Moovers :A Mobile Indoor Positioning System based on Wi-Fi and Bluetooth Technologies

by

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Abstract

Abstract-Due to the lack of accuracy and robustness, Indoor Positioning System has now become a major with huge concerns worldwide especially with the rapid increase in multimedia services and data. Therefore, there is a need to enhance the accuracy of indoor localization by exploiting the capability of the available technologies. In this paper, a hybrid indoor localization system that is based on Wi-Fi and Bluetooth Low Energy (BLE) communication technologies is proposed. The main infrastructure of the proposed system is to use Wi-Fi tritleration method to determine the position of users at indoor areas based on Wi-Fi signal strengths. Then, the position obtained by the Wi-Fi tritleration method is used to check whether the user exists within one of the indoor locations supported by BLE or not. This enables the localization process with beacons to get higher indoor positioning accuracy than Wi-Fi. Experimental results show that the proposed system can achieve average error of less than one meter compared with the existing indoor positioning systems. This vindicates the suitability and reliability of the proposed system.
Keywords: Indoor positioning, Localization, Wi-Fi trilateration, Beacons

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Chapter 1

Introduction

1.1 Introduction

1.1.1 background

The Bluetooth and Wi-Fi devices has become of extreme benefit when it comes to Indoor Positioning System (IPS). IPS may be used in malls, universities and hypermarkets maps, so it is commercially wanted[1]. Many people spend most of their time in indoor places, so service related indoor environment become increasingly important and global LBS market also grow [2]..most of the recent IPS systems have problem issues with accuracy. As GPS is used outdoor and gives high accuracy however its not suitable to be used indoor due to the strength of satellite signals is very poor.IPS generally needs two components, The hardware that produces signals and a device(user) which needs to know the location.As GPS can't be reliable due to low precision, IPSes used Bluetooth and WIFI.Many approaches are used in indoor localization such as Time of arrival (TOA) , Received signal strength(RSS),Angle of arrival (AOA) and fingerprint.In this project we will work on improving the accuracy of IPS that can be combined with many market applications that can provide a smooth user experience indoor and provide many services to the client to determine the indoor location precisely and support their users with services making it easier for them to perform any required task in a matter of no time.

1.1.2 Motivation

The main goal of our system is to raise the accuracy of indoor positioning systems by using BLE beacons.Challenges that are taken into consideration along with the accuracy is minimizing the cost of such a system. Some of the implemented similar systems to our proposed project have faced challenges while implementing such as identifying the exact location, deflection of accuracy due to some obstacles.These obstacles are represented in walls inside the room and some human behaviour that influence the propagation path of the real signal of APs, which cause the received signal strength indicator(RSSI) increasing/decreasing instantly[3].

1.1.3 Problem Definitions

Enhancing the accuracy of Indoor localization that can be integrated with many market applications to offer several services to world-wide clients and users.

1.2 Project Description

Developing an indoor positioning system with the aid of external hardware and several algorithms to achieve best locating results and improve locating accuracy.

1.2.1 Objective

The aim is to reach the best accuracy results in IPS (Indoor positioning Systems). Indoor position system provides the positioning service to the indoor users, where the GPS coverage is not available. The challenges for most signal-based indoor positioning systems are the unpredictable signal propagation caused by the complex building interiors, and the dynamic of the environment caused by the peoples' movements. It faces noisy indoors the most which is crucial in such environment. Our main objective is to improve the accuracy of IPS facing the obstacles in intelligence way by using multiple techniques and algorithms.

