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Building a Testing Platform for Wireless Location Services

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Abstract

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Elisa Oyj commissioned this thesis. Elisa Oyj offers indoor location services to its corporate customers. The current users of these services are healthcare and social services companies. Elisa has a small-scale testing environment used to validate substantial changes like major upgrades before implementing the changes at customer sites. There is a growing need to evaluate features from the latest software versions and new systems simultaneously. The goal for this thesis assignment is to be able to provide better tools for the needs of the customers and expand the used platforms to include more of the requested features.

This thesis focuses on designing and implementing a testing environment that can be used not only to test the current location services but also to assess other vendors and new products and features. The idea is also to use the environment as a training and testing sandbox that does not affect services in production. The site can also be used as a demonstration environment for customer cases.

The environment that was designed and implemented in this thesis assignment is currently in use for testing the second iteration of vendors. There is also an evaluation phase implementation with new location services that are not in use with our current customers. The environment is improved with every iteration of new software and when adding new vendors' products.

Keywords: RTLS, Location Tracking, Location Service, Testing Service, Wireless Triangulation, Wireless Locating, BLE Locating, WLAN Locating.

Contents

List of Abbreviations

BLE	Bluetooth Low Energy. Bluetooth communication technology that uses small amount of power.
GPS	Global Positioning System. Most used wireless location system in the world.
RTLS	Real Time Location System. Generalization of a wireless location system that can locate items.
Tag	Device that is sending wireless beacons or data which is collected by a system.
WLAN	Wireless Local Area Network. Most used way of communicating wirelessly with a device to network.
IoT	Internet of Things. Concept of communication of physical devices and systems between each other.
IP	Internet Protocol. Protocol consisting of address for network device to communicate.
PoC	Proof of Concept. Working concept of system. Usually, the first step in the implementation of any new products.
VLAN	Virtual Local Area Network. A virtual partitioning of networks within the same group of network devices to have different end devices to be separated.
VM	Virtual Machine. Virtualized server or host.
SQL	Structured Query Language. Server for data storage where information can be kept and easily queried.

1 Introduction

This thesis has been made for Elisa Oyj. Elisa is a telephone and internet service provider that also sells and manages wireless location services. The current wireless location systems are WLAN (Wireless Local Area Network) based setups. In recent times many network vendors have been starting to include BLE (Bluetooth Low Energy) technologies in their WLAN access points. This transition in vendor philosophy has sparked Elisa's interest in also providing BLE location services. The availability of the new features and technologies means that they should be evaluated in a laboratory environment. Testing in a controlled environment helps in finding out the best practices and capabilities of the new products. The need for testing environment has led to this thesis where the focus is on creation of the environment and the first testing parameters for the first device pools. The dedicated testing environment needs to be scalable and easily upgradable to fill the need for technologies available now and in the future. The environment will also be used to develop skills for Elisa's consultants and production personnel as the implementation of the new test environment increases the needed expertise for understanding customer environments. The environment makes it possible to evaluate multiple systems simultaneously and to assess the limits of the software with the available resources. The idea is to be sure that there are no external factors slowing down the system and that the results of the system comparison are independent of the network and resources.

The general information part of this thesis focuses on the indoor location systems and how they work. The first part is the summary of different technologies that can be used for location services. Their pros and cons are listed, and the different systems are compared. The goal is to provide information about the strengths of each system and to help the reader to get familiar with the presented alternatives. The idea is also to provide an overview of indoor location systems' features and additional benefits that can be achieved with IoT (Internet of Things) integrations. The IoT features are not primarily used for extracting location information, rather the WLAN or BLE environment is used to transfer the messages for analysis.

Literature part of this work showcases different vendors and service providers offering location services that operate in Finland. Their features and strengths are explained.

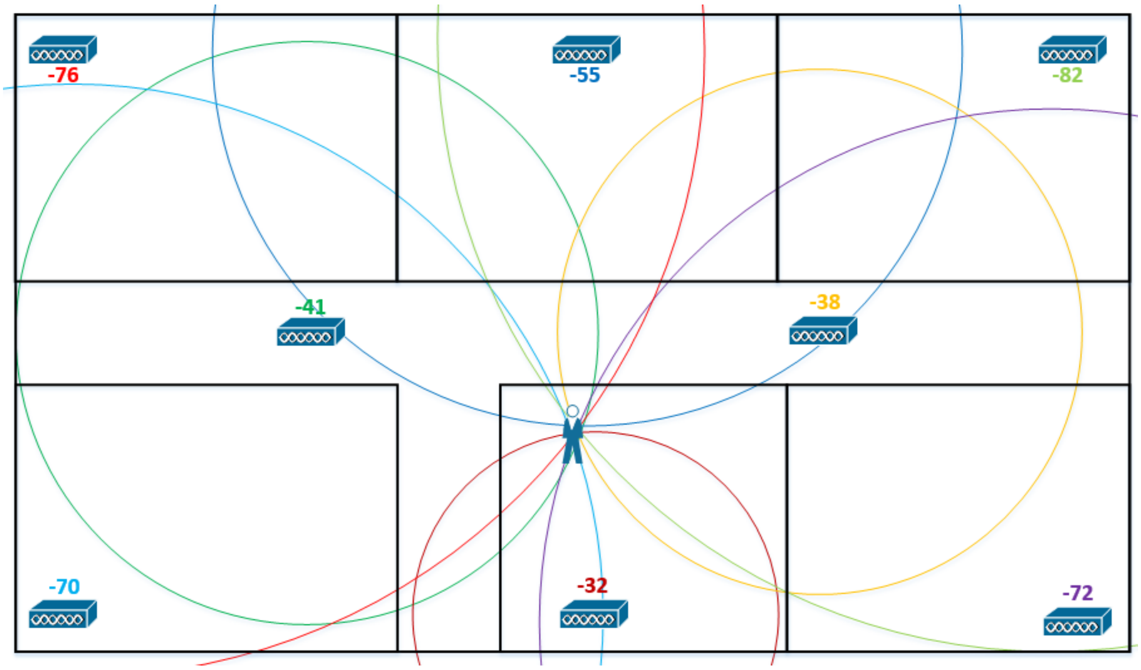
In the technical part the focus is on the testing environment. The design phase presents how and why this solution was implemented. This includes the desired features and how they have been implemented following the best practices. In the building part the technological solutions and equipment used are discussed and background on -how we ended up with them is explained. The goal of the implementation was to use the equipment already available while constantly maintaining the ability to upgrade the system in the future. The network was built as a backbone of the system and the main service part is the virtual environment where there can be several different versions of software running simultaneously. The flexibility and ease of operating virtual environments are the main reasons for virtualization.

This thesis resulted in a fully functional, dynamic environment that matches the goals set for the implementation. Namely, this means that the system can be updated and expanded without requiring to rebuild the whole environment. There are already findings that will be the next improvement items and we have plans for the new services to be tested.

2 Wireless Location Service Basics and Background

Wireless location services are a broad definition of services used for locating something via wireless method. Usually there is a transmitting device, receiving device and processing device or server. The principle is that there are sensors which transmit or receive signals. There are multiple ways of implementing location services. The main differences between the implementation methods are in capturing the information for the location calculations and where the calculations are made. The calculations can be done either locally in the device which is being located or the device can send the captured raw data to a service for the calculations. There are also services that collect the data and process it independently without communicating directly with the located device.

Many wireless technologies can be used to extract location information. The most used ones are WLAN and BLE. There are also systems using other protocols such as Zigbee, LF (Low Frequency), Active RFID (Radio Frequency IDentification), IR (Infra-Red) and US (Ultrasound) [T.1].



[P.1] Triangulation example picture.

In the picture the signal strength values are shown as WLAN signals in dBm. The number is minus sign and smaller number is higher signal strength so excellent signal is -35dBm or smaller, good signal strength is -64dBm or smaller, adequate signal strength is -80dBm or smaller and anything above that is weak signal strength.

The basic principle is similar in GPS (Global Positioning System) where the received signal strength is stored, and the location is calculated based on the known location of the sending device or the receiving device. When there are more than three receiving/sending devices the location can be calculated with triangulation. Increasing the number of receiving/sending devices improves the accuracy of the calculated location [T.2]. The only major difference comparing wireless location services and GPS is that the location services are not maintained by a government entity and the location capable areas are usually confined to maximum of a campus area, like a large hospital or a college campus.

2.1 Real-time locating system

RTLS (Real-time locating system also known as real-time tracking system) is a general framing of location systems. It is based on wireless location services at its core concept. RTLS is vendor independent generalization of the definition of how to operate location services. The two basic techniques of locating are using choke points or locating in relative coordinates. Either of the techniques can be used independently or they may be used together. The fastest and most accurate results are achieved by varying the used method based on the specific aspects of the locating area.

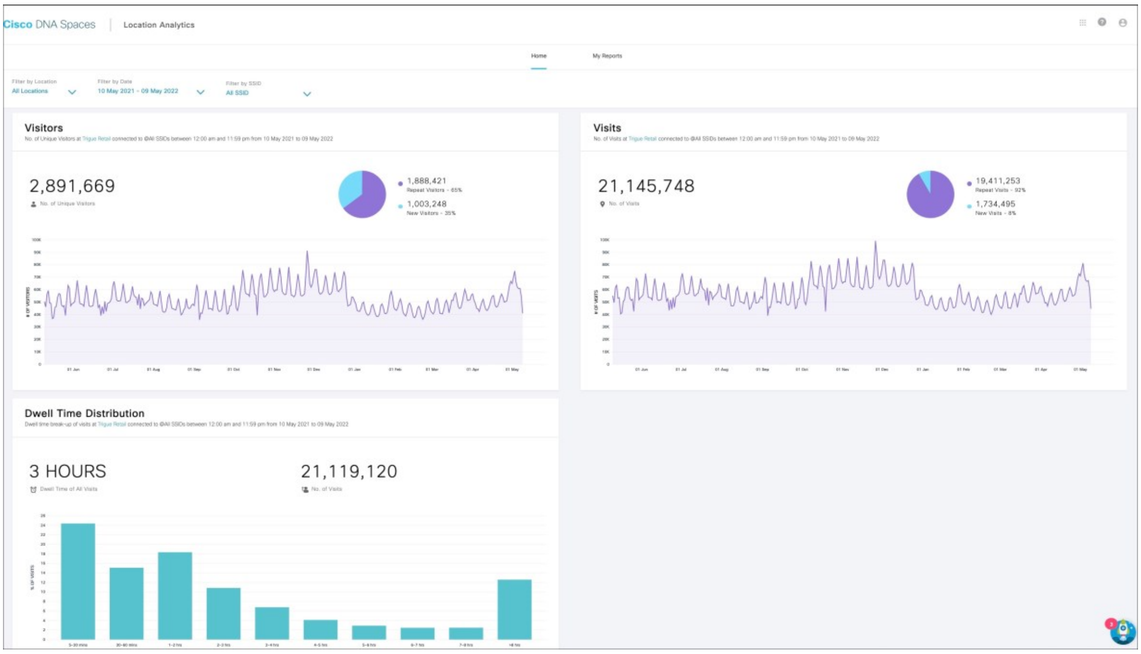
Locating choke points is implemented on a path which is usually an entrance/exit or a narrow passing between two or more areas. In most systems a choke point is used as an area transference and the system logic collects the transference direction with two subsequent choke point devices working as the choke point. Choke points can be implemented with wireless technology to trigger a special event in the system or user device [T.3]. In WLAN location system a BLE beacon may be used as a choke point for area transference or as a point of interest by the elevator that opens a floor guide on the device being used.

