Czech Technical University of Prague Faculty of Transportation Sciences

Department of Transport Telematics

Technology of iBeacon and its application for people with special needs

MASTER´S THESIS

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MASTER'S THESIS ASSIGNMENT

(PROJECT, WORK OF ART)

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Guides for elaboration

During the elaboration of the master's thesis follow the outline below:

- description of iBeacon technology and its application in field of Smart Cities
- research of iBeacon technology use in the Czech republic and abroad
- proposal of information system for using iBeacon technology by people with special needs (e.g. blind and visually impaired people)
- practical application of proposed solution for use in the Ukraine
- analysis of usebility of proposed solution (result analysis)

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iBeacon for Developers [online], 2017 (https://developer.apple.com/ibeacon/)

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Title: Technology of iBeacon and its application for people with special needs

Author: Dmytro Kochkurov

Field: Intelligent Transport Systems

Type of Thesis: Master’s Thesis

Abstract: This master’s thesis is aimed to develop an accurate, effective wireless indoor navigation system for people with special needs using iBeacon signals.

Papers are also dedicated to investigate advantages and disadvantages of iBeacon technology use and its application in the field of Smart Cities.

The overall aim is to develop the indoor navigation system for passenger transport terminal (bus station) which can be used not only by people with disabilities (visually impaired) but also by general public.

Key Words: Indoor navigation, Bluetooth Low Energy, iBeacon

Used abbreviations

API - Application Programming Interface

APP – application

APS - Accessible Pedestrian Signals

BLE - Bluetooth Low Energy

CMS - Content Management System

GPS - Global Positioning System

ICT - Information and communication technology

RF - Radius frequency

SDK - Software Development Kit

TIS - Transport Information System

URL - Uniform Resource Locator

Content

List of Figures

List of Tables

Introduction

Technological innovations that allow determining the location, as well as various kinds of navigators a very demanded. The most widespread are specific applications on smartphones that use different methods and inputs for positioning. There are several technologies that are used for indoor navigation. However, the indoor navigation is really complicated, so that the accuracy of indoor positioning is affected by the huge amount of signal interference. Most wireless internal positioning systems rely on signal level indicators from wireless emitting devices.

From another side, it is important to ensure that all categories of users of public facilities are independent in their mobility and do require the assistance of other people. There is a particular problem of indoor navigation for people with specific needs. With the use of modern technological solutions, this task can be solved.

In this thesis, we propose a system utilizing iBeacon for indoor positioning. In this system, iBeacon can accurately locate where the user is in an indoor environment and give him/her required instructions for further movement. We aim to provide a more accurate, effective wireless indoor navigation system using Bluetooth Low Energy signals. The assignment rose at the Faculty of Transportation Sciences mainly for the purposes of people from the project Traffic Models and Traffic Control, because this area has not been significantly examined yet there. They can use it as an overview of possibilities in this area or use it as a base for their future work with these systems.

The developed indoor positioning system has several essential advantages and has specific application for people with special needs.

According to the conducted analysis, the iBeacon-based system is proven to be an effective solution to indoor positioning.

The thesis starts with the description of iBeacon technology use and its application in the field of Smart Cities. It continues by Research of iBeacon technology use in the Czech Republic and abroad. Then there is more complex Proposal of the information system for using iBeacon technology by people with special needs. It is followed by Practical application of proposed solution for use in Ukraine The last chapter is dedicated to the analysis of usability of the proposed solution.

Chapter 1. **Description of iBeacon technology use and its application in the field of Smart Cities**

1.1 The concept of a Smart City

The rapid increase in the number of inhabitants of modern cities, economic, environmental and social problems require the search for new solutions. Some cities decided to function in a smarter way to solve concerns. Recent practices to make cities better for living have become successful cases for new city development strategies [36].

Four crucial elements of a smart city can be distinguished: land, citizens, technology, and governance [7]. “Smart” has become a new buzzword to describe technological, economic and social developments fuelled by technologies that rely on sensors, big data, open data, new ways of connectivity and exchange of information [18].

At the same time, Smart City can be considered as a city well performing in 6 key “smart” fields of urban development: environment, people, governance, economy, living, and mobility [14]. Every one of these components can be divided into several elements. In this work, we are paying the main focus on the mobility.

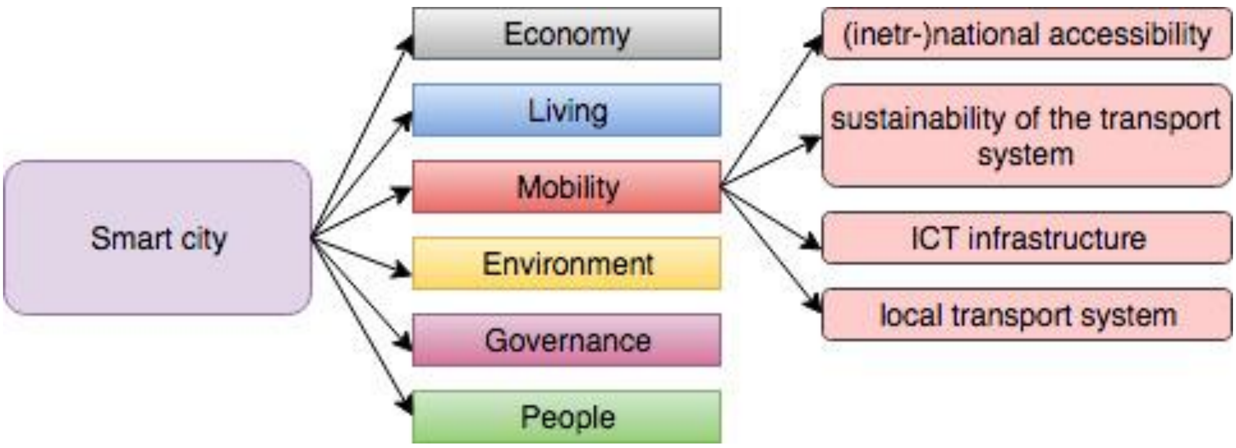

Figure 1 Structure of the concept of “smart-city”

(Source: Self-developed)

The smart city concept promises competitiveness and economic growth through highly educated talent, high tech industries, and pervasive electronic connections. Creating conditions for continuous learning and innovation is a prerequisite for achieving smart cities.

There are varieties of technologies used for solving particular mobility problems in smart cities. The complexity of technology in the smart cities arises from the fact that the variety of smart applications enabling the smart world require different precisions, different smart devices hosting these applications carry different sets of sensors, behavioral characteristics of the different sensors in different environments are complex, and the availability of maps and the need for the visualization platform for different applications are quite diversified [40].

Mobility management represents one of the most important parts of the smart city concept [46]. Worldwide leaders in IT and networking are working for the development of new and the most comprehensive solutions for smart cities [41].

In Europe, in 2015 there were already 100 smart-cities [8] and their number is permanently growing. The European Commission's Smart Cities and Communities Stakeholders Platform lists the following five Czech cities supporting the smart city initiative: Prague, Ostrava, Havířov, Jeseník and Hlinsko [55].

1.2 General overview of iBeacon technology

iBeacon is a protocol developed by Apple and introduced at the Apple Worldwide Developers Conference in 2013. iBeacon is an implementation of an indoor positioning system using Bluetooth Low Energy (BLE) technology, which Apple has developed to help provide location-based information on mobile devices with a minimum amount of power required.

As any other information system iBeacon system contains the following elements:

hardware - iBeacons – BLE transmitters; Mobile phones with Bluetooth turned on – Beacon scanners;

software - mobile applications and iBeaon service admin screen;

data – all the information transmitted in the system (e.g. internal files, summary reports, forecasts etc.);

procedures – all the interactions in the system (e.g. internal transactions, updating, modeling, simulating, analysis, etc);

people - iBeacon system implementers (Institution which wants to implement iBeacon platform; Developers and App makers) and end-users (people, who will install and use the application on their smartphones).

It is considered that originator of the system development is the ordering customer (institution). It has to buy and install BLE-transmitters, order software from developers and app-makers, make advertisement of the iBeacon-based services for end-users. End-users should install the app on their smartphones, and to use it. Simplified scheme of the functioning of the iBeacons environment is presented in Figure 2.

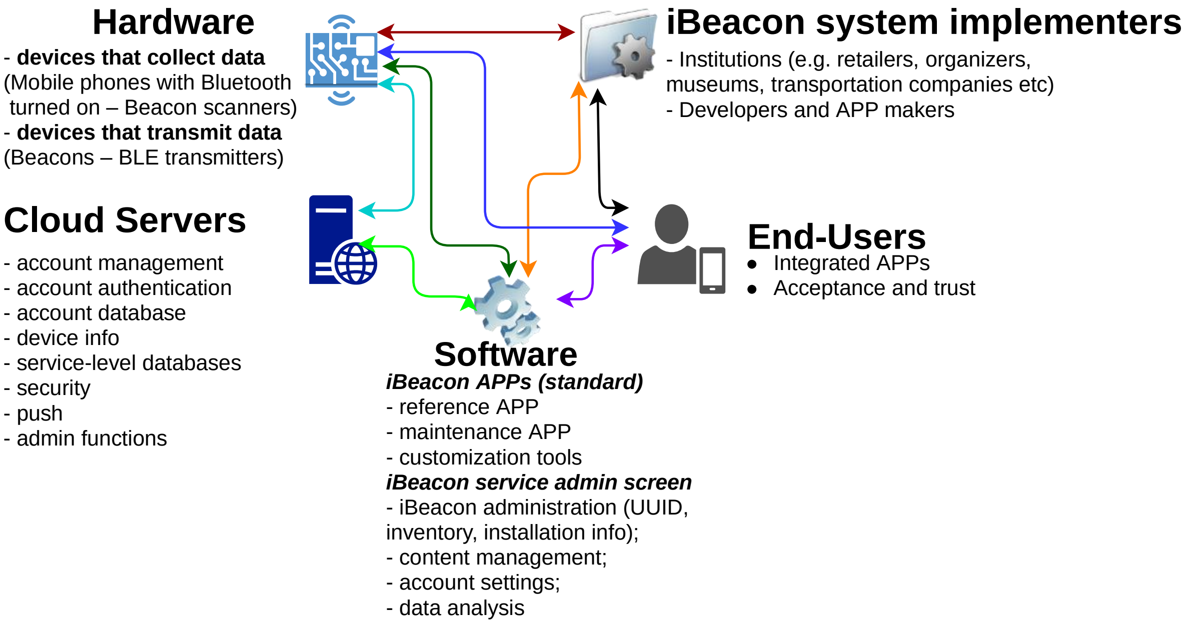

Figure 2 Simplified iBeacons environment system

(Source: Self-developed)

iBeacon system working process can be divided into 6 steps and its Simplified scheme is presented in Figure 3. It is important to remember that all the steps mentioned can be accomplished only in the case if there is operational software.

