Indoor Positioning: Technologies and Use Cases in Retail Context

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Abstract

Indoor positioning systems (IPS) are required in buildings to offer the possibility to position people and assets indoors, as the widely utilized GPS signal cannot penetrate through walls. IPSs are already implemented in many indoor environments. Several indoor positioning technologies exist, but none of them is clearly a dominant technology over the others. Consequently, this study identifies the different kinds of indoor positioning technologies and methods as well as the use cases they are used in. For this purpose, six companies using or developing indoor positioning systems were interviewed. The interviews were held in person, and they were 60-minute long semi-structured interviews with a set of questions in Appendix 1. In addition, two companies interested in indoor positioning, and that are working with retail were interviewed in 30-minute semi-structured interviews with questions in Appendix 2. Indoor positioning is employed in the interviewed companies to help users to navigate in public spaces; raise employee satisfaction in an office; improve customer service and satisfaction in malls, stores, and restaurants and develop processes and safety in warehouses. These different use cases have distinctive specifications and needs for indoor positioning, and thus, there is not a simple solution as to which technology is the right choice for a particular use case. Nevertheless, three points affecting the choice of indoor positioning technology were concluded from the interviews: 1) the accuracy of a technology, 2) whether the positioning happens through a tag or a mobile device, and 3) if positioning infrastructure, such as anchor nodes, can be installed in the building. Finally, based on the interviews, a suggested model for an indoor positioning system for a retail company is presented in a form of a Value Network Configuration.

Keywords Indoor positioning, positioning technology, use case, interview, localization

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Sisäpaikannusjärjestelmiä tarvitaan rakennuksissa, jotta ihmisiä ja tavaroita voidaan paikantaa sisätiloissa, sillä ulkona yleisesti käytetty GPS signaali ei pysty läpäisemään rakennusten seiniä. Vaikka sisäpaikannusta käytetäänkin jo useissa eri sisätiloissa ja useita eri sisäpaikannusteknologioita on olemassa, mikään niistä ei ole selvästi hallitseva teknologia. Tässä tutkimuksessa tunnistetaan eri sisäpaikannusteknologiat ja –tekniikat kuten myös niitä hyödyntävät käyttötapaukset. Tätä varten haastateltiin kuutta eri yritystä, jotka käyttävät tai tarjoavat sisäpaikannusjärjestelmiä. Haastattelut olivat puolistrukturoituja, kestivät 60 minuuttia ja ne pidettiin kasvotusten. Lisäksi haastateltiin 30 minuutin puolistrukturoiduissa haastatteluissa kahta kaupan alaan liittyvää yritystä, jotka ovat kiinnostuneita sisäpaikannuksesta. Haastattelukysymykset ovat liitteissä 1 ja 2. Sisäpaikannusta käytetään haastatelluissa yrityksissä käyttäjien navigoinnin helpottamiseksi julkisissa tiloissa, työntekijöiden tyytyväisyyden kasvattamiseen toimistossa, asiakaspalvelun ja asiakkaiden tyytyväisyyden parantamiseen ostoskeskuksissa, kaupoissa ja ravintoloissa sekä prosessien ja turvallisuuden kehittämiseen varastoissa. Näillä eri käyttötapauksilla on hyvin erilaiset vaatimukset ja tarpeet sisäpaikannukselle, joten ei ole olemassa vain yhtä hyvää teknologista ratkaisua tietylle käyttötapaukselle. Haastatteluista oli kuitenkin mahdollista muodostaa kolme sisäpaikannusteknologian valintaan vaikuttavaa asiaa: 1) sisäpaikannusteknologian tarkkuus, 2) tapahtuuko paikannus mobiililaitteen vai käyttäjän kantaman tunnisteen kautta ja 3) voiko paikannusjärjestelmän tukiasemia asentaa rakennukseen. Lopuksi esitellään ehdotelma sisäpaikannusmallista arvoverkkokonfiguraatiolla (*Value Network Configuration*) vähittäiskaupan alan yritykselle haastatteluiden perusteella.

Avainsanat Sisäpaikannus, sisäpaikannusteknologia, käyttötapaus, haastattelu, paikallistaminen

Preface

This thesis topic was suggested by my colleague and thesis advisor Aki Teronen as a continuation for previous student projects at Fluido Oy. Our research of indoor positioning will continue in a form of another thesis from this topic focusing more on one specific indoor positioning technology. This thesis is an overview to indoor positioning by going through the most important technologies and use cases.
I want to thank all the people who participated in my interviews. You all were a great help and I really appreciate your taking the time and meeting with me. I want also to thank my supervisor Professor Heikki Hämmäinen for giving valuable advice for my thesis as well as my thesis advisor Aki Teronen by suggesting such an interesting topic and providing his help.

Furthermore, I want to thank Janes for supporting me throughout the process. I'm very grateful for you!

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Annukka Karppinen

Contents

Abbreviations

AI	Artificial Intelligence
AOA	Angle of Arrival
AP	Access Point
BLE	Bluetooth Low Energy, Bluetooth 4.0
CRM	Customer Relationship Management
DOA	Direction of Arrival
GDPR	General Data Privacy Regulation
GPS	Global Positioning System
HF	High Frequency
IPS	Indoor Positioning System
LF	Low Frequency
MAC	Media Access Control
NFC	Near Field Communication
RF	Radio Frequency
RFID	Radio Frequency Identification
RSS	Received Signal Strength
RSSI	Received Signal Strength Indication
TDOA	Time Difference of Arrival
TOA	Time of Arrival
UHF	Ultra-High Frequency
UI	User Interface
UUID	Universally Unique Identifier
VNC	Value Network Configuration
WPS	WLAN Positioning System
WLAN	Wireless Local Area Network

1 Introduction

Indoor positioning is required in buildings as the widely utilized GPS signal cannot penetrate through walls, and people spend a great amount of time indoors. Buildings can be complex, and it may be challenging to perceive the layout or find other people from the buildings. Indoor positioning systems (IPS) can be utilized to help people navigate indoors and to help businesses improve their processes or their customer service. They can be employed for instance in warehouses, offices, airports, shopping malls, hospitals and in many other spaces where the services need to be improved or the brand to be modernized. IPSs can bring a direct monetary benefit for a company or it can indirectly bring more sales by improving the company image and customer service.

1.1 Motivation

In indoor positioning, several different kind of technologies exist but none of them has become clearly dominant technology over the others. As there are very different use cases in different indoor areas, it is important to understand which technology is suitable for a particular use case. Indoor positioning is a growing market as the indoor positioning technologies become more accurate and companies want to differentiate and modernize their image [1]. Indoor positioning can open new business opportunities for Fluido, as companies may want to integrate their data from indoor positioning systems to their Customer Relationship Management (CRM) platforms.

1.2 Research Questions

The research questions of the thesis are the following:

1. What technologies are utilized in indoor positioning?
2. What are the use cases in indoor positioning?
3. Which indoor positioning technology is suitable for a particular use case?
4. How can indoor positioning be utilized in retail?

The aim for this thesis is to gain understanding of different indoor positioning technologies and different use cases of indoor positioning with emphasis on positioning in retail.

The research scope of the thesis includes most commonly utilized technologies and emerging technologies in indoor positioning. The thesis reviews shortly the techniques in indoor positioning and privacy aspects of IPSs to achieve a basic level of understanding of indoor positioning principles and the user perceived privacy in indoor positioning. In addition, various kinds of use cases are introduced and finally, a suggested way of implementing an IPS for a retail company is presented based on use cases and interviews of companies working with retail.

1.3 Research Methods

The research methods in this study include interviews and a Value Network Configuration. The interviews are considered to be the main qualitative research method of the thesis. Two types of semi-structured interviews held in person were performed: firstly, six companies utilizing or developing indoor positioning systems were interviewed in 60-minute semi-structured interviews with a set of questions in Appendix 1. These interviews form the case studies presented in chapter 5. Secondly, two companies working with retail were interviewed in 30-minute semi-structured interviews with questions found in Appendix 2. In addition to the interviews, Value Network Configuration is utilized based on the interviews to present a suggested IPS model for a retail use case.

1.4 Structure of the Thesis

The thesis is divided into seven chapters. Chapters 2, 3, and 4 are literature review of indoor positioning. To calculate the position of the user, different kind of positioning methods can be used. These methods are introduced in Chapter 2. In chapter 3 the most commonly utilized indoor positioning technologies are presented as well as a new emerging technology, 5G which will be available for indoor positioning in the near future. Chapter 4 provides a short introduction to user privacy in indoor positioning systems as the user plays a central part in indoor positioning systems.

Chapters 5 and 6 include the qualitative study of the thesis, that is, the semi-structured interviews. In Chapter 5 companies that are currently using indoor positioning or develop indoor positioning solutions were interviewed. Each interview forms a different case study with its own use case. Chapter 6 presents two companies related to retail that would potentially be interested in indoor positioning. Furthermore, the chapter includes a suggested implementation of indoor positioning combined with Salesforce's cloud-based CRM and marketing platform with a help of a Value Network Configuration for companies in retail. Chapter 7 concludes the thesis with a discussion of the findings.

2 Indoor Positioning Methods

In this chapter the most common indoor positioning methods are presented briefly, to have an overview of the theory: fingerprinting, trilateration, and Angle of Arrival. Trilateration has two different kinds of techniques to measure the distance between transmitter and a receiver: Time of Arrival (TOA) and Time Difference of Arrival.

2.1 Fingerprinting

Fingerprinting is an indoor positioning method utilized with technologies such as WLAN [2] and Geomagnetic field [3]. Fingerprinting consists two phases: off-line and on-line phase.

1. Off-line phase:
   In off-line phase the fingerprint database is constructed. The signal strength to access points are measured from different reference points. The characteristics of each reference point are stored to the database.

2. On-line phase:
   A mobile device measures the received signal strength (RSS) from its position and the measurements are compared to the fingerprint obtained in the off-line phase.

