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Resource Positioning System Product Development

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Abstract

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The goal of the work was to move from a concept to a final product on a replacement of the existing resource positioning system (RPS) in use by Aiforsite, with the finalisation of the project being carried out by setting up a prototype network, which would work as a final test for the viability for the new system in a real customer setting on a construction site. Included in this was the testing of different system components, their evaluation and finally product development, much of which was carried out. Unfortunately the final goal of the project, that was the setting up and testing of a prototype network, was ultimately not carried out due to various circumstances. Nevertheless the work done has paved the way for further work down the line towards the final product.

What was achieved was a good understanding of the system and its various components, a workflow for producing tests and analysing their results, further development of various aspects of the product (such as different aspects of the hardware and firmware being developed, device configuration nailed down), an evaluation of the financial viability of the system, cooperation between Aiforsite and Wizzilab and various other aspects.

This thesis works as a summary of the work done over two years, spanning dozens of tests, documents and discussions. Many of the conclusions drawn are more widely useful outside of the context of this project, and many of the practices and lessons can be carried out in future product development projects.

Keywords: IoT, Resource Positioning System, Location Tracking System, LoRa, Dash

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Työn päämäärä oli paikkatietojärjestelmän saatto konseptista tuotteeksi korvaamaan Aiforsiten siihen asti käyttämän paikkatietojärjestelmän. Projektin viimeinen askel piti olla paikkatietojärjestelmän protyyppiverkko, minkä oli tarkoitus toimia testikenttänä aidolla asiakkaan rakennustyömaalla tuotteen viimeisen vaiheen toimivuuden testaukselle valmista tuotetta kohti. Työ sisälsi järjestelmän eri osien testausta, niiden toimivuuden arviointia ja kehitystä, mikä pitkälti toteutui. Valitettavasti projektin viimeisin päämäärä (mikä oli prototyyppi verkon asennus, testaus ja arviointi) ei toteutunut. Kaikesta huolimatta työ pohjustaa tulevaa työtä järjestelmän valmiuteen saattamiseksi myytäväksi tuotteeksi.

Aikaansaannokset olivat esimerkiksi järjestelmäkokonaisuuden ja sen komponenttien ymmärryksen rakennus, testien toteutuksen ja niiden tuloksien analysoinnin prosessin muodostaminen, järjestelmän eri tasojen kehitys (esim. Laitteiden speksit ja konfigurointi), järjestelmän taloudellisen kannattavuuden arviointi sekä Aiforsiten ja Wizzilabin välinen yhteistyö.

Tämä opinnäytetyö toimii koosteena yli kahden vuoden, monen testauksen, raportin ja keskustelun sisältämälle työlle. Monet tämän työn johtopäätöksistä ovat hyödyllisiä laajemmin eri tuotekehitysprojekteissa yhdessä tämän työn ohella saavutettujen käytäntöjen ja oppien kanssa.

Avainsanat: IoT, Paikkatietojärjestelmä, LoRa, Dash7

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List of Abbreviations

API: Application Programming Interface. It is the interface that computer programs use to interact with each other.

ACK: Acknowledgement. Confirmation sent on the reception of a message. In this case always downlink (downwards in a device hierarchy: Network -> Gateway -> Device).

BLE: Bluetooth Low Energy. Radio technology using the 2,4 GHz frequency band with a low power consumption (when compared to regular bluetooth signal).

D7: Dash7. Open source network protocol using the public 868 MHz public radio band (EU).

DPTA: Discussion, Planning, Testing and Analysis. A method of performing the testing and quality assurance portion of a product development project simplified into a four (or five) part loop for a small product development team.

FSK: Frequency Shift Keying. A radio signal modulation technique where binary data is transmitted through the shifting of frequency up and down instead of through the signal waveform (amplitude).

GFSK: Gaussian Frequency Shift Keying. A form of Frequency Shift Keying that uses a narrower bandwidth by changing the shape of the signal pulses to have softer peaks, which reduces the amount of interference the signal creates.

GW: Gateway. Communicates with anchor devices downlink and the network hub (in this case the cloud) uplink. Is the bridge between the service and the end devices.

IoT: Internet of Things. A network that connects a system or series of devices to another system, series of devices or the internet through a wireless connection.

LB: Link Budget. A measure of the total transmitted power in a radio system. In this project, always from the perspective of the gateway device. A lower value corresponds to a higher quality signal. Measured in Decibels.

LoRa: Long Range. Low power wide-area network modulation technique that uses the 863-870MHz frequency band (EU).

LoRaWAN: Long Range Wide Area Network. Where LoRa defines the physical layer of the technology, LoRaWAN defines the application and Media Access layers.

LPWAN: Low Power Wide Area Network. A wide area network using radio signals to cover a large area with typically a low density of devices with a low power consumption.

PRR: Packet Reception Ratio. The percentage of packets sent by an anchor and received by a gateway device.

RPS: Resource Positioning System. A system of devices and software to track the positions of resources within a set location or locations.

SF: Spreading Factor. A factor at which the transmitted LoRa signal is spread out into a wider time frame in order to aid reception and increase hearing range for receiving devices.

WNT: Wirepas Network Tool. The Wirepas proprietary user interface and software used in the management and monitoring of the Wirepas resource positioning system.

WPE: Wirepas Positioning Engine. The backend software handling the raw data of the Wirepas system end devices and converting it into more tangible location information.

UAS: University of Applied Sciences. A type of higher education institution concerned with a more practice-oriented goal of educating students for professional work life than a regular university.

1 Introduction

This thesis documents and explains the process and reasoning behind a project pertaining to the product development and testing of a new version of a Resource Positioning System for Aiforsite Oy.

The value of this work for Aiforsite is to supplement or replace the previous RPS in use by the company. Aiforsite is constantly looking into developing and / or acquiring better technological solutions to improve functionality and service for their customers and internal use. The previous RPS has certain limitations, which can be overcome with this new system.The details of these systems and their differences will be outlined in the next chapter.

My involvement with the subject of the thesis began in Q1 of 2021, as this became the subject of an innovation project course. Similarly to this thesis, the work of said project was carried out for Aiforsite. The work of this thesis is a more or less direct continuation of the innovation project and work I continued at Aiforsite for the project afterwards as a part of my internship and subsequent employment, though at that point the project was no longer a primary focus.

1.1 Aiforsite

Aiforsite is a company providing IoT products and digital solutions to construction companies globally. Aiforsite was founded in 2016 in Espoo, where the current company headquarters are located. The main focus of the company is in increasing productivity of the work performed on site using a combination of IoT devices, algorithms and artificial intelligence. [1]

Aiforsite was founded as Bliot in 2016 and later changed its name to the current one in 2019.

1.2 Wirepas

Wirepas is a Finnish IoT solutions developer and provider based in Tampere. They work in partnership with various companies to provide full IoT products and services for customers. For the Resource Positioning System currently utilised by Aiforstie, the software and protocol components are provided by Wirepas and the hardware comes from other partners of Wirepas. The company was founded in 2010.

1.3 Wizzilab

Wizzilab is a French IoT software and hardware solutions developer and provider based in Montrouge. The company provides the anchor and gateway hardware and firmware for the new RPS being developed by Aiforsite. The company was founded in 2010.

1.4 Goals and Scope

The goal of this work was to first evaluate the suitability of the Wizzilab system as a replacement for the Wirepas system for Aiforsites use case. Secondly, the goal was to test the system's fundamental functionality and to suggest improvements and fixes for the eventual prototype system, and then, to further test, after fixes and upgrades have been made, to then finally move on to testing a prototype of the system network.

After testing and evaluation was concluded, further feedback was provided to Wizzilab, and since it was found satisfactory, the system will be implemented into development. Additionally, the documentation process of its ramp-up, use, upkeep and ramp-down will be begun.

Other parts of the project occur in parallel, but nevertheless fall outside the scope of this work (such as development of the positioning engine, which is done in-house at Aiforsite).

Due to the amount of testing and the nature of the project, many details in this work will be omitted or abbreviated for confidentiality reasons, to protect intellectual property and/or to save time / tighten the focus of the thesis paper.

Some of these omissions include (but may not be limited to):

- any building floorplans and any documentation which showcases building floorplans (apart from the floorplan of the Keilaranta 1 offices, which is only of the first floor and is both available to any guests and was requested from the building management)
- Any correspondence between Wizzilab and Aiforsite, which will at most be mentioned in passing
- Many types of plans and their documentation, especially test plans, due to the test plans relying heavily on building floor plans and because including all of the different planning documentation would take too much focus away from other areas due to their quantity
- The specifics of internal discussions
- Any documentation relating to the financial evaluation of the RPS systems
- Specific device specifications (e.g. make and model and related information, often found in product specifications sheets)
- Anything to do with the development of Aiforsite proprietary software, including software and code developed for the RPS project.

2 Background

This chapter will detail and/or outline the most important concepts concerning these Resource Positioning Systems as well as explain their functions in general terms.

In order, the chapter will explain what a RPS is and what its components are as well as requirements set upon the system by the use case. This is followed by some information relating to radio signals and how the concepts relate to the project. The chapter is finalised with the RPS systems in comparison.

2.1 Explaining Resource Positioning Systems (RPS)

Resource positioning systems are used for locating resources within a set area outlined by the RPS network with a combination of hardware and software. There are different reasons why one might want to keep a track of resource positions (The points relevant for the use case of the system as it is offered by Aiforsite are given in bold-face):

- **Tracking / verifying the location of valuable tools and assets that move around (workers, excavators, tool boxes, building materials, etc)**
- **Measuring worker presence in relevant areas (useful for takt production)**
- Tracking vulnerable human resources in hospital and healthcare environments
- **For the purposes of fire safety in case there is a need for evacuation**
- **For performing analysis based on historical data on resource positions to identify chokepoints and hangups in the work process**
- Other.

An RPS is generally composed of three different device types: **Gateways**, **Anchors** and **Tags**.

Although a Gateway necessarily differs from the other two, the function of Anchors and Tags does not delineate their respective hardware from each other. Depending on the specific device, the role of Anchor or Tag may be interchangeable. Thus the role of Anchor and Tag, unlike the Gateway, specifically refers mainly to the function of the device and not its form, though it tends to be more cost effective to acquire separate tag devices as they typically have more competition and systems place lower requirements on these types of devices.

Some systems the role of the anchor is played by the Gateway, while other systems offer the option of the Gateway acting in the role along with dedicated anchor devices in the network. Using a gateway device as an anchor may be preferable in very small use cases where not a lot of area is covered. However, in larger than singular room examples, cost starts to become a prohibiting factor, dedicated and notably cheaper anchor devices will need to be used.

2.1.1 Gateway

The gateway is the most important singular device in any RPS or RPS network. Whenever information from Anchor and Tag devices in a network travel to the end user, it needs to first reach the Gateway, which it relays uplink through a wired or wireless internet connection.

Note: For most use cases by Aiforsite, a wired connection to the Gateway is either impractical or not possible, for this reason a greater emphasis is placed on the quality of the link the gateway has to the internet wirelessly through WiFi.

The Gateway is the device responsible for sending messages downlink from the Network Server and Uplink from the end devices into the server.

Downlink and Uplink refer to the direction of communication for the message. The terms originate from satellite communication where messages downlink would literally come down from a satellite and messages Uplink would travel up. The terms are generally used to inform as to the direction which a message is travelling in relation to an end device and a network. [2, p. 12; 3]

2.1.2 Anchor

In a Resource Positioning System, an anchor device is a system component measuring the distance between itself and beacon devices, also known as Tags, in the system and relaying the measurements uplink in the network to the gateway.

2.1.3 Tag

A tag device needs to be of sufficiently small size and weight, so as to not burden the wearer or be inconvenient in bulk when attached to a resource. Same as the anchor, the device also needs to have a sufficiently sized battery. Ideally a tag will not need to have its battery replaced before a given project is over (in the case of Aiforsite, about 1-2 years).

2.1.4 Requirements

For the purposes of resource positioning in construction environments, various requirements need to be met (in alphabetical order):

- Accuracy in data
- Affordability
- Capability to withstand different conditions

- Obtrusiveness (lack-thereof)
- Power consumption
- Wireless Network capability

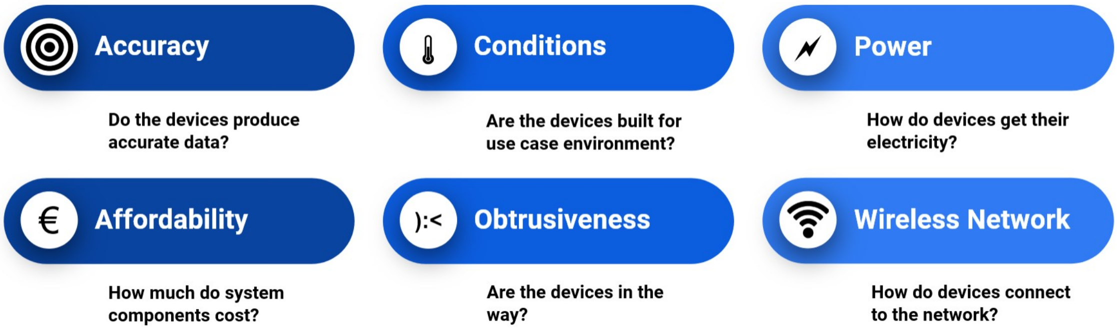

Figure 1. Resource Positioning System device requirements.

Accuracy

Depending on the site, different levels of accuracy may be desired / requested. The system needs to correctly identify resource positioning at least at room level accuracy reliably.

Affordability

The system and devices must provide functionality at such prices, that clients will not be discouraged from adopting the system due to cost. An individual site might have dozens of resources to track that may require hundreds of devices to keep a track of depending on the size of the site.

This will not be handled into detail in this work, but which has influenced various decisions in the background and has been taken into account in the selection process.

Conditions

Conditions inside a construction site may be highly varied. Devices will regularly have to contend with copious amounts of particles in the air. Depending on the site and their location within it, they may also be exposed to the elements, which adds additional requirements.

In short, the devices need to be able to withstand conditions that include outdoor weather and dust and other particulate matter.

Obtrusiveness

The system should be sufficiently unobtrusive as to not hinder work on site. The most affected part of the system, the tag device, is the most important when looking at obtrusiveness.

For this use case, the tag device needs to be small and light enough to be comfortable to wear on person or be convenient to carry and not cause neck strain.

Power

Access to the electrical grid for tens to hundreds of small electrical devices is unobtainable and impractical for the large majority of construction sites for the majority of their project spans. Gateways are not constrained in where they can be placed due to the need to collect data in the same way that nodes are and are in low enough numbers that they can consistently be connected to on-site electrical distribution boxes.

The anchor and tag devices however need to be able to operate without an electrical grid and for sufficiently long periods of time without the need for a change of battery.

The length of construction projects varies, a site may be completed within 6-9 months for a small site to exceeding 12 months for larger sites. Delays can extend the run time of construction projects even longer [4]. For this reason, 12 months battery life in normal use should be considered minimum for anchor and tag devices.

Wireless Network

Wired connection to the internet within any given construction site will be much more limited compared to power. There is no guarantee that one can utilize a wired connection to the internet and to the network on-site. As such wireless connection between devices and the network is necessary. Any such communication also needs to be stable enough to deliver data reliably to the end user.

2.2 Radio Signals and IoT

Though there may be technologies which improve upon previous ones or are more suitable than others for their specific use case, there are no one-size-fits-all solutions for all wireless and IoT applications.

Among asset tracking, these applications also include different kinds of condition monitoring, measurement and logistics solutions.

For the purpose of understanding why the choice of different radio communication techniques and technologies matter, it is important to know a few bits of information about the different kinds of benefits and tradeoffs one makes when choosing a particular technology for a particular role or purpose.

When sending data through the air with RF (radio frequency) communication, different techniques exist with different types of modulation to varying effects. It is important to know that when communicating with RF, there is an inherent tradeoff between communication speed (bitrate) and range / reliability. It can be likened to trying to consume media, such as music, at increased speed. The faster information is communicated, the harder it is to understand, decreasing the reliability of the communication and making it harder to receive at increased ranges. The bitrate of the signal is informed by multiple different factors, such as modulation and frequency. Different modulation techniques might be more efficient than others at similar ranges.

Speed is not the only factor affecting communication reliability and range. Another factor is Tx Power, or how loudly the signal is being transmitted measured in dBm. This introduces another tradeoff, where more power is used to generate a more powerful signal to reach further distances and to be able to reach devices more reliably, for example through obstacles or environments previously difficult to pass.

There are other factors that affect range and reliability, such as bandwidth. The main thing to know is that generally speaking: Increasing bitrate and lowering power consumption is done at the expense of decreased range and / or reliability and vice versa.

Sometimes making this tradeoff is a no-brainer, such as when operating at consistently low ranges where end devices are within line-of-sight or when the amount of data having to be transferred per hour / day is so miniscule, that higher bitrates become unnecessary and power consumption becomes less of a problem with a fewer number of packets sent a day. For the former, one can think of an application such as a smart watch, which will always remain close to your smartphone, perfectly suited for technologies such as Bluetooth Low Energy. With the latter, one can consider sensor devices meant to measure water level from safe distances over a long period of time, such as lakes or water reservoirs. Many of these use LoRa for communication.

Spectrum:

All of the technologies named in this thesis use the unlicensed frequency bands for communication [5; 6 p. 4].

The main reason for their use is the avoidance of licensing costs associated with private broadbands. The downsides of the public broadbands used by LoRa and Dash7 within the EU are the duty cycle limitations imposed on them to reduce traffic on the aforementioned spectrum. This thesis will not go into detail about said limitations in this work; in short, they impose a 1% communication limit per hour on LoRa, meaning a device can take up to 6s

Time on Air per hour of communication. Dash7 in turn is limited to a more generous 3% thanks to polite access. [7, p. 5-6]

See Appendix 1 for statistics related to frequency band usage in the EU.

2.2.1 Bluetooth Low Energy

Bluetooth Low Energy, or BLE, is a low power short range personal area network created with IoT applications in mind. Its main benefits are its fast data rate and low power consumption, which make it well suited for battery operated IoT devices in circumstances where ranges remain below 30m and end points retain a line of sight relatively free of obstacles.

Despite the name, BLE is an independent and incompatible standard from standard Bluetooth. [8]

2.2.2 D7A

D7A, or Dash7 Alliance Protocol (also known as Dash7), is an open standard for bi-directional sub-GHz radio communications created and managed by the Dash7 Alliance tailored for sensor-actuator applications. D7A uses **2-GFSK** (Gaussian Frequency Shift Keying) modulation. The standard excels in reliable communications in challenging environments and can reach ranges of up to 1000m in direct line of sight operation. [9; 6]

2.2.3 LoRa

LoRa, short for Long Range, is a Semtech proprietary Radio Frequency modulation technology for Low Power Wide Area Networks (LPWANs). The technology uses Chirp Spread Spectrum **(CSS) / GFSK modulation,** which makes the signals very robust against interference. The technology also boasts a wide coverage with the capability of penetrating into and out of buildings. LoRa is made up of six different data rates, known as Spreading Factors, which allow the technology to be adapted better to different contexts. This adaptation can be done within a device on the fly thanks to the LoRaWAN Adaptive Data Rate function. LoRa is the modulation scheme used by LoRaWAN. [10; 6; 11, p. 10]

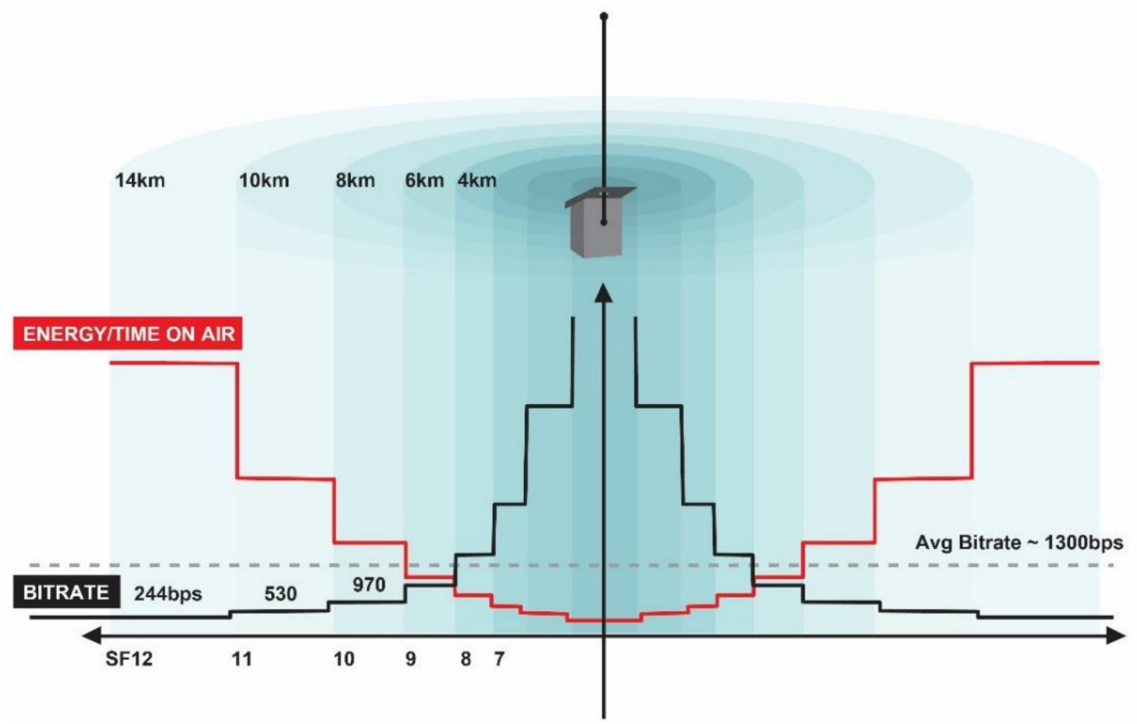

Figure 2. LoRa Spreading Factors (SF), their range and energy consumption / time on air. [7, p. 14]

With the Adaptive Data Rate, the battery consumption for a device can be optimised by switching to the lowest spreading factor possible for the device at the position it is in (obstacles and range).