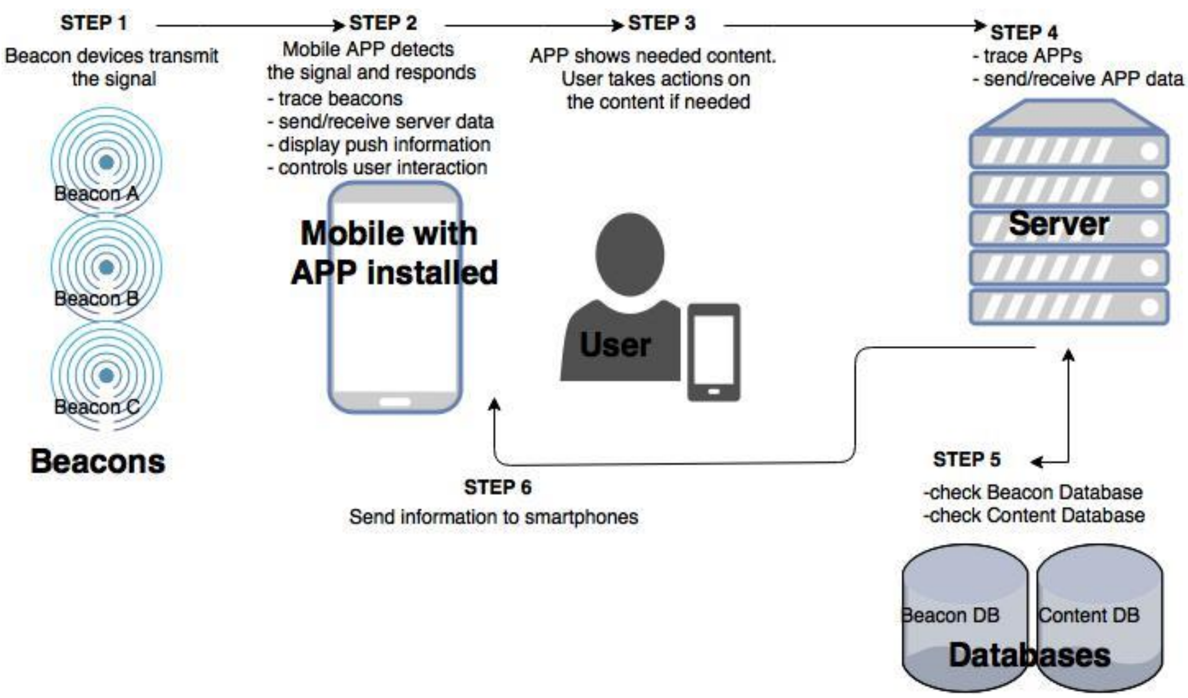

Figure 3 Simplified demonstration of beacons work

(Source: Self-developed)

As it was mentioned above the main elements in the iBeacon system are: hardware, software, people, data, and procedures. Every group of elements in the system can be desvribed with the set of particular parameters.

Table 1 Main characteristics of the iBeacon technological system which is to be developed in the project

Main elements of the system	Structural Elements	Descibtion of Parameters
Hardware	iBeacons (BLE transmitters)	standalone devices that constantly send out a UUID (Universally Unique Identifier) using Bluetooth 4.0 Low Energy. The iBeacondevices can come in different form factors.
	iBeacon compatible devices	Apple iOS devices with Bluetooth 4.0 (iPhone 4S and later, iPad (3rdgeneration) and later, iPad Mini (1st generation) and later, iPod Touch (5thgeneration)).
		Android devices with Bluetooth 4.0 and Android 4.3 and later (Samsung GalaxyS3/S4/S4 Mini, Samsung Galaxy Note 2/3, HTC One, Google/LG Nexus 7 (2013version)/Nexus 4/Nexus 5, HTC Butterfly (aka Droid DNA).
		Macintosh computers with OS X Mavericks (10.9) and Bluetooth 4.0 using theMacBeacon application from Radius Networks.
Software	Content Management System	Used to assign specific content (text, images, URLs, video etc) to certain beacons.
	SDK	Vendor-supplied software embedded in mobile apps to handle recognition of beacons and automatic retrieval of their associated content.
	API	Some vendors provide open interfaces to their systems to allow to create more customised solutions. For example, you could create a web-based app that works in conjunction with your mobile app to shows details of beacons you've visited.
	Demo and/or management apps:	Vendors may provide mobile applications to easily demonstrate the above - retrieving and displaying a beacon's content when it is in range for example. They may also provide apps that let to adjust beacons' settings.
People	iBeacon system implementers	Institution which will implement iBeacon platorm – depending on the type of operational management of the transport enterprise, this institution can be in private or state ownership. Also there can be certain support in the implementation of this iBeacon platorm from Organizations which support people with special needs.
		Developers and App makers are private companies hired by technology implementing institutions.
	End-users	Those people who will instal application on their smartphones and use it for indoor navigation in transport terminals. This application in particular will be used by people with special needs (people with visual disabilities).
Data	Data transmitted	The data transmitted is very small, its only purpose being to identify the beacon and its distance:

		UUID: This uniquely identifies a set of beacons and would typically be used to detect that a beacon belonged to a particular company. *Major number:* A number between 0 and 65535, generally used to identify a particular geographical location. *Minor number:* Also between 0 and 65535, identifies the particular beacon at the location. *TX power:* A calibration value that should be equal to the strength of the device's signal measured 1m away. On the receiving end, this information is accompanied by an RSSI (Received Signal Strength Indication) value, which can be used along with the TX power value from the beacon to estimate its physical distance.
	Metrics	The metrics that matter with respect to customer footfalls are: Visits Number of Unique visitors Number of New visitors Outside potential (people passing but not entering)
Procedures	Internal transactions	*Broadcast and Observation.* The broadcast mode and the observation procedure defined in GAP establish the framework through which devices can send data unidirectionally, as a BLE transmitters to one or more actively listening peer devices (iBeacon compatible devices). It is important to note that the broadcaster has no way of knowing whether the data actually reaches any observers at all, so this combination of mode and procedure remains faithful to its nomenclature
		Discovery. A device's discoverability refers to how the peripheral advertises its presence to other devices and what those devices can or should do with that information. The differences between the different discoverable modes and discovery procedures concern whether advertising and scanning are actually being performed but also take into account the nature of the data included in advertising packets.
		To establish a connection first starts with scanning to look for advertisers that are currently accepting connection requests. The advertising packets can be filtered by Bluetooth Address or based in the advertising data itself. When a suitable advertising slave is detected, the master sends a connection request packet to the slave and, provided the slave responds, establishes a connection. The connection request packet includes the frequency hop increment, which determines the hopping sequence that both the master and the slave will follow during the lifetime of the connection.
		Security procedures. *Pairing*. The procedure by which a *temporary* common security encryption key is generated to be able to switch to a secure, encrypted link. This temporary key is not stored and is therefore not reusable in subsequent connections. *Bonding*. A sequence of *pairing* followed by the generation and exchange of permanent security keys, destined to be stored in nonvolatile memory and therefore creating a permanent bond between two devices, which will allow them to quickly set up a

		secure link in subsequent connections without having to perform a bonding procedure again. *Encryption Re-establishment.* After a bonding procedure is complete, keys might have been stored on both sides of the connection. If encryption keys have been stored, this procedure defines how to use those keys in subsequent connections to re-establish a secure, encrypted connection without having to go through the pairing (or bonding) procedure again.
	Content Management	Used to assign specific content (text, images, URLs, video etc) to certain beacons
	Simulating	It is possible to do interleaved advertising to broadcast multiple beacon types simultaneously. For that it is needed to create a list of beacon profiles, to adjust them and switch between.
	Analysis	Use of beacons allows iBeacon system implementers to gain deep insights into consumer behaviour. For example, beacons can be used to measure how many hours a particular customer has spent in the passport control waiting area of the airport. Metrics can be tracked using beacons. A footfall analysis of all such data points allows to make informed operational and strategic decisions that in turn drive better conversion, optimise staff allocation, and improve navigation and displays.

iBeacon devices use Bluetooth Low Energy to broadcast signals. BLE is based on the 2.4 GHz frequency and as such is subject to attenuation by various physical materials such as walls, doors or other physical structures. The 2.4 GHz frequency can also be affected by water, which means the human body will also affect signals. This is important to be aware of because when the Bluetooth signal is attenuated or lessened, this affects the signal strength received by a device (smartphone). As discussed above, when the received signal strength is lessened, an iOS device's ability to estimate the proximity to an iBeacon device is diminished.

iBeacons offer different possibilities in the urban public transport sector. There are at least four ways in which this technology can be used in the transport sector of modern Smart cities [43]:

1. Improvement of transport payment systems. Installing iBeacon-enabled devices at payment gates that enable users to pay through an application on their smartphone. With online transactions, users can preload credits or cash onto the application, or the application could be directly linked to users' debit/credit cards for instant payment for tickets.

2. If trains and buses were equipped with iBeacon devices alongside platforms and bus stops, users could accurately identify when each train/bus leaves the last station, and they could move towards the platform in time for its arrival.

3. Sometimes when traveling, users do not really know which bus or train to take to reach a particular destination. Users end up spending a lot of time either asking people or transport drivers, or they spend time searching boards or online listings for details. While most people do

find results, some individuals do not know the names of areas, bus stops or metro stations, so they have problems asking for information. With the installation of iBeacon devices onboard buses and trains, once being next to the vehicle users could receive notification regarding a particular bus/train line, schedule etc..

4. With the use of iBeacon technology, passengers can receive alerts when their station or stop arrives.

All of this implementations could assist visually-impaired as well as hearing-impaired users to fulfill their mobility needs without having to rely on third-party assistance.

Chapter 2. **Research of iBeacon technology use in the Czech republic and abroad**

2.1 Definition of areas of iBeacon technology implementation

Technological solutions based on iBeacons gain general recognition in different areas (Fig. 4) improving communications and public services by development relevant information and comfortable interaction for citizens [39].

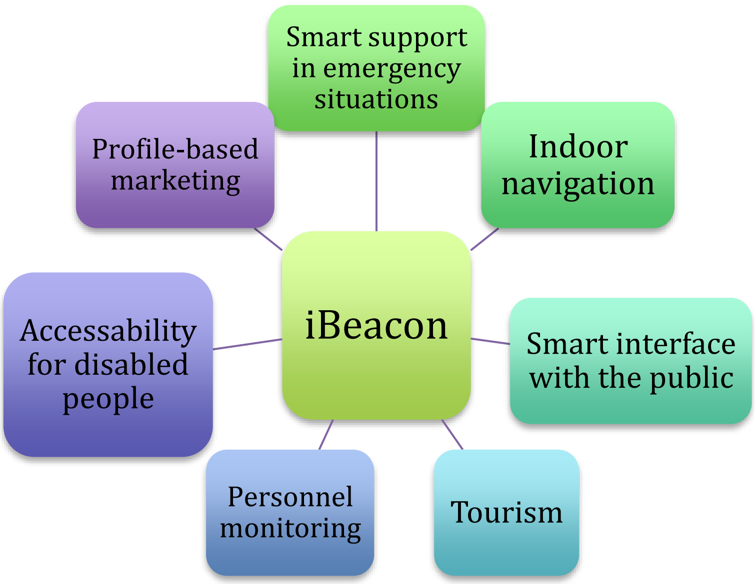

Figure 4 Areas of iBeacon implementation

(Source: Self-developed)

Smart interface with the public can be considered with various applications based on iBaecon technology for automated interactions with people based on presence detection are indicated (Fig.5). For example, using iBeacon-based applications people can automatically complete registration or request from when they enter the public office. iBeacons are starting to appear in shops to guide customers around the store, provide additional product information, and even to pay without the need to join a checkout queue – improving the overall shopping experience.

Among advantages of using this technology for issuing tickets for accessing public services, managing queues in administrative buildings are a high level of privacy and providing equal opportunities for citizens. Development and improvement of analytics are possible because of accurate detailed data about frequency, time duration, most demanded areas in public places.

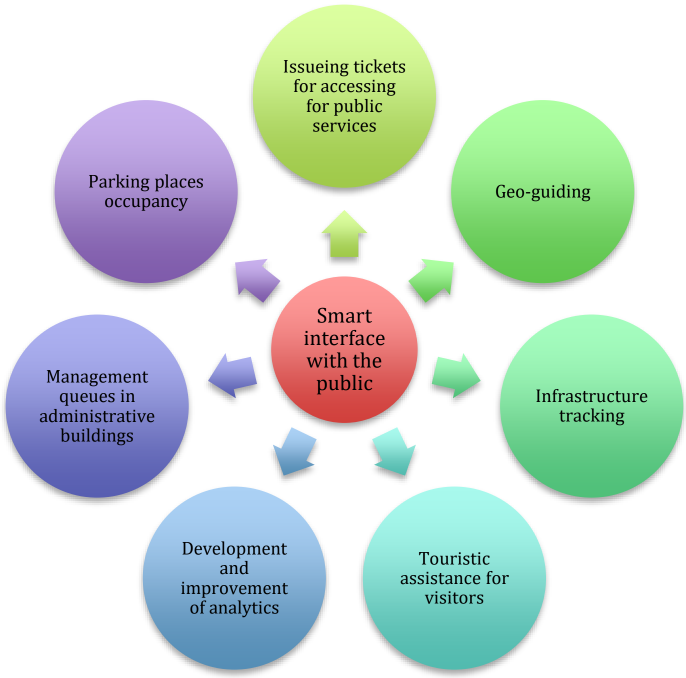

Figure 5 iBeacon use for Smart interface with the public

(Source: Self-developed)

Deployment of beacons in transport terminals can significaly improve interacting with passengers. The technology can be implemented for solving the following tasks [48, 49]:

Table 2 Possible implementation of beacon technology in transport terminals

Tasks	How to solve implementing beacons
Passenger location	Transport companies with their apps stored on a passenger's phone are able to combine the app's knowledge of the passenger, such as who they are, where they are going, and their class of travel, with accurate knowledge of their location in the terminal derived from detecting the nearest beacon. This can be useful not just for sending relevant information to the passenger, but also for locating them in the airport if they are late for boarding.
Triggering mobile boarding passes	Beacons placed at passenger touch points including check-in, bag drop, passport control and departure gates could be used to 'pull' mobile boarding passes onto the display of a passenger's smartphone at their arrival.
Indoor navigating	Beacons could provide precise and low-cost way for indoor navogating apps to guide passengers around the terminal and find the correct gate/platform.
Promotions at retail outlets	Contextually relevant messages may tell passengers to who are in, or nearby, participating stores.
Baggage reclaim	Arriving passengers can get information about which carousel their baggage will arrive on and how long they will need to wait.

