you would select the Pause button from your shown dialogue box which allows you to view the results for your specific device in that location, or to move it to another location - useful if you’re doing batch testing at a facility with a single device type!

It’s during this test that the magic of the Hyperlocation system can be viewed. If you observe what happens at a packet-level during this test, the Access Points are sending very small Block Acknowledgement Request (BAR) packets.
to the client as we discussed earlier. It’s this process of actively sending and receiving data that incites the client to continue to provide feedback to the system. It is this specific mechanism that allows us to overcome the limitations of other systems that only track probe responses which happen comparatively infrequently. The Hyperlocation system takes these packets and performs the rather complex AoA calculations on the client’s location and then provides you feedback about how accurate of a measurement it took!

While metrics for a single client like 10m accuracy (or even 1m accuracy!), average error distance, and accuracy error distance are fun to look at, most Hyperlocation deployments will go through this process of fidelity validation a handful of times. All of the rest of the location metrics and accuracy are all behind the scenes providing you more accurate location, primarily through API calls.

To call Hyperlocation anti-climactic would be to cast it in a negative light - despite the relatively straightforward way that data is being presented to you and your users. The point of the solution is to further enhance location data (X,Y coordinates) that you are already getting, making it more accurate, and all without the need for complex and time consuming calibration efforts. All of the improved accuracy comes from the orientation and placement data of the Hyperlocation antenna arrays in CMX and all of the AoA calculations (the heavy lifting) is all otherwise transparent.
Extending Hyperlocation
Location services historically speaking have required extensive development outside of the vendor provided user interfaces. With Cisco CMX 10.2 the out of box solution meets the needs for a lot of users removing the requirement of developing 3rd party applications for most use cases. For our testing we relied on the API to perform mass scripted accuracy tests to save time. The API allows you to get all of the data that is presented to the CMX user interface via simple RESTful query with a JSON or XML response. For more information on the API follow this link https://developer.cisco.com/site/cmx-mobility-services/. We’ve included a copy of our script below how simple it is to use cURL for example to make a query to start and stop accuracy tests.

curl -X POST -d '{ "macaddress": "84:38:35:5c:a2:e2",
    "floorid": "720576004803788800",
    "x": 130.2,
    "y": 71.5 }'
   -H "Content-Type: application/json"

With this simple API call via cURL we initiated a location accuracy test for the given mac address, on a specific floor, at a known location. The test results are then available via the user interface as well as by SSHing into the MSE and browsing to the test log folder.


Because the test is not timed we had to also send the API call to stop the test after it ran for awhile.
Real World Testing of Hyperlocation

Distance: 0.08m
50% Accuracy Error Distance: 0.06m
For our testing Cisco setup two CMX platforms: one for RSSI and one AoA Hyperlocation. All Access Points were connected to a single Cisco 2504 Wireless LAN Controller running 8.1.131.11 code. 9 3702i Access Points were used for each scenario mounted in the same locations. RRM was not configured differently for each set of Access Points. Our goal was to mimic a real world office environment as closely as we could. Figure 7.1 shows the Richfield office plan along with the Access Point and test locations. As you can see the office contains open areas, walled offices, and cubicles. We chose to perform our testing in the open areas as well as the cubicles. Again the location choices were not picked to be the best case scenarios, they were simply chosen to get a mixture of possible scenarios a client device would be in. Cisco created a grid system allowing for any point on their grid to easily and precisely be determined. The X&Y coordinate system they developed is correlated to the X&Y coordinate system used in Prime Infrastructure and CMX for the testing application mentioned earlier. In the real world when you are testing your deployment you will still need to figure out some system that can precisely correlate data points from where you are to the X&Y used by CMX. One could do this with laser distance...
finders and known points but we are not going to get into that in this paper. Once we had the known testing locations determined we chose two different testing plans: single client device and multiple client devices. There should be no difference in single vs multiple but we decided given the fact that we had access to 100 clients (same clients we used in our other papers for the AP2700 stress test and RX-SOP test) it made sense to try it.