Locating in relative coordinates is based on defining coordinates for different areas on the floor plan. All the locating devices with fixed positions are placed on their designated coordinates. The located devices’ position is calculated in relation to these fixed locations of transceiver and/or receivers and the device is placed on the same coordinates. Locating with relative coordinates is meant for open or vast areas where the distance between locating devices is greater and the location must be approximated by the system. There are both artificial intelligence and machine learning solutions that can improve the end accuracy with the information of previous and present location data. Also, the best result is achieved when the system is finetuned by providing the precise locations of devices to the system and it calculates the deviance and adjusts provide more accurate coordinates.

2.1.1 Location analytics

The selling point of RTLS in the eyes of the management level is the analytics from the system and the added monetary value of the knowledge on how persons are moving around the facilities and how changes in area layouts, information screens and points of interest change the movement and paths taken [T.4]. The main point of RTLS is that all the location data is collected and used to show the data in other ways than just location on a map. The collected data can be used to display vastly different analytics based on the need and use case of the organization. Some examples of these are discussed in the following paragraphs. The facility services management gets the visitor counts, repeat visitors, dwell times per area and passers-by. This information can be used to evaluate the different areas for their importance / value. In a shopping center example, the specific store locations can be individually assessed by the passer-by ratio compared to the overall visitor count [T.5]. The idea is to show where the store is getting most visitors, and the behavior can be monitored for a longer period to see how the store’s showcase and other changes are affecting the visitor count / behavior. Health care can use the dwell times to track patient waiting times and can measure the unnecessary waiting of admitted patients outside their patient rooms. For example, a surgery patient is going for a pre-surgery doctor meeting and is waiting outside the doctor's office for 30 minutes, while the walk from the patient room to doctor’s office is 3 minutes. In corporations’ eyes it can be intriguing to track the productivity of the employees. One of the examples is Amazon with their fulfilment center's tracking the employee breaks and productivity on an individual level and creating personal goal to get the maximum productivity out of the employees. Generally thinking the more acceptable way of tracking productivity is to do it on a section or team level to measure the overall performance rather than an individual performance.

The acceptability of tracking employees and customers is derived from European Union’s General Data Protection Regulation (GDPR). Where the privacy laws and human rights laws are defined for member states. The point of GDPR is to better the individuals’ control over the information which is collected from them and to simplify the regulations for international business.



[P.2] Cisco Spaces - Location analytics picture.

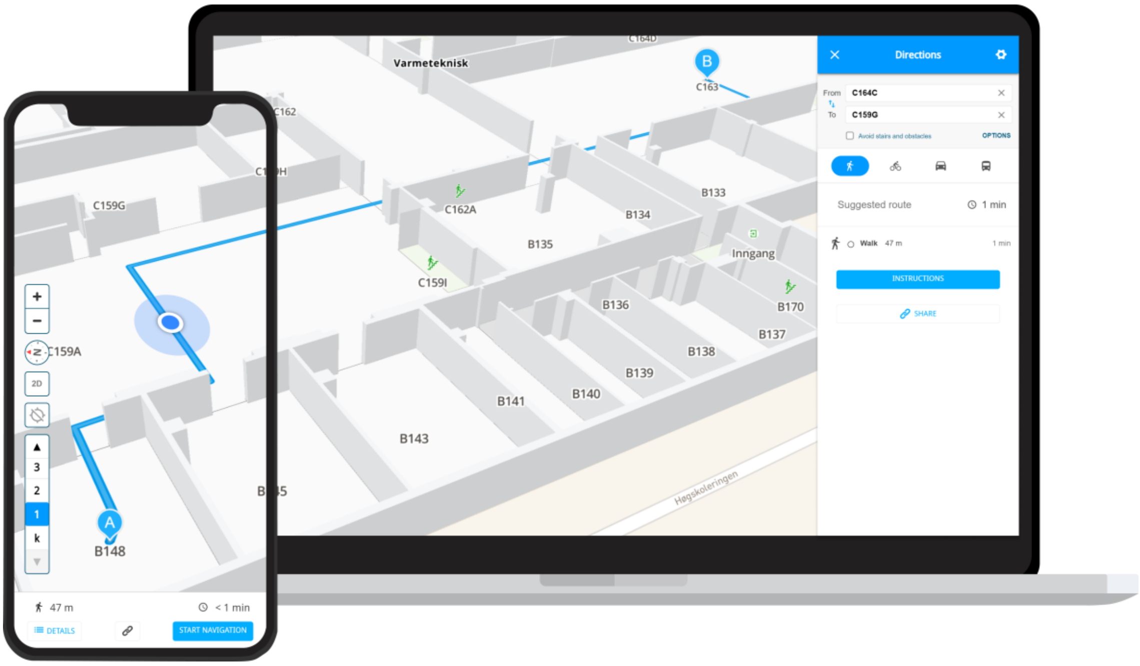
For legal and privacy related purposes visitors are often offered the possibility to opt-out from the tracking. In some countries this has been made quite difficult because every person that opts out from the tracking is affecting the accuracy of the analytics. This has inspired consumer electronics companies like Apple and Samsung to implement MAC randomization on their devices [T.6, T.7]. Those help the individual to mask their identity and make it harder to get accurate behavior patterns on return visits.

One excellent example of people exposure tracking implementation was the Finnish Koronavilkku covid-19 exposure app, which is a location analytics software [T.8]. All the phones with the application are sending device identification messages and all of them are receiving the messages. The software on the phones stores the unique keys of the messages and when an infected person inputs a special code in the app all the users that have that person's unique keys in their phone will get an exposure notification. The privacy is protected by not giving the information of where and when the exposure has occurred but only that it has been in the last 10 days and the person is instructed to self-quarantine and be tested.

2.1.2 Wayfinding

Indoor car GPS like navigator is a way of getting the most value of a location system. The idea is to help people and devices find the best way from point A to point B. In a small simple area, there is not much value but in a larger site or a gigantic campus area there is a great benefit to it. The basic version of the indoor wayfinding is already in use in most of the Finnish shopping centers as an interactive information displays with maps with step-to-step picture directions that you can load to you phone with a QR-code. The next step the system can provide to a user is to load an indoor navigator for real time directions [T.9]. The indoor navigator shows the user's current location all the way to the target location.

The advantage of the indoor navigator is that it is updated in real time so if there is an elevator or escalator that is out-of-order the directions can be automatically updated [T.10]. Also, if the users want to deviate from the selected route the system can calculate an alternative route. There are a few ways of getting the directions to the user. The user can login to a specific internet page and get the navigator from there or there can be a dedicated app for that. The wayfinding is not always an innate part of an RTLS system. There are companies that provide wayfinding features on the most common RTLS systems like MazeMap is doing with Cisco Spaces. There is no need for a place specific app for each implementation as wayfinding is independent of the service operator.



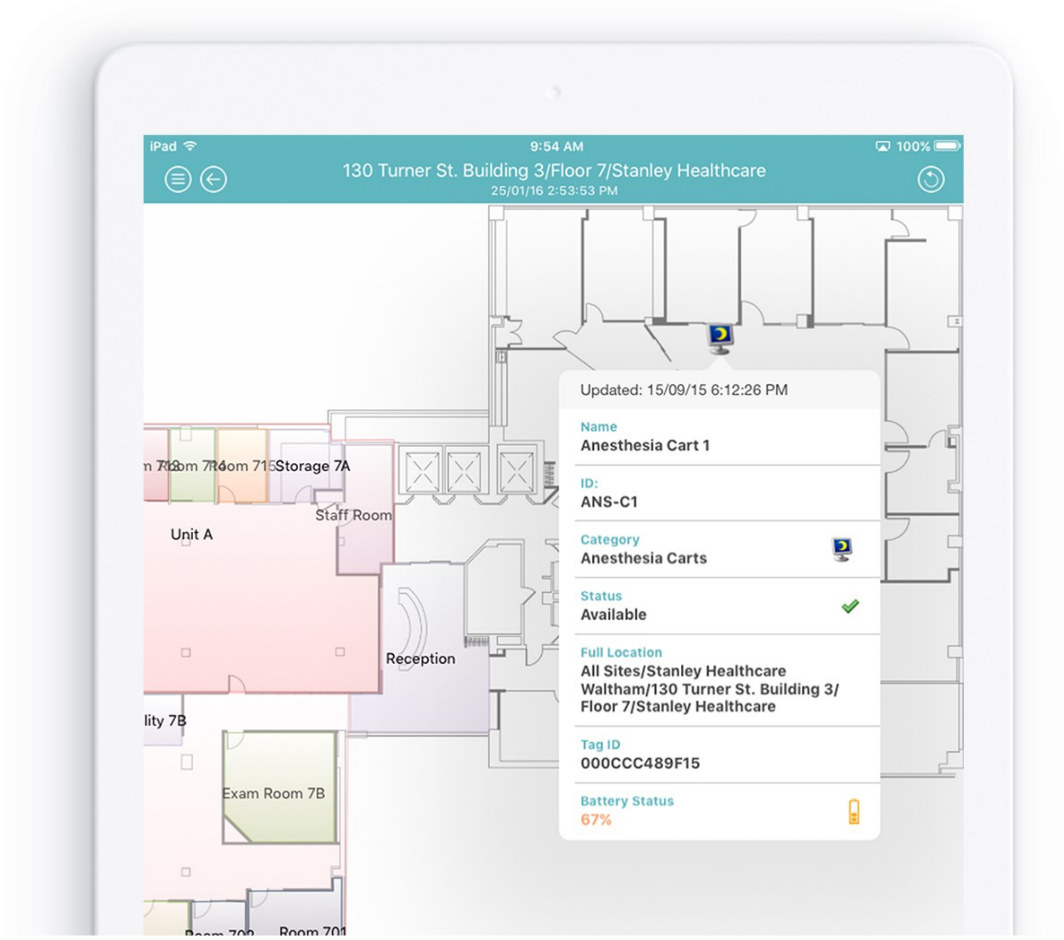
[P.3] MazeMap - Blue dot navigation picture

Wayfinding is also a way to get the visitors to log into the system and to participate in location tracking to bring more information to the location analytics. Usually getting the wayfinding to work the individual must accept the terms of the service and allow themselves to be tracked. Further, the users must connect to the wireless network or turn on Bluetooth on their device to get a more accurate location.