2.2. Use of iBeacon technology in the world

Speaking about the use of iBeacon technology we should mention the experience of the Columbus city (Ohio, USA). The entire city has launched the “Columbus Safe City” initiative. With an app citizens receive messages via Bluetooth about what is happening in the city. For that 1,300 beacons were installed around the city. People can receive not only important messages regarding safety but also can report public hazards (non-emergency situations – it is not a replacement for 911) [24].

World-known company IKEA has launched beacon deployment in its stores as part of their in-store marketing. For those visitors who have IKEA Family app installed on their mobile devices, In-store push notifications are sent. Beacons were installed in the lobby, in the restaurant, and in the checkout area. The IQmobile platform enables the interaction between the beacons and the IKEA Family app so that shoppers are welcomed on arrival, an invitation to take a break at the food market and enjoy a free coffee is displayed or a reminder to use the reward card when checking out pops up. The use of proximity market enables IKEA to allow sales associates to add value in other areas where they might be more needed [34].

The Amsterdam’s iBeacon Living Lab project centers around a public Internet of Things (IoT) infrastructure throughout the city. The key element in this project is the use of iBeacons technology. This enables the interaction with citizens through the use of their smartphones [23]. The goal of the iBeacon Living Lab is to provide an IoT infrastructure, Actionable Open Data and a developer-friendly network. One of the projects introduced by the iBeacon Living Lab is the Amsterdam Beacon Mile. The Amsterdam Beacon Mile is a route of 2 km with beacons installed along with it. This is a testing area for applications such as public wayfinding, tourist routes, iBeacon signing, Hyperlocal points of interest and augmenting existing apps with additional proximity data. Citizens can find the city’s Beacon Mile between Amsterdam Central Station and the Marineterrein.

Besides that, other comprehensive real-life examples of the use of iBeacon technology as a component of the smart-cities are Bucharest, London, San Francisco and some others.

A fleet of 40 Enterprise iBeacons was installed in May 2015 on all buses and trolleybuses circulating in Bucharest, Romania on two public transport lines [54]. The main target of this solution is to guide people with visual disabilities to independently use the public transport network in the Romanian capital area, without having a personal assistant, and without relying on other passengers or the transportation company personnel. The functional process from the perspective of the user follows these steps:

1. The user installs the mobile application and comes to the bus station.

2. The bus (equipped with a uniquely identified iBeacon) approaches the station where the user is already waiting. The iBeacon installed on the bus continuously emits a Bluetooth Low Energy signal.

3. When the vehicle is approaching at a distance of 50-60 meters (depending on the architecture of the area), the user's mobile phone receives a notification saying that the bus is coming.

4. When the bus arrives at the station, the iBeacon's buzzer repeatedly broadcasts a Beep signal. It will allow the user to identify the desired bus if more vehicles arrive simultaneously in the same station.

5. After the user goes on the bus, notifications and buzzer sound signals automatically stop. The process repeats when the person reaches another bus station and notifies the application that he expects a vehicle from another transit line.

Another approach was used in London, where underground (subway) stations have been equipped with iBeacons [53]. The beacons can guide blind users from the station entrance to the correct train platform, and from the platform to the station exit at the destination. Beacons' signal pulse are reprogrammed the from once a second to 10 times a second to ensure more accurate location data. They're positioned on ceilings (to maximize signal exposure) and are particularly important at escalators and long hallways

Another example of common use of BLE technology is air transport. Airport Council International has even developed a special method guide «Airport Terminal Beacons Recommended Practice". In this document basing on the most advanced practice, they give not only recommendations about technical implementation (including Web Services, Registry Standards, and Security), but explain such important economic aspects (Building Beacon Business Models, Cost recovery etc.) [1].) Such airports as Hong Kong International Airport, Hamad International Airport, Chhatrapati Shivaji International Airport (Mumbai), Tokyo Haneda Airport, Bologna Airport, Heathrow Airport, John F. Kennedy Airport (New York) have already implemented BLE technology, and according to their experience it allows significantly increase quality of passenger experience [4].

One of the world best airports Changi (Singapore) uses beacons in its passenger service to achieve "do it yourself "basis. Due to this technology passengers are able to receive updates on retail or other commercial offerings, do a self-check-in of their bags, bag tagging, and automated immigration checks [30].

Miami International Airport launched its “MIA Airport Official 2.0” app which is based on the use of beacon technology in 2016. The main purpose of the application was to make finding the gate, shopping, and dining at the airport easier for visitors and locals alike [50]. This application allows passengers to scan boarding passes and receive turn-by-turn, blue-dot navigation guides to their gates which includes estimated walk times, real-time flight updates, even suggestions for nearby shopping and dining, based on a customizable personal profile.

Another example of a successful use of iBeacons is at San Francisco International Airport. Over 300 iBeacons were installed throughout the airport’s Terminal 2. The corresponding smartphone application was developed with input from blind people. It can work actively, guiding the user to a specified destination, or passively, alerting the user of things like restrooms, restaurants, departure gates, and even power outlets as he or she walks through the terminal. The system is even powerful enough that a user can simply point his or her smartphone down a corridor and obtain a list of things that can be found in that direction [22].

In Europe, Nice Côte d’Azur Airport has used SITA’s beacon technology in order to offer personalized information to passengers through its new multi-functional app. The new mobile application for passengers was developed to work with the recent opening of its renovated Terminal 1 retail area. It allows receiving retail information and other offers relevant to where they are located at the airport [35].

2.3. Use of iBeacon technology in Czech Republic

In Czech Republic, iBeacon technology receives recognition from the public. It is mainly used in tourism and social networking. At the same time, we cannot tell that there are very spread. In general, it is applicated only for proximity marketing, tourism, and social network.

One of the first projects was developed by Czech innovative company Neogenia, which is located in Brno. This company was the first one in the country who has done iBeacon project, called “Spothill”. The target of the project is to be a national pioneer of proximity marketing [38]. The combination of individual scenarios will then enable the trader to target his/her campaign to individual types of customers. In each application, customer preferences are stored that can serve to filter the bids [44].

The mobile application called "Grevin Praha" is developed for visitors to the museum of wax figures Grévin in Praha. It was designed to bring visitors a new dimension of the museum experience [19]. This application offers on-site downloads without the need for a 3G connection thanks to Wi-Fi access exclusively dedicated to App Store. This on-site download will also be available to visitors from abroad without incurring additional data roaming charges. It is available in 4 languages: Czech, English, German, and French.

Another use of beacon-technology is a new application for cognac fans in the Czech Republic. This application uses beacons to for making bars all the more social. It allows users to see the connected bars that are the nearest and the hours they are open. Entering into the bar user can see who else is there from the application (their name and photo). Users can even invite each other to a drink via the application [25].

An ambitious project called Tour-Prague iBeacon App is in the process of development. It is a native iBeacon platform for tourists and travelers. It contains location-based notification on the lock screen, postcard camera, on-map menu, and a step tracker [29].

At the same time, it is not common to implement BLE technology for the intelligent transport system in Czech Republic.

Chapter 3. **Proposal of information system for using iBeacon technology by people with special needs**

3.1. General requirements to the system

Mobility and physical disabilities differ in the degree of severity of the limitations of resistance to paralysis. Some mobility problems are caused by conditions that arise at the time of birth, while others are the result of illness or physical trauma [45]. The different types of physical disabilities can temporarily or permanently affect the physical performance and/or mobility of a person. There are six general types of disabilities :

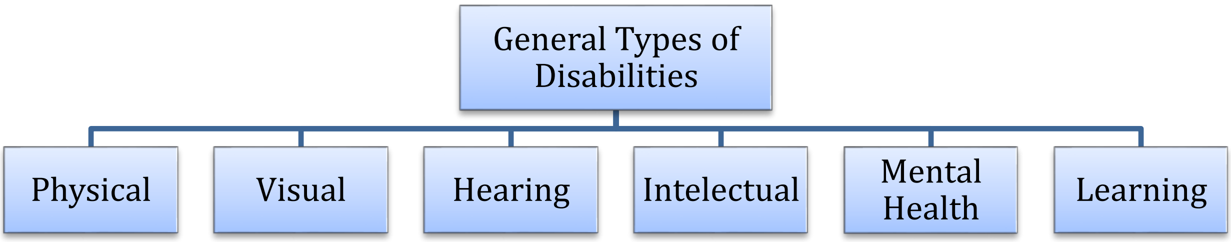

Figure 6 General Types of disabilities

(Source: Self-developed)

Physical access to public infrastructure may be not the only obstacle for a person with a disability. The common accommodations for people with mobility impairments include priority registration, accessible space/furniture, adaptive computer technology, accommodation and convenient parking.

In this project particular information system for using by mainly people with visual disabilities is developed. People with visual impairment is one of the groups of people with special needs. An estimated 285 million people worldwide have a visual impairment that cannot be corrected with traditional glasses or contact lenses. Of these 285 million, almost 40 million are completely blind [42]. 90% of blind people live in low-income countries. The blind community depends on sighted people for a significant amount of information and assistance.

There are different tools exist for blind people. Special role among them is played by navigators in unfamiliar environments, such as Global Positioning System (GPS) for outdoor navigation, white canes and guide dogs for obstacle avoidance, and Accessible Pedestrian Signals (APS). But any of them can be used for guidance through unfamiliar indoor environments.

On the other side, there are technologies which can be used for indoor navigation. Main advantages and disadvantages of those technological solutions which already exist on the market were taken into account.