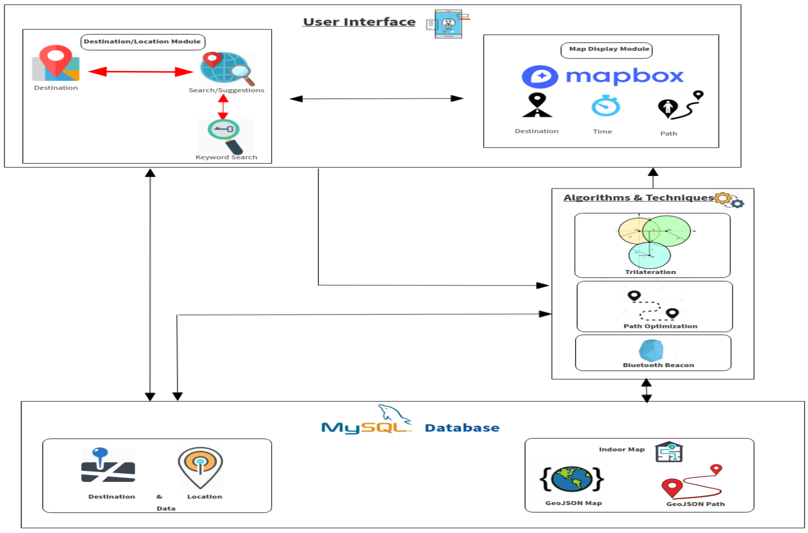


FIGURE 1.1: System Overview

1.2.2 scope

1. System will be able to scan for WIFI AP's and BLE Beacons.
2. System will be able to collect fingerprint RSSI values from both AP's and Beacons.
3. System will include Google maps to show the buildings in which beacons are set to be provided by IPS system.
4. The user will be able to draw the buildings floor-plan within the system.
5. User mark POI's in floor-plans.
6. System will show notifications based on the user certain location.
7. System will show configuration details of beacons AP's.
8. System can track people inside a certain building.
9. System will integrate between both WIFI and Bluetooth to achieve high accuracy.

1.2.3 project overview

The proposed system is an indoor positioning system.Our system consists of three components:

The user interface,algorithms, techniques, and database. The user interface consists of a destination list module and a map module which allows the user to input or search for his desired destinations and view the map respectively.The search results access the trilateration technique in order to locate the user indoor location then allow him to put his desired destination and this data is processed by path optimization algorithms in order to give a shortest path to the user from his indoor location to the destination. The database component contains destination information and Indoor floor plan modules. The saved info modules interact with the keyword search by gathering the destination information and their respective location. The Indoor floor plan modules provide information to the path optimization algorithm to generate maps and locations of products.

1.3 Similar system information

WLAN Based Real Time Indoor Positioning: Literature Survey and Experimental Investigations[4]. The motivation of this paper is to reduce the cost of developing IPS. The paper shows that several technologies were developed for only indoor localization purposes. However, currently, they are not commonly used due to their cost and performance. So if a low-cost and relatively high-performance location determination technology is developed; it will have the potential to be used widely and it can become a popular way of localization. So compared to the other indoor positioning techniques, wireless systems are easier and cheaper taking into account that many buildings and structures have an existing WLAN infrastructure. The problem is achieving high accuracy and low coast are hard to be combined together. The researchers solved the problem by introducing wireless localization techniques. The main result they reached is combining wireless Localization Techniques, Localization Methods Using WLAN, Fingerprinting Approach, K-Nearest Neighbors, Bayesian Classification, RF Propagation Loss Models, Multilateration and The Kalman Filter. Reading this was important to me as it shows how to balance between accuracy and low coast while considering the complexity and robustness.

Indoor Positioning Based on Experimental Space Segmentation Method [5]. The motivation of this paper is developing an easy and simple approach without any additional hardware. The problem is reaching satisfying accuracy results. The researchers solved this problem by presenting a kind of segmentation method, named experimental space segmentation. The main results they reached that they proposed an experiment in real WLAN environment indicate that the proposed methods lead to improvement in the accuracy. This paper was useful because it is simple, easy to implement and doesnt require any hardware.