First let’s review our single client testing we performed. Cisco had predetermined 20 locations for testing, we tossed in 2 random ones as well. For each of those 22 test locations we used a Cisco provided iPhone and an NSA Show provided Samsung Tab4 (thanks WLPC!). What was interesting about using an iPhone and an Android device was the fact that we did see on occasion where the iPhone and Android roamed differently which impacted the accuracy for AoA more so than RSSI. Figure 7.2 shows the data recorded for each of the data points for both the iPhone and Android device when using Hyperlocation. Figure 7.3 similar shows the data when using RSSI. As you can see the accuracy using Hyperlocation is considerably better than using RSSI. This data also shows what happens when a client decides to poorly pick an Access Point to associate to. You can see from the Android chart the spike in accuracy for the Hyperlocation test, this is where the Android device was in the cubicle area and did not appropriately pick the Access Point to roam to. Prior to continuing with the tests we chose to turn off and back
on the wireless in order to get it to choose a better Access Point to associate to. Before you question whether or not this impacted the legitimacy of the data we had a healthy discussion about this during the test. It was our (Sam and I) decision that we weren’t testing roaming algorithms, we were testing location accuracy, so we felt we should allow the Hyperlocation algorithm to have the best chance to calculate the location of the device. When looking at the cumulative distribution function (CDF) charts comparing the error distance (m) for both AoA and RSSI when can easily see how advantageous it is to deploy Hyperlocation antennas to reduce the error distance across both open areas (Figure 7.5) and cubicles (Figure 7.6).

Figure 7.4 Error Distance for Open Area

Figure 7.5 Error Distance for Cubicles
For our multi-client test we chose a mixture of Apple and Windows based devices to perform the accuracy test on. These devices were scattered throughout the area as the purpose of the test was not to stress test a single location but to test multiple calculations at the same time. As you can see most devices were highly accurate. The ones with large spikes in error accuracy had chosen poorly for associated Access Point. We did run subsequent tests after fixing but wanted to highlight initial power on scenario.

Figure 7.6 Multi-client Test Locations

Figure 7.7 Multi Client Error Accuracy
Use Cases

Retail

The Hyperlocation solution can be used in a variety of verticals and the Retail environment is one of the most easy to digest. In today’s world of the ever growing concern about “show rooming” (visiting a brick and mortar facility just to purchase online) is driving a laser like focus on customer loyalty and engagement for the visitors to retail locations. Leveraging Hyperlocation to increase device level fidelity has significant appeal to the rewards program administrators. Between very targeted coupons and better dwell-time alerting, it will be quite valuable to those looking to increase visit to purchase rate. For example, it could be that a big-box tech retailer has an app that they encourage their reward program customers to download. After an opt-in, it’s possible to understand where that users smart-phone is at and if they dwell in the home theater section of the store - perhaps in front of a TV that is on sale, for more than a few minutes, an alert could be sent to a sales associate to go engage that customer, educate them about the current sales promotions and assist with inventory level checking, financing, or any other need the customer may have. While Hyperlocation plays a pretty transparent role in the use case, being able to determine location accurately is a critical component to differentiating between bothering a casual shopper and an interested buyer.

Museum

Today’s modern museum has evolved into a digital, on premises, learning environment rich in media and information that goes well beyond the traditional exhibit. Leveraging the Hyperlocation solution to improve fidelity has many use cases in this environment. The museum of
the past may have used a device for an audio guided tour instruction the visitor to move from exhibit to exhibit and describe various aspects of it. It’s easy to envision a new model of patron engagement centered around a smart phone style of device with a museum specific application loaded on it. The fidelity improvements of a tracking solution could then feed the application data about where specifically patrons are at as well as how long their patrons are dwelling in a particular area or in front of a specific exhibit. Having a higher level of engagement in this environment makes for a better experience for the visitor and improved analytics into successful exhibits which leads to return visit patronage and significantly improved satisfaction - and most importantly higher levels of retention and learning.