The higher end of the LoRa Spreading Factors have the longest range, but also take the longest amount of time to relay the same data and thus use a larger amount of energy and eventually run into the unlicensed broadband duty cycle limitations on amount of air traffic caused, i.e. they run out of budget to communicate messages of sufficient length to use in certain applications.

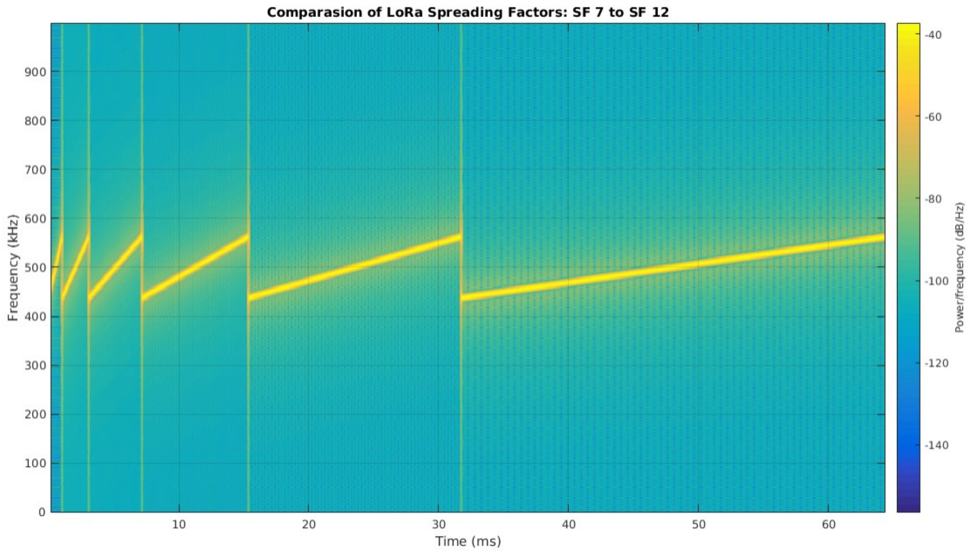

Figure 3. A spectrogram of an example of LoRa Spreading factors. [12]

2.2.4 Comparison Between Different Radio Signal Technologies

The ranges shown below (Figure 4) concern Line of Sight communication.

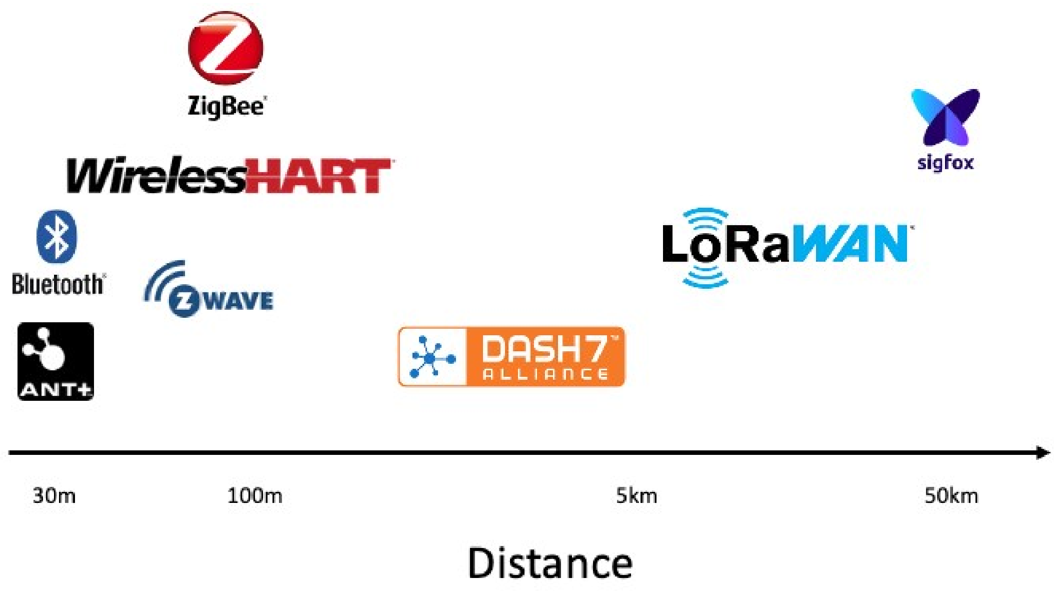

Figure 4. Wireless communication technology ranges roughly. [13]

The purpose of this comparison is not to explain why one technology is better than the other or why one is used over another, but to highlight why these techniques are often used together in the same systems to supplement one another.

It is acknowledged by both the Dash7 Alliance and Semtech, that neither of their solutions are applicable for all situations and that for better overall coverage and availability, both solutions benefit from being deployed in a system together [7, p. 13-14; 10]. The same is the case for Bluetooth Low Energy.

For this reason a system benefits from the use of all three technologies in allowing the optimisation of power consumption and bitrate while keeping the capability of communicating at longer distances than would be possible with only BLE or D7A.

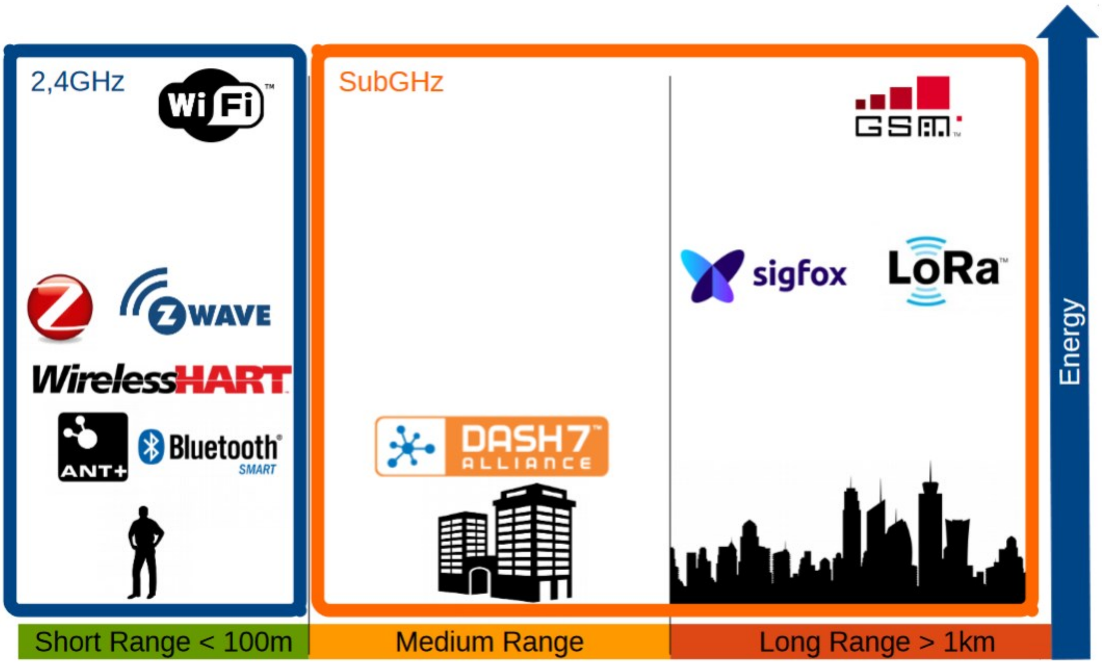

Figure 5. Range and energy consumption tradeoff. [14]

For more detailed information on the performance of BLE, D7A and LoRa, see **Appendix 1**.

2.3 Wirepas vs Wizzilab

Both systems operate, so that data is collected by nodes (tags and anchors) and sent to the Gateway device, which forwards the data to the network server and from there on to the application server.

In the same way, messages can be sent downlink from the application server all the way to the end device. This can be used by the system in regular use or the end user can use this to send configuration messages and updates downlink to the end devices.

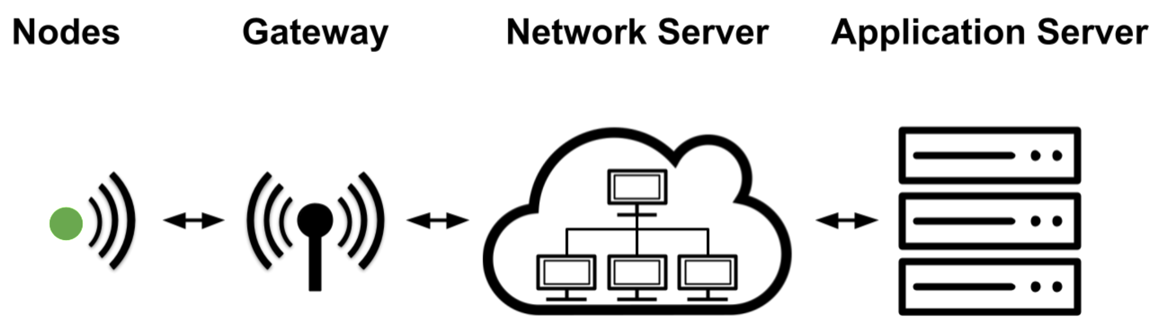

Figure 6. RPS network structure.

In both Wirepas and Wizzilab systems it is possible to send configuration messages downlink wirelessly, however the extent to which one can configure devices this way is more extensive in the Wizzilab system.

The Wizzilab system also makes it possible to update end node firmware wirelessly. Updating firmware or sending commands in this way for the Wizzilab system requires the use of Dash7, meaning that not every node can be updated in the field unless a gateway is brought closer to the end devices in the edge of the hearing range of other gateways.

The two systems not only use different ways of connecting gateways and end nodes (see figure 7). The form of path that messages take within the network is a part of network topology.

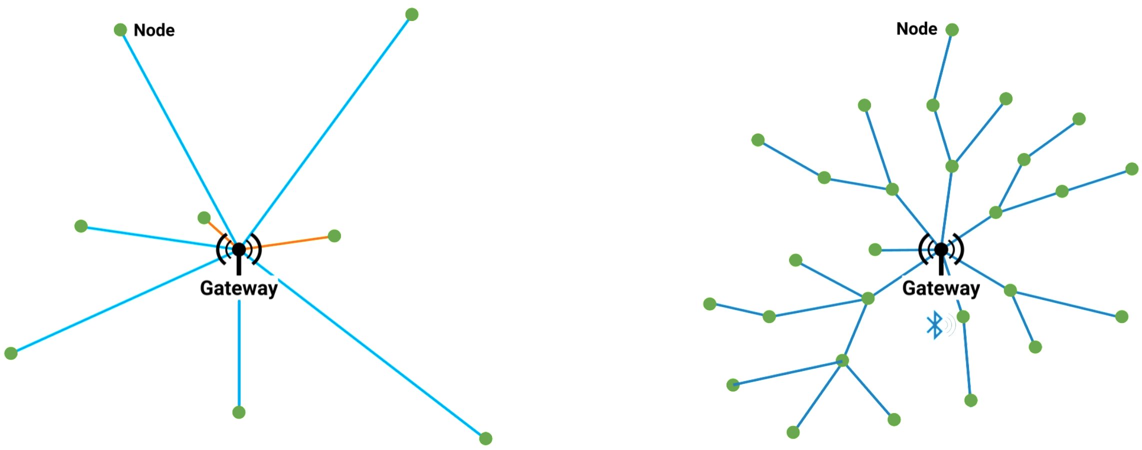

Figure 7. Wizzilab (left) and Wirepas (right) network topologies.

In the Wirepas system, the network uses a mesh topology to connect devices to the gateway and vice versa. This protocol is called Wirepas Mesh This means that devices not only connect directly to the gateway themselves but also work as bridges for devices too far to connect to the gateway directly themselves. This extends the communication range much further than the BLE radio signal of the devices would usually allow, however this comes at the cost of using more power for the devices that have to route a large number of messages from other node devices.

The Wizzilab devices connect to the gateway in a star topology, meaning that all devices connect directly to the gateway without communicating with each other. This has the upside of making the power consumption of devices more consistent and predictable as well as giving the network fewer possible points of failure. In both systems the gateway device is a potential point of failure. With the wirepas system, this can be mitigated by the routing while in Wizzilab the larger ranges mean that one will need less of the gateways to provide backup connection points for the anchor nodes. However the star topology in a vacuum has much less reach. This is counteracted in the Wizzilab system thanks to the use of LoRa and Dash7, meaning that the network can reach a much larger area of coverage in practice with similar numbers of gateways in use and with a lot fewer anchor nodes as they are not required to act as bridges for other anchor devices.

The number one difference between the systems is their range of communication. For Wizzilab, using Dash7 and LoRa for Gateway ↔ Anchor communications allows the two to communicate much more reliably and at ranges that span more distance and obstacles than is possible for the Wirepas system without expending more devices to bridge the gaps.

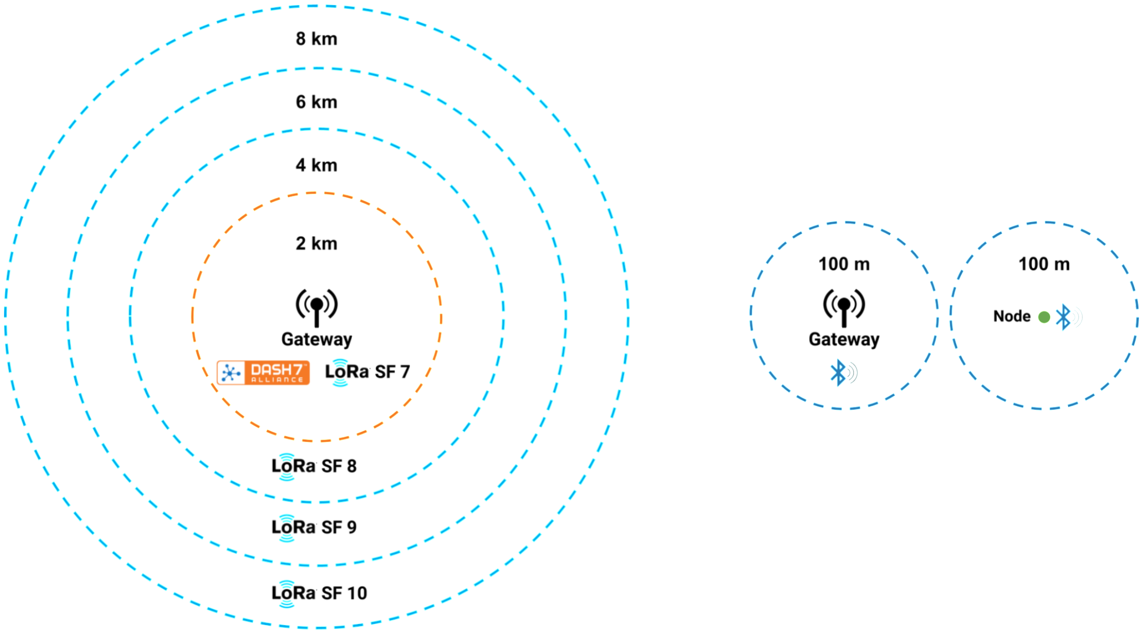

Figure 8. Wizzilab (left) and Wirepas (right) network communication ranges. Image not to scale.

Finally for the Anchor ↔ Tag communication both systems use a BLE based communication scheme, supporting both Eddystone and iBeacon devices.

The Anchor and Gateway devices are proprietary to Wizzilab for their RPS solution. Tags on the other hand may be selected from a large pool available from the market. The selection process and criteria for the specific Tag devices selected by Aiforsite for this project are outlined in more detail in another thesis by Eemeli Uotila [15].

Software

The Wirepas system uses a Wirepas proprietary positioning engine (called the Wirepas Positioning Engine or WPE), user interface and software (Wirepas Network Tool or WNT). The data from the system is then routed through an API to the Aiforsite product. The Wirepas user interface is bypassed for the end user of the Aiforsite product. Wirepas software is still used when setting up and maintaining the system for sites.

With the Wizzilab system, Aiforsite will create their own proprietary positioning engine and user interface software.

3 Timeline and Process

This chapter will go through the big picture of the project leading up to writing this thesis from a personal standpoint. In the Timeline section I will outline roughly the timings of various stages of work on the project from a personal standpoint and in Process you'll be given an overview and simplification of how I went about conducting the work behind this thesis.

More detailed explanations about the actual groundwork will appear in later chapters.

3.1 Timeline

I was first acquainted with Aiforsite and the subject of this thesis in early 2021 during our innovation-project course in Metropolia, for which we selected Aiforsite for our group project. The first subject of the project provided by Aiforsite ended up not happening and a second subject was offered which we then took. This subject was "Rakennustyömaan paikkatietojärjestelmän jatkokehitys", which roughly translates to: Construction site location tracking system further product development.

After the course, I continued work on the project on my subsequent internships and employment at Aiforsite, though it ceased to be the main focus of my work by the second internship, which began later into 2021. After the completion of the cost estimates, which were mainly done by the Project Manager, there would be a lull in the project continuing to 2022.

The project did not regain the sole focus of my work in aiforsite for the rest of the time I spent working on it. Instead it would progress piecemeal as more work was done in the backend and as co-operation with Wizzilab progressed. 2022 would see more testing and updated specifications for the device, which would progress it toward the prototype product. The firmware of the updated devices were then tested a couple months later. Late 2022 would also start what would be the final construction site tests for the project on my end and what was originally supposed to be the products prototype network.

Below in figure 9 you'll see a detailed graph of the timeline of the work:

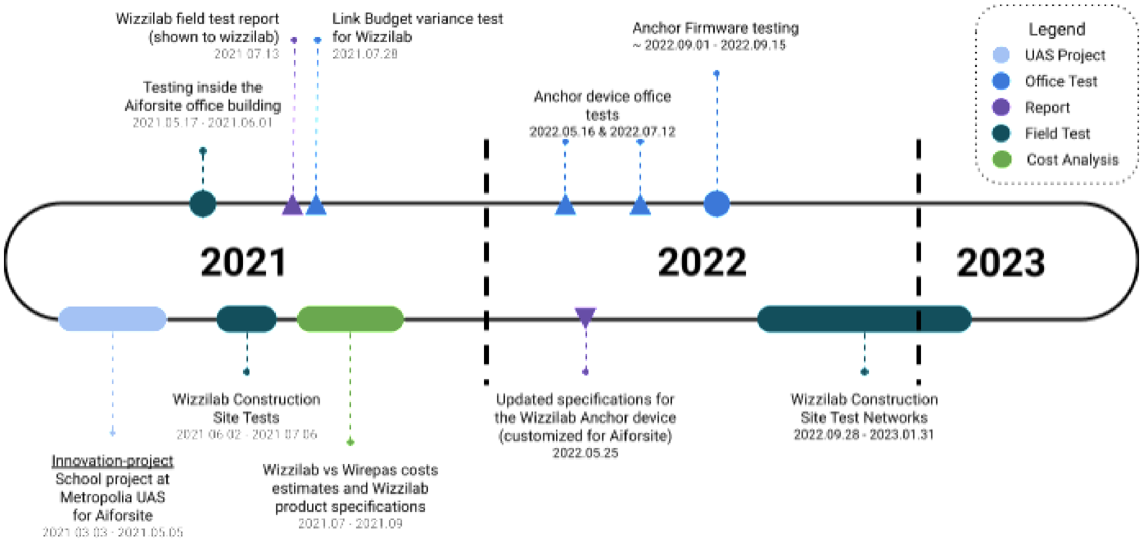

Figure 9. Project timeline.