Design and Implementation of Indoor Postioning System Based on IBeacon[6] With increase in data and multimedia services, demand for locating has increased in complex indoor surroundings, which needs to determine the location information of the mobile terminal. The goal of this paper is to design and implement a mobile-based indoor location system.The lack of accuracy and the weak signals from I-Beacon devices in current indoor positioning system.They design and implements an indoor positioning system based on I-Beacon with the algorithm based on Euclidean geometry distance with combination of Gaussian function and unscented Kalman filter, these two are used to determine the maximum value at the RSSI, it can efficiently solve the problem of signal propagation, affected by interference.The results the researchers reach. Among these, the ratio between the drawings and the actual distance, the actual average error is 2.5 times then average measurement error. The average location error of the indoor location algorithm was only within 4 meters, the walls and barriers in the tracking surroundings might affect this result, the algorithm has strong real-time positioning and robustness.The combination of euclidean distance, Gaussian function and Kalman filter helped to lower the accuracy rate only within 4 meters. The System is dependable enough to locate the current location of the user and can overcome the constraints indoor positioning system environment the algorithm has strong real-time positioning and robustness.

A Mobile Indoor Positioning System Based on iBeacon Technology[7] The goal of this research is to implement a mobile-based indoor positioning system using mobile applications (APP) with the iBeacon solution based on the Bluetooth Low Energy (BLE) technology.The system is developed for the need for medical stuff to track the locations of their patients.the hospital emergency room overcrowding is common in countries around the world Because of the limitation of human resources and beds, patients will undoubtedly spend a lot of time waiting. While the patients are waiting, their locations are always not fixed as they might move around in the hospital, so the medical staff might spend much time to find them.An application is installed on the patients mobile device after they are registered. The application automatically recognizes in the background the BLE signal then these RSSI is utilized by the mobile application and selects the nearest beacon and uploads the beacon information on the system server. Furthermore, the patients real-time location is estimated on the based on the detected Ibeacon signal and the beacon location mapping table stored on the server side. The medical staff, which are the monitoring side, can access patients locations through web browsers or mobile devices. Thus the medical stuff can track the locations of their patients.The proposed system achieved 97.22 accuracy of the locations classification. The error prediction is estimated to the adjacent subarea within 5 meters that might be affected by the obstacles and walls in the tracking areas.This paper helped us to understand more about localization systems that uses Bluetooth low energy to enhance indoor positioning systems which is cost effective and easy-to-deploy solution.

Indoor Wi-Fi Positioning System for Android-based Smart phone[8] To propose a a personal indoor/outdoor WPS system on the smart phone using RSS(received signal strength) of signals from dense Wi-Fi access points dedicated for localization.The Wi-Fi signals provide a low precision for tracking the locations. Therefore in order to to acquire more accurate location of the target, Wi-Fi Aps dedicated for localization should be installed in the target area.RSS from each AP is measured three times and the mean value of three RSSs is calculated. We use the difference between the mean value and each training value. If the difference is below a threshold (T), the training value is withdrawn and then the mean of filtered training values is calculated again. Finally, the mean value is compared with the value of database and a proper location on the map is found.When displaying the smart phone at a certain cell, the color of cell is changed to white. The number indicated in the cell means the cell ID. Installed APs dedicated for localization at specific locations can improve the positioning accuracy .New algorithms such as Kalman is used to filter errors and noise from signals .A proper scan time and threshold is required to yield a lower error rate.

Indoor Bluetooth Positioning using RSSI and Triangulation Methods[9] To analyze general wireless technologies and RSS based Bluetooth positioning using mathematical models to analysis the relation between the RSS and the distance between two Bluetooth devices.Developing low cost and easy-to-deploy location aware applications. These applications can be used in many scenarios such as assets management, staff tracking, indoor tourist guiding in museums, train stations and airports.Three distance based algorithms are used for Bluetooth positioning: Least square Estimation, Three-border and Centroid method.These algorithms were analyzed to improve the positioning accuracy. Result analyses show that the RSS based triangulation positioning yields very good results.This paper helped us to compare between the different indoor positioning systems techniques such as WIFI and Bluetooth and to compare between the three algorithms Least Square estimation,Three-border and centroid and compare their different results when tested.