The main challenge in fingerprinting is that the RSS may suffer from reflection, diffraction, and scattering in the indoor environments. Several different kinds of positioning algorithms exist in fingerprinting including probabilistic method, deterministic method, neural networks, k-nearest-neighbor, support vector machine, and M-vertex polygon. [4] [5]

2.2 Trilateration

Trilateration is commonly utilized in WLAN positioning and in ultrasound positioning systems [6]. It is based on estimating the position of the target by measuring distances from several anchor nodes. Usually Time of Arrival (TOA) or Time Difference of Arrival (TDOA), that are two different lateration techniques, are utilized to compute the distance between the target and anchor nodes. To determine the distance in TOA and TDOA the attenuation of the emitted signal strength is calculated or the signal travel time and the radio signal velocity are multiplied. [4]

2.2.1 Time of Arrival

TOA is based on measuring the distance from a positioning target to three anchor nodes with known coordinates. These anchor nodes are depicted in Figure 1 as A, B, and C. If the radiuses from the transmitting anchor nodes A, B, and C can be measured to the point P, the target, circles with radiuses R_1, R_2 and R_3 can be drawn. These circles intersect at the point P, which is the location of the positioning target. [5]

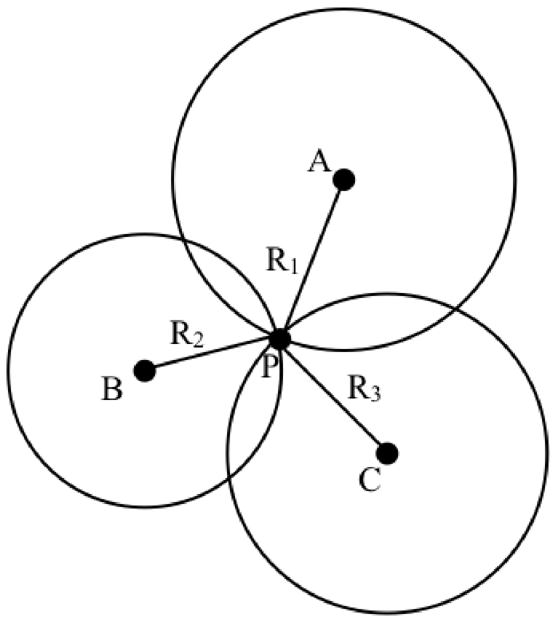

Figure 1. Positioning based on Time of Arrival

Time of Arrival requires at least three reference points in order to compute the 2D position of the target. In TOA, one-way propagation time is measured between the anchor nodes and the receiver, through which the distance is calculated, as distance is directly proportional to the signal propagation time. The challenge in TOA is that the transmitters and the receivers must be strictly synchronized and the transmitting signal needs a timestamp label in order for the receiver to determine the distance the signal has traveled. [4]

2.2.2 Time Difference of Arrival

Time Difference of Arrival is based on the different arrival times of a transmitted signal to multiple anchor nodes. To measure TDOA, the mobile transmitter needs to lie on a hyperboloid with a constant distance difference between two anchor nodes. In order to determine a 2D position of the target, at least two anchor nodes are required. The TDOA estimates are commonly computed using correlation techniques. TDOA can be estimated with cross correlation between the received signals in two anchor nodes. Cross correlation requires the anchor nodes have the same time reference and reference signals, but the positioning target does not need to be synchronized with the nodes. A delay measurement based TDOA, which is another method for TDOA estimation, does not require initial synchronization between anchor nodes. Delay measurement-based measuring method can be exploited e.g. for WLAN positioning. [4]

2.3 Angle of Arrival

Angulation is based on computing angles between multiple reference points relative to the positioning target. Angle of Arrival (AOA) or with another name of Direction of Arrival (DOA) is an angulation method where the positioning target is found with at least two angle direction lines. These angle direction lines are formed from the radiuses of anchor nodes A and B with known locations to the P, the positioning target in Figure 2. With two measured angles of α and β, the 2D location of the target can be computed. In order to compute the 3D position on the target, three stations are needed. The benefit of AOA is that only few measurement units are needed to compute the 2D or 3D position of the target, and time synchronization of the receivers and transmitters in unnecessary, unlike in TOA. The disadvantage is that usually complex hardware is required and the location estimation is less accurate the further the positioning target moves from the transmitter. In order to position the target accurately, the angles need to be precisely measured. The accuracy may be limited in wireless networks due to multipath reflections, shadowing, or the directivity of antenna aperture. [4]

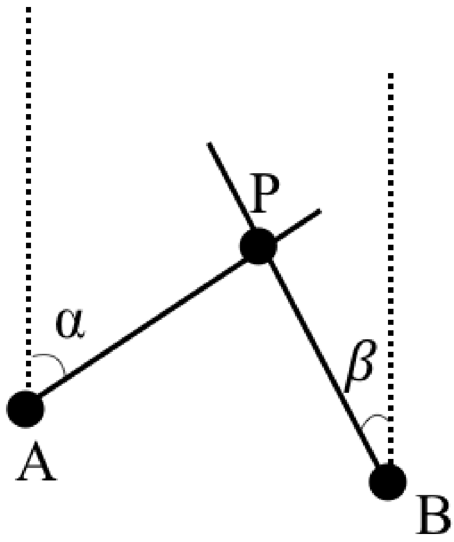

Figure 2. Angle of Arrival

3 Technologies in Indoor Positioning

In this chapter several different indoor positioning technologies are introduced. These technologies are Bluetooth Low Energy Beacons and Tags, WLAN, Geomagnetic Field, RFID, NFC, Ultrasound, vision-based positioning as well as the emerging 5G technology. Several indoor positioning technologies exist, but none of them is yet dominating the market. Some of these indoor positioning technologies are being utilized concurrently in order to provide reliable positioning [7].

3.1 Bluetooth Low Energy

Bluetooth 4.0. standard, with another name Bluetooth Low Energy (BLE) made it possible to exploit Bluetooth in indoor positioning. In the older version, Bluetooth Classic, the discovery process was too slow that it would have been efficient to position with Bluetooth. BLE has a faster discovery process as well as lower energy consumption than the Bluetooth Classic. [7]

Bluetooth Low Energy is being employed by BLE Beacons and Quuppa's proprietary positioning technology based on Locators and Tags [8]. This chapter presents both of these technologies.

3.1.1 Beacons

BLE Beacons are small and affordable transmitters that have a long battery life. Because of these features they are a practical solution for indoor positioning, as they can be placed in spots where other localization technologies, such as WLAN access points, would be difficult to power or install [7]. For instance, Estimote beacons have a battery life between 2 to 5 years depending on the beacon model, which makes it possible to install beacons in challenging locations without the need of accessing the beacons regularly for battery change [9]. There are several Beacon vendors such as Blue Cats, Estimote, Blue Sense, Kontakt.io, and many others [10]. Estimote's Proximity Beacon is presented in Figure 3.

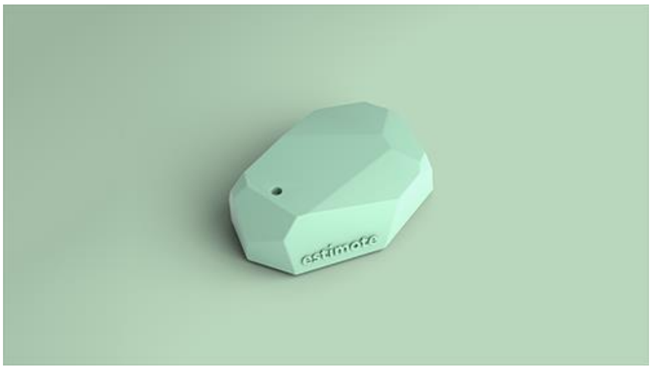

Figure 3. Estimote's Proximity Beacon. [11]

Beacons are built from three main pieces: antenna, battery, and a Bluetooth chipset. BLE Beacons exploit the Bluetooth 4.0. standard where the 2.4 GHz spectrum is divided into thirty-nine 2 MHz channels. Thirty-six of the channels are reserved for data and these channels are utilized by the device-beacon pairs that are connected with each other. Three of the channels are reserved for advertisement messages that a beacon sends to announce its presence to nearby devices. BLE beacons broadcast these advertisement messages that can be received with a device that supports Bluetooth 4.0. or higher. The Bluetooth signal is fairly short range which means that in order to build an area with adequate coverage, multiple Beacons are needed. Kriz et al. [7] measure beacon positioning error to be between 1 to 4 meters. Beacon positioning is usually obtained with trilateration or with cell-based method, where the location of the target is determined based on the beacon coverage areas. If the target is located on a coverage area of three beacons, it can be deduced that the target is located on their region intersection. [7], [12], [13].

The advertisement messages of BLE beacons are not secure as they are open and can be read with any device. This can be a security threat as it is possible to hijack and replay the advertisement and mimic a beacon with some other device, such as a mobile phone. Consequently, the beacon vendors Kontakt.io [14], Estimote [15], and BlueCats [16] have solved this security threat by utilizing ID shuffling, secure Universally Unique Identifier (UUID) or secure mode to prevent malicious parties to cause harm to or with the beacon infrastructure. [12]

3.1.2 Tags

Quuppa is an indoor positioning technology vendor and manufacturer, and they have a different approach to Bluetooth Low Energy in indoor positioning. They utilize advanced antennas, called Locators, and Tags (Figure 4) that can be carried by a person or attached to an asset that is being tracked. The Locators are installed to a ceiling and they detect the Bluetooth signal transmitted by a Tag. The direction of the transmitted signal is determined with Angle of Arrival (AOA) and the result is sent to Quuppa Positioning Engine that computes the position of the Tag. In addition to the hardware Tags, also

Figure 4. Quuppa's QT1-1 Tag [17]

mobile devices or any BLE-enabled devices can be positioned with Quuppa's positioning technology [18]. Once the Locators are installed, the Quuppa positioning system does not require maintenance as the system is monitoring itself. For instance, the Locators have inbuilt accelerometers to indicate if a Locator is touched or moved. The positioning accuracy of Quuppa positioning system is from 0.5 meter even down to centimeter accuracy. [8] [19]

3.2 WLAN

The commonly utilized WLAN indoor positioning technique is based on Received Signal Strength Indication (RSSI) and the method of fingerprinting, which is constructed based on the received signal strength. Another method for WLAN positioning is trilateration where the position of the mobile device is computed based on the coordinates of the WLAN access points. WLAN is a convenient choice for an indoor positioning system as existing WLAN infrastructure can be utilized while implementing a WLAN positioning system (WPS). WPSs have been implemented in public spaces, such as train stations, universities and hospitals and it has been a popular choice in indoor positioning. [5] [20]

The advantage of a WPS is that many of the buildings already have WLAN access points that are covering the building area, and thus, additional investments are not required for new WLAN access points. On the other hand, the disadvantage of WLAN is that if there are changes in the environment, also the fingerprint should be changed in the database and the offline-phase calibration needs to be performed again if fingerprinting is utilized. Also some areas in the building might be challenging to include into the coverage area because of signal propagation and the materials used in the building. The variations in the signal strength and coverage area effect on the accuracy of the indoor positioning. According to Koivisto et al. [21] the WLAN positioning accuracy is 3 to 4 meters when fingerprinting is utilized. As the WLAN access points may not be possible to install on every location in the building, the research [7] of Kriz P. et al. suggests to utilize BLE Beacons with WLAN to improve the accuracy of indoor positioning. [2], [20]

3.3 Geomagnetic Field

In indoor environments, the building materials such as steel structures may cause anomalies into the earth's magnetic field inside the building. These anomalies can be exploited to fingerprint the building area and utilized in indoor positioning. A magnetic sensor, such as the compass in a smart phone, can be utilized to track the position based on the created database of the building. [3]

Li et al. [3] represent the Earth's magnetic field as the following: "The Earth's magnetic field is described by seven non-independent parameters: declination (D), inclination (I), horizontal intensity (H), vertical intensity (Z), the north (X) and east (Y) components of the H, and total intensity (F) [.]". This is depicted in Figure 5. The true north is the Earth's rotational axis, while the magnetic north can be found with a compass and indicates the Earth's geomagnetic pole position. The declination (D) is the difference between these two theories of north, while inclination (I) on the other hand, is the angle between the horizontal plane and the total intensity (F) that is computed positive into the Earth. [3]