Table 3 Comparison of existing sollutions for indoor navigation

Existing solution	How it works	Disadvantages
Google Indoors [16]	Indoor Maps uses the same interface as Google Maps and is accessed through it. It is reliant on businesses uploading floor plans and maps of their indoor locations to Google Maps and offers a static view rather than an interactive one, but it is one way of finding your way around selected venues. The “You are here” icon provides some navigation features.	Google Indoors only works for selected venues but not in all countries (mapped places include some airports, certain train and underground stations, and museums). It is needed to have the latest version of Google Maps. Consumes a lot of energy of the mobile device. Unadjusted for disabled people with visual disabilities.
Mally [27]	Using computer vision and 3D technology, Mally creates 3D maps of the mall for users. The app itself is quite nifty, allowing to view a 3D map, a 360-degree view, plot the route and also to access lists of shops, events, offers, and floors.	Mainly focused on shopping-centers navigation. Consumes a lot of energy of the mobile device. Unadjusted for disabled people with visual disabilities.
MApp [31]	It includes a range of maps of theme parks, shopping centers, universities, train and London underground stations, parks, zoos and aquariums, airports, hospitals, and arenas. It uses user’s location to suggest nearby places that are MApped and provides average distances.	User can not navigate through the selected map. There is a collection of maps for places. Essentially it is like having access to a database of PDF maps on user’s phone or tablet. Unadjusted for disabled people with visual disabilities.
Be My Eyes [5,17]	This app allows a sighted person to “be the eyes” for a blind person in need of help moving through an unfamiliar environment and will work indoors or outdoors using a live video connection. Blind users can request help from a sighted person and the sighted users will then be called for help. As soon as the first sighted volunteer accepts the request for help, a live audio-video connection is set up between the two and the sighted user can tell the blind person what they see when the user points their phone at something using the rear-facing camera.	Requires assistance from another person. Consumes a lot of energy of the mobile device.
Blavigator [3]	It is a prototype vision system for persons with very low vision. A normal webcam connected to a portable computer or smartphone is worn at chest height. The computer analyzes the video frames to identify	Does not guide the user to the specific point inside the building. Requires a camera use. Consumes a lot of energy of the mobile device.

	valid walking paths and obstacles just beyond the reach of a person’s white cane.	
NaviTerier [37, 57]	This system was developed in the Electrical Engineering Faculty of Czech Technical University. It consists of smartphone, navigation application and in advanced prepared data files with structured description of the building. Optional equipment (Bluetooth and/or system of QR codes) can be used. Nowadays it is also used for outdoor navigation using GPS. When user is entering the building, system sends him/her the first set of information describing the surrounding environment (opened by keyword “DESCRIPTION”) and then after the keyword “ACTION“ are placed instructions what user should do to reach end of the current segment. When user reach end of the segment, he/she press the Next button in the application and receives description of the next segment. Same process is repeated until the final destination is reached.	Application is available only for iOs devices. User must give feedback to system continuously (push buttons of his/her smartphonr to get further instructions). For indoor navigation there is a potential problem with loss of synchronization between real position of the user and relative position expected by the system. Synchronization points must be added to minimize negative effect of this issue, but visually impaired person cannot use them independently.

In the iBeacon based solution which will be developed we are going to cope with most of the disadvantages which have existing technological solutions:

- Adjusted for disabled people with visual disabilities
- Low energy consumption;
- Does not require the assistance of another person except user;
- No need for WiFi, 3G or GPS enabled on a smartphone in order to communicate with beacons;
- Providing indoor navigation without WiFi or GPS;
- Ability to register for system notifications when user enters or leaves beacon region.

A use-case of Bluetooth Low Energy Beacons is their implementation in the bus stops. Besides putting the bus timings on the transit board, it would be better if the bus stop broadcasts this information through Bluetooth. Since BLE is a low power consuming technology, it is completely feasible for the user to receive this information from the bus stop. Bus terminals can broadcast the information through Bluetooth beacons and the shoppers around them receive a notification in their cell-phone about the sale.

For successful development of the project, its technological characteristics should be chosen in advance. The iBeacon based mobile application which is to be developed has to meet the following basic requirements:

- Applications have to be very stable and simple to use;
- The application set needed to include support for the full line of modern smartphones based on iOS and Android.
- On the back-end application has to smoothly integrate with legacy datastore of geo-information services.

All the critical aspects should be set and controlled not only during the initial phase of the project but during all the life circle. Main aspects of the iBeacon based application for people with special needs are described in Figure 7.

From another side, this project should be described according to its business functionality also. This means understanding not only of the main business (monetary) relations between stakeholders of the project but also clear its functions for achieving goals of the project deployment (Fig.8.).

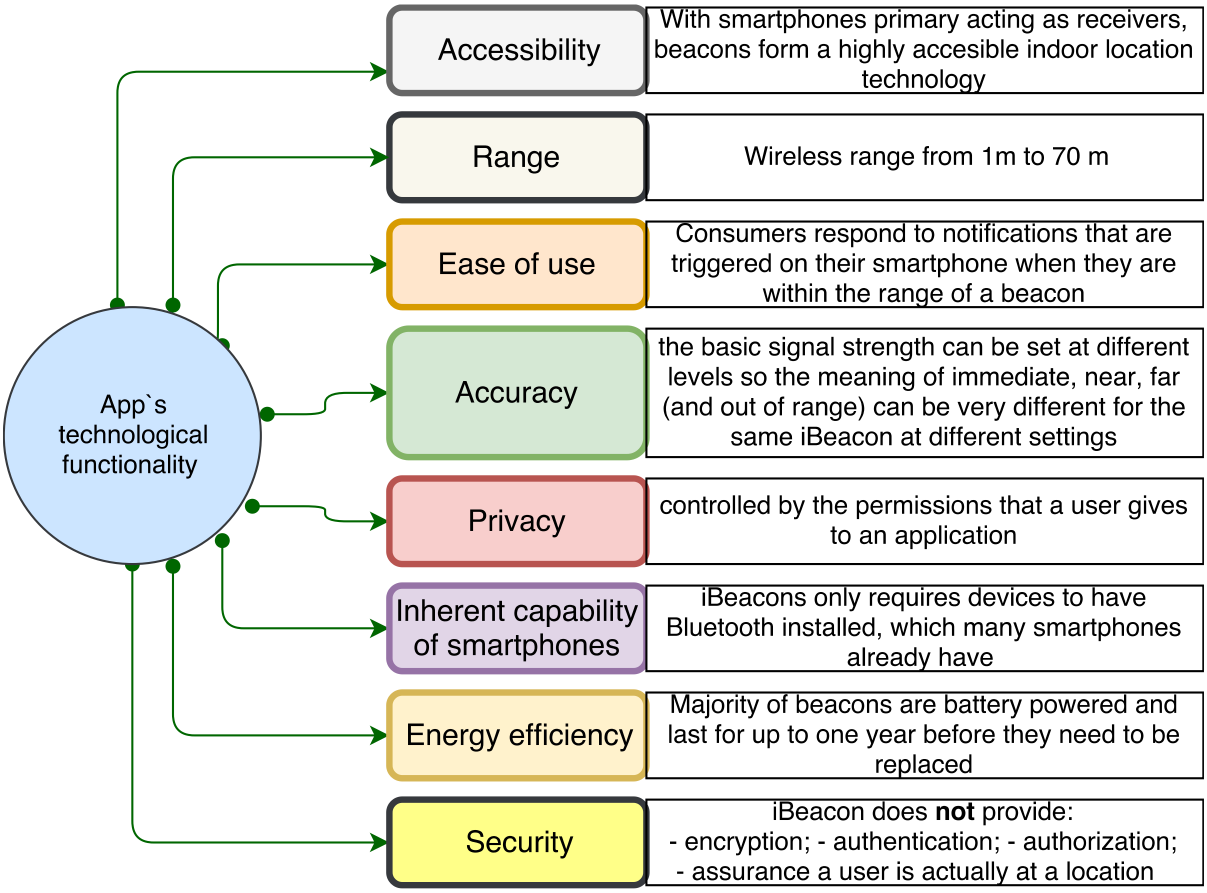

Figure 7 System identity in the context of technological functionality

(Source: Self-developed)

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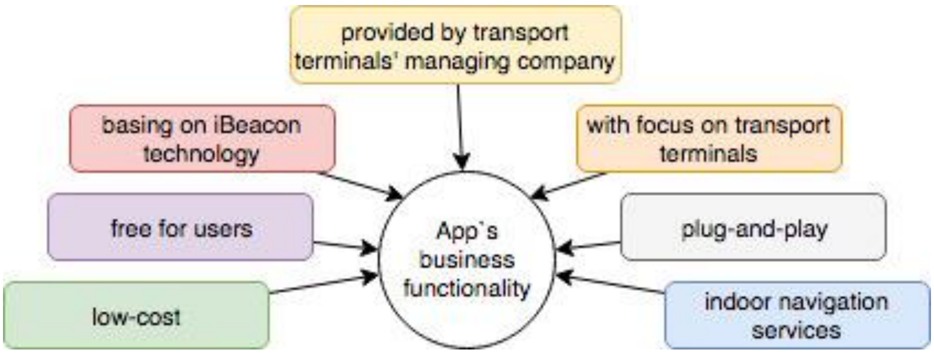

Figure 8 System identity in the context of business functionality

(Source: Self-developed)

3.2 Hardware Selection

Classic Bluetooth was famous for its short distance connectivity in a cellular phone. This communication was a breakthrough over conventional IR communication as it did not require line-of-sight communication. The result was marvelous. It got famous among the cellular phone users and almost every vendor started to support Classic Bluetooth. The idea of the Bluetooth was simple enough for any layperson. It is not required any technical knowledge from a user in order to send files and pictures to someone else's device. All you need to do is to enter the same passcode on two devices before pairing them [6].

Bluetooth Low Energy hardware is now a separate industry where manufacturers are making it easier for people to deploy BLE in their own devices. Different kinds of beacon-devices are widely available for the use today. And the question that has to be solved in this project is: Which kind of Bluetooth Low Energy hardware to choose among those which are available in the market?

The advantage of dedicated beacon hardware is that it is cheaper than using general-purpose hardware, and it is optimized for the beacon task [12]. We have compared four options developed by Estimote [9], Gimbal [15], SmartBeacon [51], Kontakt.io [26], and iBKS [2].

Figure 9 Beacons' exterior comaprison (Estimote, Gimbal, SmartBeacon, Kontakt.io, iBKS)

(Source: Self-developed with the use of official web-sited of device manufacturers)

Some dedicated iBeacon hardware runs on batteries. The iBeacon protocol is simple, and the hardware was designed to run on small batteries for extended periods of time. One of the major reasons for designing such a simple protocol is that it allows beacons to be made cheaply. Additionally, such a simple protocol can run on battery power for extended lengths of time, which enables proximity applications to be developed for areas that might otherwise be inaccessible if beacons were required to be connected to a higher-power source [12].

Table 4 Comparison of Beacons' technical characteristics

Manufacturer	**Characteristics**						
	Type	Platforms	Expected life	Price	Replaceble battery	CMS	CMS (open to other manufacturers)
Estimote	Battery Panasonic CR 2450 3V	iOS, Android	2 years	~35€	Yes	No	No
Gimbal	Battery Sony CR2032 3V	iOS, Android	Not indicated	~25€	Yes	Analytics/ Actions: text, URL	No
SmartBeacon	Battery Panasonic CR 2477 3V	iOS, Android	1 year	~33€	Yes	Analytics/ Push Messages/ Actions: text, URL, Image, Video, Audio, Webservices	Yes
Kontakt.io	Battery No brand CR 2477 3V	iOS	2 years	~30€	Yes	Analytics/ Push Messages/ Actions	No
iBKS by Accent Systems	Battery No brand CR 2477 3V	iOS, Android	3,5 years	~13€	Yes	Analytics/ Actions: text, Push Messages, Audio, Webservices	No

As it is planned to implement the system in already built transport terminal with already existing electric installations it is critical to have beacons which will have batteries as power supply. That is why we are choosing among these six options. Besides that it would be better to have a possibility to use beacons with replaceable batteries, it will allow using the system for a **longer** time without the needing to replace hardware itself.

In the case of implementation of the iBeacon technology for public transport information system, it is important to support all kinds of operational systems (both iOS and Android). This will allow involving a bigger amount of potential users. Because of this parameter, we have discarded the possibility to use beacons produced by Kontakt.io.

Another very important moment is the availability of the Content Management System. This will allow transport terminal managers to make certain changes in beacons' configurations if it will be needed (e.g. change of the schedule). It would be also useful to gather user-generated content such as comments, reviews, feedback, and surveys from users and feed this data into CRM.

Because of this parameter, only beacons produced by Estimote, Gimbal, SmartBeacon, and Accent will be considered.

Besides that, it is important to remember that for visually impaired users of public transport information system it is important to get audio notifications, and only SmartBeacon and iBKS by Accent Systems allow to manage this type of content. But, every device of SmartBeacon is 20€ more expensive than iBKS, and for this project, the price can be a very important parameter, so we will use iBKS by Accent Systems hardware.

3.3 Building iBeacon Network

The main particularity which has to be taken into account before the development of the application is that iBeacons don't receive or process any information. As a result, while beacon hardware is very simple, in contrast, the application has to be complex.

iBeacons report location to the application via two operations: monitoring and ranging. Both operations are related to the position of a mobile device relative to an iBeacon, but they each convey slightly different information.

In consequence of the features of iBeacon protocol, some functions in the iBeacon-based system must necessarily be performed by applications running on mobile devices.