3.2 Process

Here I will outline the general structure of the work process.

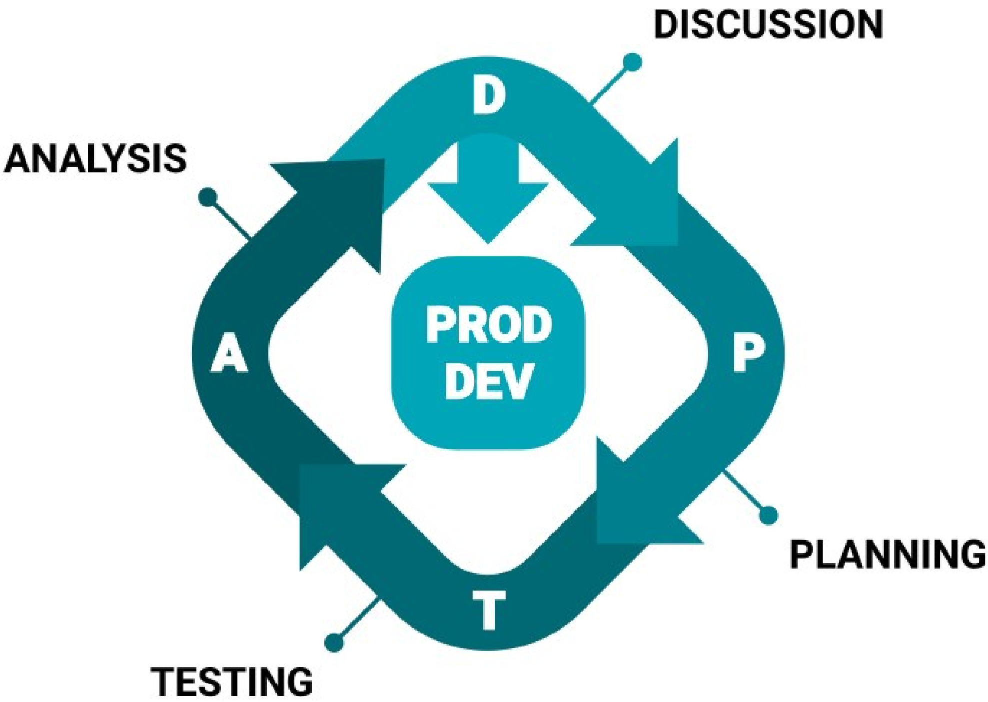

Figure 10. Product development and testing process.

In the above figure 10 I have a simplified image of the process in general terms, which can be shortened into the acronym: DPTA, short for Discussion, Planning, Testing and Analysis. In the middle of the loop is a node labelled "PROD DEV", which is fed from the discussion phase of the loop and stands for product development.

Discussion:

The "first" phase in the process loop and the phase at which the loop concludes is the Discussion phase. This will include all the relevant project staff and personnel that will take part in this round of the process, though not necessarily in one single meeting. This step might take place during multiple different meetings, for example: one meeting might be to go over analysis from previous tests, the next might be to outline future tests and a third meeting between personnel conducting the tests.

In this step we outline the requirements and goals for proceeding work in the next few phases. This includes, for example, setting any parameters for upcoming tests, discussing the goals of these tests and outlining any additional requirements, such as scope. This step might also include some planning as to what the test environment should be or look like, which will be expanded in the planning phase.

When we return to this phase from the analysis phase, this phase also includes going over the results of the test analyses, which feeds into the product development and further tests if necessary.

Planning:

In this phase we have already concluded the goals and scope of necessary testing for this round in the process in the previous phase and we now move on to planning the test round more concretely. This will include allocating the exact number of devices necessary for testing, picking the work site or location for the test or tests (if that has not already taken place in the Discussion phase), and planning the various steps to the tests, such as for how long and in what way the tests are conducted. By the end of this phase one should have a good idea of where, how and when to conduct product testing and with who.

It is vitally important to think ahead about the method of data collection and plan around it. For some types of testing, it may be necessary to have people both on the ground interacting with the system as well as someone to monitor the system while this is being done. It is important to know when events in the real world occur so that they can be effectively compared with the data.

To make sure that the testing goes as smoothly as possible, plan ahead and make a checklist of all the necessary devices and gear beforehand.

Testing:

This phase includes the tests which were planned in the previous phase. The goal of this phase is to gather data about the function of the product to a satisfactory degree for the next phase: analysis.

For the analysis it is important to carefully document the tests. It will be useful to document any events and errors so they can be looked over in the analysis and discussion phases. For example: “Network goes offline at 13:15”.

This phase might take place during multiple different site visits and over a longer period of time depending on the system being tested.

Analysis:

This step includes going over the data and the test documentation. The goal of this phase is to make sense of the test data and come to conclusions about the current condition of the tested product or system in the areas tested. If conclusions can not be made due to the quality / quantity of the data or due to some other factors, the tests either need to be redone or more tests need to be planned in the next loop.

The outcome of this phase should ideally be a report (length decided by the nature of the testing done and the data collected) or document, in which the relevant parties can go over the results of the tests done and on the basis of which one can continue the process through the next loop. The questions which should be answered by the analysis are raised during the discussion phase and the data and documentation of the tests should be enough to feed those answers back into the discussion phase of the loop.

3.3 Methods

The methods employed in testing would evolve over time. What remained the same, were the fundamentals of marking device locations on a floorplan of the test location and then documenting the test timing and locations for specific devices and gathering and archiving the received data. Especially early on a lot of the documentation was done with hand notation on the part of timestamps and device locations. These would be noted at the time of installation for the devices and at the time of testing for the timestamps.

Later tests would see the implementation of a 360-camera, which was used to document the time and precise location of the devices without having to mark them down manually at the time of testing.

Relevant to the methodology, there were two different kinds of tests performed (excluding the firmware tests, which will be detailed at a later chapter): Anchor connectivity tests and beacon link-budget tests.

The former types of tests were to test how the anchors connect to the network. In the case of Wirepas, this would include testing how the devices connect to the gateway in a mesh network, as outlined in an earlier chapter of this thesis. In the case of Wizzilab, this would mean testing how well the anchor devices connected to the gateway device and how the connection was maintained. These tests were mainly done in the earlier portions of the project.

In these tests, devices would be placed at different distances from each other and the gateway(s) and then the connection to them was monitored to see how far they could stretch their wireless connection. Part of these tests was also to place them behind a set number of walls, doors and ceilings of different types to see how well the signal could penetrate through different obstacles.

The beacon link-budget tests were done to measure how effectively the systems could spot resources with different kinds of anchor placements. Anchors would be placed in different rooms and spaces and then beacon devices would be carried into the space or near it to measure how well the system could track resources carrying these devices. This would inform product development and system use practices (for example: how dense should the installation of anchor devices be in a network) down the line for the system.

Tests for Wirepas were conducted by monitoring the network during testing through the Wirepas proprietary software for the system called Wirepas Network Tool. Data would be gathered by documenting status and changes for the test devices through said tool in real time.

For Wizzilab, the raw data from tests was gathered from the proprietary user interface provided by Wizzilab for the management of the RPS network. Data from there would be archived to a separate document and then parsed and visualised using google sheets to help with the analysis process.

4 Project Beginnings

The work got its start as the subject of an Innovation Project course in Metropolia UAS back in 2021. The course took place during early- to mid-2022. After the course work I continued on the project in-house at Aiforsite beginning in summer 2022.

4.1 Innovation Project

The innovation project was a course done in the Metropolia UAS, for which the subject matters were provided by companies with students allowed to choose their project subject and subsequently the company. The first subject we ended up selecting with Aiforsite ended up not happening due to a third party pulling out of the project, and so we had to begin on a new subject about halfway through the course. This new subject would be called “Rakennustyömaan paikkatietojärjestelmän jatkokehitys” or translated into english: “Further development of the construction site location tracking system”. The project parameters were given by the project manager, with whom we maintained contact throughout the project.

The goals of this project were very similar to the goals of this thesis work, though with a lower scope, and would not end up being reached. One of the goals being the establishment of a prototype network, which would not end up taking place due to lack of time. Another goal, which would be reached sometime after the course, was to measure the feasibility of replacing the already in-use Wirepas system with the Wizzilab system.

The project provided some useful data, however conclusions as to the feasibility of the Wizzilab system as a replacement system for the Wirepas system could not be reached at the time of the project. We did manage to conclude some basic facts about the systems, such as the flexibility of the Wirepas Mesh structure and the longer range of the Wizzilab devices in practice. Further tests would have to be done after the project at Aiforsite.

For more details on the project, see Appendix 2 (in Finnish).

4.2 Continuation

After the project at Metropolia was over, I applied to work at Aiforsite for my first internship at the company, which would be focused around the continuation of the product development of the project under the direct management of the Project Manager.

Details about the testing done throughout the first internship and subsequent work will be detailed in the next chapter.

5 Testing, Refinement and Additional Specifications

This part of the thesis features the various types of testing performed on the system, which worked to support and direct the development side of the product development process. Additionally, feedback (which was based on testing and needs) was provided to the manufacturer (Wizzilab) to make updates and changes to the firmware and hardware.

The following chapters are a collage of dozens of different tests taking place over a one and a half year period during 2021 to 2023. The contents of these chapters will be focused on testing and results of said testing, with some attention given to other aspects, such as additional product specifications that were a product of the process outlined in chapter 3.2 of this thesis.

5.1 Keilaranta Tests: 05.2021 - 06.2021

The first proper round of testing took place in mid-2022 and consisted of three sets of anchor-gateway signal tests and two sets of anchor-beacon signal tests. All of these tests were performed in the Keilaranta 1 office building, mainly focused on the first floor of the building and limited (on the part of the Wizzilab system) to the 16 test anchors and 2 gateway devices available at the time.

5.1.1 Anchor Signal Test 1

During the first test, 16 anchor devices were placed around the office building. 2 GWs were placed in the Aiforsite office upstairs on the third floor. Most of the anchors were placed all around the first floor with a couple outside the building on the building wall. The anchor devices were then monitored for around 20 minutes and the data was compiled into a google sheets document.

One thing that was noticed, was that a number of redundant reports were sent by anchors and then received by the gateways when the devices were on the edge of the hearing range of the LoRa SF10 modulation. This was likely a result of the devices sending a report to the gateway, the gateway then receiving the report and sending an acknowledgement message -> the anchor would be just far enough to not be able to hear this acknowledgement and would resend the report to the gateway.

This was a part of the regular function of the anchor devices, where they would send a report a certain number of times before giving up when not receiving an ACK message from the gateway that the report was received. Normally this would work to make sure that the gateway would receive reports from anchors even when the connection is spotty, however when the gateway has already received a report, sending more is a waste of battery as the same reports would be sent by the anchor device up to its programmed maximum before moving on.

5.1.2 BLE Signal Test 1

This test was performed to crudely measure the penetration of the BLE signal and the ability of the anchors to detect these signals through thin walls. Meeting rooms on the first floor of the office building were used for this purpose. 3 BLE beacon devices (tags) were placed either side of the row of 5 nearly identical meeting rooms. Inside each room was placed a single anchor device. 5 different tests were performed, where the anchor devices were placed around the rooms in different positions to see what kind of device positioning would provide the most ideal results (figure 11).

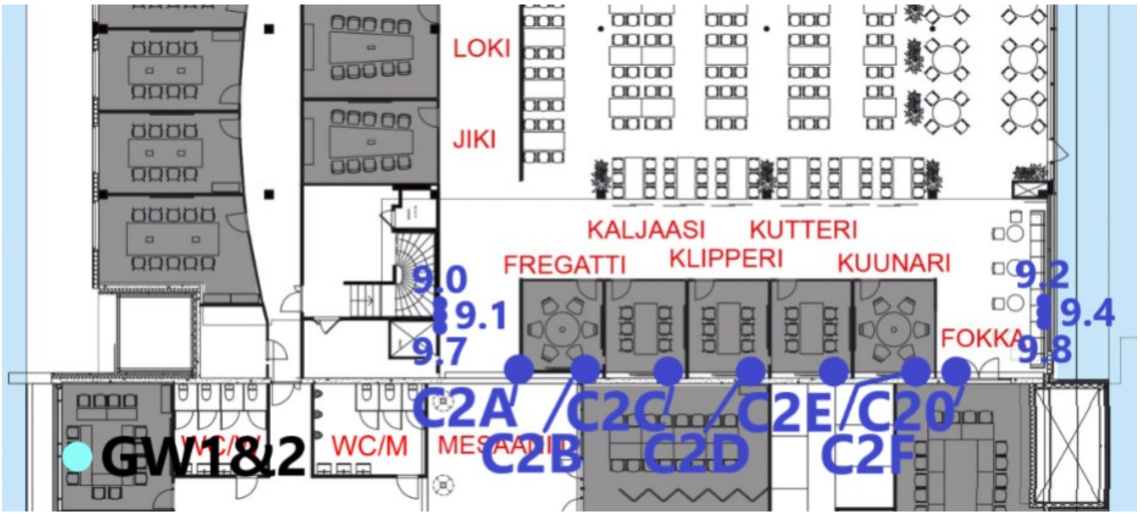

Figure 11. BLE signal test device placement during one of the parts of the test.

During this test, antenna alignment (horizontal vs vertical) was found to make a difference. With many radio communication devices, it is (more or less) important to align antennae properly. With wire (and some other) antennas, this generally means aligning the antenna of the receiving device perpendicular to the one of the device sending the signal. This is due to the antenna gain, which resembles a donut that wraps around the antenna in wire antennas.

5.1.3 Anchor Signal Test 2

A continuation of the previous anchor signal test, anchors were placed on the outer wall of the office building and their signal quality to the gateway was measured over a two hour period. The 2 gateways, as with the previous test, were placed in the Aiforsite office on the 3rd floor, as pictured in figure 12.

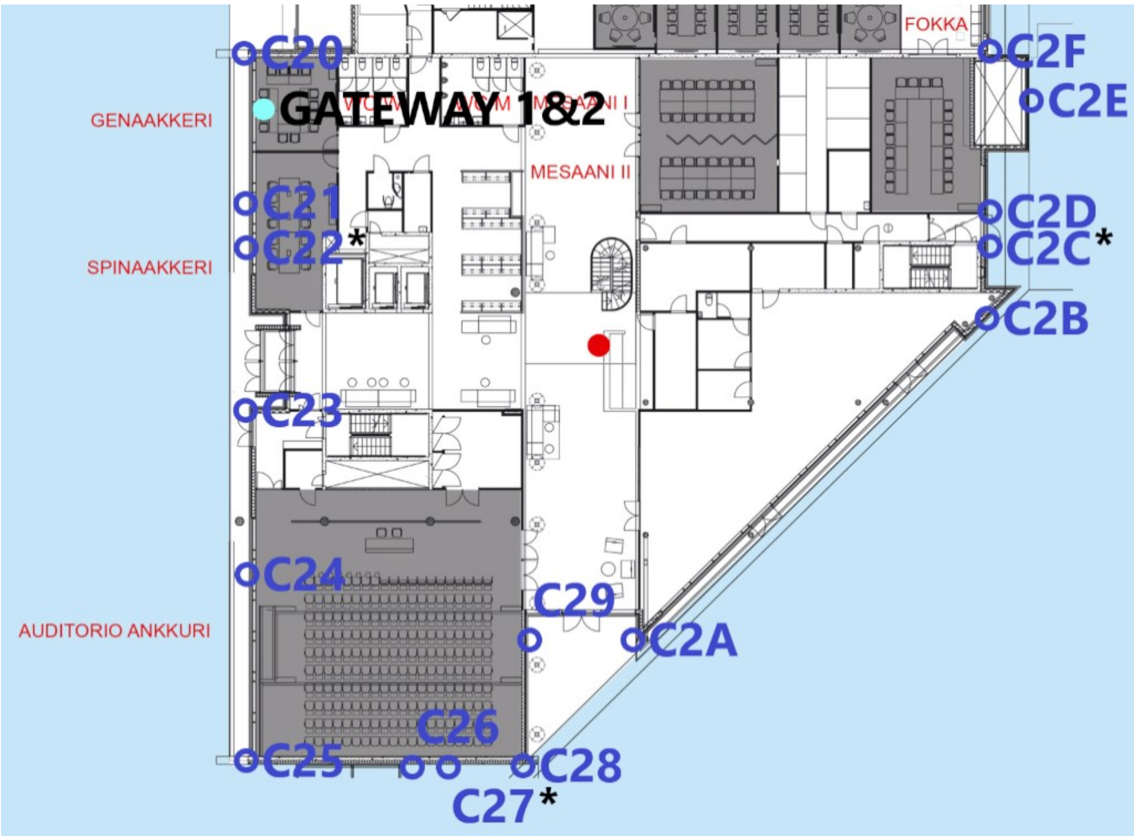

Figure 12. Anchor signal test 2 device placements.

Unsurprisingly, the anchors whose paths were blocked by multiple walls of concrete had a spottier connection, but could still manage to send a reasonable quantity of reports to the gateway despite the distance and the amount of obstacles.

5.1.4 Anchor Signal Test 3

This test was performed to see how well the signal could penetrate into stairwells, which are typically constructed with thick concrete walls in buildings and would pose a challenge for the system.

Two sets of tests were performed during a period of 25 minutes. During the first test, 3 anchors were placed around the stairwell on the first floor in different spots. The second test used 2 different devices placed on the first and 2nd floor of the stairwell in different spots from the first test.

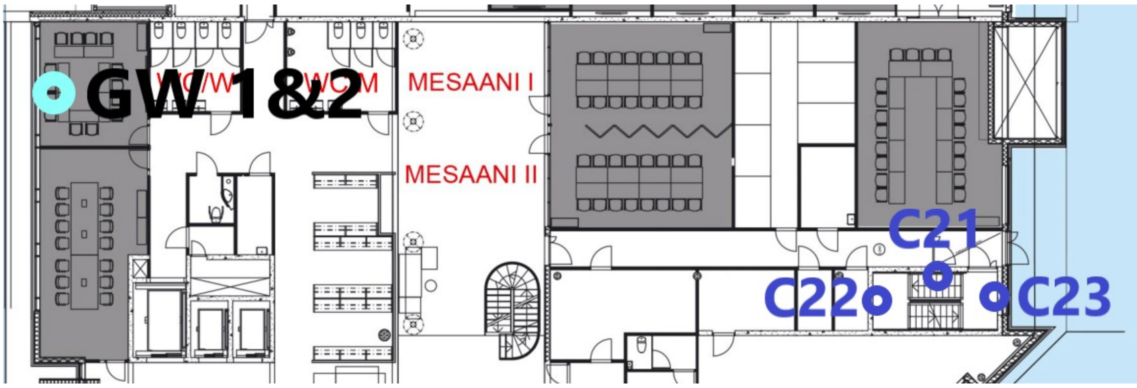

Figure 13. Stairwell test 1 device placements.

During the first test, though operating with a lower quality signal, the vast majority of reports made it through to the gateway from anchors C21 and C23, with C22 missing only about a fourth of the reports from the test period.