In a large campus with multiple buildings there can be a hybrid system that uses the indoor location system inside the buildings and RTLS/GPS outside depending on the accuracy of each system [T.11]. These bring out the best of both worlds by operating in both closed indoor and closed outdoor areas with the addition of open outdoor areas.

2.1.3 Asset management

One of the most beneficial aspects of RTLS when not tracking people is asset management. The idea is to track a device by its own wireless sensor or by attaching a location enabling tag to it. The benefit is to track the more expensive or critical devices and with analytics to use them more wisely. Organizations can have thousands of different portable devices that need to be maintained and kept in good condition. With asset management you can track thousands of devices and easily find them when it is time to get them maintained or clean them. One of the many use cases examples is that in a hospital there are IV Pumps and Ventilators that need to be regularly maintained to meet the operational and patient safety requirements [T.12]. The locator tags are mounted on the medical devices to be located by the RTLS system and the management software informs the whereabouts of these devices. The maintenance department knows where every device is and whether the device is in active use for patients or available for maintenance. [T.13]



[P.4] Securitas Healthcare – Asset Management picture

Asset management analytics can also be used to regulate the device quantities and utilization rates to better decide how many new devices, and rental devices are needed to keep up with fluctuating needs [T.14]. This high-level device management can also be done on a smaller scale as in par level requirements on certain devices per area or department [T.15]. A notable example of local par level is an emergency room entrance with wheelchairs. The number of needed wheelchairs is set in the system at fifteen and the par levels are set between 12 and 18 pcs. If there are more than eighteen wheelchairs or less than 12 an automated event is triggered, and a notification is sent to the wheelchair management department for action. Usually there is more than one par level and when there are too many items somewhere, there will be too few somewhere else, so the wheelchairs need to be moved from one par location to another. It is important to know how many items are needed and how much they are used to balance the amount that should be owned to the amount that can be rented on a needy basis.

2.1.4 Staff protection

One of the most critical and most demanding implementations of the location system is staff protection. The general idea is that the personnel carry locating tags or their mobile devices which are used as locating devices. If the person feels threatened or there is something wrong, he or she can trigger an alert with a push button and the exact real time location of the person is forwarded to security personnel and/or to other personnel in the area. This is a valuable functionality in healthcare and other professions where employees are working alone in the room with customers/patients [T.16].

[P.5] Securitas Healthcare – Location tag picture

When tracking personnel there are many aspects to consider about the privacy of the workforce [T.17, T.18]. For example, European GDPR (General Data Protection Regulation) states that systems cannot be used to track employee performance and break times. When implementing staff protection, the data is collected in a way that individual employees cannot be identified with it. The location data is sent with several minute intervals unless the panic button is pressed, which triggers the location delivery interval to seconds. Another way to prevent identifying an individual person is to deliver and not to specify who is the one carrying it.

2.1.5 Other use cases

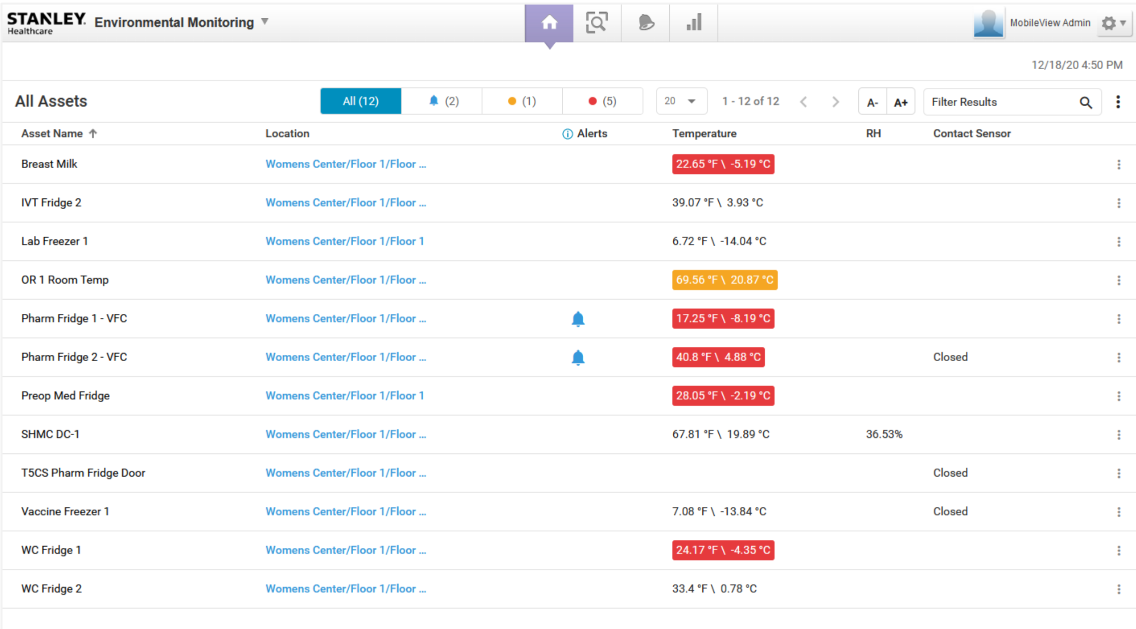
The RTLS communication network can be used to transfer additional information on top of the location data. The information can be various sensor data from the device or a status of a push button on a device. Additional information can be used and analyzed by the location tracking software, or it can be forwarded to a separate software that manages and analyses the data. Separate software for analyses helps the location systems to be more usable and feature rich and the customer can run additional services without the need for multiple overlapping location or communication networks for collecting information. The openness also helps both the location service providers and additional feature providers to focus on their own technology and give an altogether better product for the end customer.

2.1.6 Event triggered notifications

The bread and butter of RTLS systems are automated triggers from different events happening in the area. There can be any triggering events that can be imagined and not all the notifications need to be provided for the users. There can also be notification for logbooks and for various automated systems. The versatility of the used system impacts what you can do with it and most of the systems on the market these days are incredibly open about integrations for different additional services. Furthermore, the located device can add features like smart functions that can also trigger events on their own or the device can receive notifications and operate based on them. In assisted living there can be a fall management system that alerts the staff if there is a problem. The system can be implemented for the whole residence but only activated for the specified residents. The system is aware if there is such a person present at the time of the alarm, so the false alarms can be mitigated. Also, there can be automated alerts if a certain resident or a device moves to a specific area. A person suffering from a memory disorder may move freely on the ward but if he or she tries to leave, the automated doors and elevators are set not to respond to their passage. Also, if a tracked device is removed from the premises an alarm is issued and the device is remotely locked if possible.

2.1.7 Environmental monitoring

All the devices in the system do not have to be involved in the locating process. Within the same locating infrastructure there can be IoT sensors that collect data from the environment. There can be any environmental data one can imagine but the most common ones are temperature, humidity, air quality and water leakage [T.19]. Environmental monitoring can be done as a stand-alone service or as a part of a wireless location service. The advantage is to get more value out of the entire system, especially if the communication network must be built specifically for the system.



Asset Name	Location	Alerts	Temperature	RH	Contact Sensor
Breast Milk	Womens Center/Floor 1/Floor ...		22.65 °F \ -5.19 °C		
IVT Fridge 2	Womens Center/Floor 1/Floor ...		39.07 °F \ 3.93 °C		
Lab Freezer 1	Womens Center/Floor 1/Floor 1		6.72 °F \ -14.04 °C		
OR 1 Room Temp	Womens Center/Floor 1/Floor ...		69.56 °F \ 20.87 °C		
Pharm Fridge 1 - VFC	Womens Center/Floor 1/Floor ...		17.25 °F \ -8.19 °C		
Pharm Fridge 2 - VFC	Womens Center/Floor 1/Floor ...		40.8 °F \ 4.88 °C		Closed
Preop Med Fridge	Womens Center/Floor 1/Floor 1		28.05 °F \ -2.19 °C		
SHMC DC-1	Womens Center/Floor 1/Floor ...		67.81 °F \ 19.89 °C	36.53%	
T5CS Pharm Fridge Door	Womens Center/Floor 1/Floor ...				Closed
Vaccine Freezer 1	Womens Center/Floor 1/Floor ...		7.08 °F \ -13.84 °C		Closed
WC Fridge 1	Womens Center/Floor 1/Floor ...		24.17 °F \ -4.35 °C		
WC Fridge 2	Womens Center/Floor 1/Floor ...		33.4 °F \ 0.78 °C		

[P.6] Securitas Healthcare - Environmental Monitoring

One example of environmental monitoring in hospital settings is drug and medicine storage fridges. The drugs and medicines need to be kept on a specific temperature and humidity settings. The job is usually done by a nurse going to the fridge, verifying the current temperature, and logging it in the fridge's logbook manually. The logs are collected weekly or monthly and stored on a database where you can see batch temperature reading for each medicine, so if there is a problem with the medication the cold chain of the storage can be verified. In a hospital environment the cold chain is an important part of medicine safety and if there are deviations in the temperatures the whole fridge's content can be discarded. That is the reason to have not only a log of temperatures but an alert when the temperature is starting to deviate from the safe level. There are stand-alone solutions like fridges that automatically log the temperatures but not hospital wide system that work with all the other location services and stores all the data on the same system for analytics. The whole hospital wide system is a key advantage. Furthermore, a desired temperature range for specific fridges can be set and if the temperature goes out of the set range, the system can log the information and trigger an alert for the people responsible for that specific fridge. For example, the alert can be sent to the wards nurse stations. [T.20]

2.1.8 Device / Room / Area condition monitoring

The located devices can have other physical additions like buttons to press and depending on the button and the type of press it can trigger a different kind of event. One example for a use case is to have a fixed tag placed on a room and a specific type of button press indicates that the room is dirty, and it needs to be cleaned. A notification of this event is forwarded to the cleaning staff. This eliminates the need to call specific people to let them know that something has changed. This can also be done with located devices that have been used and need cleaning or maintenance. The same locating system is used to transmit the information about change to all the people who need this specific information and only to them. There is almost no information that can be sent with this kind of monitoring.