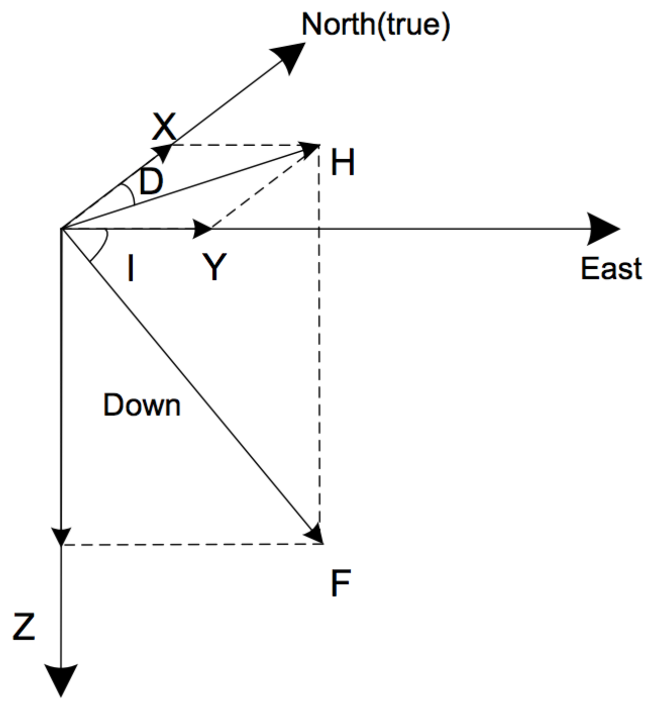

Figure 5. The parameters of Earth's magnetic field [3]

The challenge in utilizing geomagnetic field in IPS is that the data of magnetic field consists of only three components: X, Y and Z directions. In addition, if the true north is unknown or the way of measuring the magnetic field is not the same, only two directions can be utilized, as X and Y cannot be separated. For instance, the user might not hold the phone in the same position as when the measurements were made while the database was created for fingerprinting. When three components are utilized, the error in the positioning accuracy field can be as low as 0.6 meters, but when two components are utilized the positioning accuracy is much worse, even up to 10.3 meters. Moreover, electronic devices or moving objects containing ferromagnetic materials such as elevators or cars may cause disturbances to the magnetic field and affect the accuracy of the positioning. [3], [22]

The advantage of geomagnetic field is that it is not necessary to install additional infrastructure in the building, and Earth's magnetic field is available every-where and relatively stable. Geomagnetic field is a cost effective indoor positioning solution since no tags are needed nor it requires maintenance, such as battery change. [3]

3.4 Radio Frequency Identification and Near Field Communication

Radio Frequency Identification (RFID) is an identification technology which utilizes Radio Frequency (RF) signals. The identification is based on exploiting passive or active RFID tags. The active tags require a battery while the passive tags are activated by RF signal from the RFID reader. The electromagnetic field generated by the reader powers up the tag and the data in the tag is read and sent to the RFID reader. The reader position can be estimated with trilateration. [23]

RFID operating frequency is the electromagnetic frequency that the tag utilizes to communicate with the RFID reader i.e. mobile phone. The RFID operating frequencies are from 125 kHz to 2450 MHz and they have different properties. The low frequency (LF) is considered to be 125–433 kHz, 13.56–433 MHz is high frequency (HF) and 300 MHz to 1 GHz ultra-high frequency (UHF). Frequencies above this are called microwave frequencies. The LF signals have read range up to 10 cm, while HF has read range of 1-100 m. The UHF and microwave have a read range of 1 to 2 meters. [23]

A study of Saab *et al.* [24] lists relevant studies of using RFID in indoor positioning systems. Both active and passive tags have been utilized in indoor positioning and multiple tags are needed for accurate positioning. For example, to achieve an accuracy of 3.25 meters in a 250 m^2 area, 21 active tags were placed. To obtain more precise accuracy of less than one meter or even down to 0.01 m, numerous tags are required.

The advantage of RFID is that the tags are affordable and passive tags do not require maintenance as they do not have batteries. In addition, RFID tags can be easily placed in many indoor surfaces such as floors, walls, or ceilings in order to provide sufficient indoor positioning accuracy. The disadvantage is that several tags are needed within short distances from each other for accurate positioning. RFID indoor positioning systems can be utilized in complex indoor environments, such as offices and hospitals, and it can uniquely identify users and equipment. In Figure 6, two different kind of passive tags are presented. [20]

Figure 6. Passive RFID tags [25]

Near Field Communication (NFC) is based on RFID technology. It is a bidirectional wireless communication technology that utilizes the same 13.56 MHz HF band as RFID and is compatible with the RFID tags [26]. Its read range is couple of centimeters and thus its commercial use cases are currently in mobile payments and other secure communications between mobile devices. Other use cases in NFC positioning are commonly in the industry use to locate, maintain, and monitor fixed assets [23].

A study of Ozdenizci et al. [27] suggests utilizing NFC Internal as an indoor navigation system. The system requires NFC tags installed around the building, an indoor navigation application to read maps and a NFC enabled mobile device. In order to navigate inside the building, the user needs to tap a NFC tag to read an URL that contains a map of the building and download it from a server. The application on the mobile device starts automatically and utilizes the downloaded map information for navigation. The user is able to choose a destination in the building and the application guides the user to the destination. To fix the position during navigation, the user can tap other NFC tags in the building.

The positive aspect of this system is that it is fairly easy to implement and the passive NFC tags are affordable. However, in order to position the user with the mobile device, the user has to find a NFC tag to get the accurate current position. As a result, a real time location of the user cannot be provided with the positioning system that Ozdenizci et al. suggests.

3.5 Ultrasound

Ultrasound is employed in indoor positioning and its source of inspiration has been bats that utilize ultrasound to navigate. The technology is based on ultrasound pulse that is emitted by a tag or a device carried by the target of positioning. The sound is picked up by receivers mounted on the positioning area. Ultrasound positioning systems can also function in the opposite order: the emitters are installed in the building and the positioning target carries the receiver depending on the manufacturer. To compute the location of the target, trilateration is often utilized in ultrasound positioning systems. Usually the ultrasound hardware exploits 40 kHz frequency, which is a much higher frequency than what smart phone speakers can produce. Ultrasound positioning is considered to be a suitable solution for a room level positioning as ultrasound signals cannot penetrate through walls, unlike for example, radio frequency signals. [6], [20]

As the positioning accuracy of ultrasound positioning is less than one meter, it can be considered very accurate positioning technology. For instance, Telocate offers an IPS based on ultrasound with positioning accuracy of 20 cm [28]. According to the survey of Gu et al. [20] the positioning accuracy of the two commercially unavailable systems, Cricket and Active Bat, can even reach accuracy of 10 cm and 3 cm respectively. The price of ultrasound based IPSs vary between the systems as for instance, Cricket is inexpensive while and Active Bat is considered expensive.

The disadvantage of ultrasound positioning systems is that the positioning accuracy may suffer from reflected ultrasound signals as well as from other noise in the positioning area. Also the obstacles between the ultrasound pulse sender and receiver may deteriorate the positioning accuracy. [20]

3.6 Vision-based Positioning

Vision-based positioning is based on camera technology, where a person is recognized form a video. An example of vision-based positioning is Toshiba’s artificial intelligence (AI) technology that is able to identify and track a person from multiple surveillance camera feeds. It is possible to derive features between different people by increasing luminance and multi-channeling as well as recognize individuals in different camera feeds. The technology analyzes the camera footage and detects characteristics and behaviors of people, such as age and gender. The use cases for Toshiba’s AI technology are crime prevention and finding lost individuals, for example children, from large facilities. [29]

Vision-based positioning systems can be very accurate, as some of the existing technologies may reach even µm accuracy and thus, their use cases are in surveying and industrial metrology. The indoor positioning systems utilized for navigation have 2 to 30 cm error in the positioning. The positioning method is based on Angle of Arrival as camera-based systems measure image coordinates that depict angular information. The observations are 2D images that represent the positions in 3D world. [30]

The advantages of vision-based positioning are that one camera is able to cover a wide area, and the users do not need to carry a separate device for positioning. The drawbacks in vison-based positioning are that it does not provide privacy for the people being detected, and the detection accuracy is affected by the changing environment conditions such as the brightness in the room. The position information is based on the saved vision information in a database, and any changes in the environment affect in positioning. This requires that changes are made in the database every time the environment is changed. [20]

3.7 5G Positioning

5G is an emerging network technology that is expected to be utilized in positioning as the 5G positioning accuracy should be one meter or less in outdoor areas. One of the benefits of 5G is that the positioning of mobile device is energy efficient and it will consume less of the mobile device battery, as 5G networks will utilize frequently transmitted uplink pilot signals at the access nodes for channel estimation. Furthermore, these signals can be employed in positioning in a network-centric way where the position is estimated in the access nodes or in a central processor, and thus, the position calculation does not need to happen in the mobile device. This network-centric positioning technique is able to provide a pervasive and high-accuracy positioning that can run in the background constantly. The continuous positioning of the mobile devices makes it possible to track the current and past locations of the positioning target. When the mobile device location and movement information is processed with predictive algorithm, the network could predict the movements of the user based on the mobile device's position information. [21]

The mobile device's position can be obtained under the network coverage area, even in the indoor environments. 5G networks are expected to be ultra-dense networks where the inter-site distance is expected to be from a few meters to some tens of meters. In indoor positioning several access nodes are installed in one room for accurate positioning. It is also expected that the 5G access nodes will have smart antenna solutions such as support for multiple-output techniques, which is suitable for accurate Angle of Arrival (AOA) estimation and which enables accurate positioning. In addition, the expected network densification would cause the mobile devices to be with Line of Sight with multiple access nodes which is suitable for positioning purposes. [21]

According to 5G-PPP [31] 5G is expected to launch around year 2020 for commercial use, but Telia [32] has announced that it will launch its 5G network in 2018 in Helsinki with the partnership of Nokia. As the 5G is still an emerging technology the 5G indoor positioning hasn't been yet adopted into commercial use.

3.8 Comparison of Indoor Positioning Technologies

In this chapter a comparison of the different indoor positioning technologies is presented. Table 1 summarizes the technologies introduced in chapters 3.1 to 3.7. The accuracies of positioning technologies are based on the literature review and they may vary between technology providers as well as on the installation frequency of the system infrastructure. Different technologies are suitable for different use cases as their accuracy and installation style varies.

The main difference in the installation is whether additional infrastructure is required or not. For instance, WLAN and Geomagnetic Field are beneficial when there is no willingness to invest in separate IPS devices and the accuracy of the IPS is not required to be very high. In addition, if the accuracy of e.g. a WPS is not high enough in certain areas, the WPS can be accompanied with beacons to improve the positioning accuracy.