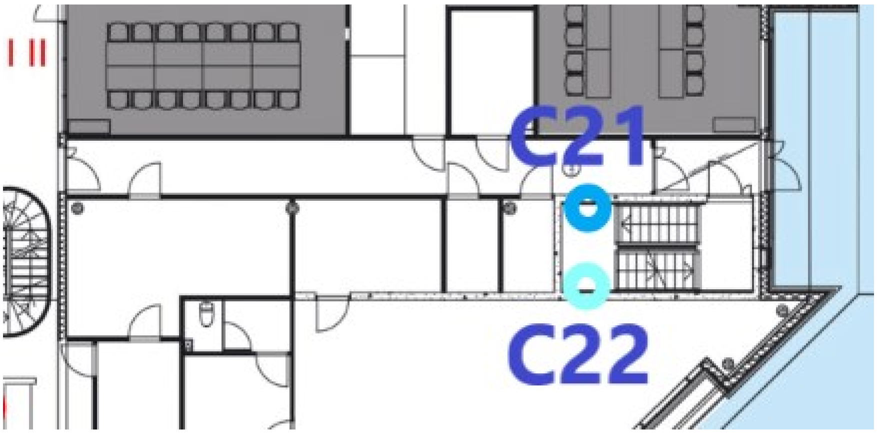

Figure 14. Stairwell test 2 device placements.

The second test would also see similar results, with the anchor on the second floor (C21) delivering most of the reports from the test period and the anchor on the first floor (C22) missing only around a fifth of the reports.

5.1.5 BLE Signal Test 2

1 tag was placed either side of the row of 5 nearly identical meeting rooms. Inside each room was placed a single anchor device and two additional devices were placed outside of the meeting rooms on either side of the row.

4 different tests were performed, where these anchor devices were rotated between the rooms to try and eliminate or control for differences in the individual anchor devices.

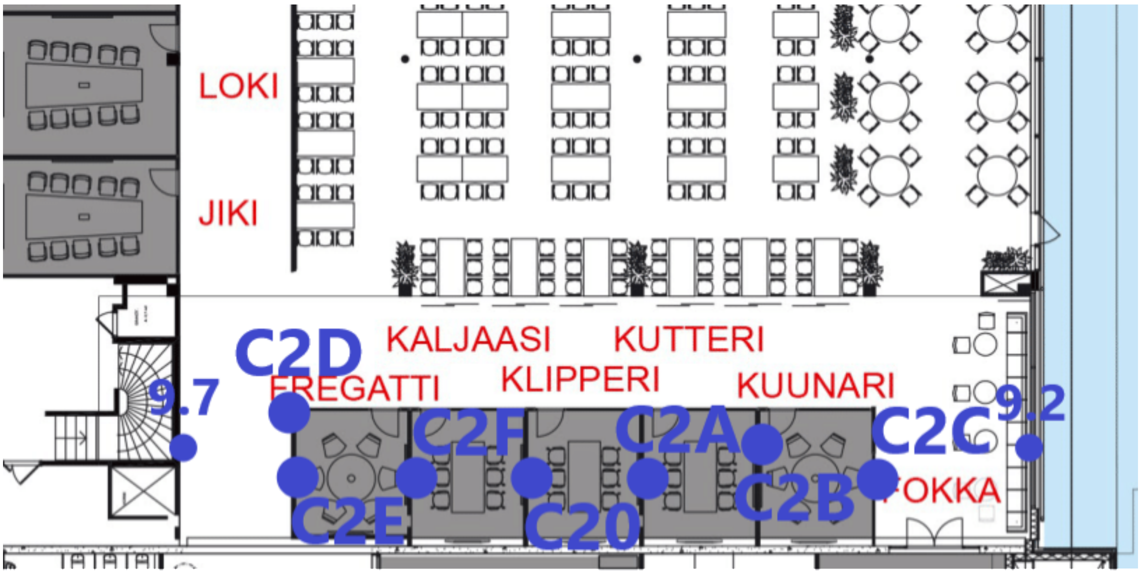

Figure 15. Device placement of the BLE signal test 2 part 4.

In retrospect, this test was somewhat flawed, as the BLE signal could feasibly bounce off the far side of the room, thereby bypassing the need for it to penetrate multiple walls and confusing the data.

During this test, we did notice a discrepancy between the detected link budget (or LB) values in some of the devices as compared to the others. This would be confirmed during later testing.

5.2 EKE Helmi Tests: 06.2021 - 07.2021

The site consisted of three buildings: A, B and C. All three buildings are connected to each other in an L shape around an inner courtyard built on top of the building parking hall facing away from the site office.

Figure 16. EKE Helmi construction site top down image.

North of the site, on level with the first floor of the building, are the site offices. The site offices are constructed as standard from shipping containers and make a two storied building with various rooms for use by construction site crew and administration.

Below figure 17 shows a simplified picture of the site offices and buildings:

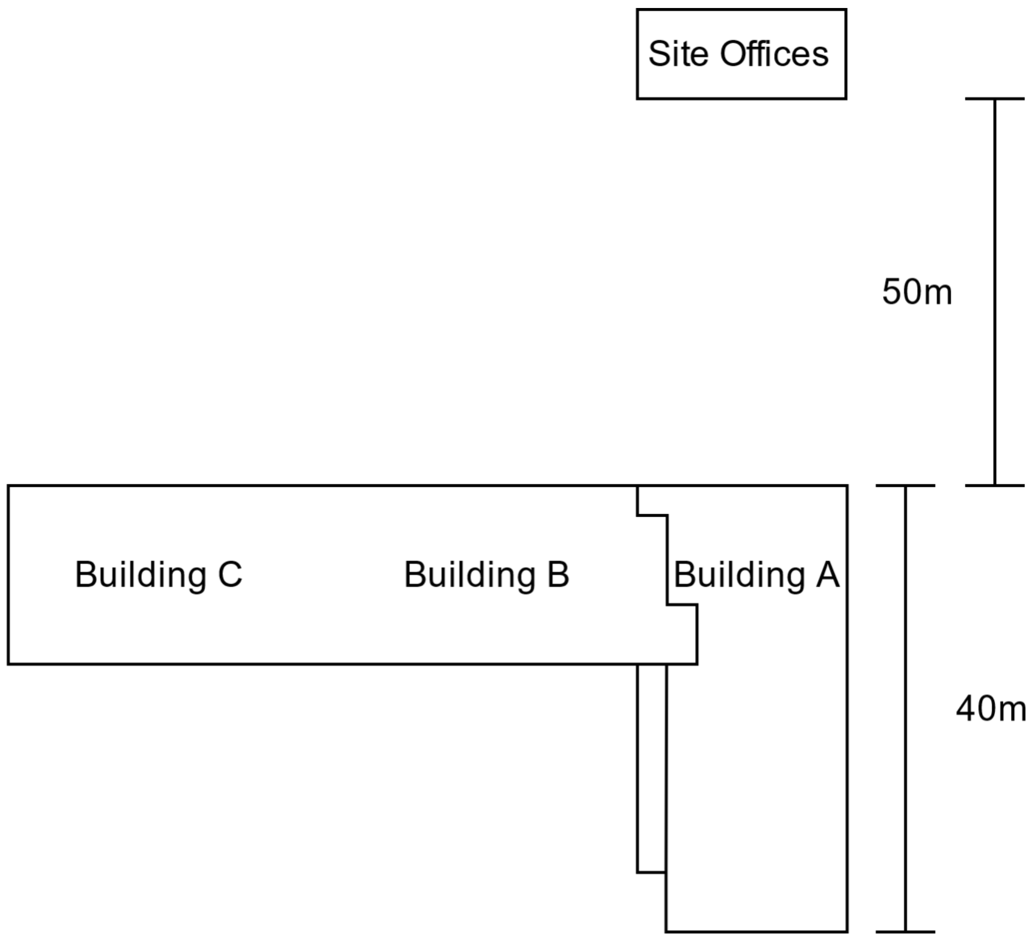

Figure 17. EKE Helmi construction site top down labelled and simplified.

All of the field tests conducted at EKE Helmi were done in Building A.

Figure 18 is a picture of the site from the side showing building A in relation to the side office. The perspective is looking from west to east:

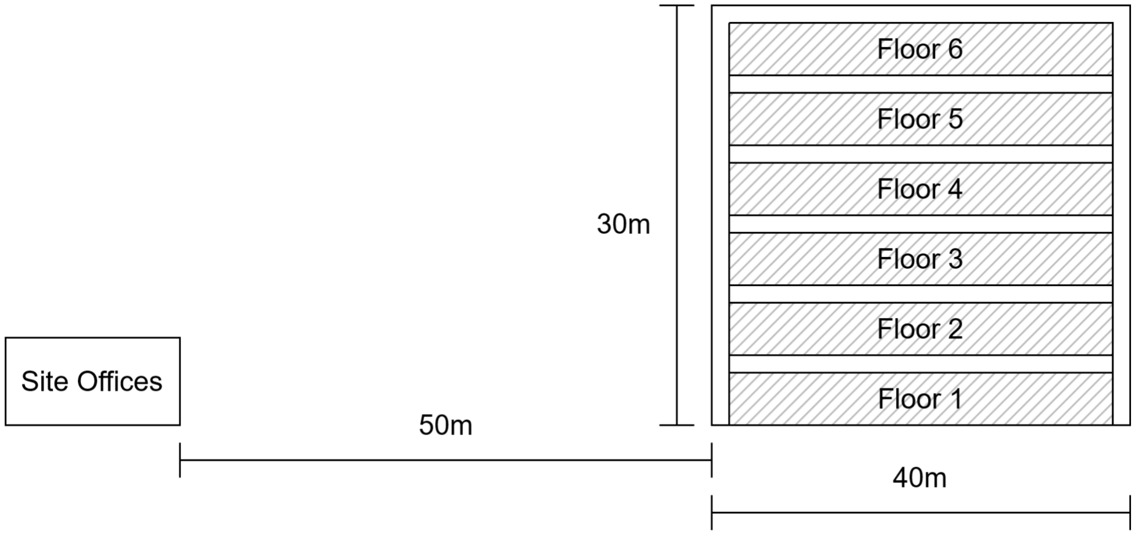

Figure 18. EKE Helmi site offices and building A simplified side profile.

During the anchor - gateway signal tests performed in the construction site, data would be collected over a 24h period, during which a single anchor device should send about 1440 reports (one every minute). At the end of the 24h period, data would be compiled and the quantity of the received reports for each anchor would be gathered to measure packet reception ratio, or PRR, along with other statistics.

5.2.1 Test Setup 1

This test setup consisted of 4 different testing scenarios using 2 different gateway devices and 16 anchor devices. Different gateways were set up at different times and with different configurations to see their effect on the stability of anchor - gateway communication.

After this, some testing was also done to see how well the devices detected tags in a construction site environment delivering acceptable results.

Scenario 1:

Anchors were placed on floors 1 through 6 with the gateway (GW 108CC / 108DB) with an optional cellular modem on floor 4 using the Dash7 NOR and LoRa SF10 profiles. The gateway was installed on the central hallway.

The goal was to see how well a single gateway, placed in a central location within the building, could reach anchor devices placed around the building. Figure 19 is an image of the rough device placement on top of the previously introduced simplified side profile of the site:

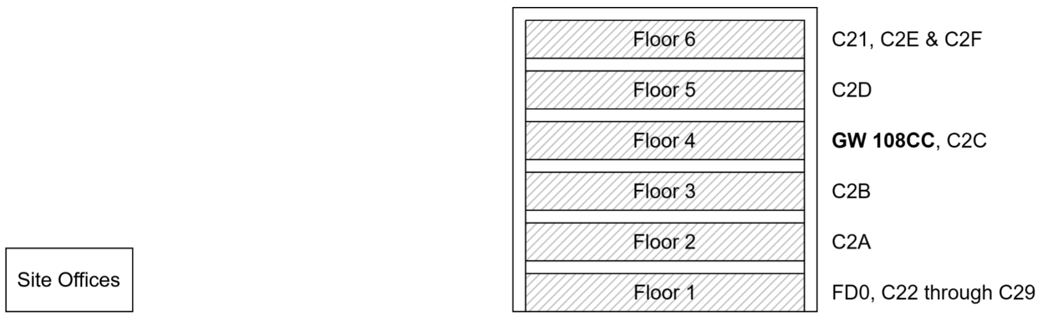

Figure 19. EKE Helmi test setup 1, scenario 1 simplified side profile.

The largest placement of devices was concentrated on the first floor, the next most populated being the 6th floor and each floor in between having one device in the central hallway. Below is a graph (figure 20) showcasing the PRR of the various anchor devices. The blue portion of the pillar in the graph is expected to meet the yellow line in cases where all packets have been received by the gateway. The red portion of the pillar represents packets which consist only of the device reporting that it has moved (the device had their magnetometer triggered).

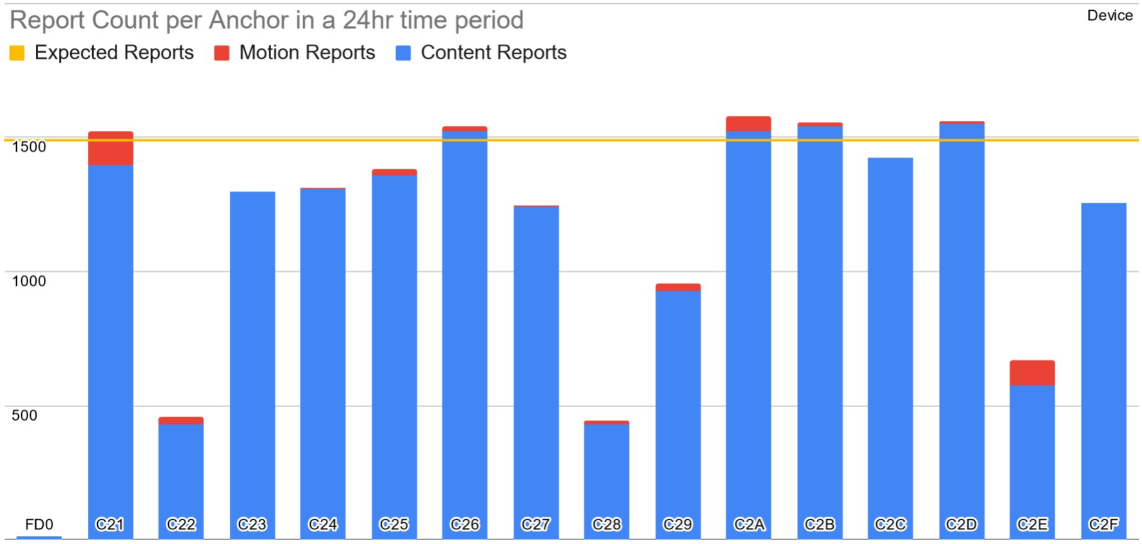

Figure 20. scenario 1 anchor PRR.

This positioning of the devices produced a varied spread of results, with some devices being able to communicate without issue and others having an absolutely abysmal PRR. The most terribly performing links were with devices that had to communicate through the most amount of construction material. Those being the devices on the first and 6th floors. At least one of these devices (C22) in addition to being three floors below, was also behind an elevator shaft.

Scenario 2:

A second gateway (GW C410 / CEF) was turned on at the site offices on level with floor 1 of the A-Building. The gateway was using the Dash7 NOR and LoRa SF8 profiles. Otherwise the condition of the network remained identical.

Note: The figure below (figure 21) has an error: GW C401 should be GW C410. This error also shows up in figure 26.

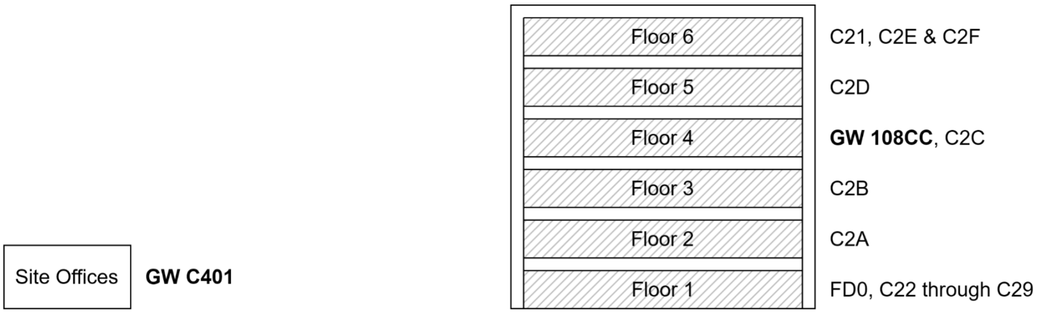

Figure 21. EKE Helmi test setup 1, scenario 2 simplified side profile.

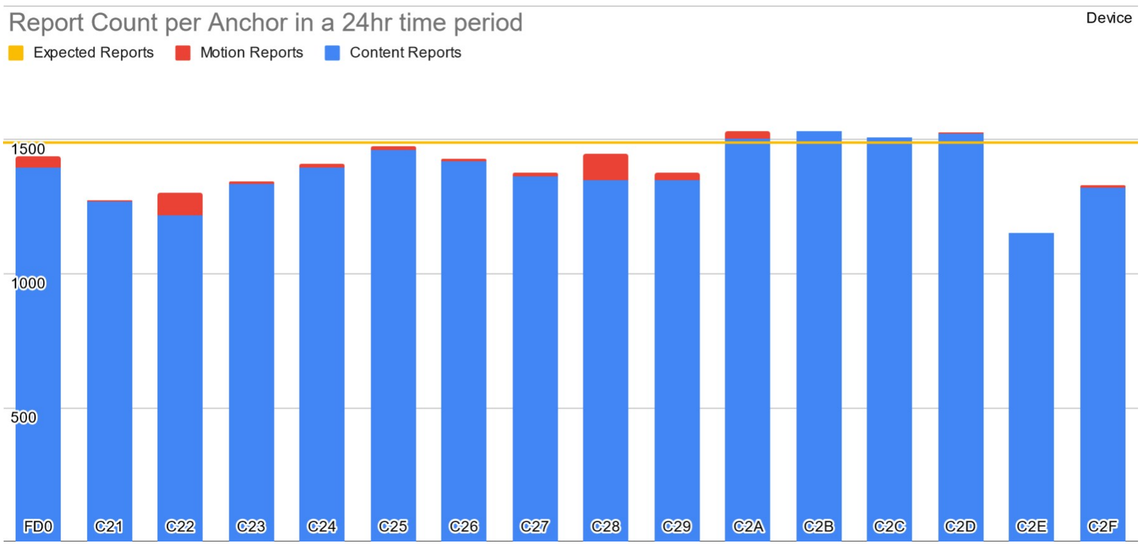

Figure 22. scenario 2 anchor PRR.

Figure 23 shows the quantity of packets received by the gateways in total:

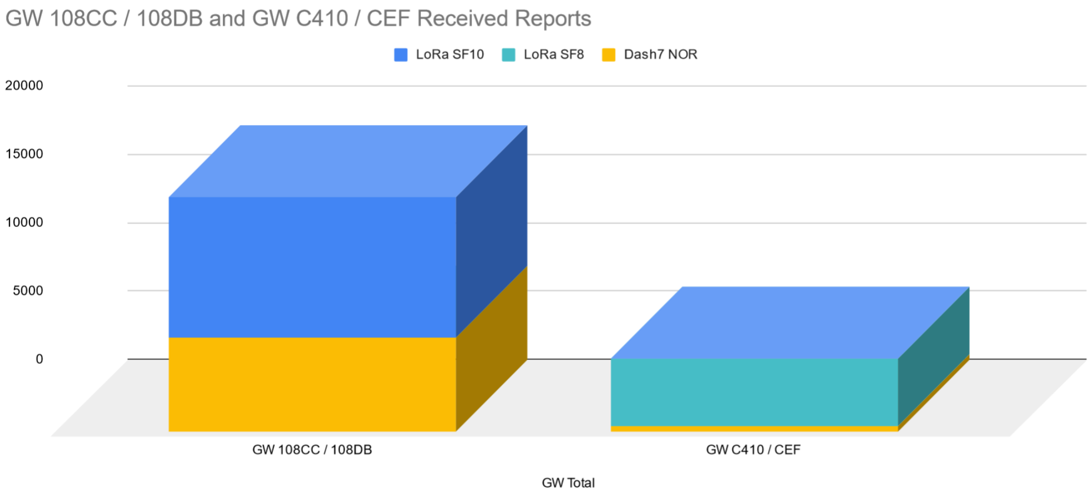

Figure 23. Report destination gateway division.