This paper[10] studies the indoor positioning system by using wireless Ethernet IEEE 802.11 (Wi-Fi). The aim of this study is to examine several aspects of location fingerprinting based indoor positioning that affect positioning accuracy. The main problem of this paper is to discover the aspects of the location and the impacts of human behavior on RSSI distribution that could affect the positioning accuracy. In this system, the software operates in two separated location-fingerprinting phases; the first phase is calibration phase (offline phase) and positioning phase (online phase). In calibration phase, the software has the following functionality: 1) load and view map of the building; 2) view list of all available APs and their current RSS in the current position; 3) perform fingerprinting by tapping on the current position in the map. Functionality in the positioning phase: 1) load and view map of the building; 2) estimate position (inform of coordinates as well as a point on the loaded map). Then uses the weighted k-Nearest Neighbors algothrim to indicate nearest points by Calculate the Euclidean distance in the signal space, the estimated location q considered as average coordinates value of k nearest neighbors, which have minimum Euclidean distance. They applied a new algorithm to filter error signals and find the location of the smart phone. It acquires a proper scan time; the positioning accuracy achieved in the performed experiments is 2.0 to 2.5 meters. This paper is important because it is using the Wi-Fi signals which is easy to implement and requires low cost than other indoor positioning system.//

Beacon applications in information services[11]. The motivation of this paper; Beacon is regarded as an important development is that its micro-positioning function is more precise than GPS. The problem is, the acquisition of user location through the built-in GPS of the App is a common occurrence, but this positioning method puts the devices battery duration time on the line. When the user opens Google map to navigate, the user will notice the battery drops fast. The researchers solved this problem with the emergence of Beacon technology; users can continue to navigate without consuming too much energy. The main results is Beacon indoor positioning technology, applied in physical stores in the past could only obtain purchase records after checking out rather than purchase records during the purchase process. This paper was important to us as it shows the importance of beacons in indoor positioning system.//

Indoor Positioning System Using Wi-Fi Bluetooth Low Energy Technology,[12] Exploiting the feature of Wi-Fi signal detection from android smartphones, they built an app for user positioning in indoor environment. For testing purposes, we use pre-installed Wi-Fi access points and Beacon devices based on Bluetooth Low Energy (BLE) technology for indoor positioning at the department by using the classical RSSI based trilateration algorithm. They have developed an Android app for indoor positioning, which is based on RSSI measurements of Wi-Fi access points pre-installed in the department. They intend to export the system to BLE based technology using Estimote beacon devices (or Eddystones) in the similar way, and perform a comparative study between Wi-Fi and BLE technology for indoor positioning. They found that by using Wi-Fi: the accuracy comes out to be around 77.59 percent for x-coordinate and 88.41 percent for y-coordinate, and by using BLE technology: they got two coordinates in different scans first result, accuracy was 96.61 percent for x-coordinate and 66.10 percent for y-coordinate and for second result, accuracy was 81.5 percent for x-coordinate and 80.5 percent for y-coordinate. After averaging, accuracy is 89.10 percent for x-coordinate and 73.3 percent for y-coordinate.//

Applying Kriging Interpolation for Wi-Fi Fingerprinting based Indoor Positioning Systems [13] This paper focuses on the Wi-Fi fingerprinting method, and reports an improved IPS by combining spatial interpolation, k-nearest neighbor (KNN) and naive Bayes classifier (NBC). To be specific, the proposed IPS improves the fingerprint database, based on the site survey, an interpolation operation is included to automatically generate a certain number of interpolation points and associated fingerprints.in the offline phase. In the online phase, given real-time RSS measurements between a target and a fixed number of Wi-Fi APs, the target location is estimated by using the fingerprint database, NBC and WKNN. Extensive experiments are carried out in our lab, and show that the proposed IPS with 28 observation points is able to achieve the average positioning error of 1.265m, which is less by 46.6 percent than the counterparts of the traditional IPS with 28 observation points and is even comparable to the traditional IPS with 112 observation points