[P.7] Securitas Healthcare - Patient Flow Solution with RoomCheck™

Additionally, all the waiting times and changes in condition are logged and analyzed. This information can be used as a measure of response times and duration of a waiting state before the responsible persons do maintenance or cleaning. Condition monitoring can also be used for validating the number of the needed devices and rooms as well as validating the needed personnel. If there is no device available when needed or the waiting times for maintenance or cleaning are too long the information can be seen from the system and management can fix the issues.

2.2 WLAN Location

WLAN location tracking is based on triangulation. The basic implementation is that WLAN access points receive the location signals sent on 2,4GHz frequency and forward those to the location engine. The location data forwarded via the WLAN uses only a small amount of bandwidth and thus has little effect on the network performance. This is one of the advantages of WLAN location especially since the communication systems are used widely. The additional benefits for being widely used is that WLAN networks are often remotely monitored and managed, so problems in the network and the devices are triggering alarms. WLAN location is not a vendor specific and some of the systems support multiple WLAN vendors. The WLAN networks are not cheap, but the benefit is that there is a need for it anyway so making the network locating capable is not that big of a leap. The key is to balance the number of WLAN access points to the needs for location accuracy. The more accurate and extensive location tracking WLAN the more capable and resilient network for Voice Over WLAN and regular WLAN traffic.

The drawback of WLAN location is the price in case the only need is to locate devices and not have wireless access to local network. Also, the technology has a high energy consumption, and the batteries drain quickly. In location services the location data transmit interval can be adjusted to provide longer battery life. From a 5-minute interval to 30-minutes is the same difference than from a month to an approximately a year. The transmit interval might also be too long for certain use cases and the actual need of system defines what kind of location devices and location intervals are used. The ones that need a more frequent transmit interval are mostly rechargeable and more expensive because of that. The price of the access points does have a drastic effect and the more high-end ones are used in demanding wireless network traffic. The capacity and qualities do not affect the location. Some of the more high-end access points have an antenna array which can measure the direction of the signal, which helps with the locating accuracy. A good location accuracy design of wireless network has multiple benefits like a strong secondary signal strength and greater fault tolerance because of the amount of access points. If there is a need for high capacity and fault tolerant wireless network, there is not a substantial difference adding the location capability to the network at the same time. Depending on the needed location accuracy the access point quantity is in most estimations 20% to 30% more when compared to best practices of regular high use WLAN.

2.3 BLE Location

BLE location tracking is based on the affordability and battery life of the components. It is cost effective way of doing location tracking. The basic locating principle is triangulation, and the systems operate as a mesh network that forwards the tracking information to a gateway which is connected to the location engine. The cost savings are gained through not needing to implement special wiring for the devices. Most location beacons are either battery operated or only need basic electricity from a basic outlet. The low cost and battery effectiveness are also advantages on the tracked device side, as the BLE chips are cheap, and the battery drain is low. The best advantage from the low cost and great battery life are light weight, small signature location tags that are inexpensive. Some of them have a fixed battery with 3 months of battery life and they cost five euros each.

The drawbacks of the BLE location are that it is a separate communication network that mostly cannot be used to transfer any other data. Also depending on the gateways there can be some problems with single points of failure. If the only gateway or one of the limited gateways is down, how is the continuation of the operation ensured. Also, in battery operated location beacons even if the battery life is something like 5 years the battery needs to be changed and if you have something like 1000pcs of these in a building it is a great hassle to change them all. The key is to design a location system that has overall cost efficiency and is resilient with all the various parts.

2.4 WLAN vs BLE

Both the WLAN and BLE operate in the same way when placing the location sensors. The main location method is triangulation, and the located devices can also send out other data at the same time. The main differences in the communication methods are that BLE can only be used to transfer simple information with the location data, whereas WLAN system can be used to transfer all wireless data from the premises at the same time with the location data. The implementation costs are different as the BLE system does not need specific cabling and WLANs system needs ethernet cabling. Every premises needs ethernet cabling if there are any network devices, and most places need a wireless network for data transfer so even with a BLE system most places need a WLAN network.

The biggest WLAN vendors have brought a hybrid system to the market that has both the WLAN and BLE location systems in the same access points. They even have their own BLE only location beacons that can be used to cost effectively increase the accuracy of the BLE without adding more than the needed WLAN access points. These systems are bringing the best of both technologies together with cost effective locating tags and the needed backbone of the wireless network. In these hybrid networks you can have the best of both worlds, but it is going to cost more than a basic network. [T.21, T.22, T.23]

BLE's advantage compared to WLAN is the ease of installment and cost effectiveness when the system is installed to a premise already in use. The meshing network feature and need of only basic electricity wall plug mean that the system can be installed in hours to an existing building. The installation is not affecting the use of the premises during the installation and the system can be set up and running quickly.

WLAN's advantage compared to BLE in an environment already in use is that there most likely is a wireless network and even if it is not a location capable network it can be enhanced by adding more access points to achieve the capability. There will be more work as the new access points have to relate to a cable. In a new building there usually is good enough basic cabling so there is not much additional cabling needed. WLAN system should be planned already when a building is being designed. The access point placement and the cabling can be done in the construction face.

3 Wireless Locations Services platforms

3.1 Ekahau RTLS

[P.8] Ekahau - Vision

Ekahau is a Finnish company that used to offer RTLS, but their RTLS business was sold to AiRISTA FLOW in 2016. Ekahau RTLS system introduced the groundbreaking Ekahau Site Survey -Wi-Fi survey product line. The Ekahau RTLS system operates by first surveying the WLAN by using the survey software and then importing the survey file to the location system with the location-based signal strengths. The system used the location-based survey data to calibrate itself. The calibration was accurate, and the survey can be repeated when there are changes in the WLAN access points or in the environment. Basically, the fingerprints of signal strength in every location in the mapped area were used as reversed, so if the survey file implies that in certain spot specific access points have been measured with certain signal strengths, the system interprets that the followed device with the same signal strengths by those access points must be at the surveyed location. There are multiple automated calibrations, and the system fine tunes the locations based on tag location behavior. [T.24]

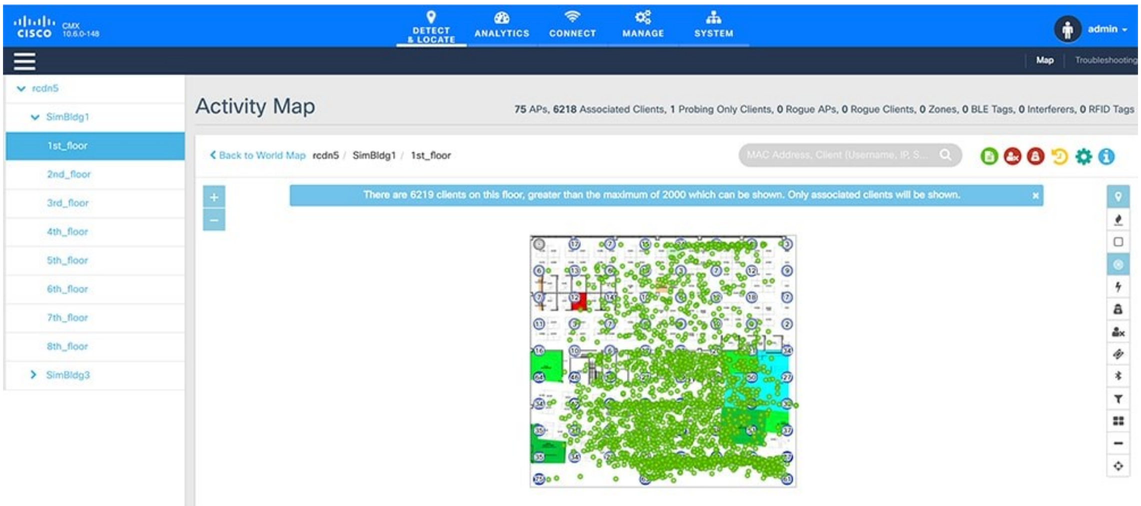
3.2 Ekahau Site Survey

[P.9] Ekahau - Site Survey Pro

Ekahau Site Survey Pro was introduced as a lightweight survey and wireless network RTLS compatibility testing tool, but it quickly got more usage than Ekahau' s RTLS solution. Ekahau has ever since been focusing on the site survey tool and done major improvements in the software which was completely renewed couple of years ago. New features have been introduced, for example iPad Survey and Ekahau Insights; a service that analyses the survey data and presents all the data from one project in a simple overview. Ekahau Pro, the site survey tool operates by collecting survey data by using precision survey device Ekahau Sidekick. The data is being collected and placed on a floor plan of the surveyed area. Based on the collected data Ekahau Pro shows the calculated access point locations and the measured signal strengths visually displayed on the floorplan. Broad and specific WLAN signal data is displayed in useful ways. For example, SNR, Channel Interference and Secondary Signal Strength can be displayed. This information can be used to validate the wireless network for different use cases like RTLS or VoIP based service. Validation is based on general and vendor specific WLAN design best practices according to the desired end use case. It is possible to simulate the environment based on known wall materials or signal attenuation from an APoS Access Point on a Stick survey. Ekahau Site Survey Pro is not a WLAN vendor specific product. It supports most of the in-use vendors and access points. The main importance of this is that in the 3D simulations they use the measured antenna attenuations of the real devices when displaying the signal strengths. Ekahau supports most WLAN vendors and access points on the market. [T.25]