Table 5 Distribution of functions in iBeacon-based system

Function	*Function's provider*	*Notes*
Monitoring	iBeacons	A high-level view of whether a device is within range of a specified beacon. It indicates that both the beacon and the mobile device are loosely within the same space, as defined by whatever the transmission characteristics of the beacon are.
Ranging		Specific to a single beacon, ranging uses its transmissions to estimate the distance from a mobile device to a beacon.
Reporting on nearby clients	Mobile application	Beacons are transmitted in only one direction, with no response from mobile devices. Without any handshaking or reception built into the protocol, there is no way for an iBeacon to learn about devices in its immediate area.
Enabling mobile devices to learn about other devices		iBeacons cannot directly assist in establishing device-to-device communication. iBeacons are limited by the transmit-only protocol; a receiver cannot determine from the contents of a beacon transmission whether it is the only receiver of that beacon or one of several hundred.
Send a message to a mobile device		An iBeacon's transmission consists of three numbers to uniquely identify what the device is near. To translate those three numbers into an action or a message, an application needs to be involved.
Get access to latitude and longitude information		Transmit identification numbers, not a geographic location. In order to get latitude and longitude, an app would need to either use a technology like GPS or translate an iBeacon's numerical identifiers into a geographic location using a mapping database.

To ensure the functioning of the system, it is necessary to perform the following main actions:

1. Identify the places for installation and the required number of beacons;
2. record / configure the contents of each beacon;
3. Ensure that the information message can be played on the user's mobile device.

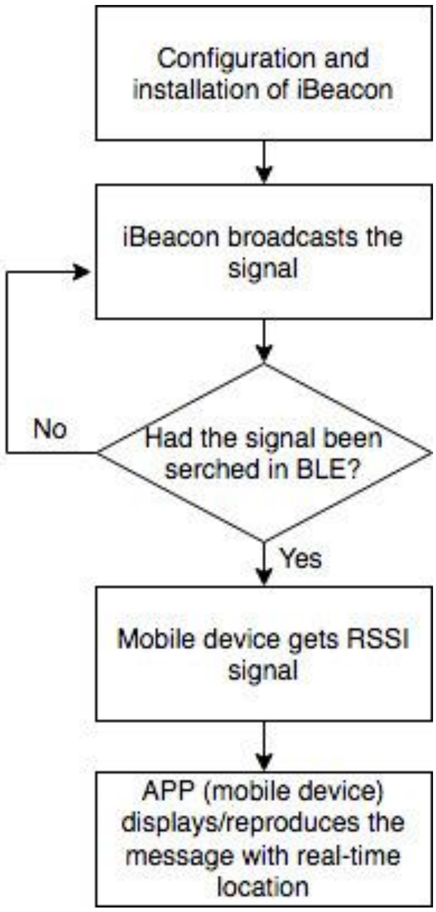

Figure 10 System algorithm

(Source: Self-developed)

For the functioning of the system, iBeacons must be placed in a room for which indoor navigation will be conducted. The number of iBeacons depends on the number of objects that are inside the transport terminal and for which you need navigation (platforms, toilets, cash desks, etc.). For smaller buildings, only a few iBeacons may be required, but complex buildings may require a large number of proximity points.

The choice of locations depends on the number of proximity points that are required for the application. For the basic message (e.g. "Welcome to the transport terminal") several iBeacons with high power can easily cover the area with the transmission of the beacon. It is necessary to choose places above human high, with an unobstructed view of the sight line.

Compared to other types of networks (e.g. data-oriented, such as Wi-Fi), selecting locations for iBeacons is much easier. This is because the Bluetooth signal requires lower signal-to-noise ratios, use frequency-hopping to avoid interference and require lower power.

3.4 iBeacon Configuration

It should be noted that special software is required for configuring / to put content on every iBeacon and to deliver messages to users' mobile devices.

There are various software solutions/platforms which allow configuring/to put content on every iBeacon. As some manufacturers (e.g. Gimbal, SmartBeacon, Kontakt.io etc.) offer content management system for iBeacons as part of the service it can be used and it is not necessary to develop a new software for this task. In some cases specific applications are developed for these purposes [47].

As we have chosen Estimote we can use Configuration Tools which are provided by the manufactirer of the beacons. Estimote app [10] is used for the management of Estimote Beacons, Stickers, and Mirrors. Connect over Bluetooth to any of devices to manage the settings or access the built-in sensors .

One of the highlights of the app are the demos. It allows to see Estimote Monitoring in action with the Proximity demo, working both in the background and the foreground, and try different Mirror scenarios with Mirror demos.

The app allows to securely manage the following:

- Enable/disable packets (e.g. Estimote Monitoring, iBeacon, Eddystone);
- Modify the broadcasting power and the advertising interval of each beacon;
- Sync the pending settings with the Estimote Cloud;
- Request the ownership transfer of your beacons;
- Check the readings of accelerometer, temperature or other sensors;
- See the battery status and the estimated remaining battery life with the current settings.
- Update beacons’ firmware.

The app works with the Proximity Beacons, Location Beacons, Location Beacons with UWB, Mirror, and Stickers. It’s only compatible with Estimote devices.

The configuration process consists of the following steps:

- Install and setup;
- Connect to a beacon;
- Configure iBeacon Service;
- Change Connectable Mode;
- Configure Advertising Window;
- Lock Beacon;

- Disable relock Beacon;
- Change Device Name;
- Factory Reset.

Configuration of the following fields has to be done:

- Advertising interval: is to be set in milliseconds (ms) from 100ms to 10000ms;
- TX. POWER: Radio TX power values in hexadecimal (00 – 07). Next table shows the equivalence between power and hexadecimal value to be set:

Table 6 Equivalence between power and hexadecimal

	Pwr (dBm	HEX value
MIN Pwr	-30	00
↓	-20	01
	-16	02
	-12	03
	-8	04
	-4	05
	0	06
MAX Pwr	+4	07

- CAL. POWER 1m (dBm)
  - Calibration Power: The transmit power as measured 1 meter away from the beacon.
  - Values between -126dBm and 127dBm.
  - It is suggested by the manufacturer to use -58dBm as default configuration value and we also encourage you to update it after calibrating again once the beacon is placed.
- UUID [HEX]: A 16-byte hexadecimal (32 hex chars) organizational identifier for the beacon. Example: BA1C51BAB3147EFEE8E5252423222120
- Major [HEX]: A 2-byte hexadecimal (4 hex chars) group identifier for your beacon. Example: 0E56
- Minor [HEX]: A 2-byte hexadecimal (4 hex chars) unit identifier for your beacon. Example: 09FA
- Extra Byte: If enabled, the battery level is advertised in the iBeacon Frame

From another side in order to configure the connectable window, 2 parameters must be set:

- Connectable period: how often the beacon enters in connectable mode.

- Connectable window: how long the beacon is able to connect.

In order to configure the advertising window, 2 parameters must be set:

- Advertising ON: what time the advertising starts
- Advertising OFF: what time the advertising stops

The difference between ON and OFF times cannot be greater than 17h. This configuration can be used in our case to stop advertisement when transport terminal is closed according to the schedule (e.g. at night).

3.5 Users' Application

The main task of the mobile application is to be a platform which allows delivering messages to users' mobile devices.

As soon as a user will be nearby a placed beacon and he/she will turn on the lock screen, there should appear a notification (beacon's unique identifier) and facilitate user's interaction.

Information which has to arrive at the end-user should consist of:

a) name of the point/facility of the transport terminal (e.g. number of the platform, toilet, bar, ticketing office etc.);

b) visual sign – using commonly-used big size signs (for partially sighted users and foreigners);

c) short sound message (for visually impaired users).

Figure 11 Example structure of the message appearing user's mobile device

(Source: Self-developed)

Taking into account the particularities of the system the main requirement is to reproduce the message from the beacon. And for this purpose, it is not obligator to develop a completely new application. Any bus station in Ukraine has already developed a mobile application, besides that it is obvious that at the very beginning of the implementation of the project it will be extremely challenging to ensure a wide spread of this application installation and use. In case if the transport terminal will invest only in the beacons hardware, but will use already developed software from a third party the entire project can become much more affordable due to essential savings on application development costs, design costs etc. The application should be as simple as possible, should not require long tutorials. Preferably it should be a single screen application. Its customization can be related with adjusting of the size of the text message, and regulation of the volume for a voice message.

At the moment (February 2018) there are about 50 already developed applications on Google Play Store which the main function is to read beacons. For iOS users, there is a similar application available also in AppStore.

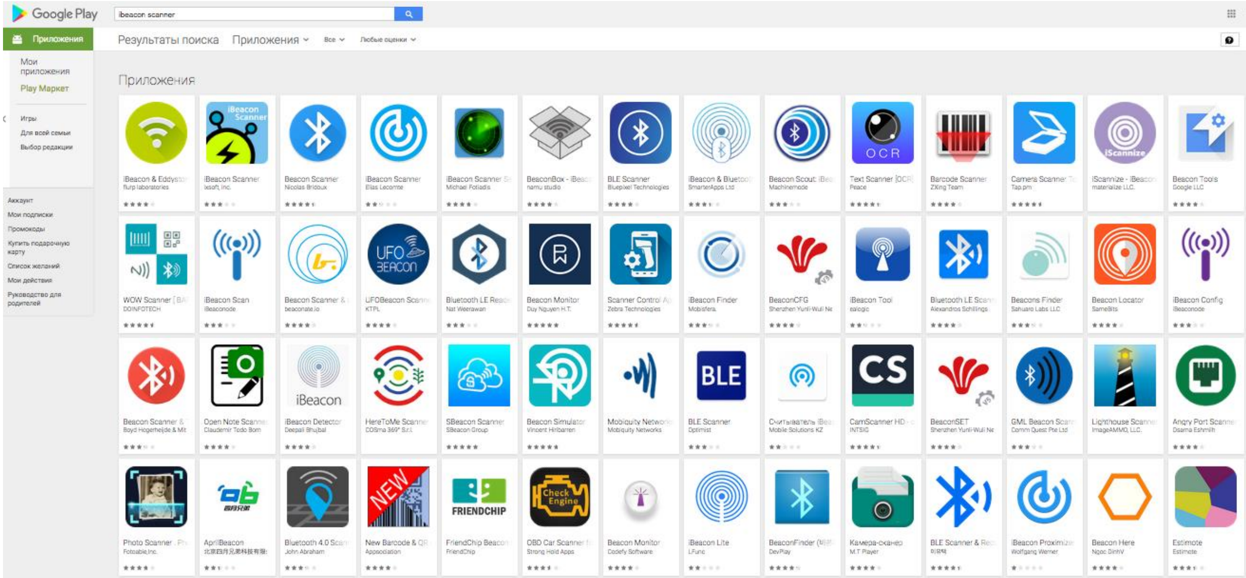

Figure 12 Varity of iBeacon scanner mobile applications aviable on Google Play Store

(Source: self-developed using Google Play Store)

User needs to install any of them on his/her mobile device and can start being an active participant in the transport terminal indoor navigation system.

From another side creating a new application can have its possitive sides also. It can be adjusted for using by visually impared passengers, and can contain more comfortable interface.

3.6 Use Case Viewpoint of Ibeacon System

The iBeacon system under consideration consists of the following elements:

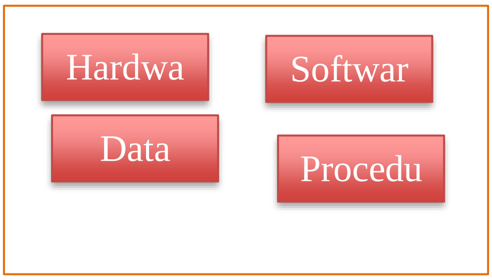

Figure 13 Elements of the system

(Source: self-developed)

Actors and Use Cases:

The design and development of a system must take into consideration the interactions of the subject system with entities external to it, i.e. those entities which lie beyond the system boundary.

To achieve this, the overall functionality of the subject system is decomposed into several coherent fundamental units, each of which describes a set of interactions between an external entity and the system. Each such unit of interaction is known as a **use case**.

The external entities which interact with the system are referred to as **actors**.