1.3.1 Similar System Description

Over the last years, indoor localization and navigation is becoming a hot topic. With the increasing number of buildings, there are many indoor positioning systems nowadays and each of them have a different accuracy, we aim to develop and get better accuracy. As mentioned in [6] their main problem was the lack of accuracy and the weak signals from the I-Beacon, they implement their system based on Euclidean geometry distance with combination of Gaussian function and unscented kalman filter, these algorithms determine the maximum value at the RSSI and solve the problem of the weak signals. This research will assist us in our proposed system to get clear and strong signals and ends the problem of signal propagation. Android Application for Wi-Fi based Indoor Position: System Design and Performance Analysis[10] is also an research studies the indoor positioning system but depend on Wireless Ethernet IEEE 802.11 (Wi-Fi) standard, their problem was to discover the aspects of the location and the impacts of human behavior on RSSI distribution that could affect the positioning accuracy, they divided the tested area by 20 cells with some Aps were installed. They uses location-fingerprinting phases; the first phase is calibration phase (offline phase) and positioning phase (online phase). In addition, the weighted k-Nearest Neighbors algothrim to indicate nearest points. They found that when increasing the number of AP expected accuracy rate increase remarkably. Applying Kriging Interpolation for Wi-Fi Fingerprinting based Indoor Positioning Systems[13], this paper, improves the Wi-Fi fingerprinting based IPS by efficiently combining the universal Kriging (UK) interpolation method, K nearest neighbor (KNN) and nave Bayes classifier (NBC). Specially, the proposed IPS takes into account the comprehensive features of received signal strengths (RSSs) by adopting the UK method and area partitioning, the average positioning error of 1.265m

Point of comparison	Algorithm used	Device used	Accuracy achieved	Average location error	Test points
DESIGN AND IMPLEMENTATION OF INDOOR POSITIONING SYSTEM BASED ON IBEACON	Euclidean geometry distance, and combined with Gaussian function and Unscented Kalman filter.	Bluetooth Low Energy technology based on the I-Beacon	Not mentioned	Within 1- 4 meters	15 different test points
Android Application for Wi-Fi based Indoor Position: System Design and Performance Analysis	K-NN and Euclidean geometry Distance	Wireless Ethernet IEEE 802.11 (Wi-Fi) standard	Not mentioned	2.0 to 2.5 meters.	The area is divided by 20 cells With some APs were installed
Proposed Project	Euclidean geometry distance, Gaussian function, Unscented Kalman filter.	Bluetooth Low Energy technology based on the I-Beacon	-	-	-

FIGURE 1.2: Related work comparison

📌	Enter Your deadline as start and end date	20/08/17	26/06/18
📌	Information gathering	20/08/17	30/08/17
📌	Survey and proposal	01/09/17	25/09/17
📌	Proposal Presentation	26/09/17	16/10/17
📌	SRS writing and presentation	17/10/17	10/11/17
📌	SDD writing and presentation	11/11/17	20/01/18
📌	Implementing GUI design	21/01/18	01/02/18
📌	Designing Database	02/02/18	15/02/18
📌	Implementing Application	16/02/18	31/05/18
📌	Validating and testing	01/06/18	25/06/18
📌	Final Presentation	26/06/18	26/06/18

FIGURE 1.3: Time plan Table.