When a high positioning accuracy is required, BLE tags, RFID, Ultrasound, and Vision-Based positioning perform well in this aspect. On the other hand, all of these technologies require installations in the building and while using BLE tags or ultrasound the user may need to carry a tag or an emitter. 5G positioning should be accurate in the outdoor areas, but as it is an emerging technology, the indoor positioning accuracy is difficult to determine in practice.

Table 1. Comparison of Indoor Positioning technologies

Technology	Installation	Advantages	Disadvantages	Positioning Method	Accuracy (m)
BLE Beacons	Easy installation in different surfaces in buildings, multiple beacons are required	Quite affordable, easy placement, long battery life	Maintenance needed: battery change, Multiple bacons are required	Trilateration, Cell-based method	1–4
BLE Tags & Locators	Locators installed in the building, user carries a tag	Very accurate	Requires installations in the building	Angle of Arrival	0.1–0.5
WLAN	No need for additional infrastructure	Affordable, no need to invest in positioning devices	Environmental changes affect the positioning accuracy, WLAN APs might not cover the whole building	Fingerprinting, Trilateration	3–4
Geomagnetic field	No need for additional infrastructure	No need to invest in or install positioning devices, available in every building	Electronic devices may cause disturbance to the geomagnetic field, challenging to make positioning accurate	Fingerprinting	0.6–10.3
RFID	Easy installation in different surfaces in buildings, multiple RFID tags are required	affordable, easy placement	Multiple tags are needed for accurate positioning	Trilateration	0.01–3.25
NFC	Easy installation in different surfaces in buildings, multiple NFC tags are required	affordable, easy placement, no need for maintenance	Multiple tags are needed for accurate positioning, not real time positioning	-	Not in real time
Ultrasound	Ultrasound receivers/emitters installed in the building	Accurate positioning	Accuracy might suffer from echo, other noises, obstacles	Trilateration	0.03–0.2
Vision Based positioning	Cameras installed in the building	User does not need any positioning device, one camera covers wide area	No privacy for the people being detected, changing light conditions may affect accuracy	Angle of Arrival	1–4
5G	Many access points required in indoor environments to form ultra-dense network	Will be available in many spaces	Not yet in commercial use	Angle of Arrival	Not available yet

4 Privacy in Indoor Positioning

According to a study of users' privacy concerns conducted by Barkuus et al. [33] the users' concern of location privacy can be dependent on the type of application that is tracking their position. The applications that actually track the users position cause more concern among users than applications that simply utilizes the position. In addition, if the user finds the application useful the privacy is less concerning than when utilizing a less useful application. According to the study, the users were not overly concerned when using positioning services in general.

Even though the users were not too concerned on their location privacy there are still some negative effects if the user positioning privacy fails. Duckham et al. [34] identify three negative effects:

1. Location-based "spam": The user may receive unwanted marketing spam based on the user's position information.
2. Personal safety and wellbeing: If the user's position is shared to unwanted parties this may lead to undesirable or harmful confrontations. The users should not be able to be tracked by stalkers or malicious parties.
3. Intrusive inferences: The location of a person can be exploited to infer an individual's personal preferences such as religion or political views.

In addition, the positioning accuracy and the coverage area of the positioning system have a significance on the privacy of an individual. A very precise positioning creates more information of the location than a more ambiguous positioning and a global positioning more than a local positioning. Moreover, the geographical location effects on privacy as positioning in an urban area is found to be more intrusive than positioning in nonurban areas. [34]

Privacy is also crucial when designing positioning systems for retail. If consumer data is not handled properly, it may cause tracking of the consumer location and identity. This might lead to uninvited marketing, price discrimination, or unauthorized utilization of data. It has been shown that consumers were more concerned from their privacy when they received a personalized shopping list based on their purchase history. Even though personalization is found to be beneficial and adds value for the consumers, they may still remain concerned about their privacy. However, when the positioning data is utilized in personalizing location aware marketing, the personalization overrides the consumer's privacy concerns even when the users receive push-notifications, that are likely to trigger spontaneous purchasing. On the other hand, the users tend to feel less insecure about their privacy when they can initiate the contact with the merchant by themselves instead of receiving marketing based on their location. This applies especially to users who have been victims of personal data thefts as this way the users have more control over their personal data. The location aware marketing should be adapted to the consumers' preferences and their willingness to share personal information. [35]

Regulations are, of course, an important part of user privacy. The newest privacy regulation is General Data Protection Regulation (GDPR), and it has come into effect on 25th of May 2018. GDPR changes how the personal data of individuals in European Union is being handled, and it has a broad influence on the individual's privacy. According to GDPR the data of an individual cannot be processed unless the individual has given a consent of processing the data. GDPR defines personal data as "any information relating to an identified or identifiable natural person" which also includes location data of an individual. In addition, according to the Article 25 "Data protection by design and default", only the data needed for the specific purpose should be held and processed of an individual. [36]

In order to provide an indoor positioning service, the user needs to give a permission to process the personal data, and the system should not hold any unnecessary information of the user. In the case of indoor positioning system, the system should only track the user only in a specific area or a building to respect the user's privacy and location aware marketing should be adapted to the user's personal preferences.

5 Case Study

The different use cases for indoor positioning systems presented in the following chapter were acquired by interviewing companies, that are currently utilizing indoor positioning or develop indoor positioning solutions. The interview questions can be found from Appendix 1, but as the interviews were semi-structured, the questions were not strictly followed or presented in a prearranged order. The interviews are considered to be the qualitative study method of the thesis. Goal of the interviews is to gain understanding of possible indoor positioning use cases and their technological implementation. In total six companies were interviewed in face-to-face meetings with duration of 60 minutes. Table 2 lists the date of the interview, interviewed companies and their fields.

Table 2. List of the interviewees

Interview Date	Company	Field	Chapter
14.6.2018	Telocate	Indoor Navigation and Sensing	5.1
25.6.2018	Tieto	Softwares and Services	5.2
26.6.2018	Finavia	Airport Operator	5.3
28.6.2018	Espoo City Library	Public Library	5.4
19.7.2018	Proximi.io	Mobile Positioning	5.5
31.8.2018	Empower IN Oy	Energy, Industry, and Telecom services	5.6

5.1 Case – Asset Tracking and Restaurants

Telocate is an indoor positioning company, which was founded in Freiburg, Germany in 2014. Their ultrasound positioning systems are being utilized for instance in asset tracking in warehouses and in a restaurant to improve customer service.

Telocate's ultrasound positioning system consists of an ultrasound emitter carried by the target and several receivers installed in the building. The emitter can be either a smart phone or Telocate's own ultrasound emitter. Instead of the usual 40 kHz utilized in ultrasound positioning, Telocate exploits a frequency of 20 kHz in their systems, since this is the frequency that smart phones are able to emit. The sound of the emitters is received by microphones in receivers, which can be attached to a ceiling. The position of the emitter is then computed with the TDOA method. Telocate's receivers do not require battery maintenance as the receivers can be connected to USB power, a

WLAN, or a network. The positioning accuracy of the indoor positioning system can be as precise as 10 cm, but in practice, the accuracy is 20 to 30 cm, which is especially beneficial for use cases that require high positioning accuracy. The operating range of a receiver is up to 20 meters, and one receiver is needed every 50−100 m^2. If there is at least the minimum number of recommended receivers installed in the building, Telocate's systems can filter out the echo. In this case, it is possible to analyze which receivers pick up irrelevant signals and eliminate echo signals with residuum check. Telocate's ultrasound receiver and emitter are demonstrated in Figures 7 and 8, respectively.

Figure 7. Telocate's ultrasound receiver

Figure 8. Telocate's ultrasound emitter compared to a 10 cent coin.

One aspect that Telocate aims to improve in the future is the number of targets positioned simultaneously on real time since currently, it is possible for 32 ultrasound emitters. On the other hand, when the update rate of an emitter tag is smaller, and the positioning is not required to happen in real time, more tags can be positioned. Telocate exploits round-based positioning where each tag is located every 300 ms to increase the positioned tags up to 100 or even more. With this method 100 tags can be positioned in 30 seconds.

In the following chapters, two different use cases are presented with Telocate's technology: asset tracking in warehouses and customer positioning in a restaurant.

5.1.1 Asset Tracking in Logistics

Telocate systems are most commonly utilized for asset tracking in warehouses, where the data acquired from the positioning is exploited in the analytics. Telocate's precise positioning makes it possible to save time by showing exactly from where and on which side of the shelf an asset needs to be picked. The person who picks the asset from the shelf can carry the ultrasound emitter attached to either headphones, a wrist band, or the picking wagon. The picking route is recorded by receivers in the building, and Telocate delivers the data analytics for the customer company. The customer can then analyze the data and rearrange the pick, and thus, the overall process can be optimized. For instance, in a test project of Telocate, the places of the containers in a warehouse were swapped, and this small swap increased the picking efficiency by 4%. The data from the indoor positioning can be a direct monetary benefit for the companies with large warehouses, such as car manufacturers.

5.1.2 Restaurants

Telocate's ultrasound system has been utilized in Kaimug, a Thai fast food restaurant, which is located in Basel, Switzerland. The concept of Kaimug is to provide a positive customer experience, quick processing of the orders, and affordable prices. When customers enter the restaurant, they can order the food on a computer and after placing an order, the computer ejects a puck. Afterwards, customers can sit down at a table and relax while the order is being processed. Once the food is ready the waiter can locate the right table by the ultrasound that the puck emits and bring the meal there. Thus customers are not disturbed by the sound of a buzzer, and they do not have to stand up to get the dish from a counter.

This restaurant project had been implemented in cooperation with Pyramid, which is an industrial computer manufacturer. Pyramid had provided the computers, which were utilized by the customers to order the food, while Telocate was responsible for the positioning of the customers. The reason why Pyramid wanted to offer the indoor positioning possibility for restaurants was to distinguish it from Asian competitors. Pyramid did not utilize the positioning for statistics, such as table utilization, cleaning, or other information, but this could have been completed as well. In this project the round-based positioning was exploited, and hence, it was possible to position more than 100 customers in the restaurant. The ultrasound puck was employed to track the customer only inside the restaurant and it did not contain any information about the customer.

Similar to the warehouse use case, the positioning had to be accurate enough to prevent the tables from getting mixed with each other. For this reason, ultrasound-based positioning had been the choice in this use case.

5.2 Case – Services for Offices

Tieto is an IT-company based in Finland with 14 000 employees in 20 countries [37]. One of their products is Empathic Building, an indoor positioning system designed to improve employee and customer experience. Empathic Building is utilized in offices to show the current location of colleagues on the map as well as free meeting rooms and desks.