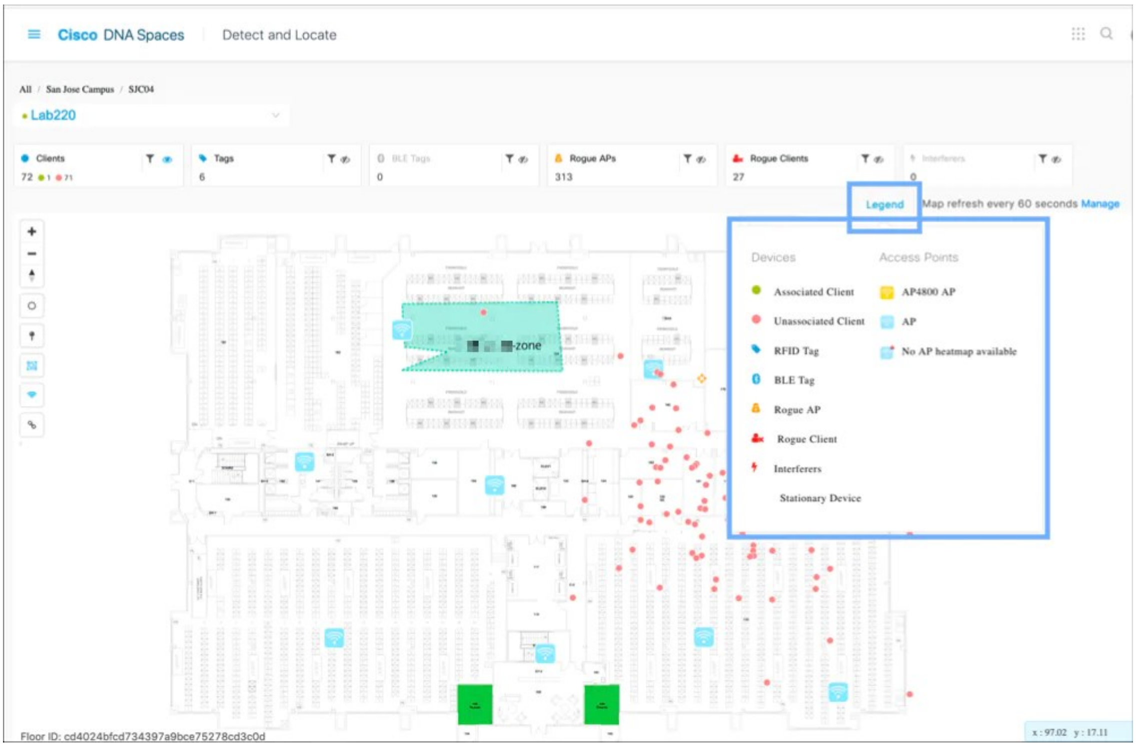
3.3 Cisco MSE / CMX / Spaces

Cisco is one of the biggest names among network vendors in the world and location services have been available with their own products and via integrations to location systems by other vendors. Cisco used to have WLAN location service as the only option but with the release of Cisco Spaces and the new 9xxx series access points there is officially a BLE solution that can be used at the same time as the WLAN location solution as they are not exclusive [T.26]. The older x8xx series access points are capable for BLE tracking with a BLE USB dongle attached to the access point.



[P.10] Cisco - CMX

Cisco CMX uses WLAN Controllers and Prime to get the device signal information from the access points and the access point location information to CMX. CMX does the location calculations, and the needed applications are run on the cmx [T.27]. CMX is usually a local appliance or a virtual appliance. Cisco Spaces uses a Spaces Connector to connect the WLAN Controller to the Spaces cloud. There is also an option to replace Cisco Prime with DNA Center that mostly depends on the use case and is Prime or DNA Center in use in the network.

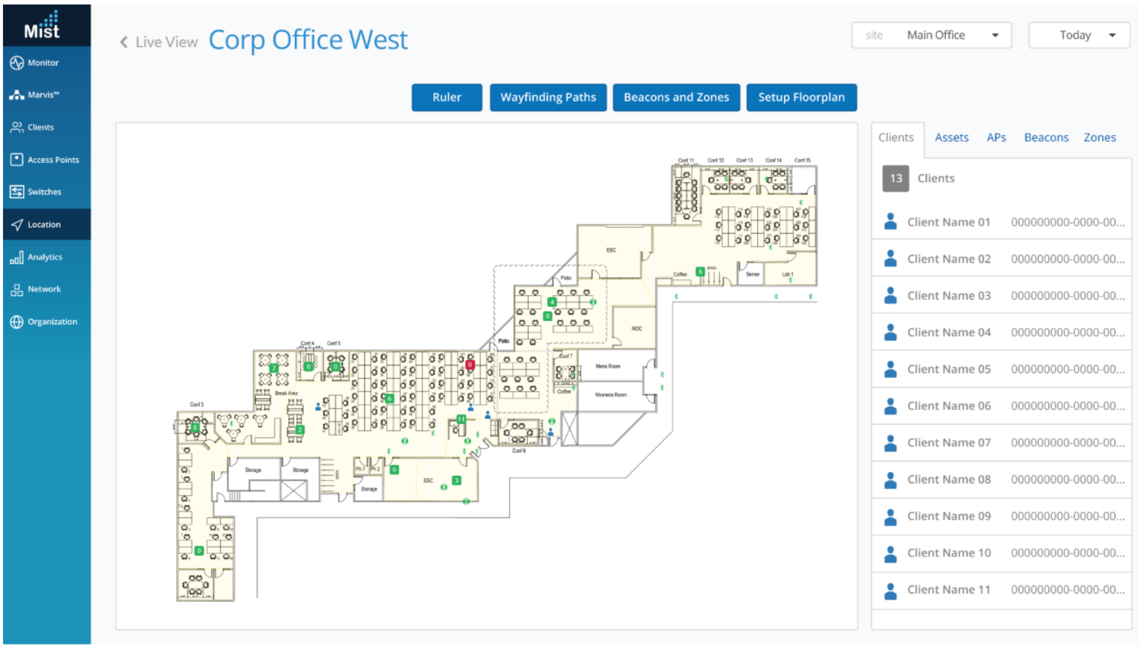


[P.11] Cisco - Spaces

Cisco has been working with AeroScout for a long time and both support each other's services better than any other two vendors.

3.4 Juniper Mist

Mist is a newcomer in the WLAN and location services scene. They differentiate themselves to their competitors with an AI (Artificial Intelligence) cloud that automatically adjusts the network and the performance of the client devices based on their functionalities and actions in the network. This is also exemplary on the location side where the calibration is based on the current location of the device and its past location events. The systems recognize the device and calibrate how the device is located based on the past location events and how the devices are in the moment. The system also considers how the device is supposed to move in space. If the device seems to penetrate a wall the system corrects the location and expects there to be a doorway when going through walls. Same as moving from floor to another, system expects the device to use of a stairway or elevator.



[P.12] Juniper Mist – Location tracking

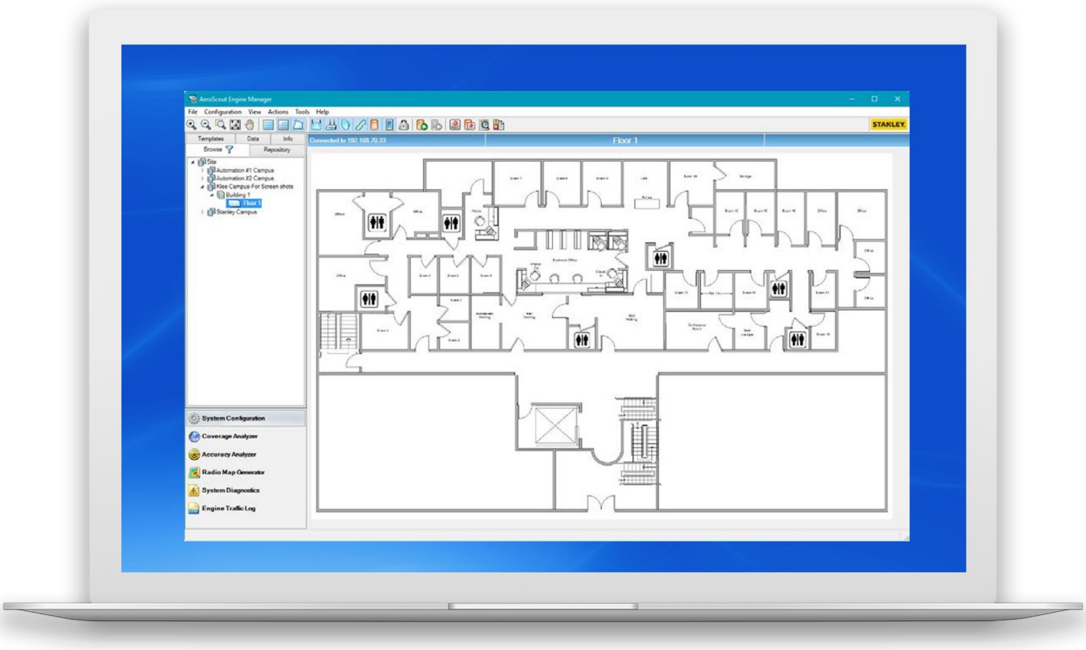
Mist is capable for both WLAN and BLE location tracking, but BLE is preferred as the access points have directional BLE antennas. There are eight antennas for sending and eight for receiving BLE signals. The BLE signal receiving is used by the system to locate devices which are sending data as locating tags. The sending antennas have two uses. The antennas send signals that are used by devices to do the locating by themselves. The antennas can also locate devices and send signals that work as a virtual BLE gateway and can wake-up nearby devices. Using antennas for transmitting BLE data is one example of performing wayfinding. The user's device receives antenna signals, and it forwards them to the cloud. Signal strength is calculated in the cloud and the location information is passed to the located device. [T.28]

Mist offers BLE access points that are more affordable than WLAN access points. BLE access points function is adding BLE coverage for the location service without impacting the WLAN network. The use case is when the WLAN is used for regular communication and BLE is used for location services.

One of the best qualities of mist devices is the operating system that uses bus service architecture. The software design is meant to be updated as a hot swap to a specific feature level. This means that there is no downtime for basic updates and the changes can be implemented during usage.