Use Case View, Model and Diagram

The use case view is “the aspect of the subject system concerned with specification of the behavior of the system in terms of use cases.”

A use case model is “a model of the system which represents the system as observed form the perspective of the use case view.”

A use case diagram is “a diagram that shows the relationships among actors and use cases within a system.”

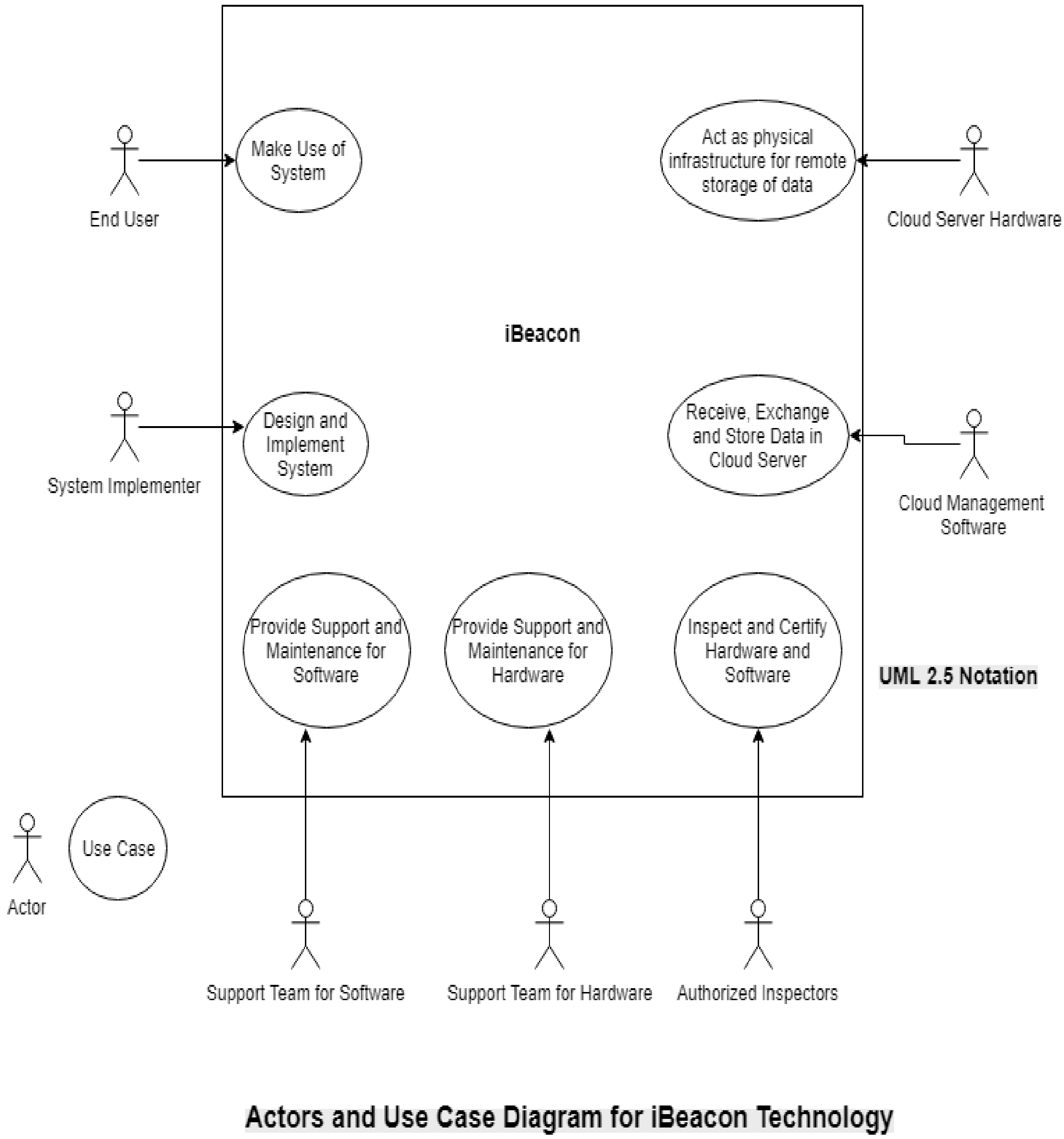

Figure 14 UML based on design of the system

(Source: self-developed)

Actor	End User
Actor Designation	A1
Use Case Designation	U1
Use Case Description	Uses iBeacon technology to acquire information (especially location) regarding facilities such as restrooms, escalators, etc.

Actor	System Implementer
Actor Designation	A2
Use Case Designation	U2
Use Case Description	Designs and Implements iBeacon technology (including system concept, hardware and software prototypes)

Actor	Support Team for Software
Actor Designation	A3
Use Case Designation	U3
Use Case Description	Provides regular and emergency maintenance for software system used in iBeacon

Actor	Support Team for Hardware
Actor Designation	A4
Use Case Designation	U4
Use Case Description	Provides regular and emergency maintenance for hardware devices used in iBeacon

Actor	Authorized Inspectors
Actor Designation	A5
Use Case Designation	U5
Use Case Description	Conducting inspection and certification for hardware and software systems used in iBeacon

Actor	Cloud Management Software
Actor Designation	A6
Use Case Designation	U6
Use Case Description	Receive, exchange and share data with other components of information systems of iBeacon

Actor	Cloud Server Hardware
Actor Designation	A7
Use Case Designation	U7
Use Case Description	Physical infrastructure that supports remote collection, exchange and storage of data.

Chapter 4. **Practical application of proposed solution for use in Ukraine**

4.1 Accessibility of Ukrainian transport system for people with visual impairment

For Ukraine, the problem of social protection of the disabled people is particularly significant in connection with the steady trend towards increasing the proportion of people with disabilities in the general structure of the population. If in the early 90's of the last century, the total number of disabled people in Ukraine was about 3% of the total population or 1.5 million people, in 2008 their number was 2.65 million people, including 122.6 thousand Disabled children, that is, the proportion of persons in this category in the general structure of the population is 5.3% of the total population, respectively, their number has grown by almost 1.6 times [60].

Comparing the EU and Ukraine programs to support people with disabilities, it was found that the list of areas of implementation is very similar. But the EU action plan is at a higher level. In particular, the problem of adapting public transport to the needs of the disabled is not resolved [59]. In Ukraine, there is no accurate official statistics on the number of people with visual impairment, according to unofficial data, it is about 100 thousand people, in Kiev - about 4.5 thousand.

Urgent issues are the arrangement of urban and suburban transport for the transportation of persons with disabilities and the allocation of parking places for their cars. Local authorities should take appropriate measures to equip the bus, trolleybus and tram lines with at least one transport vehicle for the transportation of people with disabilities. It is also necessary to purchase railway passenger cars that are most adapted for the transportation of this category of persons. Need to organize a disability support service at airports and stations, to ensure the smooth operation of lifts and other technical equipment intended for wheelchairs and other small mobile population groups.

In Ukraine, nowadays buses are extremely popular and the most inexpensive form of intercity and international travel. During the last year, almost 66% of all domestic passenger transportation had been done by the road transport (buses) [61].

Every Ukrainian town has one or more bus stations where intercity buses come and go. Buses come and go at all hours of the day according to their posted schedules. These include full-size state buses, full-size private buses, and the "marshrutki" (minibusses) [21].

The last research related with the accessibility of transport and infrastructure for disabled people had been done in 2016 by All-Ukrainian public association "National Assembly of People with Disabilities of Ukraine" [59]. According to this research, there is an absence of systemic complex approaches in the state policy in the transport sphere. This can be considered being the main reason for lack of accessible physical environment/infrastructure, lack of information availability, especially for people with sensory impairments and visual impairments. At the same time safety of people with disabilities is not ensured in transport. Service quality and culture for disabled passengers is very low.

Accessibility of the public transport in Kiev has the better level than in the other cities of the country. In particular, all new trolleybuses and buses in Kiev have the low landing, equipped with sound traffic lights on the streets of the city. Also, for disabled people, there are places on parking lots with the corresponding designation, and the number of road signs has increased, which warn drivers of the road crossing blind. In the metro, all 92 entrances to the stations are equipped with sound guides. On the platforms of 4 stations ("Lybidska", "Khreshchatyk", "Teatralna", "Ploshcha Lva Tolstogo") are equipped relief limiting lines. Subway employees were required to accompany the disabled on the subway, assist with landing and landing in the car. The same applies to the International Airport "Kyiv" (Zhulyany), where the blind are obliged to serve in an emergency.

One of the main problems for people with visual impairments is the inaccessibility of information: lack of voice announcements about stops, lack of general information or incorrectly provided information (small font), lack of information boards; lack of maps for users with visual impairments. Nowadays there is any indoor navigation system deployed in Ukrainian bus transport terminals.

4.2 Development of the iBeacon-based Information System

High-quality passenger information system is necessary at bus stops/stations for the modern, predictable and competitive public transport. The goal of this system is to improve indoor navigation in the transport terminal (bus station “Teremki”) using the available media that include smartphone and the Internet.

As at the moment, there are no such systems and technological solutions for indoor navigation inside the transport terminals in any of the bus stations in Ukraine. But similar systems exist in other countries.

At the very first step, it is planned to develop an Information System only for one bus terminal (this project is described in this Master thesis). After successful implementation of this project, it can be adopted for other bus stations or other transport terminals also. The most ambitious goal could be to gather all the transport terminals information systems into one platform and to spread its functionality.

Our main concern is to establish the system which concentrates on the public services of Transport Information System (TIS) include pre-trip and/or after-trip transport information, source location, destination and additional information related to indoor navigation inside the transport terminal. We propose a system that accomplishes user requirements using most sophisticated way through the available media and ensures the best and unbiased solution.

From a passenger perspective, the requirements of knowing the information about the optimal route (the route that will take less time) come forward.

In the developed information system we propose on the usage of voice and text messages as possible media for transmitting the desired information.

In this project, it is planned to use the information in offline mode: messages that will be transmitted by beacons are prepared in advance and are patched on each beacon by the administrator. In case of a change in the information to be broadcast by a particular beacon, the administrator must re-record a new message. As far as beacons in this project are not connected to the network, it is necessary to work with each of them in close proximity. On the one hand, this is a disadvantage of the system (the administrator cannot configure the beacons from his/her workplace), but on the other hand, such a system is much better protected from external unauthorized interference and has a more simple structure.

All the information operated in the iBeacon-based Information System is routed to the Information system of the bus terminal. It includes data about schedules, platforms, ticketing offices etc.

From one side administrator has to perform several tasks: first of all he/she uploads application (see Chapter 3.5) to the Internet, besides that, he/she uploads information about the transport terminal navigation to the database. After that administrator has also to upload information from the database to every beacon - configure beacons (see Chapter 3.4). The mail of ibeacons to send a data (UUID , major, minor) :

UUID – short indicator which consist of 32 numbers and letters and splits for 5 groups and divided by dashes.

UUID: f22265w3-4vb1-7e52-2479-kj5b21f0753g

Major ID: 1

Minor ID: 2

Each beacon an own unique UUID. Major and Minor numbers which help to identify concrete UUID.

From another side there is the user of the iBeacon-based Information System. It is considered that the users are public transport passengers, including passengers with special needs (e.g. visual impairments). First of all user has to download an application from the Internet to his/her smartphone. Once he/she arrives to the transport terminal (bus station) he/she will start receiving UUID from iBeacons to the smartphone. The user is the one who makes the decision about the optimal route basing on the available information.