Empathic Building can be employed with three different methods: the first is People Light, where the user shares the location manually by dropping the avatar on the map in the Empathic Building mobile or desktop application. The second method is People Mobile, where the user downloads an application to a smart phone, which generates a positioning ID, and the phone computes the position with the help of beacons installed in the building. The third method is People Pro, which utilizes Quuppa's Bluetooth Low Energy based indoor positioning technology. In this version, accurate positioning requires network connected locators, that are installed to the ceiling, and a server that computes the position of the user. To secure full coverage, one locator is needed every 30 m^2 in the office environment. The user will need to carry a small tag, which is detected by the locators. The benefit of the tag is that the smart phone battery is saved when the position computation happens on the server rather than on the user's phone. The tag battery life is 1.5 to 2 years and the positioning is with up to 10 cm accuracy and is very precise compared to the beacon-based positioning with 2-5 meters. Of course, the accuracy depends on how frequently the locators or beacons are installed. The more precise People Pro system is twice as expensive as the People Mobile.

Tieto utilizes Empathic Building People Pro in their new office, which is a 21,000 m^2 campus area. When moving to the new office, the real concern for the employees was how they will find their colleagues from the office, while using an activity-based office where the employees would not have have their dedicated desks or working areas. The solution for this concern was an IPS. The response to this change was positive, as Tieto measured a clear difference in the employee satisfaction compared to their old office, where an IPS was not utilized. With the help of Empathic building, the employees can find their colleagues from the map as well as find a desk that fits to their current working mood, and see which desks are free and which are currently in use or have been recently used. In addition, Tieto wanted more employees to work at the office, as previously only 55% of the employees were simultaneously present at the office. The plan to improve this with an IPS was successful as nowadays the presence of the employees has risen to 70 percent. Furthermore, the IPS reduces administrative work of the employees and leaves more time for the actual work. Firstly, the employees can share their current mood along with their thoughts and links to work materials on the Empathic Building avatar. This reduces the amount of emails being sent and handled. Secondly, the indoor positioning reduces the need to book meeting rooms as the employees can see with one glance the real time situation of the rooms.

Empathic Building can be integrated to other systems through its open API interface. For example, some of the customers of Tieto have utilized the data to optimize indoor temperature and measure the carbon dioxide level within an area. In addition, the IPS can be also utilized to optimize cleaning: the work shifts and rotas are determined based on the data, which areas of the building are utilized and how many people have been on each floor. The cleaning capacity is then calculated based on the utilization of the building. Consequently, cleaning costs are reduced as well as unnecessary cleaning of rooms that have not even been used.

In order to make the IPS more exciting for the employees, Tieto wants to gamify the employee experience in their office. Gamifying offers users a possibility to earn coins by being active in the office by sharing, helping and meeting people or using different spaces and work desks. The coins can be then exchanged for lunches or cups of coffee.

5.3 Case – Analytics and Navigation at an Airport

Finavia is a Finnish airport operator which operates the Helsinki-Vantaa Airport in Finland. The Helsinki-Vantaa Airport utilizes indoor positioning to analyze passenger flows throughout the airport and to offer the travelers a possibility to navigate at the airport.

For analyzing the passenger flows at the airport, Finavia exploits dedicated WLAN sensors and WLAN Access Points to position the devices at the airport. The WPS positioning accuracy is typically in the order of 10 meters and it utilizes trilateration to compute the position. There are two ways, in which Finavia can track the movements of passenger flows with WPS. Firstly, passengers may join the free airport

WLAN and in this case the positioning happens by identifying the mobile devices' MAC addresses. Secondly, if a passenger does not join the free WLAN, the device may be anonymously tracked at the airport by utilizing a hashed MAC address, by which the passenger cannot be identified, and the original MAC address cannot be reproduced. The anonymous tracking is based on the concept that the device sends a probe request along with the unique MAC address, or in some cases, a generated address in the MAC format, when the passenger's mobile device searches for WLAN. The MAC address is then modified to be an ID number that cannot be traced back to the original MAC address. Once this is done, this ID is tracked along the airport and utilized for analytics. It must be noted that not even the generated IDs can be traced with 100% certainty around the airport, because the ID space is smaller than the original MAC address space – i.e. two original MAC addresses can be represented by the same ID. This is good for user privacy, and still does not harm the positioning capability in a critical way on a passenger flow level.

For analyzing the passenger flows the positioning accuracy is adequate as Finavia is interested in high-level flows, such as the areas through which the passengers enter the airport or which security check they pass on their way to the airside, not where the passenger exactly is. The WLAN positioning reaches 40 to 50 percent of the passengers, depending of the passenger profile, for instance, if the passenger is a local person travelling or a transfer passenger. Some of the mobile devices have nowadays a feature which randomizes the MAC address of the device in order to prevent the tracking of the user. This is a challenge for the reliability of the analytics as some of the mobile devices cannot be tracked. In addition, Finavia had assumed while implementing the WPS, that a mobile device sends a probe request every 30 seconds, but in reality, some of the devices send the probe request only a few times during the time spent at the airport. This means that the passenger's position is found only a few times and the travelled route might be challenging to analyze.

The passenger navigation at the Helsinki-Vantaa airport is based on beacon technology and the beacon positioning accuracy is in the order of 5 meters. The beacons are currently connected to WLAN positioning sensors with USB and hence the beacons do not need any battery maintenance. In total between 300 and 400 beacons are installed at the airport. Trilateration is also exploited in the beacon-based positioning, which reduces the number of beacons needed. The beacon infrastructure supports ID shuffling, which reduces security threats against the beacon network as well as unintended use of the network.

The passengers may utilize the navigation through an application on a mobile device, that can be installed from an app store and is called “Helsinki Airport”. The application shows the passenger position on a map as a red dot as seen in Figure 9, which is a screenshot of the application. In addition, the user is able to search for gates or stores at the airport. Finavia has tested a position-based advertising in their application, where the passenger receives a discount while entering the terminal. Finavia has not utilized these advertisements greatly as they do not have any personal information of the user and they do not want to spam them with information that is irrelevant for the passenger.

Figure 9. Navigation on Helsinki-Vantaa airport

The benefit for passengers of Finavia’s IPS is first of all the possibility to pinpoint their location on the map in the application. Secondly, the analytics of passenger flows benefit in ways that are not directly visible for the passenger: the queues are reduced, services are improved, and emerging situations can be predicted. Some few individual passengers first reacted negatively on the indoor positioning because of negative or even misleading publicity in the news. Especially the fact that the MAC addresses of mobile phones are followed made some customers concerned of their privacy and it took a while for Finavia to prove the security and privacy of their indoor positioning analytics, despite the fact that it was built in and the starting point from the beginning. Lately they have not received a lot of feedback of their services and the current positioning capability is not utilized very widely among passengers as locals tend to be familiar with the airport and foreign travelers do not tend to install the application.

In the future, Finavia wants to improve their IPS and offer a possibility to calculate the fastest route from the passenger's current position to the desired destination within the airport. This functionality would take the queue situation and different kinds of processing times into consideration while calculating the route for the passenger, which would be much more beneficial for the passenger than just showing the current position. In addition of improving the customer experience, Finavia would like to offer IPS also for the employees as it would be useful for security and airport logistics. Finavia is currently in the process of improving their indoor positioning but they have not decided a final solution for their new IPS.

5.4 Case – Navigation in a Library

Espoo City Library operates the library services in Espoo, Finland. In Sello Library, Espoo City Library is utilizing IPS to help their customers navigating in different compartments within the library and to find books easier. Espoo City Library decided to start the indoor positioning project as a result of customer feedback, since customers had asked for a helping application to navigate within a library.

Sello Library utilizes an indoor positioning technology of IndoorAtlas which is based on geomagnetic field. The advantage of this system in comparison to beacons or some of the other indoor positioning technologies is that there was neither a need to build an infrastructure nor to maintain it. Espoo City Library had considered to use BLE beacons in Sello Library, but maintaining beacons would have been difficult to arrange. The positioning is accurate enough to bring customers to the correct book shelf, as the system shows the position of a user within 4 to 6 meters and the location of the materials in the library within 1 to 2 meters. When a location of a material changes, library personnel needs to update the material location into the positioning system that is based on a map of the library and shelf locations.

In order to utilize the IPS the customer needs to download an application to a smart phone. The Paikasto application has an integration to the library system and also a search functionality to look for materials in the library. The customer can search for a book in Paikasto application, and the location of the searched book is indicated on the map. As the customer is positioned in real time, the customer can easily direct towards the desired book. Through the Paikasto application the time spent in the library can be significantly reduced, as the customer can find books easier alone and there is no need to wait in a queue for help. In addition, the application can help customers who might be socially restricted to avoid human contact or asking for help. Furthermore, the IPS also helps customers to perceive the layout and the compartment order of the library. This can be a great help for customers as the library of Sello is 5000 m^2 and in two different floors.

According to the Sello Library personnel, utilizing the IPS has been beneficial as Paikasto application has reduced the number of customers asking for the location of a book or a compartment. In addition, customers have given very positive feedback of the indoor positioning application.

The indoor positioning project is currently on hold, but nonetheless Espoo City Library is interested to improve the IPS. As the application is currently only available for android, Espoo City Library would like to provide the application also on other mobile operating systems. Other improvement areas are usability of the application and other language versions in addition to Finnish. Moreover, the positioning accuracy of the user could still be improved.

In the future the Espoo City Library would like to take advantage of the RFID tags of books to help customers finding directly the desired book by utilizing the NFC reader of a smart phone, but they would not necessary exploit it for this indoor positioning application. Offering an accurate positioning is important, as the customer might not understand the arrangement of the books or know how the book exactly looks like. Utilizing the RFID tags would also reduce the workload of the staff as books would not need to be arranged in a very specific order. Espoo City Library would be also interested to gamify their application and create a virtual book shelf for the e-books of a customer.

5.5 Case – Indoor Positioning for Retail

Proximi.io is a Finnish-based company with headquarters in Helsinki. They offer different kind of indoor positioning solutions for their customers by utilizing multiple indoor positioning technologies: WLAN, BLE Beacons, Geomagnetic field and Li-Fi as well as outdoor positioning technologies. In the future Proximi.io hopes to broaden their selection of different indoor positioning technologies and envisions that indoor positioning is going to be available in every building.

5.5.1 Navigation in a Shopping Mall

One of Proximi.io's indoor positioning projects is with Tawar Mall in Qatar. Tawar Mall desired to build their brand and improve their image as a modern shopping mall, willing to serve its customers better. To do so, Tawar Mall decided to implement an IPS with Kontat.io BLE beacons in their premise.

Tawar mall is 300,000 m^2 in size on six floors and in order to cover an area of 77,500 m^2 of open areas, corridors and the challenging parking hall, 343 beacons were installed in the building on carefully chosen locations. This number of beacons guarantees a positioning accuracy of 1 to 5 meters, depending on the area inside the mall. Hence, the indoor positioning covers the shopping mall itself, excluding stores. Tawar Mall has integrated the positioning information to their CRM and marketing platform. Furthermore, they have done an integration between the product catalogue and the indoor positioning application.

Customers of the mall can utilize the IPS by downloading an application and agreeing on sharing the position information. After this, the customer has a number of opportunities to use the app. For instance, when a customer arrives by car to the shopping mall, it's possible to save the parking location of the car and once the shopping is done, the customer may navigate back to the car with the help of the map navigation in the application. Thus, the customer neither is required to remember the location of the car nor search for it in a large parking hall. In addition, through the application a customer is able to search for a store inside the building as well as find the fastest route to it. The same way a customer may search for a needed product and the application can navigate the person to the store with the desired product. Moreover, the application can be helpful for visually impaired people, as it offers audio guidance. Finally, customers may receive discount codes to stores they have visited the most.