**Airport / Theme Park**

Much like museums and retail environments, airports and theme parks have to evolve to become more efficient and engage their visitors in a more meaningful way. Hyperlocation provides a way to do this. As many that fly are aware security line wait times are increasing during peak flying hours, if there was a way to know which checkpoint was moving more efficiently than another we can route people accordingly. Knowing more precise walking paths from security to gates helps airports better understand how people are moving throughout the airport. Much like the security lines by applying the same process to ride lines we can determine how long an average wait will be for a specific ride. By providing the wait times either via an app or display boards the goal is to improve satisfaction scores by ensuring visitors get to where they are going or are able to ride the rides they want to.

**Enterprise**

In the previous use cases we stressed the importance of providing meaningful engagement to customers, patrons, visitors, etc of a location. Those use cases make logical sense when you apply them to the scenarios. When we look at deploying Hyperlocation in an enterprise environment what is the value it brings? You might want to know how your employees are moving throughout a large corporate campus, or where they hang out, but the obvious use case to me is the open floor plan concept. Now we are not implying the open floor plan that we all dislike with short cube walls, what we are
talking about is the idea of hoteling and unassigned cubicles. Imagine entering your office building and seeing in the main lobby which floors have a certain number of cubicles open allowing you to pick which floor you would like to go to. Hyperlocation with its 1m accuracy could provide this level of accuracy depicting which areas of a floor are open directing someone to an open cubicle to use.

“Is Hyperlocation a solution looking for a problem?”

Many will ask that question when they are discussing the potential use cases of Hyperlocation. The potential of Hyperlocation requires a different mindset to see. If you haven’t ever worked in operations or marketing the potential will probably not be seen, but if you have that experience it’ll be easier to understand. There are many use cases for Hyperlocation out there today whether they be customer facing (using a front-end or app) or non-customer facing. The problem is being able to fully realize those solutions.
Summary

The Cisco Hyperlocation solution provides a straightforward way to extend your wireless infrastructure to provide a highly accurate location information of your Wi-Fi connected clients back to any variety of external systems. Hyperlocation by itself is a delivery of a commitment made many years ago about Wi-Fi systems being able to provide the fidelity required for asset tracking locations - coupled with today’s app-driven world, allows us to fulfill business demands for the blue-dot navigation experience in many enterprise environments. The NSA Show first hand observed what level of fidelity you can get out of typical enterprise grade clients as well as consumer grade tablet devices and with this level of fidelity, we believe that the Hyperlocation solution is delivering today on location services that we’ve only dreamed of achieving in the past. This level of accuracy comes with a handful of design requirements that may not fit every environment. The real-world impact in your environment can be measured empirically and we would encourage you to set the expectations for your specific deployment accordingly. When used as recommended by the manufacturer, the location accuracy does exist, is easy to use, and provides a robust and extensible interface to leverage in a multitude of applications.
**Blake’s closing thoughts:**

I’ve been working with location services for awhile, having done extensive testing with Cisco 2710, MSE, AeroScout RTLS, Ekahau RTLS, and BLE solutions. Hyperlocation solves the issues of wireless based location services that we have typically seen in terms of accuracy and complexity. I’d like to see some more testing around a fully deployed blue dot navigation application to see how it compares to BLE solutions before crowning it champion of blue dot but it certainly is champion of location awareness for devices.

**Sam’s closing thoughts:**

It was fascinating to see a live environment using production hardware and software that is available for purchase today giving such accurate and smooth coordinates with such rapid refresh rates. I am quite pleased with the level of detail Cisco has managed to suss out of their infrastructure and I’m looking forward to seeing how the product continues to evolve and mature over the coming years. Location and Wi-Fi are a match made in heaven and Hyperlocation has finally given us the accuracy that we’ve been looking for out of RFID solutions for many years.