3.5 Securitas Healthcare

The location services of Securitas Healthcare are based on the AeroScout product. Securitas bought Stanley Security that included Stanley Healthcare and AeroScout in December of 2021. AeroScout is compatible with different WLAN vendor's products, but Securitas Healthcare's focus is primarily on Cisco products. In most of the other vendor's systems the WLAN devices listen and forward the location information straight to ALE (AeroScout Location Engine) which does the location calculation and displays the information on the engine and the visualization product MobileView. In Cisco Systems the locating service is in Cisco CMX or Spaces and the calculated locations are provided to ALE server. The required applications are installed and used on the MobileView server. These include staff duress, environmental monitoring, asset management and patient protection features.



[P.13] Securitas Healthcare – Aeroscout Location Engine

Securitas Healthcare has their own locating tags and location accuracy enhancement devices called exciters. The exciters are used to ease the usage of chokepoints, and they enable a true room level accuracy. There are LF (low frequency) and US (Ultrasound) exciters. All the Securitas Healthcare's tags are equipped with LF sensors and are also working as Active RFID tags. The LF is used to trigger the tags to send location data and add the exciter information in the message. The exciter information in the message is used to skip the regular location calculation and place the tags on the known location of the exciter. Exciters enable the system to be accurate on desired locations even if the WLAN / BLE coverage is not good enough to get exact location information. This can be used to perform a floor level or a building wing level locating with just a regular WLAN network. [T.29]

Securitas Healthcare uses WLAN as the primary locating technology, but the recent Cisco Spaces integration gives the possibility for BLE tracking via the Cisco infrastructure and the Aruba BLE version is also in the works.

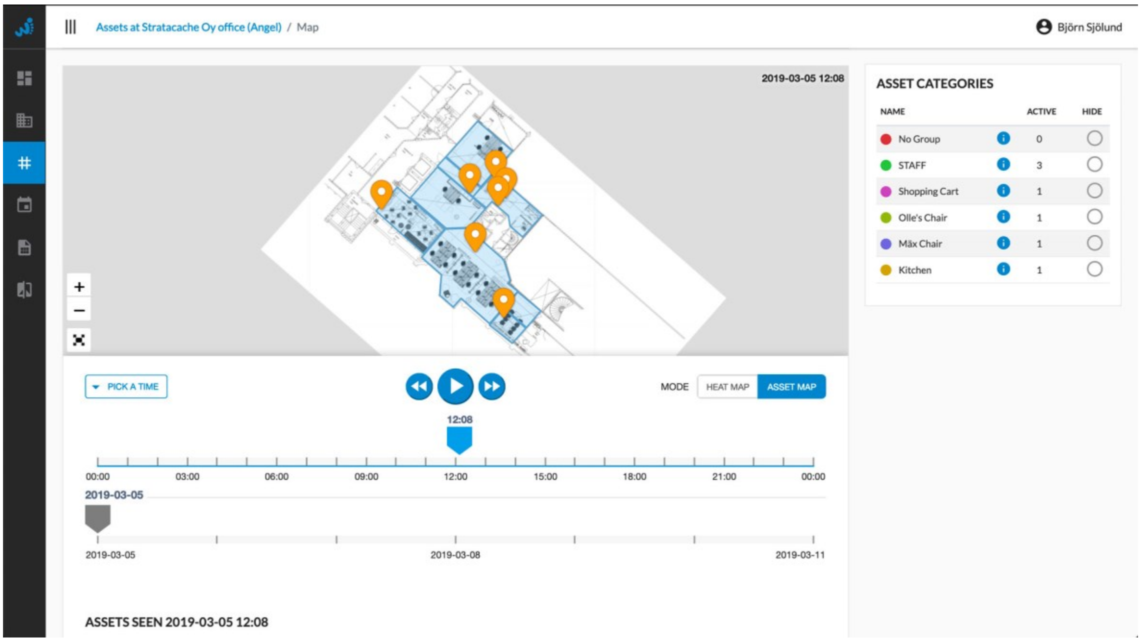
3.6 Other vendors / solutions

3.6.1 9Solution

[P.14] 9Solution - Smooth lite

9Solution is an Oulu based Finnish company with an Integrated Positioning and Communication System (IPCS) solution that works primarily via BLE and regular Bluetooth. The solution has antennas that are called Nodes that receive tags and other tracked device signals. Nodes pass the information from the received signal strength via BLE to CCU communication units that are connected to network and the CCU's pass the information to the cloud location service. The Node network is easy to install as it only needs a regular power socket or uses batteries. Also, the Nodes are primarily inexpensive and can be scattered around with low overall cost. 9Solution has many useful integrations to services that are already in use. The deployment is easy to do even to an already existing ecosystem. [T.30]

3.6.2 Walkbase



[P.15] Walkbase - Location Analytics Dashboard

Walkbase is originally Turku based Finnish company with a WLAN based RTLS analytics service. The system utilizes already existing WLAN and Walkbase's own sensors. The system follows WLAN enabled devices and calculates their location. Walkbase's system presents the information derived from the locating data, as analytics from the environment. The system is targeted for retail and the accuracy depends on the number of WLAN access points and sensors in the network. The company's emphasis is on the analytics side of the retail business and for that reason it was acquired by STRATACACHE, a retail store experience and marketing firm, in 2017. [T.31, T.32]

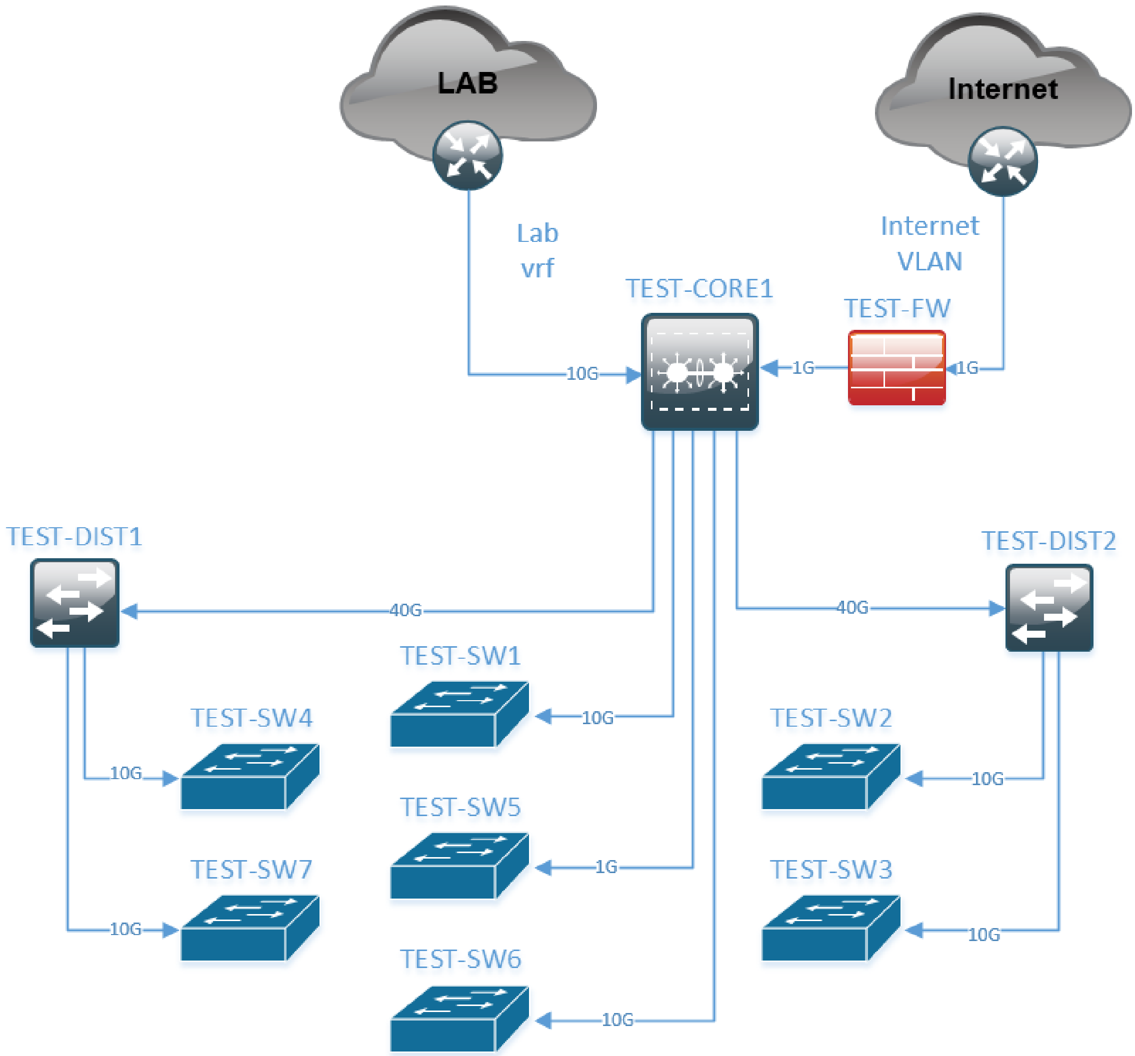
4 Building a testing environment for RTLS

4.1 Designing phase

The primary requirement for a test environment design is the need to have an easily changeable platform where different vendors' products and software versions can easily be changed from one to another. Also, the environment is required to support multiple location systems running at the same time. The core network needs to be fast and robust, so it does not affect the testing of different systems. The available premises for the environment must be taken into consideration when making the decision about the equipment. The whole environment must be compatible with the current lab environments and Elisa's monitoring system. The network must be assessed to ensure that it does not have any negative impacts to the locating system behavior.

4.1.1 Basic network

Network design started with a survey of the status of the current cabling and physical space for the network devices. The premises were confirmed to be adequate for the needs and no extensive wiring was needed to get the environment to support the large location capable WLAN network. The core network was chosen to be Cisco due to the availability of the existing devices and spare parts for future needs. In the survey three locations on the premises were chosen to host most of the networking equipment. The rest of the equipment was to be distributed based on the needs of the WLAN coverage and cabling.



[P.16] Environment network diagram

The core network consists of a Cisco 9500-16X core switch and two 3850-24XS access switches. In the first phase the core network used a Cisco 9500 for most of the routing and switching between the lab environments and location testing environment. The 3850 distribution switches were used to connect most of the network devices and servers. At first the network devices were placed in three locations but later the network was extended to cover the whole premises. The connection between the core devices was decided to be 40Gbit/s as it was enabled by the existing equipment, and as the site cabling supported it.