In general, the goal of the IPS in Tawar mall is to make their customers' shopping experience more convenient and modern as well as to improve customer satisfaction and loyalty.

5.5.2 Loyalty Application

Another ongoing project of Proximi.io is a loyalty app for a company, that has several smaller stores in different locations. An individual store does not have an indoor navigation system that would identify the actual position of the customer, but they utilize geofencing for recognizing when a customer enters the store. Each store has one beacon to identify the customer's visit and each visit is added as a point to the customer loyalty program. To keep the customer data updated, the data from the customer loyalty application is integrated to the company's CRM. The accuracy of the system is measured by how many times a visit to the store is recorded.

In order to utilize the IPS, the customer needs to download the loyalty application and accept positioning. From then on, whenever the customer visits one of the stores, points are added automatically to the customer loyalty account. This way customers do not need to open the application when entering the store. Customers benefit from this by receiving coupons and offers through the application, based on the number of their visits in stores.

The goal of the company with this geofencing loyalty application was to improve their brand image among customers and modernize the customer loyalty program.

5.6 Case – Improving Work Safety

Empower offers energy, industry, and telecommunication services in the Nordics. To improve work safety, they have developed a safety application called EmSafe that utilizes Quuppa's indoor positioning technology, and that has been developed in their own workshop. Hence Empower functions as Quuppa's retailer and sells their own solution for many kinds of industrial environments. EmSafe functions in a web-based user interface as seen in Figure 10.

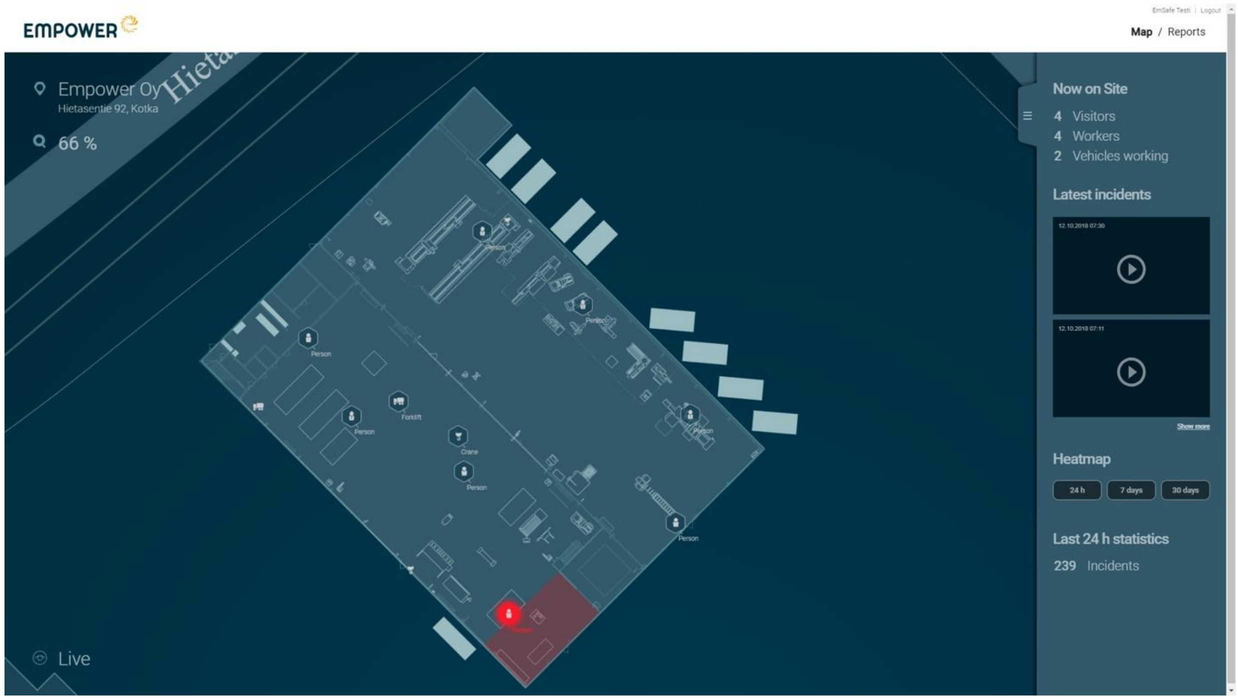

Figure 10. EmSafe's user interface

Figure 11. Machinery and people displayed in the EmSafe UI

The goal of EmSafe is to avoid collisions and danger situations between workers and machinery in workshops. To do so, each worker and heavy machine, such as crane hooks and forklifts, has to carry a Quuppa Tag to track the events in the workshop. In Figure 11, can be seen the people and machinery displayed in the web-based UI. Tracking enables the EmSafe application to record collisions or near miss situations. Afterwards these situations can be reviewed and analyzed to improve work safety in the workshop. In addition, the workers can wear safety bracelets while working. Once heavy machinery and a worker approach each other dangerously, the worker's bracelet starts to vibrate as well as a light installed in a work hall starts to blink as a warning. Furthermore, the heavy machinery such as forklifts have also an industrial tablet showing the layout of the work hall. With this tablet it is possible for the driver to get a good overview and react to it accordingly. Moreover, the positioning tags can be utilized to point out dangerous substances, such as inflammable gas bottles. As a result, companies can prevent greater damage in the building and may pull through with less significant loss from the undesired situation. In addition, it is possible to generate a heat map that indicates which areas are most utilized in the work hall. If some areas appear to be underutilized, some operations can be transferred to these areas and vice versa, if some areas are over utilized it may indicate a higher risk of a collision. EmSafe is also able to indicate at which speed the forklifts are driving in the workshop. This information can be exploited to set speed limits in the hall or to guide the drivers to drive slower to minimize danger situations.

In addition to improving safety, EmSafe can be utilized to improve processes in workshops and warehouses. Firstly, it is possible to analyze travel distances of machinery and optimize them. For instance, if one forklift has been traveling long distances in a hall according to the positioning data, the process could be optimized by using another forklift to perform part of the job. Secondly, the positioning data can indicate easily the utilization of different machines. It is possible to point out if some of the forklifts are not fully utilized and share the work tasks or even end a rent contract for some of the work machines. Thirdly, in a large warehouse the bottle necks can be identified and removed with the help of positioning as the utilization of different areas can be seen. By changing the layout in the warehouse the picking process can be improved. Lastly, the positioning can be employed to find tools form larger workshops and thus the workers do not need to spend worktime to look for them. All of these aspects help to create more effective operations and to cut costs.

Empower is utilizing Quuppa's indoor and outdoor locators for their IPS. The outdoor locators are waterproof and provide more accurate positioning than indoor locators. The coverage area of one locator depends on the height the locator is installed at. For instance, on a construction site the locator can be attached to a 40-meter-high crane and it would cover a 10,000 m^2 area. On the other hand, in Empower's workshop, which is 2000 m^2 and 8-meter-high, two different halls have 8 locators each that provide an adequate positioning accuracy. In general, the locators need to cover the whole workshop area to improve the work safety and consequently any blind spots cannot exist. The positioning accuracy is required to be very high in order to improve work safety and the accuracy is actually 10 to 20 centimeters. The EmSafe application can be integrated to other systems, but Empower has not implemented an integration in their own organization.

In general, EmSafe has improved the work safety in Empower's workshop and is part of their work safety program. With the help of the program Empower has reached only 4 accidents by 1,000,000 working hours in the entire 1700-person Empower group. For Empower, work safety has been their first priority and they have focused to improve it and will continue to do so in the future.

5.7 Comparison of the Case Studies

In this chapter, a summary and comparison of the various kinds of use cases and technologies utilized by the interviewed companies is presented. The previous case chapters 5.1 to 5.6 are summarized in Tables 3 and 4. The cases cannot be straightforwardly compared as each use case is quite different to another, but the most important choices affecting the decision between the technologies can be summarized as three points.

Firstly, the needed accuracy affects the choice of the technology as for some use cases highly accurate positioning is crucial. For instance, in warehouses the workers need to find the right products efficiently and not spend time on searching for them, or the system needs to warn workers at a correct time. In the office case, the positioning is required to be accurate since it should point to which table is free and which one is taken. On the other hand, the positioning accuracy for airport analytics does not need to be very high, as it is only necessary to track the areas that have been visited by the passengers.

Secondly, whether the positioning happens through a mobile device, tag, or an emitter is another aspect in the choice of on IPS. If a customer in a retail store is being tracked, it might be more convenient to track the customer through a voluntary mobile application which could be utilized to navigate in the shopping center or department store as well. However, if only the movements of a customer are the point of interest, the customer could also carry the tag in a shopping basket or a cart.

Thirdly, it should be decided if it is possible to install anchor nodes, such as beacons, in the building, or if the positioning capability should be implemented with an existing infrastructure such as WLAN access points or geomagnetic field. Separately installed positioning devices may require maintenance or be costly.

Other decisions when implementing an IPS are if the user should remain anonymous or if the tracking of the individual is important, and through what kind of user interface the indoor positioning is utilized. If the user is being tracked, the user should accept the positioning and should comply to the utilization of the positioning data, for example, while installing an application to a mobile phone.

Table 3. Comparison of the cases: technologies and use cases

Chapter	Technology	Technology provider	Building	Use Case	User Interface for the end user	Benefits of the IPS
5.1.1	Ultrasound	Telocate	Warehouse	Asset tracking, warehouse layout analysis	No user interface	Very accurate, improved efficiency in warehouses and monetary benefit
5.1.2	Ultrasound	Telocate	Restaurant	Improving restaurant services	No user interface	Fast food restaurant with a better service, differen-tiation
5.2	BLE Tags and Locators	Quuppa	Office	Finding colleagues from the office, finding free seats and parking space, sharing thoughts	Mobile or Desktop Application: layout of the building	Very accurate, increased employee and customer experience, increase in productivity, employees more at the office
5.3	WLAN positioning	-	Airport	Analyze traveler flows in the airport	No user interface	Passenger routes can be identified even when the passengers do not use the application or WLAN
5.3	Beacon positioning	-	Airport	Navigate at an air-port	Mobile Applica-tion: layout of the airport	No need to maintain bat-teries, customers can find places at the airport
5.4	Geomagnetic field	IndoorAtlas	Library	Navigation in a library, finding the shelf where the book is located	Mobile Applica-tion for Android: layout of the li-brary	No need to install devices in the building nor main-tain batteries, customers can find books easier
5.5.1	Beacon positioning	Proximi.io /Kontakt.io beacons	Shopping Mall	Navigate in the shopping mall, find products and stores	Mobile Applica-tion: layout of the mall	Better image among cus-tomers, improved custom-er experience and loyalty, customers able to navigate in the mall, increased sales
5.5.2	Beacon Geofenfing	Proximi.io /Kontakt.io beacons	Stores	Recognize visiting customer	Mobile Applica-tion: customer loyalty	Better image among cus-tomers, improved custom-er loyalty, increased sales
5.6	BLE Tags and Locators	Quuppa	Warehouse	Safety, collision avoidance	Web based: layout of the warehouse	Improved work safety, warehouse layout optimi-zation, optimizing utiliza-tion rates