As can be seen from figure 23, most of the packets are still being communicated primarily to the first gateway (GW 108CC / 108DB) on the 4th floor. Seeing as the packet reception ratio has improved drastically, we can assume the secondary gateway has done the heavy lifting in raising the stability of the network. We can also observe that Dash7 is not being effectively utilized on the secondary gateway.

We can infer from this, that Dash7 should ideally not be relied upon to reach devices from over 50m outside of a building and LoRa should be used instead. However, communication through floors inside a building is still possible for Dash7.

Scenario 3:

The second gateway at the site office was configured to use LoRa SF10 instead of Dash7 NOR. This was done after the previous test data revealed the underutilization of Dash7 NOR by the secondary gateway.

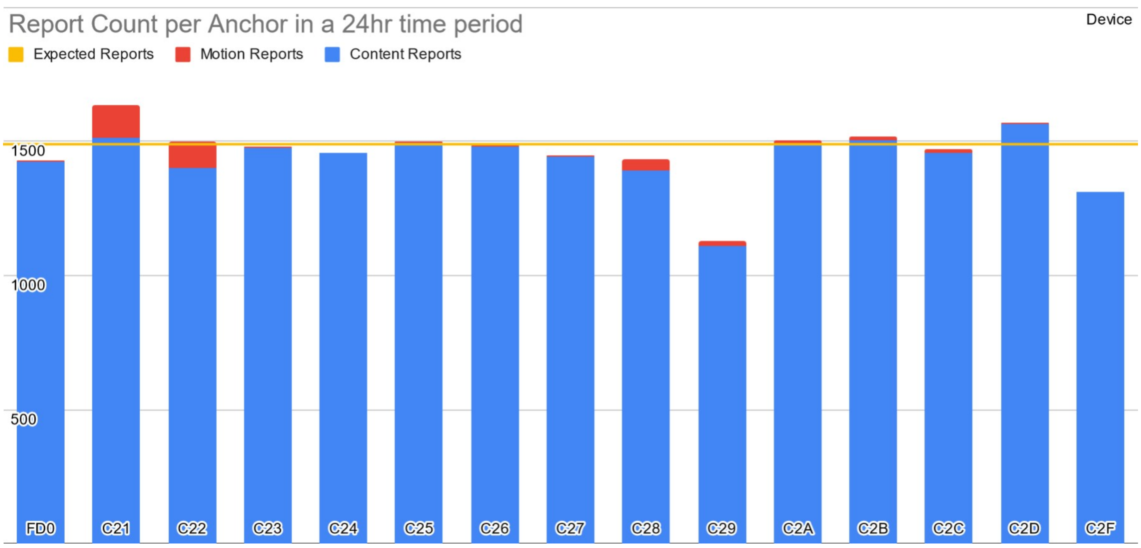

Figure 24. scenario 3 anchor PRR.

Here we see a much better result for nearly all of the devices, except with C29, which was later confirmed to have gone missing during the test period.

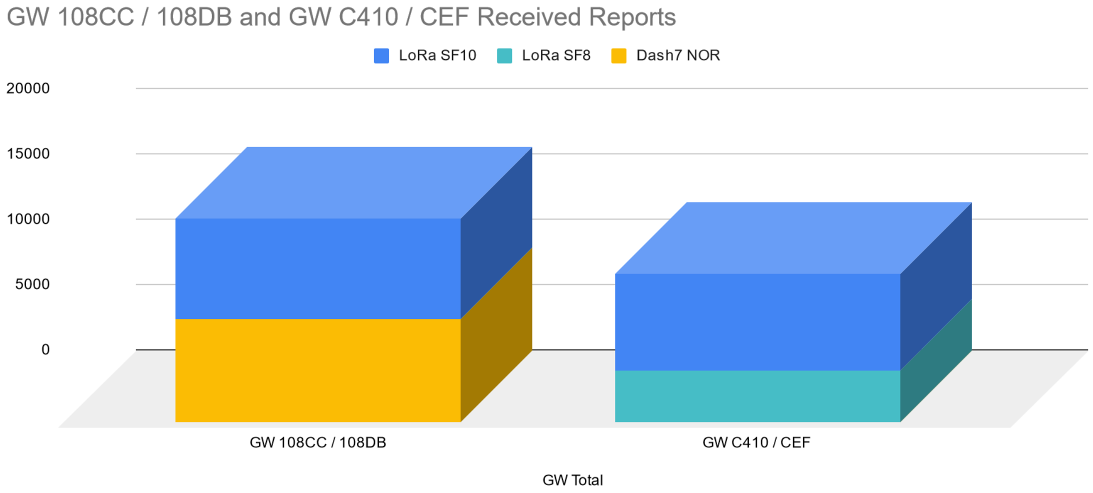

Figure 25. Report destination gateway division.

Here we see a much more even distribution between the gateways. Switching the secondary gateway to use LoRa SF10 improved PRR as well.

Scenario 4:

The gateway on the fourth floor was taken out of the site to see how well the gateway in the site office could hold up a link to the anchors.

During and after the previous test, anchors C28 and C29 had gone missing and the anchor C2E ceased sending out reports. It was later determined to have had a vital component dislodged from the circuit from taking a fall of approximately 1.5m from where it was installed onto a concrete floor.

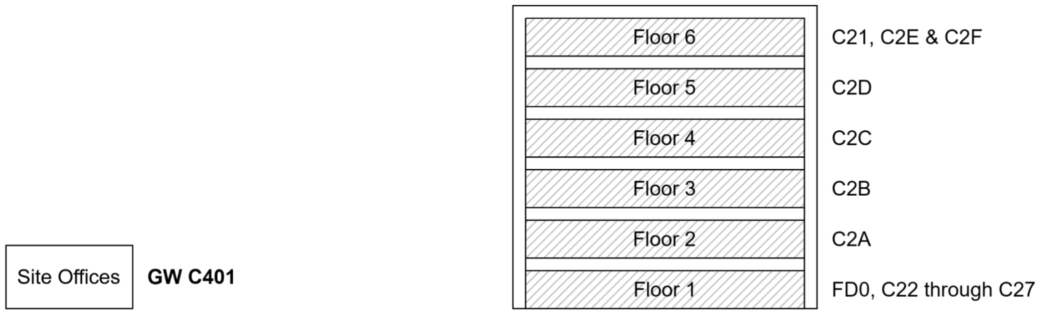

Figure 26. EKE Helmi test setup 1, scenario 4 simplified side profile.

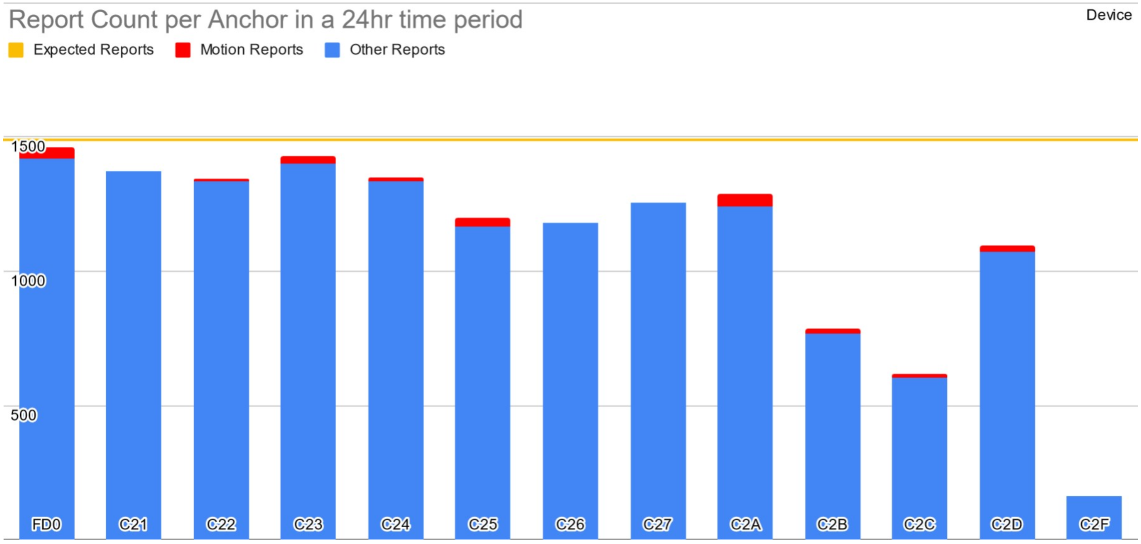

Figure 27. scenario 4 anchor PRR.

As we can see from the data, the PRR across the board has been reduced to various levels. On the first and second floors, the communication is spotty but within acceptable levels on most of the devices, but worsens when going up in floors above the second.

5.2.2 Test Setup 2

A comparison test setup was installed to benchmark the performance of the Wizzilab anchor and gateway devices against Elsys anchors and Multitech Systems gateway which use the full LoRa spreading factor spectrum through the things network. The Wizzilab anchors were placed next to equivalent Elsys devices and the Wizzilab gateway was placed next to the Multitech Systems gateway.

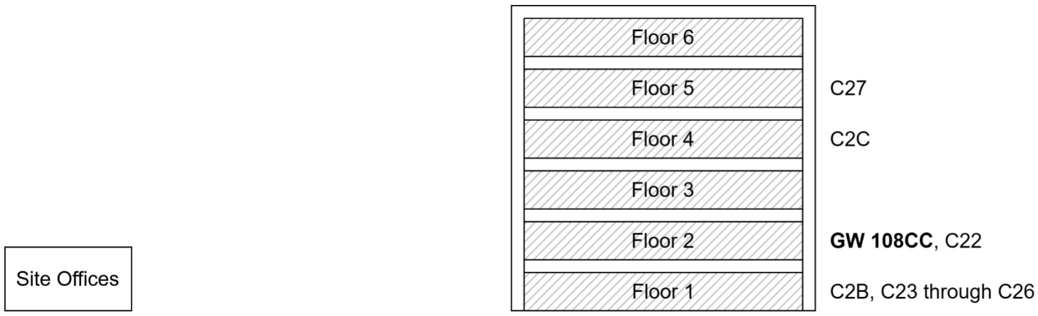

Figure 28. EKE Helmi test setup 2 simplified side profile.

Throughout the 24h period, the Wizzilab devices were found to have achieved a higher PRR. The Wizzilab anchors were sending report packets every minute whereas the Elsys devices were sending packets between every 10 minutes to 1 hour.

Note: the Elsys devices were selected from stock that was on hand and that the intended use-case of these particular devices was not resource positioning, but the gathering of weather and environmental data.

In the below figure 29 is a graph of the Wizzilab anchor PRR and in the image below (figure 30) that is the graph of the Elsys PRR.

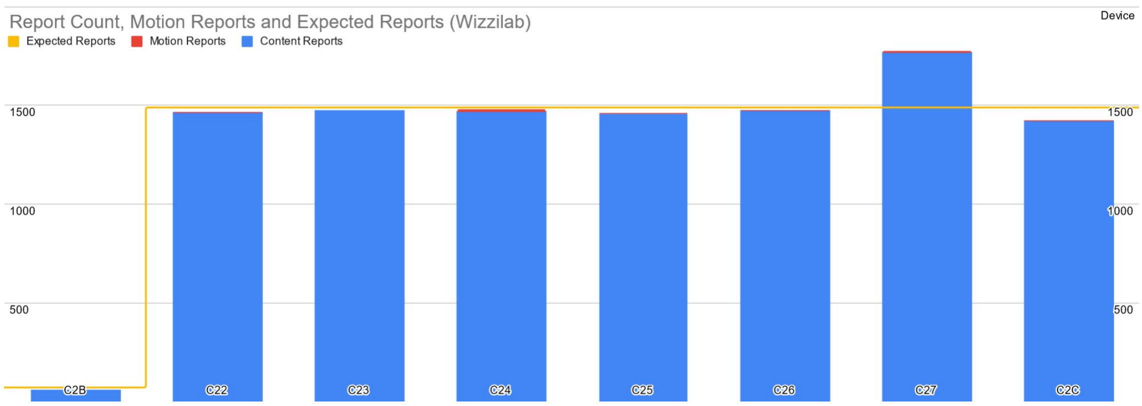

Figure 29. Wizzilab PRR.

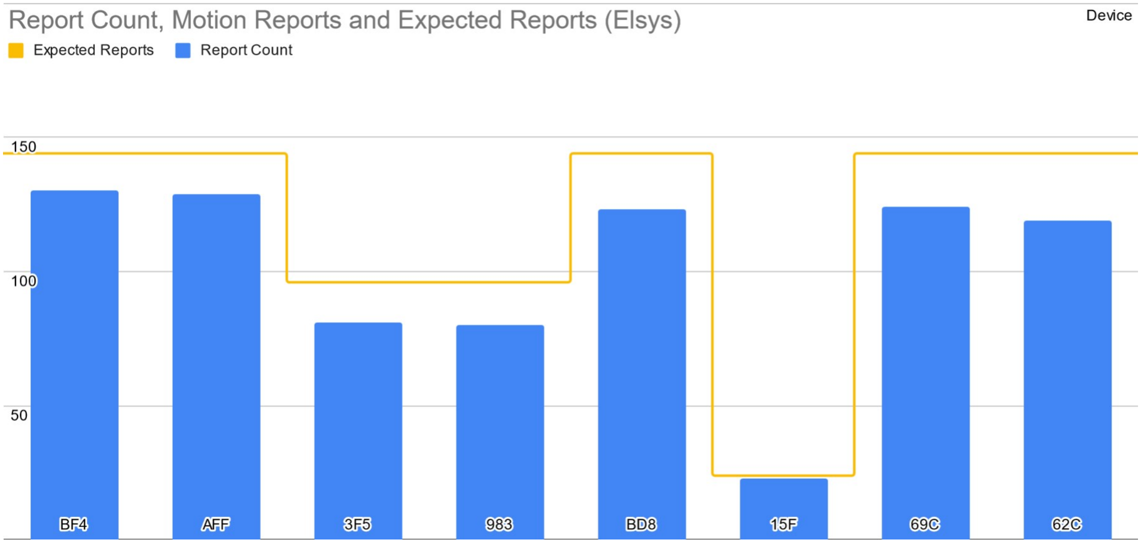

Figure 30. Elsys PRR.

The improved results over the other system are likely a result of the differing priorities between the two systems. In the Wizzilab system a high PRR was a priority and as such, the devices and their firmware has been developed and built with it in mind.

5.2.3 Test Setup 3

A third setup was tested with the anchors more evenly distributed on the floors of the building with only 1 gateway placed on the 4th floor. Anchors were installed 3 equivalent spots on each floor (except the 1st floor, which had 2 devices) each in the middle and each end of the building's central corridor.

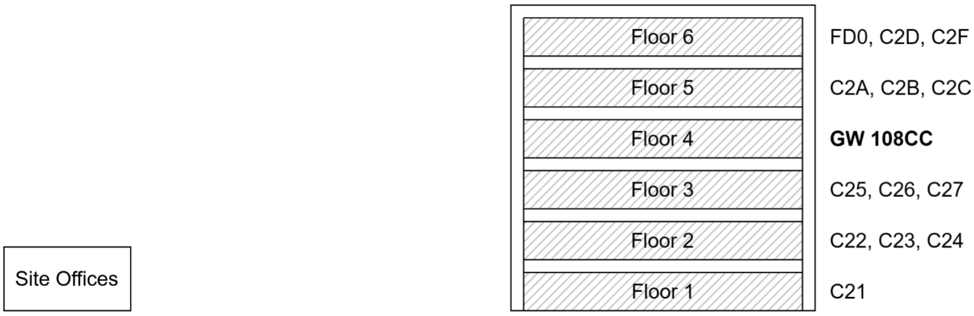

Figure 31. EKE Helmi test setup 3 side profile.

Here (figure 32) we see results somewhat better indicative of the ability of the gateway to cover different levels of the building. The gateway has fairly good quality links to devices in the floors directly above and below (apart from C2A). Floors 1 and 2 have the lowest quality links to the gateway, while the 6th floor still has a more acceptable PRR to the gateway.

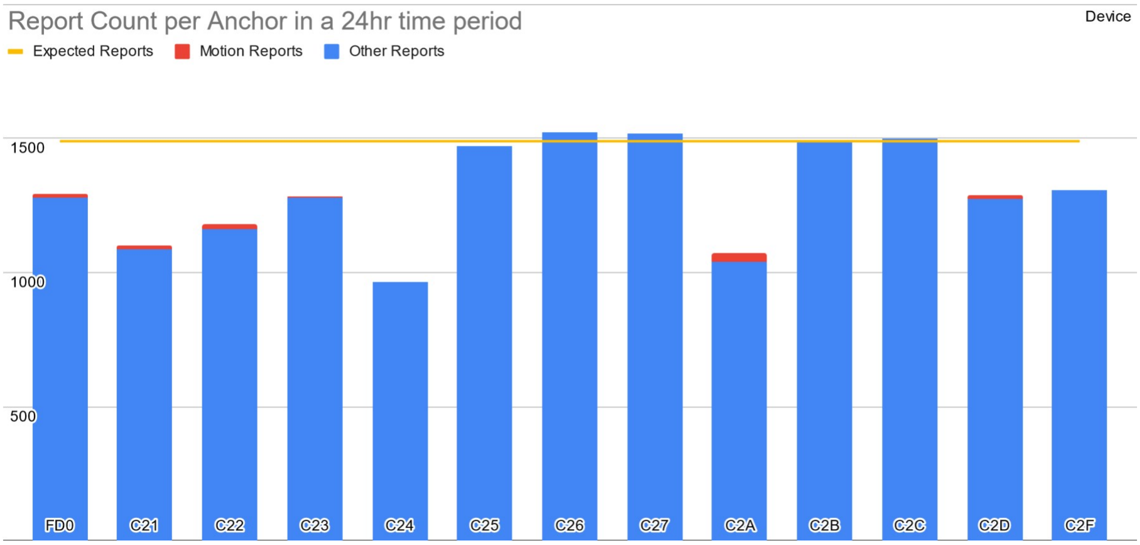

Figure 32. setup 3 anchor PRR.

BLE testing:

Some more testing was done to see how well the devices detected tags in a construction site environment.

The tests were done with the setup three anchor placement. Testing was done by roaming around building 3 while stopping in 31 different pre-marked spots on the floorplan for around two minutes for around an hour.

Once again the testing delivered acceptable results barring some individual devices, which could be explained by bad connectivity to the gateway device and highlighting the importance of good device placement (anchor and gateway).

Additionally; some tags were detected by anchors on the floor above while testing. This was an issue also seen with the Wirepas system and could be somewhat ameliorated by more consistent and thorough anchor placement.

5.2.4 Observations

There was clear inconsistency noticed in the BLE-scanning sensitivity first in late may and then later in june during the field tests and finally more definitively concluded in july with a test, the results of which were then sent to Wizzilab, see the following chapter: Tests for Wizzilab: 07.2021.

Unsurprisingly, links achieved through walls and floors perpendicularly were more reliable. This can be due to a variety of factors, most likely of which is that there is simply less wall directly between the communicating devices.

Gateways should be placed in such a way that no more than three floors stand in between a gateway and end node. For large construction sites an ideal might be a gateway every three or four floors ignoring the first and last floor and possibly a gateway somewhere outside of the building to provide coverage to hard to reach places on a given wall of the building. Building entry loss should be taken into account and gateways cannot be expected to provide a good quality link through entire buildings.

Anchors have the best link performance when not directly placed on a high density surface like concrete or steel. However, they can also perform on these surfaces.

5.2.5 Tests for Wizzilab: 07.2021

After the three different test setups in EKE Helmi, the data was analysed and a report was compiled and sent to Wizzilab. Overall the results were good.

In this report, a couple of issues were highlighted. One being a high quantity of redundant reports and another being a couple of the test devices giving inconsistent measurements of the BLE signal link budgets (measured in dB). Another test was conducted on the offending devices and three additional devices. These problems would later be amended.

6 anchor devices were placed on a table 1m away from a tag device. In the next room, 6 additional tag devices were placed next to the gateway device. The purpose of doing this was to see how the LB values differed for the devices suspected of malfunctioning, in addition to seeing if these devices could spot the 6 tags in the other room.

The test showed that the 3 devices were indeed malfunctional, as the LB values were much higher than expected (meaning the devices measured the BLE signals as if the tag was much further away than it actually was, i.e. the signal was weaker) and not in line with the other anchor devices.