The access level switches were chosen to be a mix of 9300-48P, 2960X-48LPD-L and 3560CX-12PD-S models. Three of the access switches were placed by the core devices and the rest distributed to the wiring cabinets around the premises.

The wiring cabinets housed the ethernet cabling for the WLAN access points. When possible, the connection was built as 10Gbit/s but to one location the current cabling provided only 1Gbit/s connectivity. The switches are PoE (Power over Ethernet) capable, and the lab network consists of approximately 40 pcs of access points in the location floor area.

The principle for the cabling of the WLAN access points was to use as much of the current cabling as possible. However, there was a need for more cables to get a more accurate triangulation capability, therefore more cabling was added to fill the need. The designated area was divided into different kinds of capability areas. The higher capability areas required a close placement whereas wider placements were adequate for lower capability areas. For one of the areas the access point locations were deliberately chosen not to be optimal to discover performance variations of different location systems. The access point connectivity was determined to be 1Gbit/s, but it was agreed that in some of the areas, the 9300 switch connections could be built using 2,5Gbit/s or 5Gbit/s connections if the access point supported that.

The network will be segregated with VLAN (Virtual Local Area Network) for different vendors and devices. The general idea is to build the networks to resemble real end customer environments and have the same security measures as any network. With the separation performance testing becomes possible and the network can be recovered in case of service interruptions.

4.1.2 Servers and cloud access

A testing environment which caters for any vendor and any technology requires the servers to be virtual. Use of virtual servers makes it possible for the needed attributes to be scaled up and down and even test the performance of the software with abundant resources. The idea behind this is the same as with the core network. There is a need to improve the performance without an impact of any external factors. When tested against another system with the same capacity differences in performance can be measured.

The serves chosen were available and mainly already used by Elisa. Three to five Cisco 220 M4 or M5 servers were available for the environment and for PoC projects, which can be run on customer sites depending on the needs and the lifetime of the servers. They are installed in the premises and connected with one or multiple 10Gbit/s connections, depending on the configuration, to the core or distribution switches.

There is also the possibility of having more servers in the network for dedicated purposes. For example, Cisco ISE network access control platform can be used with multiple vendors for active directory authentications on the WLAN devices if needed for testing.

The anticipated need for access to cloud resources for some of the vendors, and the need for a more future proof environment led to the addition of a dedicated 1Gbit/s internet connection with a firewall and range of public IP addresses. The decision was to use 1Gbit/s connection in the beginning and if the need arises, to update to a faster or more versatile. The firewall was chosen to be a Palo Alto P-820 to an excess number of resources and features for possible future needs.

Cloud access is used only to verify the performance of systems, which have a need for it, and the focus is to have local servers in the testing environment. The idea is not to test performances of systems that are using cloud location calculations with unknown number of resources but to compare them to services with a fixed number of resources. Some of the recently introduced and future location services are moving towards using cloud which creates a new risk for the comparison of different systems, which needs to be considered. One of the cloud location service risks is what happens when the cloud connection is down.

One difference between on-premises location calculation server and cloud is in the payment method or license cost. On-premises server cost consists of application and license cost whereas on cloud premise server cost is usually per located access point. In general, the on-premises application resources are known and can be used for the full capacity by planning. The planning of access point locations and amounts makes it possible to have the most cost-effective setup as the needed capacity for access points varies greatly depending on the placement and usage. Some of the access points must be in places with lower traffic to have adequate total location coverage. On the cloud setup the access points' load is not even but the cost is the same per access point and this means that the user is paying for the capacity and possibly not using it at all.

4.1.3 Virtual environment

The need for virtualization is derived from the need to get systems up faster and have multiple software versions for the same systems for testing. For the virtualization environment VMware was chosen with ESXi and vCenter to host and balance the virtual environment. The distributed switching and balancing of the host are done in vCenter. There is a possibility of centralized creation of VM's in the physical servers for preparation of PoC's.

The virtual networks are built with segregation and all the routing is done in the core device as everything else in the network. The physical servers are load balanced with the vCenter, if the need arises, and the testing hosts are provided with adequate extra capacity when testing the software performance. The auxiliary servers like SQL and network management are run on the same servers as the tested systems to provide a more resilient environment.

4.2 Testing and validating the network phase

Testing of the network and its connections is preparation for the eventual service test. There needs to be a baseline on what the network is capable of and how the outages in connections are managed. This prepares for the eventual system tests, where can be deliberated outages to see what happens to services when certain connections are faulty or disconnected.

The network test was prepared for the physical network and the virtual part. As there is not a good and uncomplicated way of doing point-to-point full capacity testing between virtual machines, the physical part of the network was assessed more thoroughly. Testing was done with a network tester pair (EXFO FTB-1). The end-to-end connections from the access switch to another end access switch were 10Gbit/s connections between the networks to test the routing and firewalling.

Testing concluded that the network was faster than required for the intended purpose and that the remote access networks are separated correctly from the testing networks. There are not going to be problems with remote access to the infrastructure even if the testing networks use full or excess capacity. Now, the only bottle neck in the testing network is the low speed, namely 1Gbit/s, internet connection, but it can easily be upgraded if the need arises.

4.3 Setting the testing parameters for new products

Designing testing parameters for all future products is impossible so the emphasis is going to be on setting parameters for the existing products. The testing parameters are going to evolve along with the new features and new products to better cover their use cases. Respectively, there cannot be tightly set rules for testing systems' compatibility. Therefore, a way to balance between the distinctive features is needed. The systems' most critical features need to be tested to discover the error types that the system can recover from and how to increase the resilience. Also, the end customers' requirements for the system must be considered in the test design.

4.3.1 Testing parameters for Local system

Testing of locally hosted systems is divided into three categories: server, network, and end user devices. In the server testing the following parameters are considered; 1) the stability of the software, 2) the effect of virtual resource shortages and 3) the effects of additional services like SQL servers having resource shortages or being offline at times. Networks testing is more straight forward. The parameters are 1) how outages between end client and server or 2) how unreliable network connections impact the system’s features and reliability. In the end user access device/software testing the use cases of the device and how the access is spread out in the facilities need to be considered. The end user devices may have issues in accessing the network and the needed servers. The needs of the system and the most critical services are noted and if required they are made more resilient with redundant systems. System recovery and possible issues in automated recovery are also in the testing focus. After the locally hosted system has been tested it is time to log findings and start collecting a disaster recovery plan.

4.3.2 Testing parameters for Cloud system

Testing of cloud systems is dependent on how large part of the system is in the cloud and how large it is in the local system. In general, the visualization server and the local devices connections are in the premises and the resource consuming systems, like location calculation, are in the cloud. Simple events like button presses and current temperature are usually shown in the local system. Testing is performed in the local systems, in the network’s internal and external connections, and in connections to end user devices.

The local system testing parameters are 1) the stability of the software, 2) the effects of virtual resource shortages and 3) effects of additional services like SQL servers having resource shortages or being offline at times. Network is evaluated internally for 1) how outages between end client and server or 2) how unreliable network connections affect the system’s features and reliability.

The cloud access network testing is also done separately to see 1) how ping, jitter and other timing/access problems affect the accuracy and 2) how connections problems of different components of the system affect the overall performance and accuracy of the system.

The end user device testing depends on how the device is connected to the server. If the server is in the cloud and the connection is via cellular network the testing is done differently to connecting with local network. The cellular network depends on the cellular provider and can be used as an additional connection for cloud-based systems to bring more redundancy, but it comes with the cost of two separate communication methods for all end devices. System recovery and possible issues in automated recovery are also in the testing focus. After the cloud system has been tested it is time to log findings and start collecting a disaster recovery plan.

4.3.3 Testing parameters for Hybrid system

Some systems can utilize both local hosting and cloud. There can be a cloud-based backbone system for calculation and if there are problems with access to the cloud the location tracking does not stop, instead it is assigned to be done locally. This is done with local virtual servers or a local server with enough spare resources. It is also possible to use a local system that does not have enough resources to run at full capacity. In this case, when most essential results are calculated all other data is only stored. In general, the system needs to fully support both ways of doing the calculations. Designing tests for hybrid systems is done case by case, because the testing depends so much on how the systems are communicating to the client and between themselves. The testing should include the recovery testing from failover and how the interruption has affected the data collected for analytics.

4.3.4 Testing of current product's new versions

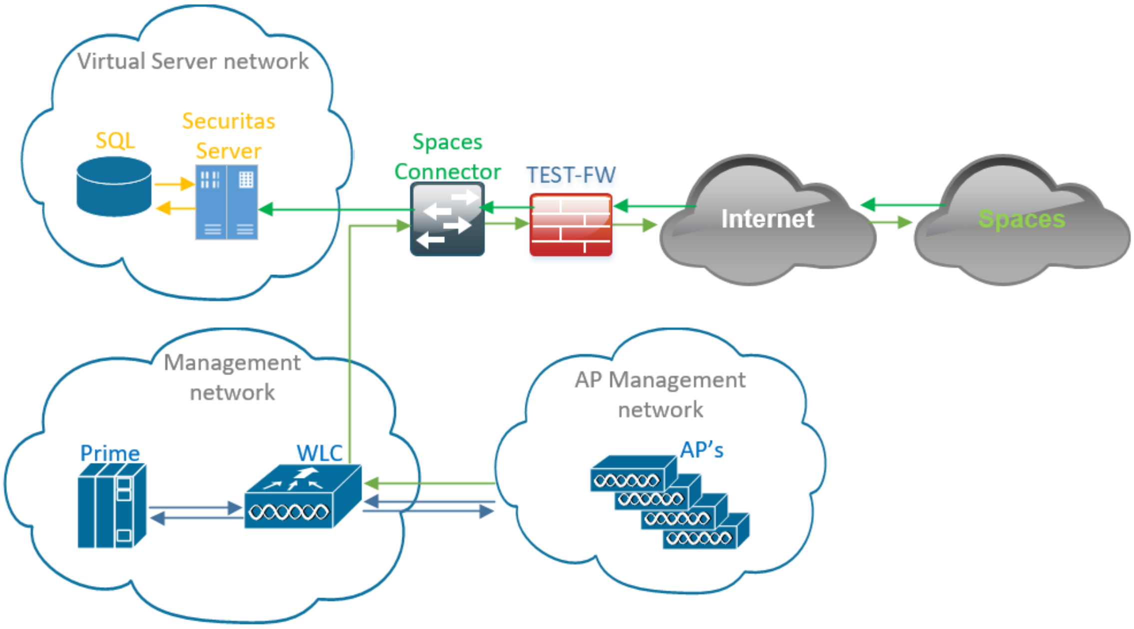
An important part of testing is to evaluate a system against its different software versions. This is vitally important when preparing to upgrade a system to a newer version with new features and when some of the used features will be changed. The main problem is not the change but the change that is not accurately known how it affects specific parts of the needed features. Some features may appear in a way that is not intended by the vendor, and therefore the most crucial use-cases must be assessed before doing a live update. The process is best initiated by testing on a dedicated testing environment before updating the production environment. This is done to ensure the production systems are not broken or changed in ways that cannot be seen beforehand. Also, the stability and impact on stored data needs to be verified before upgrading to newer software. In a virtual testing environment, there can be several different versions of the same system running and the output can be compared to see the difference in the behavior of the changes. The amount of scrutiny is dependent on the importance of not having errors in the data. On a less critical system like calculation of how many people have been in the building and which rooms have been used for cleaning, the accuracy is not that critical compared to a system where for example the temperature of donated blood is monitored to see that it is spoiled and cannot be used in a patient.