Table 4. Comparison of the cases: implementation

Chapter	Challenges	Implementation	Installation frequency	Positioning accuracy (m)	Integration to other systems
5.1.1	Limited positioning target capacity (32 emitters in real time)	Receivers installed on the ceiling, the positioning target carries ultrasound emitter	1 receiver every 50–100 m^2	0.2–0.3	No
5.1.2	Limited positioning target capacity (32 emitters in real time)	Receivers installed in the restaurant, ultrasound emitting puck positions the table	1 receiver every 50–100 m^2	0.2–0.3	No
5.2	Costly implementation	Locators installed on the ceiling, user carries a tag	1 locator on every 30 m^2	0.1	No
5.3	Not very accurate positioning, only 40%-50% of the passengers are found	WLAN access points that identify passenger with anonymous ID based on mobile devices MAC address	WLAN Access Points at the airport	10	No
5.3	Not very accurate positioning	Beacons connected to WLAN Access Points	300-400 beacons at the airport passenger areas	5	No
5.4	Not very accurate in positioning of the user, not possible to navigate straight to the book	Utilizing earth's magnetic field and showing location on an application in a smart phone	No need to install anything in the building	4–6 and 1–2	Integration from application to library system & search functionality
5.5.1	Provide sufficient positioning accuracy also in the parking hall	Beacons installed in the shopping mall	343 beacons in 77,500 m^2	1–5	Integration to CRM, product integration to IPS application
5.5.2	Recognize every time the customer visits	Beacons in stores	1 beacon per store	-	Integration to CRM
5.6	Cover all places in the workshop	Locators installed on the ceiling, workers and heavy machinery have tags	Depending on the height, e.g. 16 locators in 2000 m^2 and 8-meter-high hall	0.1–0.2	No

6 Design for Retail Use Case

For this chapter, two different companies operating in retail were interviewed to understand their interest in indoor positioning. The 30-minute interviews were held in person in a form of semi-structured interviews, as the goal was to understand their interests and current situation regarding indoor positioning. The interview questions listed in Appendix 2 were utilized as a guideline for the interviews. In addition, a suggested implementation model is presented for retail, based on the interest of the two interviewed companies and the interviews of companies in chapter 5, that are already exploiting indoor positioning.

6.1 The Need for IPS in Retail

Table 5. Interviewed companies with an interest in indoor positioning

Interview Date	Interviewee title	Industry	Referenced as
19.9.2018	Marketing Manager	Real Estate for Retail	X
21.9.2018	Head of Customer & Loyalty	Retail	Y

The interviewed companies are listed in Table 5, and the first interviewed company will be referred to as company X and the second interviewed company as Y. Both of the interviewed companies are interested in indoor positioning for their retail real estates. They would, first of all, like to help customers to locate what they are looking for more effortlessly. Second of all, both of them desire to modernize their image among customers. They would like to offer, for instance, a mobile application that the customers could utilize to navigate in their buildings.

Company X is looking currently for an indoor positioning solution and identifies either WLAN or Geomagnetic Field accompanied with beacons as possible choices of technologies for their IPS. Relying only on beacons could prove to be a costly system, as they should purchase hundreds of beacons for several different real estates. In addition to the choice of technology, Company X will also need to decide whether to offer the indoor positioning possibility in their loyalty application or if it will be freely available to everyone who downloads the indoor positioning application. In the indoor positioning application, Company X is fond of the possibility to send location-based notifications. They are interested in integrating the indoor positioning data with their CRM and marketing platforms, but they are still quite far away from the actual implementation, as they have not implemented the planned IPS yet. Company X could also consider to utilize the indoor positioning data to understand the busiest areas in the building, but they would want to clarify first what is the actual benefit for end customers and store tenants before starting to collect and exploit the positioning data. Because of this, they are not willing to save data and utilize it for analytics at the moment. In the future, the company X could benefit from the data to offer the store tenants a possibility for targeting advertisements for consumer customers, but they want to proceed judiciously because of GDPR regulation and its requirements.

Company Y is interested in indoor positioning, but first they must build a sufficient base for their systems and improve their other databases. Consequently, company Y has not made any specifications for the IPS and neither have they determined the indoor positioning technology. As the company Y is still developing their databases, they have not decided whether to include integrations to an IPS, but they could be interested in guiding the customer to a specific product and thus might consider integrating the IPS with their product database. The company Y considers utilizing the indoor positioning data to create for example, heat maps in order to understand how customers move inside the store and to improve the store layout. For instance, the data could be exploited to recognize areas that the customers visit the least to make the areas more attractive or to ease the busiest parts of the store. Furthermore, there are many other beneficial means by which to utilize this data. It can be utilized to ensure the sales attendants are where customers are and the cashiers are located well, close to the areas the customers use the most. Company Y considers exploiting the indoor positioning data to recognize customers' interests and utilize it for marketing, but they want to be careful with it and allow customers to define their interests themselves as well. Indoor positioning data cannot disclose precisely how the customer is in certain cases as the interests of the customer might shift due to changes in life.

For both of the companies the motivation behind implementing an indoor positioning system is to serve their customers better and to improve their services.

6.2 Loyalty Application Design for Retail

This chapter presents a suggested Value Network Configuration (VNC) for a retail company with a large store. The indoor positioning system is part of a loyalty program, which the customers may join by downloading the loyalty application for their mobile phones.

6.2.1 Value Network Configuration for Retail

In the VNC (see Figure 12) three actors are presented. The first actor is the retail company which will utilize the indoor positioning. The company has presumably a CRM system and a marketing platform: Salesforce's Sales Cloud and Marketing Cloud. These two Cloud Services are connected with Marketing Cloud Connector. This enables the customer data from Sales Cloud to be utilized in marketing, such as customer joining in a campaign. In order to exchange the data between the mobile application and Sales Cloud, a Mobile Backend API is needed between the two actors. It will also provide the data for visualizing the positioning data, for instance, for creating heat maps of the data. The second actor is the Indoor Positioning Provider, a company which offers the beacons utilized for indoor positioning. Beacons are an appropriate choice for a retail store as they are affordable, provide sufficient indoor positioning accuracy, are easy to place around the store, and customers can utilize mobile devices for positioning and navigation. The third actor is the end user, the end customer of the company utilizing the indoor positioning within their premise. In order to join the loyalty program, the end user needs to download the application and presumably, also has an email application where the customer can receive marketing newsletters. The end user needs to accept the positioning and the exploitation of the positioning data to utilize the loyalty application. In addition, the user can accept the pop-ups while using the indoor positioning application inside the store as well as decide to receive marketing communications if desired.

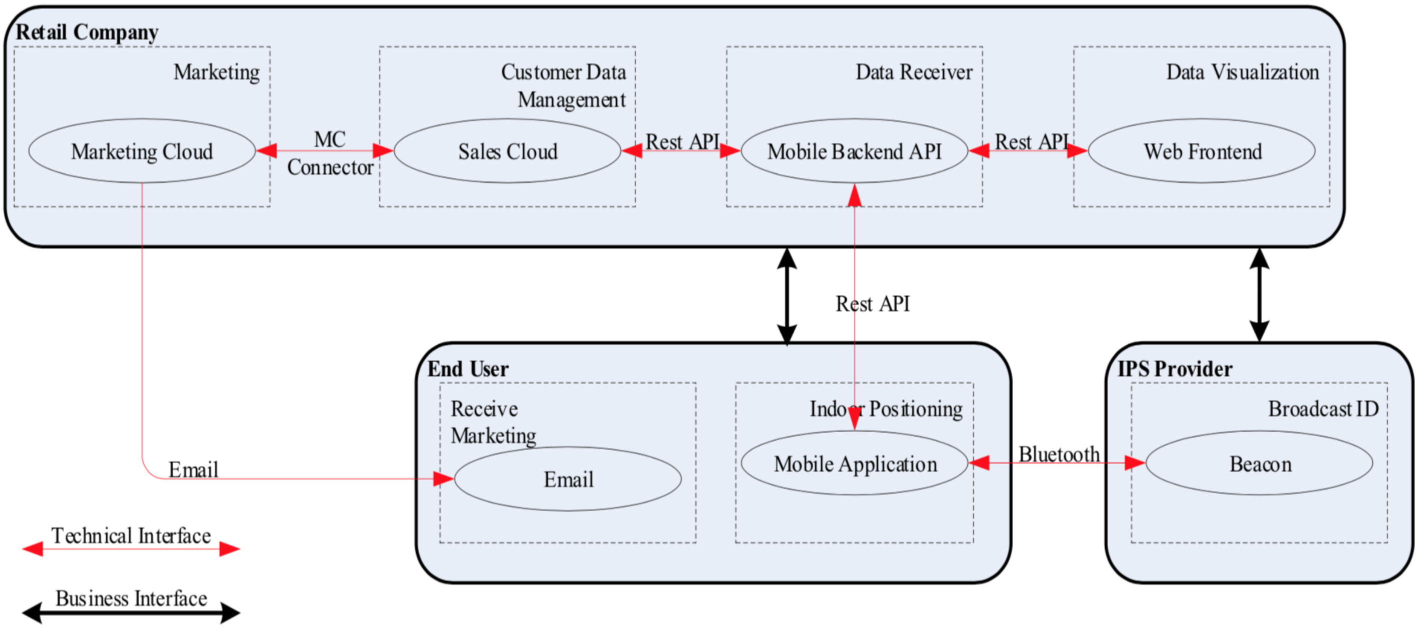

Figure 12. Value Network Configuration of an indoor positioning solution for a retail company

The beacons will be installed throughout the building in order to provide a sufficient positioning accuracy inside the store. With the help of the indoor positioning application, customers will be able to navigate and search for specific areas in the store. The beacons can track which areas of the store the customer has visited the most and based on the visit count, the areas of interest can be saved to the CRM and the customer can be added to a relevant Sales Cloud Campaign. If the customer has subscribed to a loyalty newsletter of the store, a newsletter can be customized based on the information where the customer has visited the most. For instance, if the customer has visited the sports department seven times a month, the customer may receive a loyalty email customized with sports content. In addition, when the customer's interest in sports has been identified, the customer may receive a location-based discount as a pop-up message in the application while in the sports section if the location-based notifications have been accepted by the customer. Of course, the data from the IPS would not replace the customer's own opinion but rather could be exploited as additional information about the behavior and interests.

6.2.2 Further Development for a Loyalty Application

To develop the indoor positioning and to offer an extraordinary customer service, the indoor positioning system could be further developed after implementing the basic functionalities presented in Figure 12. The development plan could include product integration, utilization of the indoor positioning by the sales assistants and other personnel, and data exploitation in real-time marketing.