Note: A LB value of 0 corresponds to a distance of 1 metre.

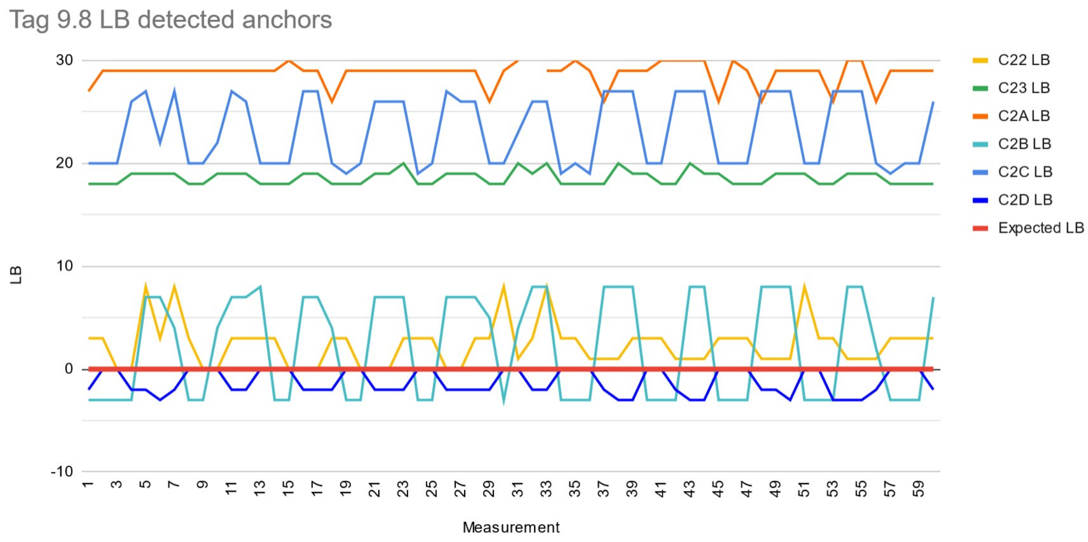

Figure 33. Link budget (dB) values for the BLE test done for Wizzilab.

In addition, these malfunctioning devices failed to spot the other 6 tag devices in the other room, while the other anchor devices spotted all of them consistently.

This was reported back to Wizzilab and the malfunctioning devices were then sent back.

In addition to this, a financial evaluation of the Wizzilab system was done, which confirmed the viability of the system against the Wirepas system.

5.3 Additional System Specifications: 07.2021 - 08.2021

A document (sheet) was produced for Wizzilab outlining the specifications desired for the system, including anchors and gateway devices and their internal functions.

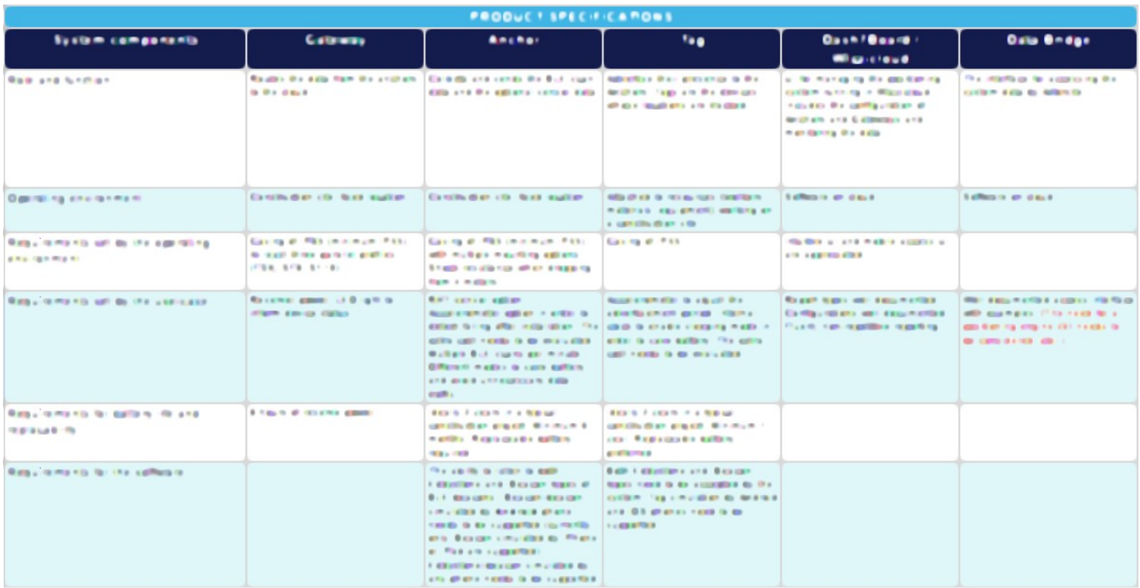

Figure 34. Product specifications sheet for Wizzilab (blurred and non-legible)

Different parameters were defined for the devices, such as the amount of time spent scanning for bluetooth signals, the interval between scans and various behaviours configurable through commands through dash7board.

Various functionalities were also requested, such as the ability to set the device to a nap or sleep mode, where it would save battery when certain operations were not necessary. In nap mode the device would be ready to “wake” on its own upon receiving stimulus such as the motion sensor going off. In sleep mode, it would remain inactive until a specified duration or until it was woken up with a command.

For gateways, there was specified the need to support at least 3 different signal profiles (Dash 7, FSK 8, FSK 10) simultaneously with the same gateway device. Additionally specified were the IP (Ingress Protection) ratings for the casing and a rechargeable battery integrated into the device as backup in case of brief power outages, which are common in construction sites for these kinds of devices for various reasons.

Other specifications were also present, but they will not be listed.

5.4 Keilaranta Anchor BLE Tests (and Specs): 05.2022, 07.2022

Specifications:

The first month would see updated specifications sent to Wizzilab for upcoming functionality of the firmware and the newly added button and LED on the anchor device.

Table 1: Anchor button functionality (updated specifications for Wizzilab)

<table>
<tr><td>MODE</td><td colspan="3">MAINTENANCE</td><td colspan="2">ACTIVE</td></tr>
<tr><td>BUTTON PRESS</td><td colspan="2">2 Seconds or less</td><td>5 Seconds or more</td><td>2 Seconds or less</td><td>5 Seconds or more</td></tr>
<tr><td>FUNCTION</td><td colspan="2">Indicate strength of connection to GW</td><td>Switch to ACTIVE mode</td><td>N/A</td><td>Switch to MAINTENANCE mode</td></tr>
<tr><td rowspan="4">LED INDICATOR</td><td>Dash7</td><td>Slow blink GREEN for 3 seconds</td><td rowspan="4">Fast blink GREEN for 2 seconds</td><td rowspan="4">N/A</td><td rowspan="4">Slow blink RED for 2 seconds</td></tr>
<tr><td>LoRa SF8</td><td>Slow blink BLUE for 3 seconds</td></tr>
<tr><td>LoRa SF10</td><td>Slow blink ORANGE for 3 seconds</td></tr>
<tr><td>None</td><td>Solid RED for 3 seconds</td></tr>
</table>

In the above table are specified the desired functions of the button found on the physical anchor device. In addition to being able to change the device mode in between "ACTIVE" and "MAINTENANCE". In ACTIVE mode, the device functions as normal, where as in MAINTENANCE mode, the normal functions, such as regular reporting of BLE beacon scanning and reports of the magnetometer being triggered are halted to save on battery. In addition, when pressing the button when the device is active, the device would send a report to the gateway and when the gateway sends back an acknowledgement, lighting up the LED on the device which can be used to see how well the device is able to connect to the gateway.

Other requested changes were:

- An additional "SLEEP" mode or function, which could be set to a timer or until further notice downlink from the gateway.
- A larger capacity for detecting bluetooth beacons from 32 to 200 by sorting them from strongest to weakest signal strength (only 32 could still be reported at a time)
- Some changes to default parameters.

Testing:

Two different tests were conducted on the ability of the anchor devices to detect BLE beacons. One would take place in May and the other July. The first test was to see if tags could be spotted with satisfactory results. The latter would concern what TX power the tags should utilize in the system for the best results.

The tests were carried out by carrying 5 BLE beacon devices and recording the specific location and durations spent in each location with a clock and 360 camera.

Note: The device performs 3 different scans a minute at 20s intervals, which was a function that was requested at an earlier point and which was delivered. By doing this and then compiling the results into a mean, median or average value for the report sent out each minute, we could eliminate many outlier values for the link budget measurements of tag BLE signal values.

For the first test, 10 anchor devices were placed around the building in range of 2 gateways. The test consisted of 3 different rounds, each of which testing a different algorithm with which the anchors measure the BLE signal. All of the routes were identical, containing 9 different points of measurement where I remained stationary for long enough that each anchor device would have time to make a scan for the BLE devices. Any detections by the anchors made between these measurement points were also documented.

The goal of this test was to see which algorithm produced the most sensible outcomes for the measured link budget values of the received BLE beacon signal measurements. At the end of the report, each location where an anchor managed to detect a tag device was also showcased per anchor.

Figure 35. Sample from BLE-beacon test report, Anchor tag detection points.

The next set of tests was performed to decide on an appropriate transmit power (Tx power) for the tag devices. 5 different tag devices were used, as in the previous test. All 5 tags were set to different Tx power levels according to table 2.

Table 2. Tag Tx power configuration

Tag	Advertising interval (ms)	Tx	Acc Sensitivity
3.1	400 ms	-8	0.1g; Full-scale: +-2g
3.2	400 ms	-4	
3.3	400 ms	-4	0.1g; Full-scale: +-4g
3.4	400 ms	0	0.1; Full-scale: +-8g
3.5	400 ms	3	0.1; +-16g

The measurements were conducted in a similar pattern to the last tests. This time, as visualisation of the detection ranges, the measurement points of specific tags were used as an outline for a rough evaluation of the area where tags could be heard by specific anchors with their specific Tx power levels.

In the figure 36 below, the anchor devices are represented by stars, where the anchor concerned is named and coloured in darker blue to the rest of the anchor devices. The areas represent each tag device, red being tag 3.5, orange being 3.4, etc. The colder the colour, the lower the Tx power. The darkened areas on the map represent zones from which there is no data.

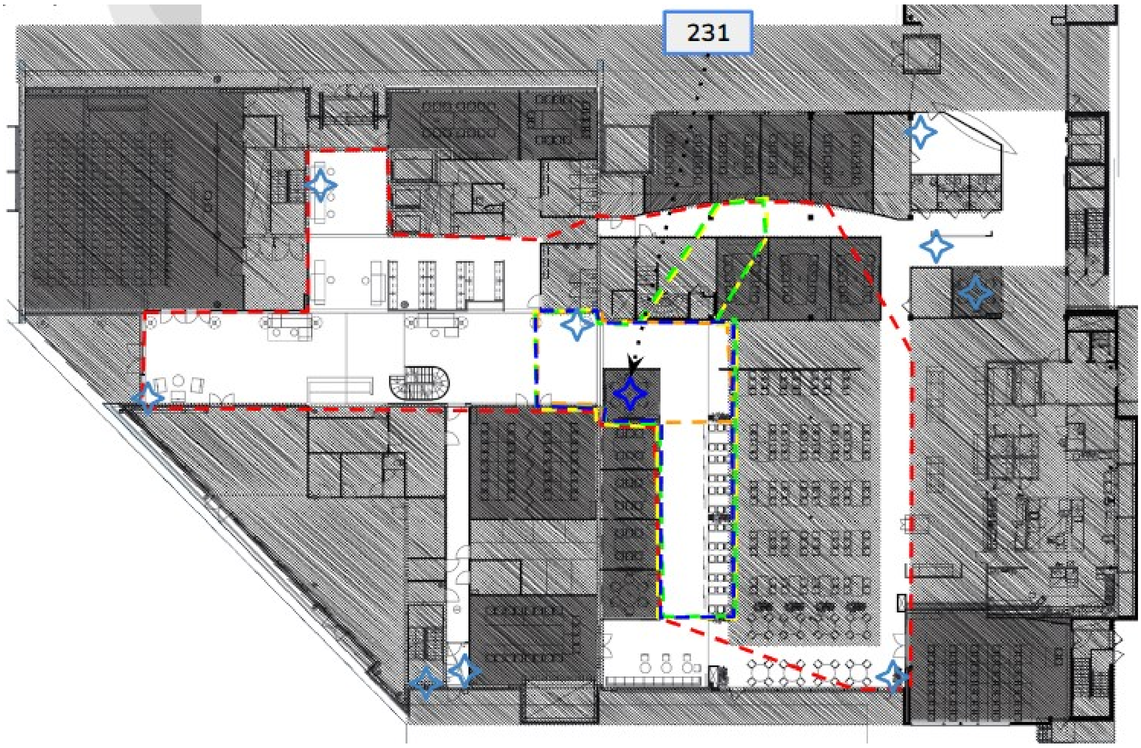

Figure 36. Sample of tag Tx power test report.

Based on the results of this test, TX power of <3 was decided on, due to the amount of times Tx power of 3 resulted in measurements from undesired locations, such as from the other side of the building, negatively skewing measurement data.

5.5 Firmware Tests: 09.2022

Two different types of testing were done. One to test that all of the updated functionalities of the new firmware was functional.

Tested were the following:

- The new button and LED functionality
- Sleep mode and command
- New beacon limit of 200 per anchor device
- Link budget filter for anchor devices
- GW RTC synchronisation

- Anchor scan synchronisation
- Change to the anchor report timestamp.

All of these were found to be functioning as intended except for the GW RTC synchronisation, which was then reported to Wizzilab.

After testing the firmware, I tested the communication range of the anchor devices using the new button and and LED functionality to quickly determine rough quality of the connection between the anchor and the gateway device from various locations inside the office building. This was done by holding 2 anchor devices about chest height, walking to the measuring point and pressing the button, then waiting for the LED to report the type of signal between the devices and noting it down.

Figure 37 explains the notation of the image that comes after it (figure 38).

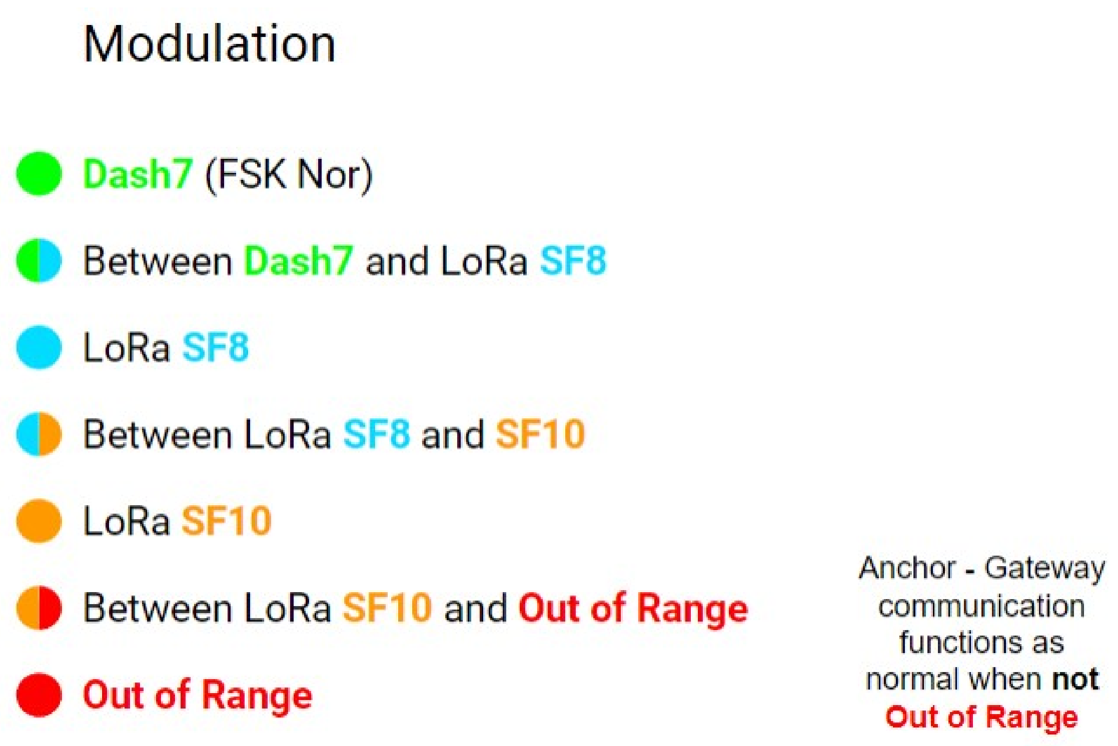

Figure 37. Anchor to Gateway communication range test notation.

Each node represents one measurement made with 2 devices at said measurement point. When both devices have the same result, this is shown as a unicolor mark. When two different results were gained, one side of the dot represents one device and the other side represents the other.

Note: Only the “Out of Range” result represents a connection where communication is non-functional.

Figure 38. Anchor to Gateway communication range test.

Note that sometimes during testing, results when the device reported the connection as red still sometimes had the report reach the gateway.

The button functionality was also updated according to the following table 3, adding a reboot function:

Table 3. Updated button functionality table

<table>
<tr><td>MODE</td><td colspan="3">MAINTENANCE</td><td colspan="2">ACTIVE</td></tr>
<tr><td>BUTTON PRESS</td><td colspan="2">2 Seconds or less</td><td>5 Seconds or more</td><td>5 Seconds or more</td><td>2 x 2s or less</td></tr>
<tr><td>FUNCTION</td><td colspan="2">Indicate strength of connection to GW</td><td>Switch to ACTIVE mode</td><td>Switch to MAINTENANCE mode</td><td>Reboot the device</td></tr>
<tr><td rowspan="4">LED INDICATOR</td><td>Dash7</td><td>Slow blink GREEN for 3 seconds</td><td rowspan="4">Fast blink GREEN for 2 seconds</td><td rowspan="4">Slow blink RED for 2 seconds</td><td rowspan="4">Blink every colour once. Loop once. (G-B-O-R, G-B-O-R)</td></tr>
<tr><td>LoRa SF8</td><td>Slow blink BLUE for 3 seconds</td></tr>
<tr><td>LoRa SF10</td><td>Slow blink ORANGE for 3 seconds</td></tr>
<tr><td>None</td><td>Solid RED for 3 seconds</td></tr>
</table>

This was then sent to Wizzilab for the next firmware update.

5.6 Tapiolan Tuultenristi Tests: 09.2022 - 01.2023

The Tuultenristi construction consisted of a five story building. All five above ground floors were used for testing. The gateway throughout all of the different tests was located on the windowsill of the site offices on the other side of the road from the building. The gateway was not on level with the first floor, being somewhat lower in elevation, as can be seen in figure 40.

Figure 39. Top down view of the Tuultenristi construction site with outlines for the relevant buildings and site office.

As said, the building consists of 5 floors above the basement level. The first two floors are larger than the floors above, taking up more space in both width and length (see the outlines of the above figure 39 in the top right corner) than the remaining three floors above. The first two floors also house an additional stairwell at the southeastern corner and also contain veranda at the southernmost tip of the floors. Most of the inside consist of open space, barring the central area of the floors, which house within concrete walls the building's stairwell, elevator shafts, maintenance closets and other essential infrastructure. The outer walls of the building consist of thick glass and steel beams.

The distance from the location of the gateway to the southwestern corner of the building was roughly 50 to 60m and to the northeastern corner that distance was about 90 to 100m (distance only on the x,y axis, not up and down).