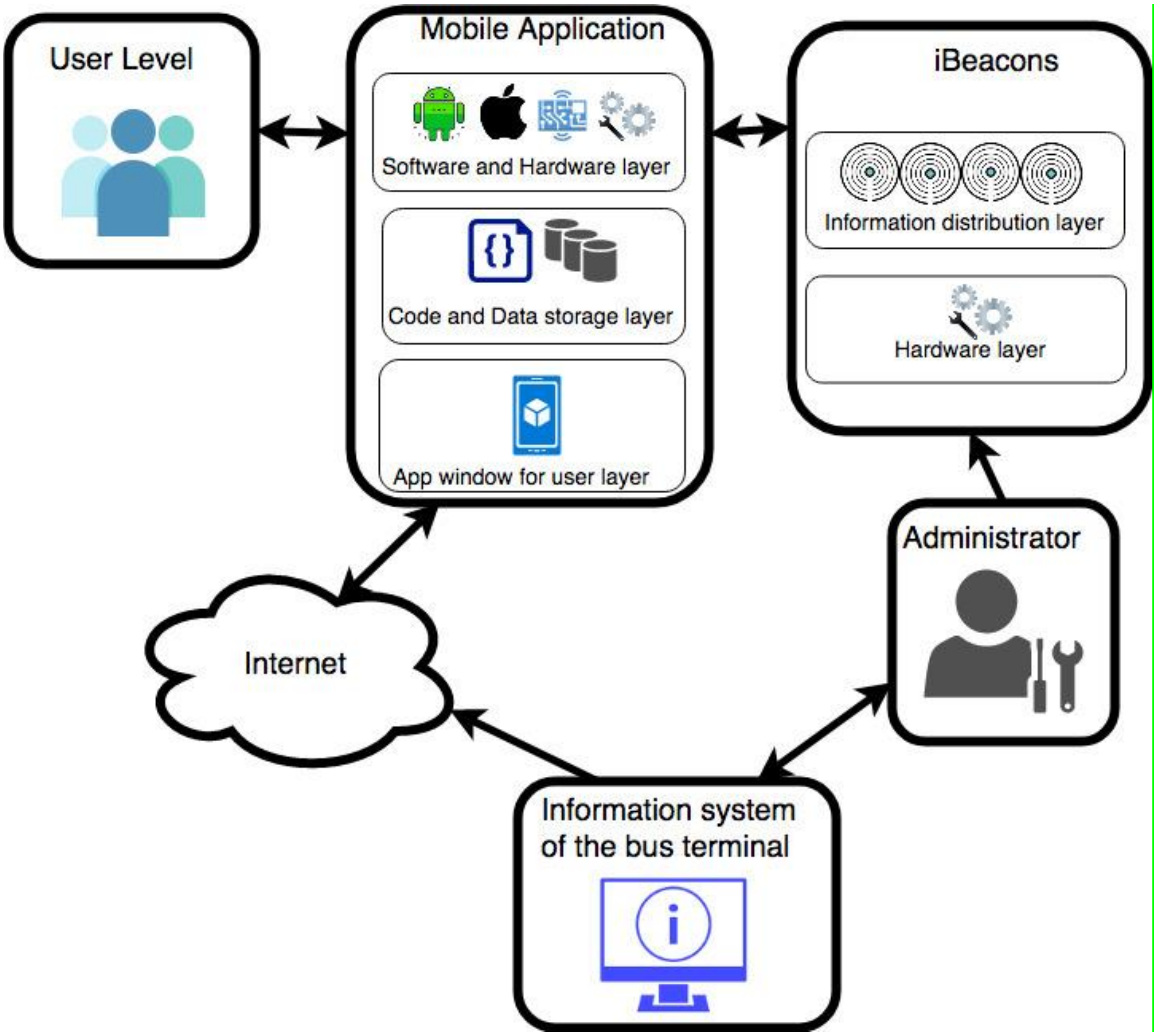

Figure 15 Architecture of the iBeacon-based Information System

(Source: Self-developed)

The main challenge of the information system is to provide the optimal amount of information (enough but not too much) (described in Chapter 5) and to place transmitters (beacons) in the right places (Fig. 15).

4.3 Particularities of the bus station “Teremki”, as the basis for deployment of the indoor navigation system for people with special needs

In this master's project, it is proposed to use the developed technological solution for indoor navigation for public transport terminal – bus station. It was chosen the bus station “Teremki” situated in Kiev (vul. Kiltceva doroga, 1L). It is a new station which was officially opened on the 8th of December 2016. Its capacity is 450 buses (9000 passengers) per day [28]. This bus station is considered being one of the most modern in the country, and in case if it will show efficient functionality similar projects may be developed in other cities.

Figure 16 Outdoor and indoor of bus station “Teremki” [58]

The new bus station is comfortable for passengers and for drivers. Passengers, while waiting for the bus, can visit cafes and shops on the territory, use the free Internet, leave their things in an automated luggage storage room, and keep track of the arrival of the desired flight using the information tab. There is also a special baby care room. The territory has 20 platforms for passengers’ pick up and drop off, bus maintenance, parking, and a carwash ramp. The building has three floors (Fig. 15) and consists of the following zones:

Table 7 Zones and facilities of the bus station “Teremki”

Floor	Zones and facilities
-1	Parking, engineering and utility services rooms, automated luggage storage room
1	Cafeteias, toilets, ticket sales office, lounge
2	Relaxation room for drivers, shops, baby care room, administrative offices

User level:

a) People with disabilities. Most for the blind people;

b) People with no disabilities;

c) Administration;

d) Station’s workers;

Ibeacon:

a) each beacon was decided to locate in important for a passenger places (e.g. platforms,ticketing offices, toilets etc.) and positioned on high 5 metres from the floor and 5 metres length around the perimeter;

b) battery - Panasonic CR 2450 3V;

c) every 6 month every beacon has to be planned controlling;

d) life time of each battery – 2 years;

e) life time of each beacon – 5 years;

f) time is taken to change each battery – 15 minutes;

g) time is taken for controlling – 30 minutes.

Mobile application:

a) mobile user interface (UI);

b) hardware: mobile phone, application, GPS, compass, bluetooth, speaker, vibration;

c) OS(Operational System) – Andoid because most of the people have android devices. Version – 3.0.

There is no obligation to cover all areas of the transport terminal with iBeacon system (e.g. relaxation room for drivers, engineering and utility services rooms etc. do not need the coverage). Therefore the general-purpose area of the bus station is 13500 m^2.

It was decided to locate beacons:

a) in the important for a passenger places (e.g. platforms, ticketing offices, toilets etc.);

b) in those places which are importing for routing – places where decision where a passenger wants to go are to be taken (e.g. intersection of different areas).

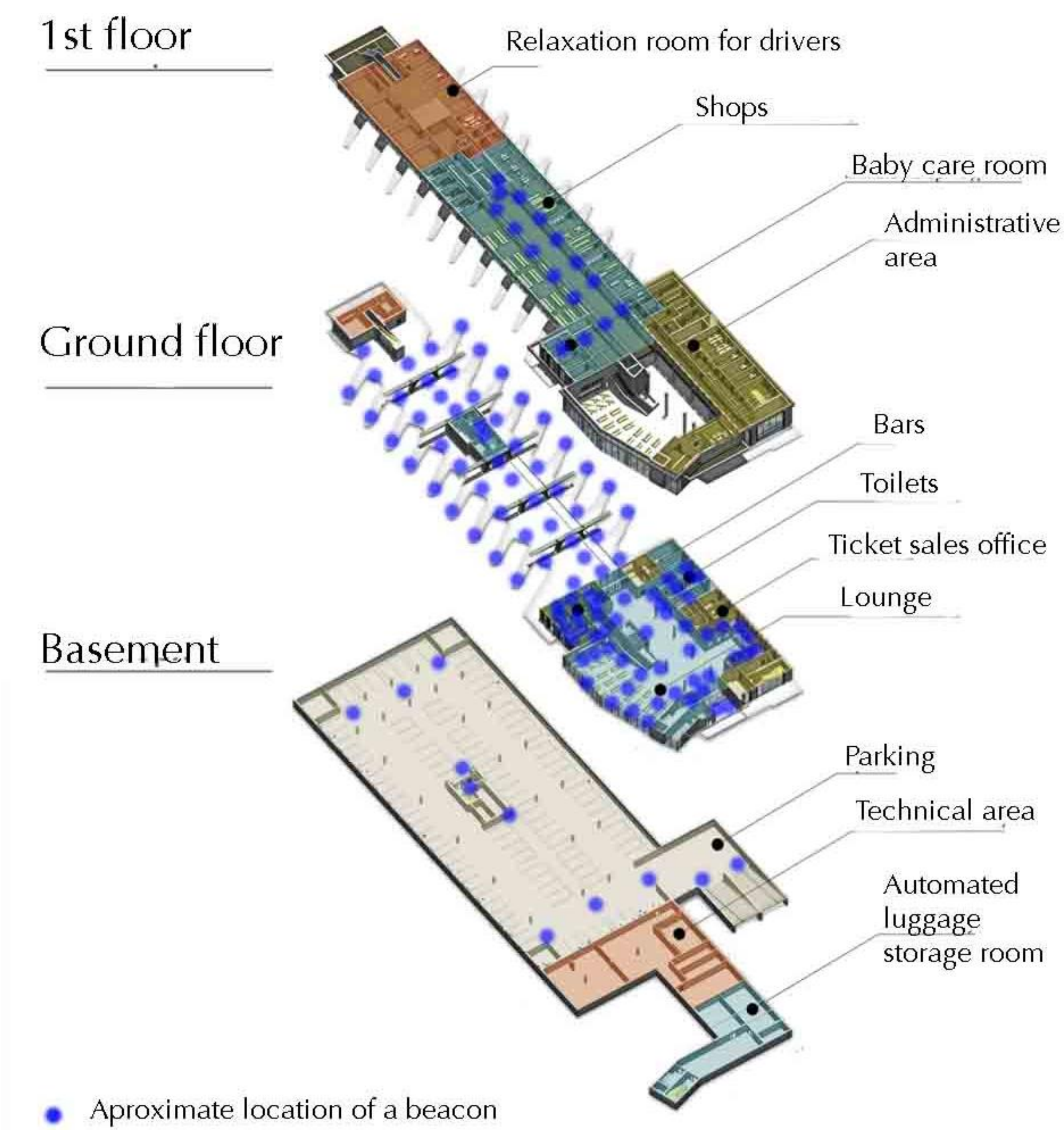

Figure 17 Layout of the Bus station "Teremki" [32]

4.4 System Installation and Maintenance

As some beacons have different signal strengths in different directions (e.g. when mounted on a wall or on a ceiling) so during the installation, beacon orientation should be noted and standardized where possible. This fact can have a significant impact on the performance of the system. In our case, it is planned to install 130 SmartBeacons.

Beacon maintenance will have a big influence on installation since small changes in performance or configuration can have impacts on the cost and effort to maintain.

The most important effects come from:

1) Advertising power – beacons send their signal at a chosen power level and the higher this is

the shorter the battery life is, though the signal is heard from further away. Beacon power levels should be set based on the beacon surroundings, but should normally be the same across the bus station to help standardize the installation and use of the beacon network.

2) Advertising interval – beacons send out their signal every X milliseconds, this should be set depending on the responsiveness required. When higher, the beacon will consume more battery.

To achieve signal stability and long-distance data transmission requirements, the SmartBeacon-4AA underwent extensive testing and modification. Its signal remains stable even in complex deployment locations. Radius frequency (RF) power demand configuration can be adjusted to a maximum radius of 80 meters.

The RF power demand configuration can reduce its radius to a minimum of 0.15 meters, which covers an area of 0.225 m2. However, it is possible that no signal will be obtained if the RF power is adjusted to a minimum.

The beacon identification should determine how the three identification parameters (the UUID/major ID/minor ID) should be specified. There are important considerations which have to be taken into account during identification of the iBeacons.

There is a hierarchical relationship between UUID, major ID, minor ID. The following standards are recommended:

- Each bus station should have its own UUID value.
- Each zone (e.g. platform, lounge, baggage service facilities etc.) within the bus station should share the same major ID value
- The minor ID can be any arbitrary value (within the permitted range defined by iBeacon profile)
- The combination of UUID/major ID/minor ID should be unique per bus station.

Under iOS Apple defines regions as one contiguous area for the purpose of a given application; generally, this refers to the entrance or exit of a major venue, such as a bus station. Each region has one and only one UUID.