4.4 Testing with first pool of products

The first product to be tested in the new environment was chosen to be Cisco Spaces locating environment with integration to Securitas Healthcare AeroScout engine. The current Aeroscout systems use Cisco CMX service and Cisco has released an End-of-Sale notification and the Cisco Spaces will be the new replacement service.

The main purpose was to learn how setup do Cisco Spaces cloud system and to make a comparison to a Cisco CMX based local system. The Cisco Spaces system is new and there is not a wide availability of information on how it compares to the old one, especially when integrating into the AeroScout system. Cisco Spaces has some additional features as support for BLE location tracking and BLE message transfer to the AeroScout system. The testing focused on the WLAN part of the system and the BLE part was not considered in this phase preliminary testing phase.

4.4.1 Building the environment for testing



[P.17] Cisco Spaces – Environment diagram

The testing environment building started with the fresh installation of Cisco 9800 WLC and Cisco Prime Infrastructure. The physical access points devices and their connections were transferred to the newly configured controller. Prime is used to collect the access point information and access point locations in the building to be imported to Spaces. The Cisco Spaces Connector virtual machine was installed in the system and used to connect the WLC and access points to the Spaces cloud server. An already configured and running version of Securitas AeroScout servers was used to receive the information from Cisco Spaces and the communication was done via the Spaces Connector. The Spaces Connector is used in the local network as the transfer point between the local infrastructure, cloud-based Spaces server and the local Securitas server. Not all the data needs to go through the Spaces server and some information like tag presses and tag send information and temperatures can be sent without the need for circulating the data in the cloud first. The Spaces connector and Cisco WLC are configured to connect to the cloud and after the synchronization the information collected by the access points is available in the Spaces cloud dashboard. The Securitas Healthcare already had an available integration in the Spaces cloud. The AeroScout information was provided to the Spaces and vice versa to get the connection up and running via the connector. Firewall changes were not needed as the Spaces connector is opening the connection to the Spaces cloud and keeping the connection open. [T.33]

4.4.2 Evaluating the product

The first test focused on location calculations in Cisco Spaces versus Cisco CMX. There was also a need to understand the differences between the systems in maintaining and upgrading access point locations and floor plans and how they affect the collected analytics. Also, there were tests for the Spaces cloud performance and how the Securitas Healthcare system recovers from issues in connections to Spaces cloud. It is important to collect user experience on issue handling to improve troubleshooting procedures.

The testing systems were built with the same access point and the same prime floorplans and access point locations. The reference environment was set up with the Cisco CMX and the testing environment with the Cisco Spaces. Neither of the systems were calibrated and the testing was done the same way with both systems. The test data was collected by Securitas Healthcare's location accuracy analytics and the results were compared between the reference and testing environments.

After the performance evaluation the system recovery and fault stability were tested. Stability and recovery testing was done by shutting down links between the Wireless Controller, CMX/Spaces Connector and between Securitas Healthcare and CMX/Spaces. After the links had gone down and the results were collected, the link was brought up and the time to recovery was measured. In the Spaces assessment, the connection from Spaces Connector to internet was also evaluated but as this did not have a corresponding test in the CMX environment the result was not compared. Both systems were tested twice, and the end results were compared.

The performance testing showed no notable differences between the systems and even though they were not calibrated, the accuracy was sufficient. After the calibration, the accuracy would have been better. However, the focus was not on accuracy but on the difference in system behavior. The accuracy test did not fail on either system, or the results were almost identical. The stability and recovery testing showed that the systems are remarkably similar at recovery and that the same recovery processes work on both environments. The only significant difference was in the local and cloud server connection but that was known beforehand and did not affect the end results.

All together both systems performed as expected and the Spaces environment did not experience any unforeseeable issues. The testing shows that in this preliminary testing, the system behavior is very similar to the CMX environment and there are no reasons for ending the testing process on the Spaces environment.

4.4.3 Conclusions on the system testing

The first location environment testing went as expected and the system performed as well as the reference system. The Cisco Spaces environment with the Connector was easy to set up and the change in testing environments for the comparison assessment was equally easy. Both systems performed well and the testing itself was assessed as straight forward process altogether. The backup service of the virtual environment made the testing process easy. It was possible to take snapshots of the virtual machines in various stages of the assessment. After adding or reversing minor changes the effects were visible.

The testing environment suited well for the assessment process. Connecting the physical network to the virtual testing system and changing the testing system to another was simple and quick. The benefits are clear especially when compared to the work needed to build two overlapping systems in the same space with double physical devices. The possibility to use the exact same network devices and network information to evaluate both systems’ capabilities is game changer on the test that have been done before this test system. Changing little things like software version in one part of the system and being able to test the change in the effects on the product gives great information on confirming system compliance and generating upgrade guides for special environments.

Assessment of the tested systems and the testing environment led to believe that this is only the beginning for the usage of this environment. There are already multiple new features and systems that are in line to be assessed in the future.

5 Conclusion

5.1 Results of setting up and testing the environment

The designing and building of the physical infrastructure were as preliminarily expected. The location of the environment fulfilled the needs of the system and the possibilities for expansion are excellent because the usage of the premises enables it. The environment was built to be scalable and easily expandable to better fulfill the different needs of various testable systems and the needs of different usages. The back-bone network is built to perform better than tested systems require. Therefore, the network behavior does not affect the system performance. Also, the network is designed to operate with different WLAN and BLE vendors. Thus, it is possible to test different network setups without vendor bias. The virtual environment is built to be able to run multiple parallel location systems at the same time and even with multiple versions of the same location system. The systems are meant to be tested with different configurations to how they perform and how changes affect the performance.

After the environment was set up the physical and virtual environments were tested and validated according to previously set parameters. The physical network was tested rigorously to perform under tens of gigabits of data strain and with network interruptions to ensure that the network performance was adequate with excess data load. The virtual environment was validated with high load even with strain to run massive campus location networks. The need of running multiple parallel systems at the same time was met for the close future but the environment is also easy to scale up when the need arises.

5.2 Review of the testing of first pool of products

The first tested product the Cisco's Spaces was selected as the successor of Cisco CMX which is currently being used in Elisa's Cisco based location systems. The current CMX systems provide the location calculations for Securitas Healthcare Aeroscout server and MobileView application. The Spaces location system will be tested considering Securitas Healthcare needs. The main difference between Cisco CMX and Cisco Spaces is that CMX is a dedicated local server and Spaces is a cloud-based solution. The need for testing arises from the inevitable change from CMX to Spaces caused by the announcement of not bringing more features to the current CMX 10.6.3 software in the future.

The setup of Spaces testing environment was done without issues and the testing focused on a commercial product. Tests were performed on failure tolerance and fault recovery comparing the CMX and the Spaces. The main concern of Spaces was the cloud connection and how connection errors affect the critical parts of the location services. Both systems were remarkably similar in the location performance and the main difference ended up being the connection type to the locations calculation server. The fault recovery and the tolerance performance results were quite comparable, and the pros and cons of both systems were balanced on the system types. The multiple diverse needs of end customers were not considered in the performance testing part. In the end Cisco Spaces performed with the same level as the Cisco CMX and the continuation of the development of Spaces is a key indication of why it is a desirable route after the CMX must be replaced.

The location environment was operating well and met the requirements that were set at the beginning of the project. The network infrastructure made it possible to use both location servers with the same physical devices and the shift between the two could be done easily when needed. Network management was built separately from the location server communication network. The connection problems were easy to generate in different parts of the networks to see the effect on the performance of the location servers. As the assessment of the testing environment, it can be said that it performed as promised and even though there are ways of making the system more complex and diverse, the current iteration is excellent for the use case.

5.3 Conclusions on the system and a verdict of the future

The overall experience with the project has been exciting and interesting. The specification and building of the system were as expected and there were not too many issues after the early stages of the project. Most of the changes that were made in the later phases were about the anticipation of new products and making the system more future proof and fault tolerant. The additional systems' complexity after the working proof of concept was the intended outcome of this project.

The experiences of the location testing environment have been positive and the need for it has been proven. During the setting up and testing phases more and more new products have become available to test and there have been more and more queries from our customers to test and plan upgrades for their existing location environment. The first tests have shown that testing and practicing environments are needed for getting more uptime for environments. The ability to test changes in a separate environment, which is set up in the same way and to see how the changes affect the downtime expectations is a game changer. The other main feature is to test new products and show how they work to end customers. There can even be comparisons between the customer's current solution and the new product to see how the performance and cost evaluations are affected. The customers, sales department and technical specialists have already seen the benefits of easy ways of proof of concepts and testing of changes.

One of the near future changes is going to be the addition of different WLAN and BLE vendors to the environment. The idea is to have specific areas done with fixed vendors and have a central location for changing the setup to the vendor that is showcased depending on the needs. That way the showroom experience can be tailored to the customer and demo needs. There are also discussions about expanding the environment to other office locations and having a movable event/conference setup. The preliminary talks suggest that the virtual environment and physical environment will stay in the current place and the other locations will be more of a showroom concept which is connected to the physical environment. That way the environment can be easily set up in new locations and brought to the customer for demo purposes. Also, as the Cisco Prime is currently under End of Sale -status we are planning on moving the environment to the Cisco DNA Center. These are only a few examples of the upgrades and changes to the environment that have been planned.

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