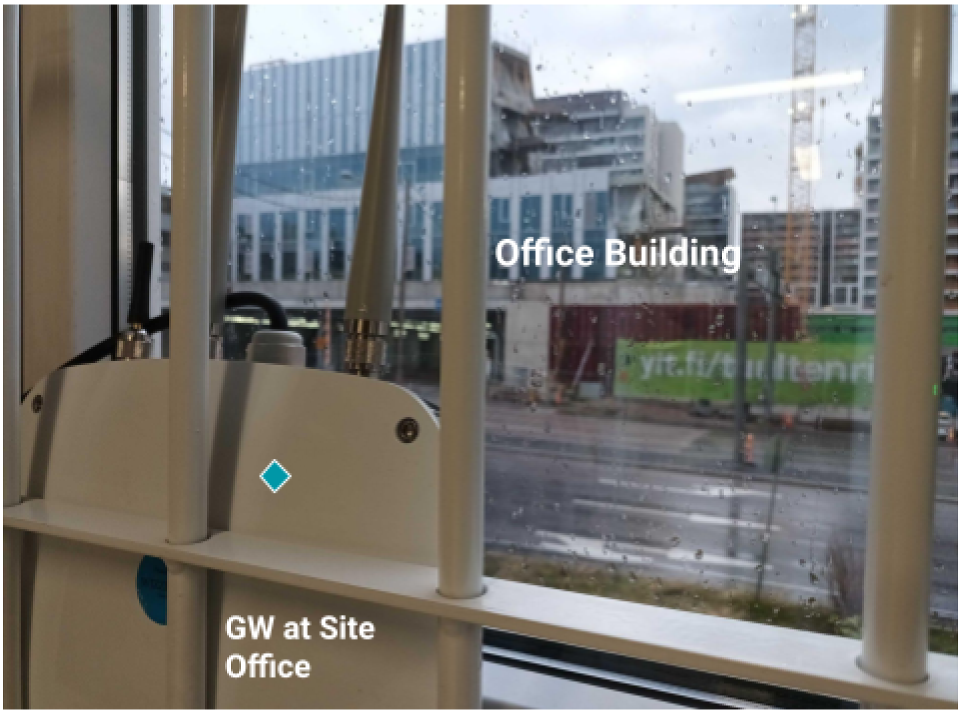

Figure 40. The site building as viewed from the location of the gateway.

5.6.1 Range tests

At this point of construction, the floors had been constructed, but were for the most part completely empty and without any internal walls (those belonging to the offices, not counting the central area containing the stairwell and elevator shafts), with some of the top floors also missing some external walls as well. This meant that there was a minimal quantity of obstacles blocking the path of any signals travelling between the gateway and

This test was performed using the same methodology as the test performed in chapter 5.4, “Firmware tests: 09.2022”. 36 different measurements were taken with two devices simultaneously:

- 1st floor: 6 different measurement points, one in the stairwell, one in each corner of the building and one additional behind the emergency stairwell (which had yet to be constructed, including the walls)
- 2nd floor: Same as the 1st floor
- 3rd floor: 9 different measurement points, one in each corner of the floor, one in the stairwell, two in maintenance closets encased by concrete walls, one in the middle and another behind where the emergency stairwell would be constructed
- 4th floor: Same as 3rd, but with 8 points with the one near the middle missing
- 5th floor: Same as 4th, but with 7 points with the point in the western maintenance closet missing (inaccessible at time of testing).

During testing, none of the points outside of the central stairwell failed to connect with the lowest modulation available (even the maintenance closets), Dash7, except for the NE corner of the second floor, which connected both devices with LoRa SF8. The central stairwell would connect with mixed results, sometimes with one device getting Dash7 and the other with LoRa SF8 and sometimes with LoRa SF8 and SF10.

The results were surprisingly good, especially considering that the central stairwell was entirely constructed out of concrete and not having its open doorways be in the direction of the gateway, but facing south.

The sparsity of indoor obstacles at this point of construction was likely a massive contributing factor as well as the general construction of the building, as most of the outfacing walls were constructed mostly of glass and the indoor spaces were designed to be open with plenty of space.

5.6.2 Test Setup 1

This setup was very short lived and was conducted with only a limited amount of devices, four on the 1st floor, four on the second and two devices on the 3rd floor. All of the anchor devices were installed on thick metal support pillars at around head height and were verified to have a stable connection to the gateway at the windowsill of the site office.

No further testing was done on this setup and the project proceeded onto the next setup.

5.6.3 Test Setup 2

This would be what would become the final test setup for the prototype network of the system. Device count would remain identical and the positions of the devices would be near identical, with four of the anchor devices being located at each corner of the building attached to the window glass of the first floor, four devices on the second floor would be attached on the four outer corners of the central concrete structure and on the third floor two devices, each in the middle of the eastern and western window glass facing each other through the central structure housing the stairwell, maintenance closets and elevator shafts.

At the time of installation early October they were confirmed to connect to the gateway without issue.

Unfortunately at this point of the project, focus was diverted away to more essential tasks in other areas and the project was left mostly unattended, leaving a long period of inaction between this and the final tests that were rapidly performed at the final minute, due to the necessity of removing the hardware from the soon to complete construction.

One final BLE test was performed last minute, but failed due to inability to handle the data and was cut short. Many of the devices had failed to connect to the gateway due to the increased amount of obstacles between the anchors and the gateway. This having occurred in late January, most of the internal walls had been constructed and much of the furniture added.

6 Finalisation

The main goal of this extended project was to execute a working prototype network of the Wizzilab RPS system customised for Aiforsite, and for which Aiforsite would have created proprietary software. This prototype network was meant to be installed on a real construction site to produce realistic data and provide value to the customers through various services provided with the aid of resource positioning data gathered on site.

Unfortunately this goal was ultimately left unrealized, as the focus and priorities of myself and my project manager, Siyan Zhuang, shifted to accommodate needs in other areas. The conclusion of my work with the project was brought to a halt after the final rounds of testing were finished, and only the work in this thesis remained after I ceased working for the company in 2023.

6.1 Challenges

One of the most overarching challenges was the scope of the work. In the beginning of the project, I did not truly have a good idea of how long it would take for the project to reach the prototype network state. This remained the case throughout the work and hampered my ability to pin down a point to conclude the thesis, which was eventually provided to me by a changing of circumstances, which prevented further work being done on the project on my part and provided a cutoff point for the thesis paper.

Related to the scope of the work, due to the extent of work done and the amount of time the project spanned, this provided an additional challenge, as increasingly long periods of time stood between the work done and writing it down into this thesis paper. This was fortunately remedied by my good memory and thorough documentation.

Another set of challenges was a changing amount of focus and resources afforded to the project. This was a large factor, accounting for most of the gaps in the work between the first and final rounds of testing and within them. In the beginning, when there were more types of testing to be done and the project was my sole focus, I could allocate all of my time to it. However, as my role was expanded throughout the company and as other projects took focus, the project was put on hold. Contributing to some of the pauses in the work, was also a reliance on outside factors both within the company and outside of it, as there were necessary pauses for software and firmware to catch up in the project for more testing and quality assurance to be able to sensibly contribute.

One final challenge was my disconnection from the project as my work ceased in April 2023.

7 Conclusions

Unfortunately the goal of a prototype network for a final product, although planned, was left unrealized while I remained working on this project at Aiforsite.

What was achieved during the project was the establishment of both the basic and financial viability of the system and its components for a prototype product.

As a continuation of the work, once the backend software is ready, a prototype network can be installed using company expertise and knowledge to execute device placement and installation in an equivalent manner to the planned final product, after which it can be tested and evaluated. Much of the work, especially the work made in cooperation with Wizzilab (for example: the specifications and firmware testing) is a solid base for the further development of the system toward a final product.

This thesis paper provides a collage of most, if not all, of the testing done on the RPS product development process for the Wizzilab system from 2021 to early 2023. Some of the lessons and conclusions, as well as the practices can be carried over to future rounds of testing for various product development processes.

Good to know information relating to RPS (and other IoT) installations in the field:
Installing gateway devices closer to the anchor devices, with at most three floors between them and ideally high-off the ground and away from thick solid concrete and metal surfaces is ideal. The same principle applies to anchor devices. Signal travels best when penetrating obstacles (such as doors, windows, walls and floors) perpendicularly.

Distance and the amount of obstacles between anchors and gateways play a factor in how well the devices are able to communicate. As a construction site progresses, more obstacles are introduced and may later be removed, necessitating regular monitoring of the quality of the various links between the devices.

The best results are achieved when achieving line-of-sight communication. This is also affected by what is known as the Fresnel Zone, which affects signal propagation in an elliptical shape from end to end on each device, which I recommend looking into if one is interested in the subject [16]. Another factor is weather, as higher humidity and temperature changes negatively affect signal quality.

Additionally other radio traffic, such as wifi and bluetooth signals coming from consumer electronics, creates noise, lowering the quality of the signal for the vital hours of the day, when resources will be most active. Be mindful that the signal quality will be lower when there is higher amounts of activity on-site, as even the devices in the system themselves can begin to interfere with each other by creating additional noise.

8 Retrospect

The goals and scope of the work were too ambitious for the paper and along with other work and circumstances slowing down the process, the thesis work ended up concluding before the project could from a personal standpoint. In hindsight it would have been more advantageous to limit the work to an earlier part of the project and write more extensively on less material over a shorter and more focused timespan.

This thesis unfortunately did not conclude as hoped at the beginning of the project for various reasons, such as time and resource constraints and the vastness of the scope of the project.

To close, I would like to give special thanks to Siyan Zhuang without whom this project could not have moved forward and Tuomas Lackman, who introduced me to the project and without whom I would never have gotten to work for Aiforsite.

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Appendix 1: Relevant communication signals specifications table

[6; 7, p. 2; 17, p. 26; 18, p. 10-11; 19 p. 12]

Modulation Scheme	Band (EU)	Rate	Bandwidth	Bit Rate [bit/s]	Typical Receiver Sensitivity	Time on Air
Bluetooth Low Energy	**2.4 GHz**	**N/A**	**2 MHz**	**125 000 to 2 000 000**	**-70 to -85 dBm**	**-**
Dash7	868 MHz	High	200 kHz	166 700	-105.0 dBm	-
		Normal	**200 kHz**	**55 600**	**-110.0 dBm**	**-**
		Low	25 kHz	9 600	-117.5 dBm	-
LoRa	868 MHz	SF7	125 kHz	5 470	-123.0 dBm	41 ms
		SF8	125 kHz	**3 125**	**-126.0 dBm**	**72 ms**
		SF9	125 kHz	1 760	-129.0 dBm	144 ms
		SF10	125 kHz	**980**	**-132.0 dBm**	**288 ms**
		SF11	125 kHz	440	-134.5 dBm	577 ms
		SF12	125 kHz	250	-137.0 dBm	991 ms

The rates highlighted in bold are the rates used in the work.

Appendix 2: Innovation Project Technical Report (in finnish)

Osaamista
ja oivallusta
tulevaisuuden
tekemiseen

Ryhmä 12: Niko Malmivaara, Charlie Samutchak, Abdullahi Omar ja Tuomas Paloheimo

Rakennustyömaan paikkatietojärjestelmän jatkokehitys

Metropolia Ammattikorkeakoulu

Insinööri (AMK)

Sähkö- ja automaatiotekniikka

Innovaatioprojektin loppuraportti

SISÄLLYS

Dokumentin versiointi

Date	Version	Editor / Approver	Summary of Changes
30.4.2021	1	TP, NM, CS, AO	Teknisen loppuraportin aloitus
3.5.2021	2	TP, NM, CS, AO	Teknisen loppuraportin jatkaminen
4.5.2021	3	TP, NM, CS, AO	Teknisen loppuraportin jatkaminen ja valmistuminen

LYHENTEET JA KÄSITTEET

AIC	Aiforsiten käytössä oleva käyttöliitymä, jonka avulla pystytään tarkkailemaan eri rakennustyömaiden olosuhteita kenttälaitteiden lähettämien tietojen kautta.
BLE	Lyhyen matkan langaton likiverkkotekniikka, jota nykyaikaiset langattomat laitteet käyttävät.
Dash7	Avoimen lähdekoodin langaton anturi ja toimilaitteen verkkoprotokolla
Gateway	Tietoliikenneverkossa käytetty tietoverkkolaitteisto, joka sallii datan virrata erillisestä verkosta toiseen.
LoRa	Oma pienitehoinen laaja-alainen verkkomodulaatiotekniikka.
Tag	Komponentti, joka päivittää paikkatietoansa ankkurille ja/tai gatewaylle. Tagilaite voidaan liittää laitteistoon tai työntekijän kypärään.
Radioteknologiat	Dash7, LoRa (Long Range), BLE (Bluetooth low energy)
WNT Client	Wirepas Meshin kanssa toimiva käyttöliittymä, jossa kenttälläteiston lähettämää tietoa on mahdollista tarkkailla reaaliajassa.
Wirepas Mesh	Wirepas Oy:n kehittämä verkkomainen paikkatietojärjestelmäratkaisu
WISP	Langaton tunnistus- ja tunnistusalusta on radiotaajuinen tunnistus, joka tukee tunnistamista ja laskemista.

1 JOHDANTO

Aiforsitella on käytössä Wirepas Mesh verkkoon pohjautuva paikkatietojärjestelmä rakennustyömaalle. Wirepasillä on oma radio protokolla, joka mahdollistaa orgaanisen laiteverkon muodostamisen.

Vahvuuksistaan huolimatta Wirepas-järjestelmällä on tiettyjä heikkouksia, joiden takia Aiforsitella tutkitaan vaihtoehtoiseen teknologiaan perustuvaa konseptia. Tämä konsepti perustuu Wizzilab-nimisen ranskalaisen yrityksen kehittämään WISP-sensoriin, joka käyttää DASH7 ja LoRa radioteknologioita yhteydenpitoon ja pystyy kuuntelemaan BLE radiosignaaleja.

Projektin tavoitteena oli päästä lopputulokseen Wizzilab järjestelmän käyttöönoton kannattavuudesta Wirepas järjestelmän tilalle tarkastellen samalla järjestelmien käyttöön liittyviä tekijöitä sekä luoda Wizzilab järjestelmälle datan parsija, että laatia tämän käyttöönotolle suunnitelma, mikäli todettiin sen olevan kannattavaa.

Projektin testikenttänä käytettiin Metropolia AMK myyrmäen kampusta. Projektiin tarvittavat pohjapiirrustukset ja lupa niiden käyttöön projektia varten hankittiin Metropolian Myyrmäen kampuksen vastaavalta henkilökunnalta.

Alla listataan lisää tietoa Wirepasista ja Wizzilabista. Vaikka projekti koskee ainoastaan järjestelmien paikannusominaisuuksia, molemmilla järjestelmillä on siitä huolimatta mahdollisuus kerätä muuta tietoa, joita mahdollisesti tarvitaan kuten esim. kosteus- ja lämpötilatietoja, joita on mahdollisuus kerätä eri yritysten valmistamilla laitteistoilla.

2 WIREPAS

Wirepas Oy on suomessa vuonna 2010 perustettu teknologiafirma, jonka kotipaikka sijaitsee vantaalla. Sen toimialaan kuuluvat langattoman verkon hallinta ja palvelut.

Projektissa käytössä oli Wirepasin kehittämä Wirepas Mesh, jonka avulla eri kenttälaitteet (ankkurit ja tagit) toimivat verkon omaisesti kiinni gatewayssa, josta tieto kentältä laitteiden keräämänä välittyy käyttäjälle.

Wirepas Mesh käyttää langattomana radiosignaaliteknologiana BLE:tä (Bluetooth Low Energy).

3 WIZZILAB

Ranskassa vuonna 2010 perustettu yritys, jonka kotipaikkana toimii Montrouge.

Wizzilab on langattomien viestintälaitteiden kehittäjä. Yhtiö kehittää erittäin pienitehoisia, matalaviiveisiä langattomia viestintälaitteita, jotka perustuvat pitkään DASH7-standardiin. Sen tuotteiden avulla käyttäjät voivat olla vuorovaikutuksessa ympäristönsä ja ympäröivien älykkäiden esineiden kanssa.

Projektissa tarkastellaan Wizzilabin kehittämää paikkatietojärjestelmää, joka toimii käyttäen BLE, DASH7 ja LoRa (Long Range) radiosignaaleita tiedonvälityksessä. Teknologian avulla on mahdollista käyttää useampaa näistä signaaleista samanaikaisesti vaihdellen käytön aikana niiden välillä, optimoiden signaalien vahvuuden milläkin kantamalla.

Paikkatietojärjestelmä operoi BLE signaalilla tagien ja ankkurin välillä, ankkurit puolestaan välittävät tagien keräämän tiedon eteenpäin gatewaylle käyttämällä optimaalista signaalia, joka on joko DASH7 tai optimaalinen LoRan SF profiili. Käytännössä tämä tarkoittaa, että annkurien siirtymässä lähemmäs, ne siirtyvät käyttämään DASH7 ja siirtyessä kauemmas ne siirtyvät ensin LoRa SF7, SF8 ja siirtyessä vielä kauemmas SF10-12.

Tässä projektissa ainoat käytössä olleet ankkurien profiilit olivat DASH7, LoRa SF8 ja SF10.

4 RADIOTEKNOLOGIAT

Allaolevat radioteknologiat ovat listattuina siinä järjestyksessä, että ensimmäisenä listattuna on BLE, jonka tiedon lähetystiheys on kaikkein tihein, mutta sen kantama on kaikkein lyhyin. Kun mennään listassa alaspäin, signaalin taajuus laajenee ja täten sen kantama pitenee, mutta samalla menetetään signaalista lähetystiheyttä. Kaikkein kantavin signaali, jota projektissa käytettiin, oli LoRa SF10 profiililla.

Huomaa, että etäisyydet eivät ole absoluuttisia, eivätkä signaalit kykene ylläpitämään kantamiaan läpäistessään rakenteita. Siitä huolimatta voidaan olettaa, että pidempi kantama => parempi läpäisykyky

4.1 BLE

BLE kehitettiin nimensä mukaisesti kuluttamaan vähemmän virtaa käytön yhteydessä aiempaan Bluetooth protokollaan verrattuna. Tämä auttaa sen operointia langattomissa laitteistoissa, joissa paristojen koko ja kustannukset rajoittavat niiden virrankulusta ja elinikää.

Sen kantamaksi on listattu < 100 m ideaalisissa olosuhteissa. BLE on erittäin lyhyt kantamainen ja sillä on hankaluuksia läpäistä rakenteita. Sen tiedonsiirtonopeutena on ilmoitettu 125 kbit/s – 500 kbit/s – 1 Mbit/s – 2 Mbit/s.

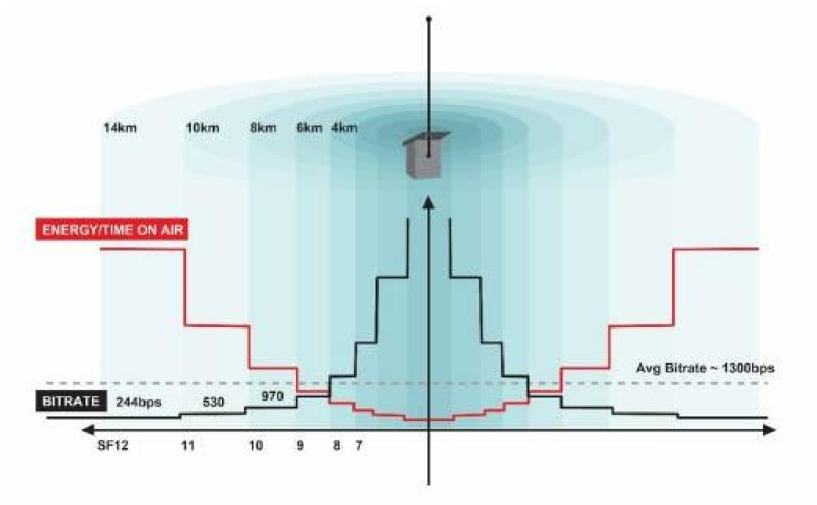
4.2 DASH7

DASH7 on kehitetty open source (DASH7 Alliance Protocol (D7A)) langaton anturi ja toimilaitteen verkkoprotokollan pohjalta. D7A alkuperä on ISO/IEC 18000-7 standardi. DASH7 avulla saavutetaan pitempi akunkesto, 2-5 km:n kantama ideaalisissa olosuhteissa ja 167 kbit/s tiedonsiirto. Dash7 avulla kyetään läpäisemään huomattavasti BLE-signaaleja paremmin rakenteita.

4.3 LoRa

LoRa on LPWAN (low-power wide-area network) modulaatio tekniikka, jolla on matala virrankulutus ja tiedonsiirtonopeus.

Vaihtamalla LoRa SF (Spread Factor) profiilia, on mahdollista muuttaa signaalin kantamaa. Spread Factorien vaihtelun avulla voidaan edelleen optimoida signaalien välitystä, minkä avulla vähennetään energiankulutusta (Kuva 1. Semtech, sivu 5). Lyhyin kantamainen LoRa signaali on SF7 4 km kantamalla. Projektin aikana käytössä olivat ainoastaan LoRa SF8 ja SF10. Alla olevassa kuvassa näkyvät eri SF tiedot mukaan lukien tiedonsiirtonopeudet.