A beacon must belong to one of the zones to be recognized. For a finer localization, some zone definitions will require additional data for the beacons. These data fields are given in the table below:

Table 8 Zone identifications

Amount of iBeacons	Zone (Location)	Category	Characteristics iBeacons'	
			Major ID	Minor ID
4	Entry of a terminal	Way finding infromation	01	01- 04
10	Area (general describtion)		02	01-10
50	Identifying a specific platform, group of platforms		03	01- 50
7	Ticket sales office		04	01- 07
2	Baggage service facilities (lost & found office)		05	01, 02
2	Information points		06	01, 02
8	Toilets		07	01 - 08
2	Baby care room		08	01, 02
10	Parking area		09	01-10
15	Lounge		10	01-15
10	Retail area or specific store in the terminal	Marketing & Entertainment	11	01-10
10	Restaurant/cafe/food shop		12	01-10

Chapter 5. **Analysis of usability of the proposed solution (result analysis)**

5.1 Concept of Usability

The International Organization for Standardization [52] defines usability in this way: «The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction, in a specified context of use».

According to this definition, there are five main components which are to be analyzed for estimating usability of the proposed technological solution:

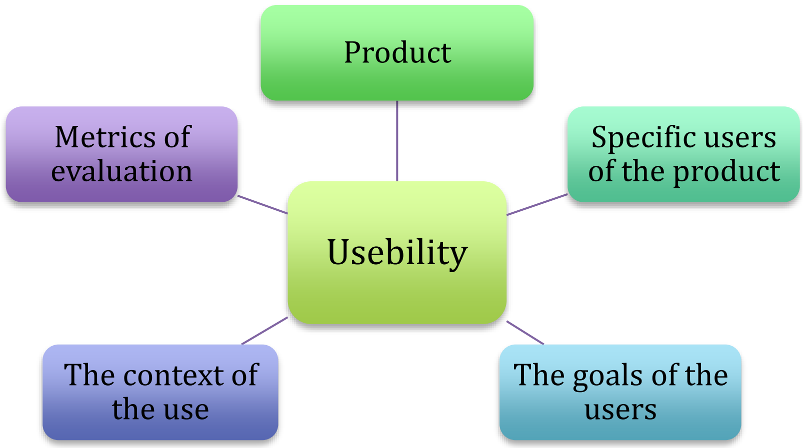

Figure 18 Components of the Usebility concept

(Source: Self-developed)

Like any other, development of the technological solution for indoor navigation for people with special needs includes several phases: discovery, design, implementation, internal testing, soft launch, and delivery. But unlike the development phases, usability testing is ongoing. It is a common practice to conduct several usability tests in order to make the mobile application the most effective and convenient.

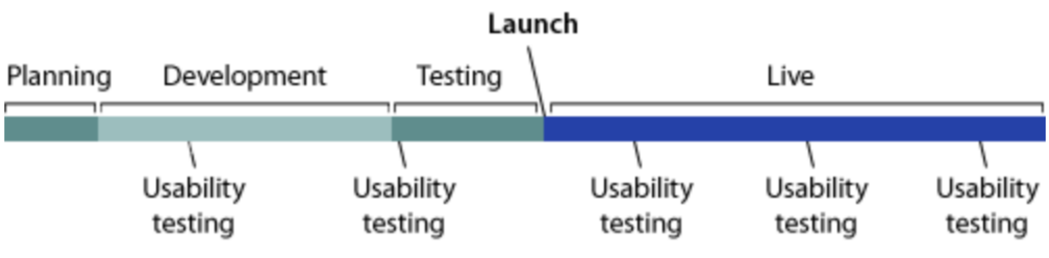

Figure 19 Phases of production and testing for user experience [11]

5.2 Development of the plan for usability test

Before the beginning of each phase of usability testing it is necessary to develop a test plan. The goal of the plan is to clearly define what will be done, what indicators will be collected, the number of test participants, and what scenarios will be used.

According to the general recommendations [13, 33] we have developed the plan of sections for usability study.

Table 9 Usability study plan

Plan Section	Explanations
Study goals	Goals must be approved by all stakeholders, and they should be the basis for the tasks.
Session information	This is a list with the duration of the sessions and the characteristics of the participants. It also includes any information on how interested parties can participate in sessions (for observation).
Background information and non-disclosure information	Explain to the participants the research scenario, the research objectives (expain that the software is to be tested, not the participants); Inform participants in what form sessions will be recorded. Ask participants to think out loud throughout the test, so that application developers can understand weak points of the application.
Tasks and questions	Ask participants a few background questions, as well as questions about their typical behavior (how would they solve the problem without using the developed application). Then ask the participants to perform the tasks that need to be checked. Generate subsequent general questions that will help determine the overall attitude to the developed application. It is also necessary to develop an evaluation scale.
Conclusion	After passing the test, it is needed to ask the participants if they have any questions, and if they have anything to tell (some recommendations may appear).

The main goal of the usability study is to estimate if the developed application performs the specified functions (facilitates indoor navigation for the Bus station “Teremki”).

The duration of the usability test sessions should be about 4 hours and should include:

- up to 30 minutes for explaining to the participants the research scenario, the research objectives;
- up to 3 hours for performing usability test tasks;
- up to 30 minutes for answering questions and giving feedback.

In every session of usability test should involve different stakeholders performing different roles (an individual may play multiple roles):

Table 10 Roles performed by different groups of usability test stakeholders

Role	Describtion
Test Participants	In every usability testing session must participate at least 10 test participants. Taking into account that this application has been developed for being used by visually impaired passengers, and for passengers without visual disabilities, control group of test participants should include: - people with degree of disablement visually impairment (not less than 5 individuals); - people without visual disabilities (not less than 5 individuals).
Trainer	Provides training overview prior to usability testing. Explains to the participants the research scenario, the research objectives (explain that the software is to be tested, not the participants). Informs participants in what form sessions will be recorded.
Facilitator	Assists in the conduct of participant interview sessions. Responds to participant's requests for assistance
Data logger	Records participant’s actions and comments
Test Observers	Silent observer. Assists the data logger in identifying problems, concerns, and procedural errors. Takes notes.

Every participant has to solve several **usability test tasks** with the use of the application:

1. Go from the entrance of the Bus station to the platform/bus;
2. Go from the entrance of the Bus station to the platform/bus through the ticket-office;
3. Go from the platform/bus to the exit of the Bus station;
4. Go from the entrance of the Bus station to the ticket-office;

5. Go from the entrance/platform to the toilet, bar, waiting area.

On each of the questions (except open-answer questions) the rating scale below should be included:

Table 11 Rating scale for answering usability test questions

1	2	3	4	5
Low	Low-Moderate	Moderate	High-Moderate	High

Besides that list of the background questions which can be useful for further improvement of the application had been developed:

Table 12 Background questions for usability test

1) How old are you? _______________ 2) Do you usually use any navigation applications (both indoor and outdoor)? ☑ ☒ 3) If «Yes» name which ones _______________ 4) How would you navigate this transport terminal if you would not have the proposed application? ____________________ ____________________ 5) Do you consider that the proposed application has made indoor navigation in the Bus station "Teremki": a) Easier ☑ ☒ ? b) Faster ☑ ☒ ? 6) What is your general impression about using this application? ____________________ ____________________ 7) Do you have any advice how this application could become more useful/convenient? ____________________ ____________________

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5.3 Metrics of evaluation for usability tests

There are three most common metrics for evaluation: effectiveness, efficiency, and satisfaction [11]:

Effectiveness shows if test participants are successfully able to complete specific tasks (e.g. finding the needed platform in the transport terminal).

- Efficiency indicates the time or the number of steps it takes to complete a task (e.g. How many times test participant needs to insert data to the mobile device? How many messages will the user receive before completing the task? etc.).

- Satisfaction usually is self-rated measures or qualitative comments done by test participants during usability testing.

For this project we can collect results and conduct the evaluation of the test result using composition of metrics proposed by U.S. Department of Health & Human Services [56]:

Table 13 Questions for metrics of evaluation for usability tests

Group of used metrics	Questions to be tracked	Explanation
Successful Task Completion	• Has the participant arrived from the entrance of the Bus station to the platform/bus? • Has the participant arrived from the entrance of the Bus station to the platform/bus through the ticket-office? • Has the participant arrived from the platform/bus to the exit of the Bus station? • Has the participant arrived from the entrance of the Bus station to the ticket-office?	Each scenario requires the participant to complete specific usebility test task with the use of the application. The scenario is successfully completed when the participant indicate they have completed the task goal. In some cases, multiple-choice questions have to be given to the participants.
Critical Errors	Questions for every task : • Could the participant to finish the task?	Critical errors are deviations at completion from the targets of the scenario.
Non-Critical Errors	For every task : Has the participant chosen the shortest/most efficient route?	Non-critical errors are errors that are recovered by the participant and do not result in the participant’s ability to successfully complete the task.

		These errors result in the task being completed less efficiently.
Error-Free Rate	For every task : How many participants could complete a task without without any errors?	Error-free rate is the percentage of test participants who complete the task without any errors (critical or non-critical errors).
Time On Task	Question for every task : How long has it taken for the participant to complete the task?	The amount of time it takes the participant to complete the task.
Subjective Measures	Quelstion to the participant after every task: Was it difficult for you to perform the task?	These evaluations are self-reported participant ratings for satisfaction, ease of use, ease of finding information, etc where participants rate the measure on a 5-point scale (Table 10).
Likes, Dislikes and Recommendations	Quelstion to the participant after performing all the tasks: • What have you liked about the app? • What you have not liked about the app? • Do you have any recommendations for improving the application?	Participants provide what they liked most about the app, what they liked least about the app, and recommendations for improving the application

5.4 Achievement of usability goals and reporting results

There are two goals for every task in this usability test:

- **100%** of test participants who successfully complete the task without critical errors.
- **80% of** test participants who complete the task without any errors (critical or non-critical errors). A non-critical error is an error that would not have an impact on the final output of the task but would result in the task being completed less efficiently.

If a participant requires assistance in order to achieve a correct output then the task should be considered as a critical error and the overall completion rate for the task will be affected.

In this project, two main factors characterizing usability (impact of the problem and frequency of the problem) are taken into account. For developing general conclusions of the Usability Test Problem Severity approach [20] can be implemented (but without "Persistence" in this case).

The approach treats problem severity as a combination of two factors - the impact of the problem and the frequency of users experiencing the problem during the evaluation.

Table 14 Impact Index for usability tests

Tracked metrics (Particular experience)	Indicator of Impact (Hertzum, 2006)	Impact Index
Successful Task Completion without any error	NoProblem	0
Non-Critical Errors	Minor	1
Critical Errors	Serious	2

Impact is assessed by indicating the percentage of users which have different experience:

$$Impact=\frac{\sum_{n}^{i} Impact\ Index\times n}{N}$$

Where N – general amount of participants in the test;

n - amount of participants with the particular experience;

i - particular experience.

So, for example, if we would have a task in which would participate 10 people, and 7 of them would have Successful Task Completion without any error, 2 would have non-critical errors, and 1 would have a critical error the Impact of the task would be the following:

$$\text{Example Impact}=\frac{0\times7+1\times2+2\times1}{10}=0{,}4$$

An impact can be any value between 0 and 1, with higher values indicating higher impact.

After Impact will be calculated for every task they are to be ranged. This approach will help to prioritize recommendations for further improvements.

Besides that, in our case, it is useful to calculate Impact separately for different groups of users (people with the degree of disablement visually impairment and people without visual disabilities)

The Usability Test Report must be provided at the conclusion of every usability test. It will consist of a report and/or a presentation of the results; evaluate the usability metrics against the goals, subjective evaluations, and specific usability problems and recommendations for resolution. The developed recommendations should be categorically sized to be helpful in implementation strategy.

Conclusions

In this thesis, we have developed a system which is based on the technology of iBeacon and can be considered as an application for one of the categories of people with special needs (visually impaired people).

Deployment of the iBeacon-based system in transport terminals can significantly improve interacting with passengers.

We also actually explain how to design and implement an efficient indoor navigation system inside the transport terminal. We have shown that significant mobility improvement is possible using iBeacon as the basis for the navigation system.

According to the analysis, the proposed system is proven to be an effective solution to indoor navigation. Besides that it allows to provide low-cost free for users indoor navigation services.

We found that BLE is easy to deploy and also fits the lower energy consumption. On the other hand, the proposed system can be considered as a basis for indoor navigation in other transport terminals.

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