A product catalogue integration to the loyalty mobile application could be implemented in order to provide search functionality for products in the store. This would enable a direct navigation to a product that is in the interest of the customer. Searching and navigating directly to a product would be especially beneficial when the store is crowded, and the sales attendants are busy helping other customers or if the products are difficult to find due to the crowd.

The IPS may also be developed further improve customer service when the sales assistants would notice customer requests in an indoor positioning application. Customers could ask for help from a sales assistant through the mobile application, and when a free sales attendant notices the customer's request, the attendant may approach the customer directly. In this way, the customers can easily ask for help rather than searching for an available sales assistant from the store. Furthermore, the customers might even utilize this function while being inside a fitting room and ask for a different size the clothes they are trying on. In addition to improving customer service, the personnel of the department store could also benefit from IPS themselves. It would allow the sales assistant easily to ask for help from a colleague as they could recognize where colleagues are located in the store. Moreover, the sales assistants could leave location-based service tickets for the cleaning or maintenance service when they realize that a specific place requires cleaning or fixing.

A more futuristic approach to utilize the IPS for retail could include real-time marketing. If a customer has accepted the exploitation of positioning data and the interest of the customer has been identified, it is possible to market in real time through, for instance, indoor billboards in the store. When the customer approaches a billboard, the content may change according to the customer's interest. Of course, the advertising should be done discreetly as the customers prefer not to receive location-based spam nor reveal their interests in public, as for example, the changing content on indoor billboards could expose their interests publicly to other people around them.

7 Conclusions

This chapter concludes the thesis and answers the research questions. As many various types of indoor positioning technologies exist, but none of them is clearly dominant over the others, the thesis studied different kind of technologies and indoor positioning use cases in form of a literature review and semi-structured interviews. The purpose of the interviews was to gain understanding of the different use cases and their technological implementation. Furthermore, a suggested implementation for a retail company was presented.

7.1 Results

In the literature review the presented technologies were Bluetooth Low Energy, WLAN, Geomagnetic field, ultrasound, RFID, NFC, image-based positioning, and an emerging technology 5G. The indoor positioning technologies are shown in Table 1.

The use cases presented in this thesis were obtained in semi-structured 60-minute interviews of companies that are utilizing or developing indoor positioning systems. The interviews had a set of questions (see Appendix 1) that were not strictly followed as the interviews were semi-structured interviews, and the goal was to understand the use case and the functionality of the IPS. The cases included companies utilizing indoor positioning to help users to navigate in public spaces; raise employee satisfaction in an office; improve customer service and satisfaction in malls, stores, and restaurants and develop processes and safety in warehouses. The cases obtained from the interviews are summarized in Tables 3 and 4. These different use cases have distinctive specifications and needs for indoor positioning, and thus, not a simple solution exists as to which technology is the right choice for a particular use case. However, three points affecting the choice of indoor positioning technology were concluded from the interviews: 1) the accuracy of a technology, 2) whether the positioning happens through a tag or a mobile device, and 3) if positioning infrastructure, such as anchor nodes, can be installed in the building.

Finally, two different companies related to retail were interviewed also in semi-structured interviews. The duration of the interviews was 30 minutes and the questions are presented in Appendix 2. Based on all the interviews, a suggested implementation for an IPS for a retail company is presented as a Value Network Configuration (see

Figure 12). The VNC represents a loyalty application based on BLE Beacon positioning.

7.2 Assessment of Results

The goal of the company interviews was to gain understanding of the different use cases and technologies for indoor positioning. These interviews affected strongly on the main results of this thesis, since the three choices affecting the decision of the indoor positioning were concluded from the interviews. If companies with similar fields and use cases would have been interviewed, it might have been more straightforward to conclude a specific technology for a specific use case. On the other hand, the goal of the thesis was to review various kinds of technologies and use cases, which in fact, are presented broadly. In addition, as several use cases for retail were introduced, it was possible to present the suggested VNC model for an IPS for retail. Since the interviews affected strongly on the suggested VNC model, the model might have been slightly different, if the interviewed companies would have been utilizing other types of IPSs.

7.3 Exploitation of Results

The results obtained in this thesis can be exploited when implementing an IPS. The comparison of the technologies in Table 1 can help to gain an overview of the existing indoor positioning technologies. Tables 3 and 4 summarize conveniently the benefits, challenges, accuracies, and implementations of different indoor positioning technologies and use cases. These tables can provide a good overview of other indoor positioning solutions, and they can be utilized when making decisions regarding the technology and implementation. In addition, the suggested model for a retail company can be exploited when scoping an indoor positioning solution for retail.

7.4 Future Research

In addition to the presented use cases, indoor positioning can be utilized in many other environments, such as in hospitals for tracking patients and equipment, or in sports to analyze the player movements on a field [20][38]. Indoor positioning is a growing market [1], and there will be more different kinds of solutions for it in the future. Furthermore, other indoor positioning technologies exist [20] in addition to the technologies presented in this thesis, as those technologies were not used by the interviewed companies, or they were not the most commonly utilized technologies, and thus, were out of the research scope of this thesis. In the future, the technologies and use cases not mentioned in the thesis could be studied further. Moreover, as this study was an overview to indoor positioning technologies and use cases, each of the technologies presented could be researched more in detail to gain a deeper understanding. Consequently, Fluido will continue studying indoor positioning in a form of another thesis focusing on BLE Beacons.

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Appendices

Appendix 1: Interview questions for companies using indoor positioning

Interview questions in English

1. What is the indoor positioning utilized for in your company / what are the use cases?

Technology and implementation:

2. Which technology are you currently using for indoor positioning?
3. Do the receivers/tags/beacons need battery change? What is the battery life?
4. How is the indoor positioning system implemented?
5. How did you decide to utilize the positioning technology you chose? Did you consider some other technologies? *(WLAN, Beacon, RFID…)*
6. What information is collected from the end user and when? *(time, location, user identified vs. anonymous?)*
7. How accurate is the positioning you are currently using in your company?
8. Is the acquired data integrated to other systems? Where?
9. How did you take security into consideration while designing your system, now that GDPR is such a current topic?

End user perspective:

10. What is the benefit for the end user to utilize the indoor positioning system?
11. How have the end users adapted to utilize the positioning service?
12. Has the system affected on user satisfaction?
13. What steps does the user need to take in order to utilize the indoor positioning? *(install app, accept positioning etc.)*
14. How does the end user utilize the indoor positioning system?

Indoor positioning provider:

15. What are the benefits of the indoor positioning system for your company?
16. How is the positioning information utilized in your company? *(i.e. Marketing, people flow, occupied places, visiting frequency, other statistics)*
17. Why did you decide to invest into the positioning system?
18. Were you able to calculate the profit for the business case in advance or how did you estimate the benefits of the system in advance?

Future prospects:

19. Could the positioning system be improved? If yes, what would be the next steps?
20. How would you see that your company will utilize the indoor positioning in the future?

Haastattelukysymykset suomeksi

1. Mihin sisäpaikannusta käytetään yrityksessänne / mitä käyttötapauksia sille on?

Teknologia ja toteutus:

2. Mitä teknologiaa käytätte sisäpaikannukseen?
3. Tarvitseeko tunnisteet / beaconit / vastaanottimet pattereita tai muuta huoltoa? Miten usein patterit tulee vaihtaa?
4. Miten sisäpaikannus on toteutettu?
5. Miten päädyitte valitsemaanne sisäpaikannusteknologiaan? Harkitsitteko jotain toista teknologiaa sisäpaikannukseen?
6. Kerätäänkö käyttäjästä jotain tietoja? Mitä tietoja käyttäjästä kerätään ja milloin?
7. Kuinka tarkka yrityksenne käyttämä sisäpaikannus on?
8. Onko sisäpaikannuksessa kerätty data integroitu muihin järjestelmiin? Mihin?
9. Miten otitte tietosuojan huomioon systeemin suunnittelussa, nyt kun GDPR on kovasti esillä?

Käyttäjä:

10. Mitä hyötyä käyttäjälle on sisäpaikannuksesta?
11. Miten käyttäjät ovat sopeutuneet sisäpaikannuksen käyttöön?
12. Onko sisäpaikannus vaikuttanut käyttäjien *(esim. Työntekijät, asiakkaat)* tyytyväisyyteen?
13. Mitä toimenpiteitä käyttäjän tulee tehdä käyttääkseen sisäpaikannusta? *(esim. Asentaa applikaatio puhelimeen, hyväksyä käyttöehdot, kantaa tunnistetta…)*
14. Miten käyttäjä käyttää sisäpaikannusta? (*Puhelimella, tietokoneella…)*

Yrityksen näkökulma:

15. Mitä hyötyä sisäpaikannuksesta on yrityksellenne?
16. Miten paikannustietoja käytetään yrityksessänne hyväksi? *(esim. Markkinointi, varatut paikat toimistossa, vierailutiheys, yms.)*
17. Miksi päätitte investoida sisäpaikannussysteemiin?
18. Pystyittekö laskemaan business casen tuoton investoinnille etukäteen vai miten arvioitte sisäpaikannusjärjestelmän hyödyt ennen investointia järjestelmään?

Tulevaisuudennäkymät:

19. Voisiko käyttämäänne sisäpaikannusta vielä jotenkin parantaa? Miten?
20. Miten kuvittelet yrityksenne käyttävän sisäpaikannusta tulevaisuudessa?

Appendix 2: Interview questions for companies not using indoor positioning

Interview Questions in English

1. Have you considered implementing an indoor positioning system for your company?
2. Where would you like to implements an Indoor Positioning System? (e.g. office, shopping center, warehouse)
3. What would you like to accomplish with an indoor positioning system? (e.g. better image, improved sales and customer satisfaction)
4. What kind of data would you like to acquire? (e.g. end user location in the building, visiting frequency, number of people in the building in specific area)
5. What would be the benefit for the end users?
6. Have you considered a specific way to implement a positioning system in your company?
    a. If yes, what technology would you prefer to use?
        i. Why did you end up with this technology?
        ii. Would you consider integrating the positioning data with Salesforce?

Haastattelukysymykset suomeksi

1. Oletteko harkinneet sisäpaikannuksen käyttöä yrityksessänne?
2. Missä haluaisitte käyttää sisäpaikannusta? (esim. Toimistossa, tavaratalossa, varastossa)
3. Mitä haluaisitte saavuttaa sisäpaikannuksella? (esim. Paremman kuvan asiakkaiden silmissä, kasvattaa myyntiä)
4. Minkälaista dataa haluaisitte kerätä sisäpaikannuksella? (esim. Vierailutiheys, loppukäyttäjän sijainti rakennuksessa, vieraillut alueet)
5. Mitä hyötyä sisäpaikannuksesta olisi loppukäyttäjälle?
6. Oletteko harkinneet jotain tiettyä tapaa sisäpaikannuksen toteuttamiseksi?
    a. Jos olette: Mitä teknologiaa haluaisitte käyttää?
        i. Miten päädyitte tämän teknologian valintaan?
        ii. Harkitsisitteko sisäpaikannuksesta saadun datan integroimista Salesforceen?