Kuva 1. Semtech, sivu 5

5 PROJEKTIN LAITTEISTO JA TYÖKALUT

5.1 Wirepas

Laitteiden testauksen päätyökaluna käytettiin WNT Client työkalua. Käytössä oli myös Aiforsiten kehittämä ja käyttämä AIC.

Fyysinen laitteisto:

- Gateway - Treon Gateway
- Ankkurit - BLUE ID MESH PUCK
- Tagit - BLUE ID MESH COIN

5.2 Wizzilab

Projektissa Wizzilab laitteiston testauksen työkaluna käytettiin dash7board.

6 PROJEKTIN SUUNNITELMAT JA TOTEUMA

Suunnitelmana oli kerätä vertailtavaa tietoa asiakasyrityksen Aiforsite Oy:n ehdotusten, sekä itse suunniteltujen paikkatietojärjestelmätestien avulla.

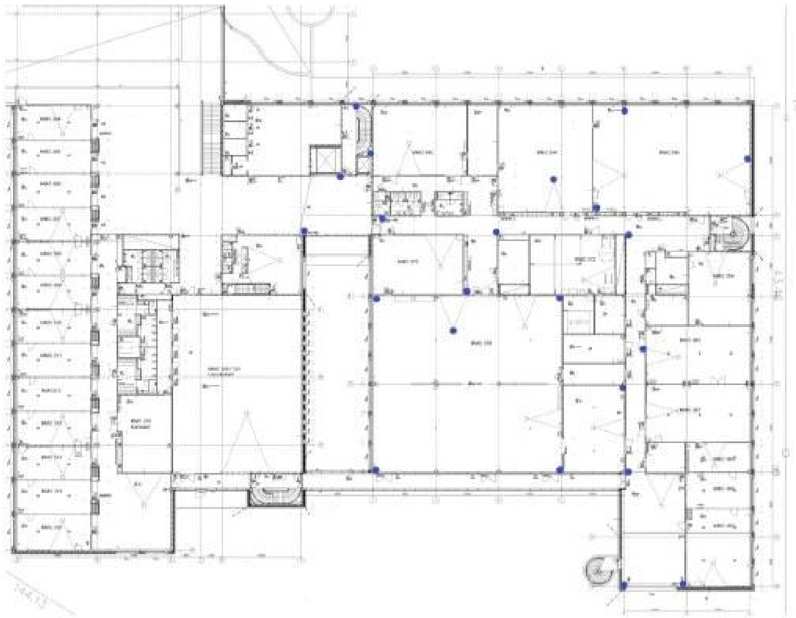
Alustimme testauksen hankkimalla tarvitut Metropolian kampuksen pohjapiirustukset paikkatietojärjestelmien ohjelmistoja varten.

7 WIREPAS TESTIT

Testiverkon rakentaminen ja ylläpito tapahtui Wirepas Network Tool (WNT) Client -ohjelmiston kautta.

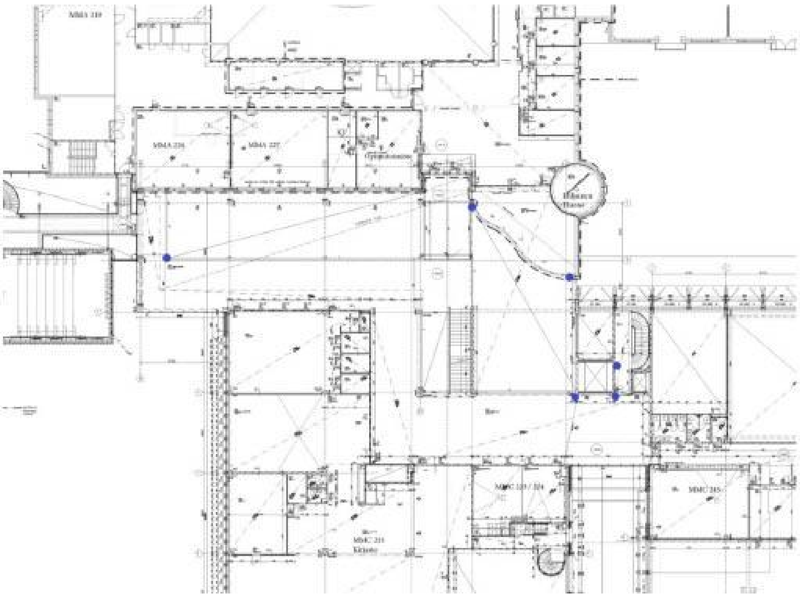
Ankkurit sijoitettiin Metropolian kampuksen 3. ja 2. kerroksiin keskitetysti C siipeen, testeihin sisältyi myös muutama ankkuri B siiven puolella. Ankkurien sijainneista tehtiin alustavat anturikartoitukset, joita käytettiin ankkurien sijaintitietojen asettamisessa Wirepas Network Tooliin testiverkon rakentamiseksi.

Wirepas ankkureita sijoitettiin 24 kappaletta 3. kerrokseen.

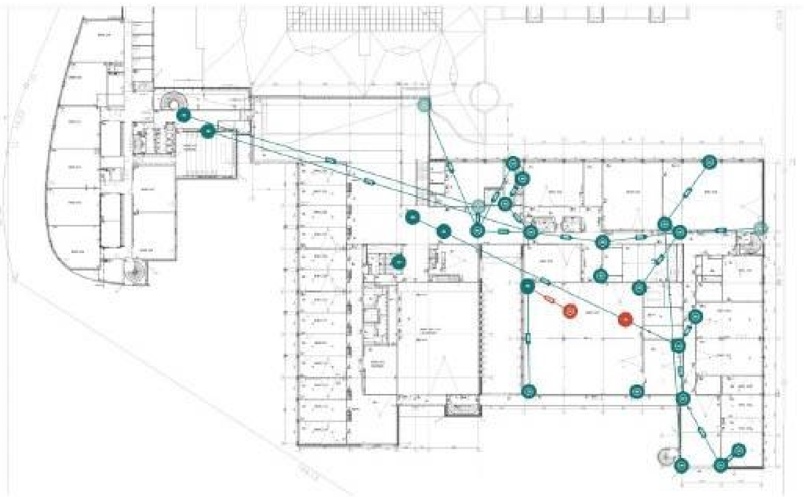


Kuva 2. Alustava ankkurikartoitus 3. kerroksen Wirepas testiverkosta

Samalla tavalla tehtiin ankkurikartoitus 2. kerroksen ankkurien sijainneista, joita sijoitettiin 6 kappaletta. Ideana oli testata ankkurien välistä kuuluvuutta eri kerrosten välillä.

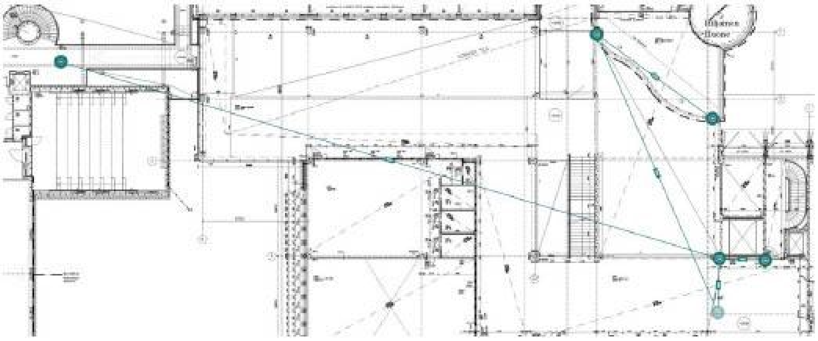


Kuva 3. Alustava ankkurikartoitus 2. kerroksen Wirepas testiverkosta



Kuva 4. WNT Client -ohjelmiston 3. kerroksen Wirepas testiverkko

Asetettua 2. kerroksen ankkurien sijainnit WNT Client -ohjelmistoon, näkymä oli ohjelmistossa Kuva 5. mukainen.



Kuva 5. WNT Client -ohjelmiston 2. kerroksen Wirepas testiverkko

Tämän jälkeen tehtiin ohjelmistoon loogisia alueita, jotka sijaitsivat ankkurien läheisyydessä. Loogisilla alueilla testattiin tagien paikantamista.

Kuva 6. WNT Client -ohjelmiston 3. kerroksen Wirepas testiverkon loogiset alueet

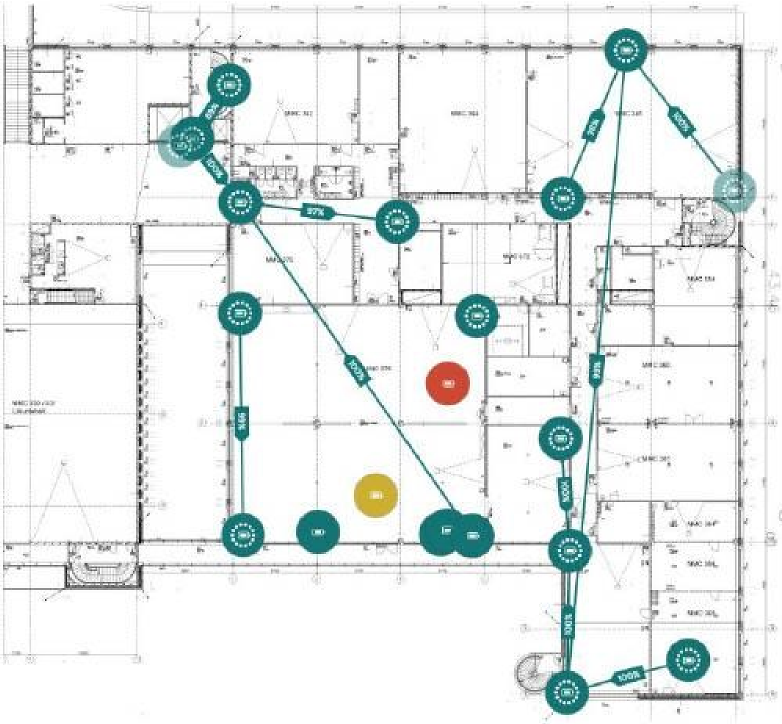
Kuva 7. WNT Client -ohjelmiston 2. kerroksen Wirepas testiverkon loogiset alueet

Suoritimme ensimmäiseksi Wirepas paikkatietojärjestelmälle yleisen kuuluvuustestin 30 ankkurilla. Ne sijoitettiin Metropolian kampuksen 3. ja 2. kerroksiin keskitetysti C siipeen, testeihin sisältyi myös ankkurien välisen kuuluvuuden maksimietäisyyden testaus B siiven puolella.

Tämän jälkeen testasimme Wirepas järjestelmän seinienläpäisyn kuuluvuutta.

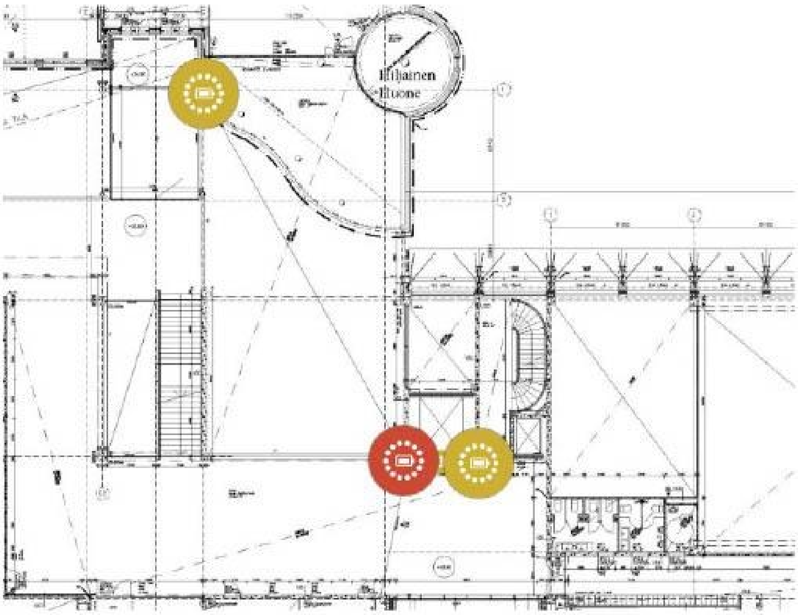
Kuva 8. Wirepas paikkatietojärjestelmän seinienläpäisytesti

Seuraavaksi suoritimme Wirepas järjestelmälle rasitustestin, jossa vähensimme käytössä olevien ankkurien määrää ja testasimme tagien paikannusta.



Kuva 9. Karsimisen jälkeinen ankkurikartoitus 3. kerroksen Wirepas ankkureista

Karsinta suoritettiin myös kampuksen 2. kerroksessa ja luotiin uusi ankkurikartoitus WNT-Client -ohjelmistossa.

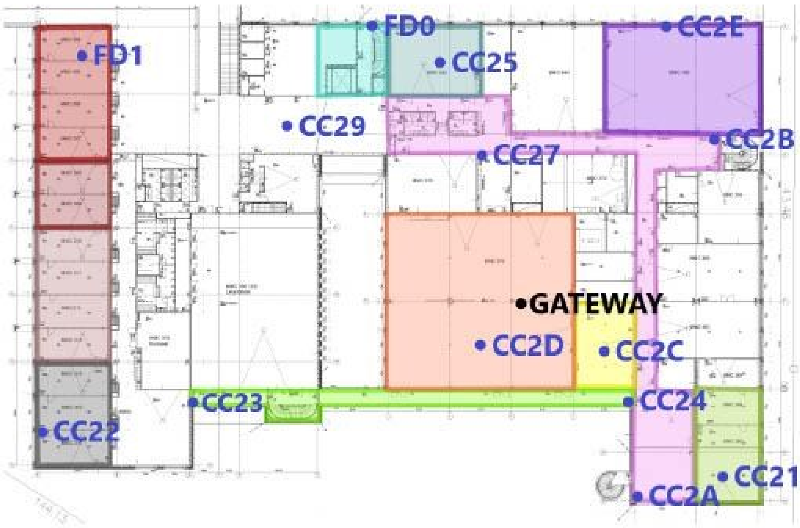


Kuva 10. Karsimisen jälkeinen ankkurikartoitus 2. kerroksen Wirepas ankkureista

8 Wizzilab testit

Wizzilab testaaminen alustettiin kytkemällä Wizzilabin gateway verkkoon ja verkkovirtaan. Testeihin kuului kuuluvuuden maksimietäisyyksien testaaminen per radioteknologiakanava ja suoritimme myös nopeahkon signaalin seinienläpäisytestin, jolloin ankkuri ei havainnut tagia.

Testeihin käytössämme oli yhteensä 16 Wizzilab ankkuria sekä 4 Wizzilab tagia. Wizzilab ankkurit sijoitettiin kampuksen 3. kerrokseen Kuva 11. ankkurikartoituksen mukaisesti, 2. kerrokseen ei sijoitettu Wizzilab ankkureita.



Kuva 11. Wizzilab ankkurikartoitus 3. kerroksessa

Ankkurien sijoitusten jälkeen testasimme ankkurien ja gatewayn välistä sekä ankkurien ja tagien välistä kuuluvuutta. Valvoimme tuloksia Wizzilabin dash7board verkkoalustalla ja syötimme JSON Formatteriin jolloin saimme datan helpommin luettavaan muotoon. Signaalin data näytti Kuva 12. mukaiselta, jossa beacon_major kertoo tagin ensimmäisen tunnisteen ja beacon_minor kertoo tagin toisen tunnisteen. Beacon_rssi kertoo signaalinvahvuuden desibeleissä.

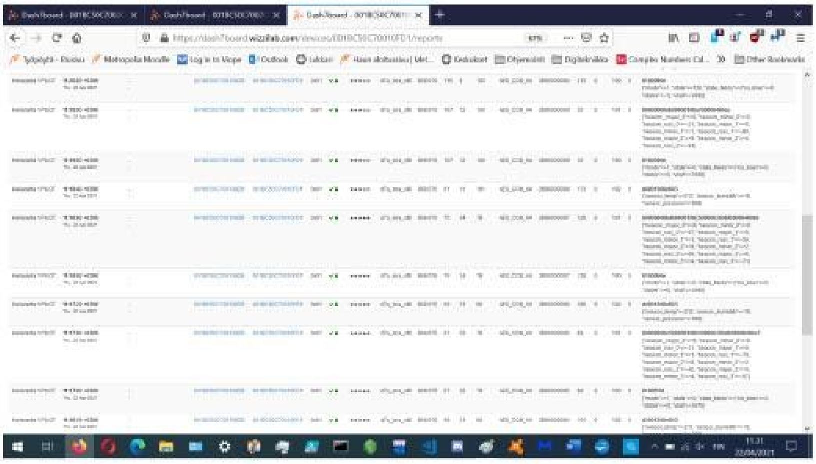
```
# Data when FSK used.
{
    "meta":{
        "uid":"001BC50C70010FD0",          # id:t
        "guid":"001BC50C700108CC",
        "gmuid":"001BC50C700108CC",
        "lb":40,                           # kuinka hyvin kuuluu tukiasemmalle
        "fid":191,
        "fname":"ble_status",
        "offset":0,
        "device_type":"01BC50C7FF000017",
        "site_id":589,
        "lqual":5,
        "ct":"d7a_fsk_nor_cs2",
        "freq":868.1,
        "status":25713,
        "s_status":2,
        "a_status":0,
        "roaming":false,
        "timestamp":1615211614             # aikaleima
    },
    "msg":{
        "beacon_major_0":9,
        "beacon_minor_0":0,
        "beacon_rssi_0":-62,               # signaalin vahvuus

        "beacon_major_1":9,
        "beacon_minor_1":2,
        "beacon_rssi_1":-58,

        "beacon_major_2":9,
        "beacon_minor_2":4,
        "beacon_rssi_2":-57,
```


Kuva 12. Wizzilab data

Wizzilabin verkkoalustalla Dash7boardissa paikannusdata näytti Kuva 13. mukaiselta. Kyseisessä kuvassa valvottiin ankkurin FD1 havaitsemia yhteyksiä.



Kuva 13. Wizzilab Dash7board

9 TULOKSET

Testiympäristössämme saimme seuraavat tulokset:

Wirepas

- Kuuluvuuden maksimietäisyys tagin ja ankkurin välillä:
- Seinienläpäisy: Ankkurit kuulivat toisensa topologianäkymästä tarkastellen, vaikka betoniseinien paksuutta oli yhteensä 33 cm verran.
- Toimiva paikannus saavutettiin 19 ankkurilla karsimisen jälkeen.

Wizzilab

- Kuuluvuuden maksimietäisyys tagin ja ankkurin välillä DASH7: n. 20 m
- Kuuluvuuden maksimietäisyys tagin ja ankkurin välillä SF8: 70–90 m välillä
- Kuuluvuuden maksimietäisyys tagin ja ankkurin välillä SF10: n. 90 m
- Seinienläpäisy: Wizzilab ankkuri FD0 ei havainnut tagia wirepas seinienläpäisytestialueen toisessa päässä, aika loppui kesken tarkemman testauksen osalta.

10 YHTEENVETO

Vertailtavia testejä suoritettiin Wirepas ja Wizzilab paikkatietojärjestelmien välillä, mutta aikataulun haasteiden myötä testit jäivät hieman kesken, emmekä kerenneet testata kaikkea mitä oli alun perin suunniteltu. Tästä syystä emme päässeet yksiselitteiseen lopputulokseen, kumpi paikkatietojärjestelmistä olisi parempi vaihtoehto käyttötarkoitukseen nähden asiakasyrityksellemme Aiforsite Oy:lle. Havaitsimme kummassakin paikkatietojärjestelmässä olevan hyviä puolia. Esimerkiksi Wirepas paikkatietojärjestelmän Mesh -rakenne on joustava ja helpottava tekijä järjestelmän asentamisessa, kun taas Wizzilab paikkatietojärjestelmässä maksimietäisyyden kuuluvuus gatewayn ja ankkurin välillä on huomattavasti kattavampi.

Testejä jatketaan Aiforsiten puolella projektin jälkeen ja suorittamistamme testeistä saatiin hyödyllistä tietoa Aiforsitelle.

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