1.3.2 Comparison with proposed project

1.4 Project Management And Deliverable

1.4.1 Tasks and Time Plan

1.4.2 Budget and Resource Costs

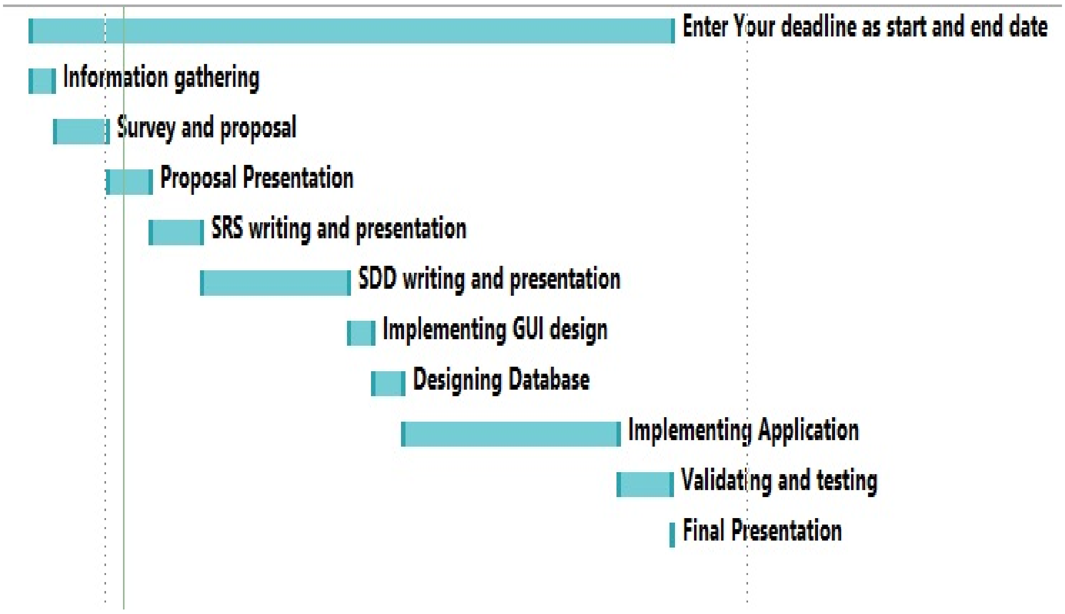


Figure 1.4: Gantt Chart.

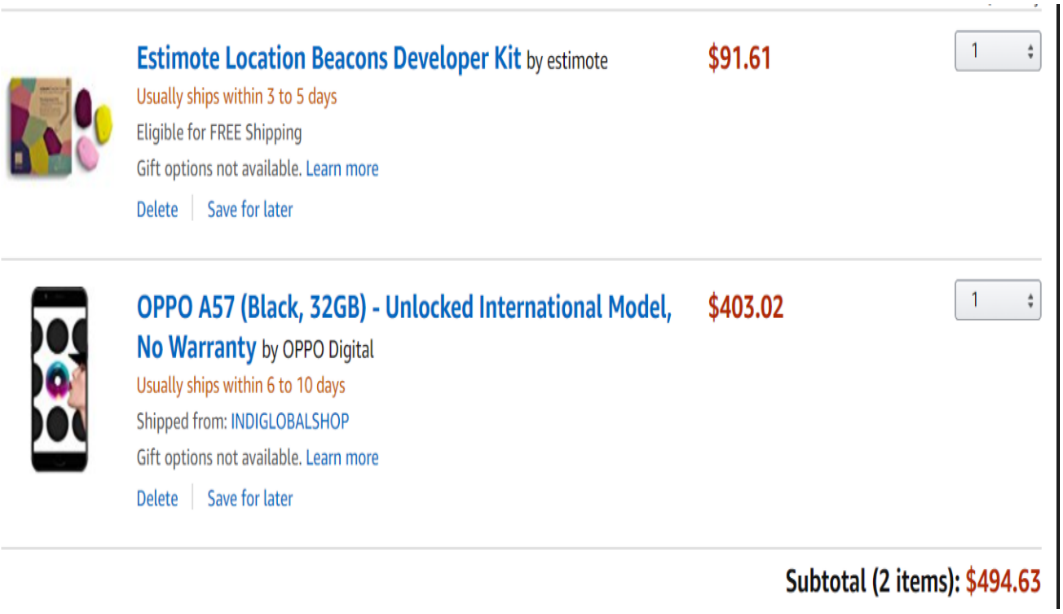


Figure 1.5: Budget

Chapter 2

System Requirements Specifications

2.1 Introduction

2.1.1 Purpose of this document

The purpose of this software specication document is to outline the requirements for IPS: detection of user position in an indoor place. It will consist of one mobile application accessible by any android phone and a web application independent and accessible with any standard compliant browser. This system will introduce the benefit of using Bluetooth beacon lowest average error and to enhance it by making use of the known indoor positions to make use of them in different fields.

2.1.2 Scope of this document

This document targets both users and business owners that would integrate their systems with the IPS system. It also may be helpful for designers and developers that may work on the IPS system in the future in many sectors.

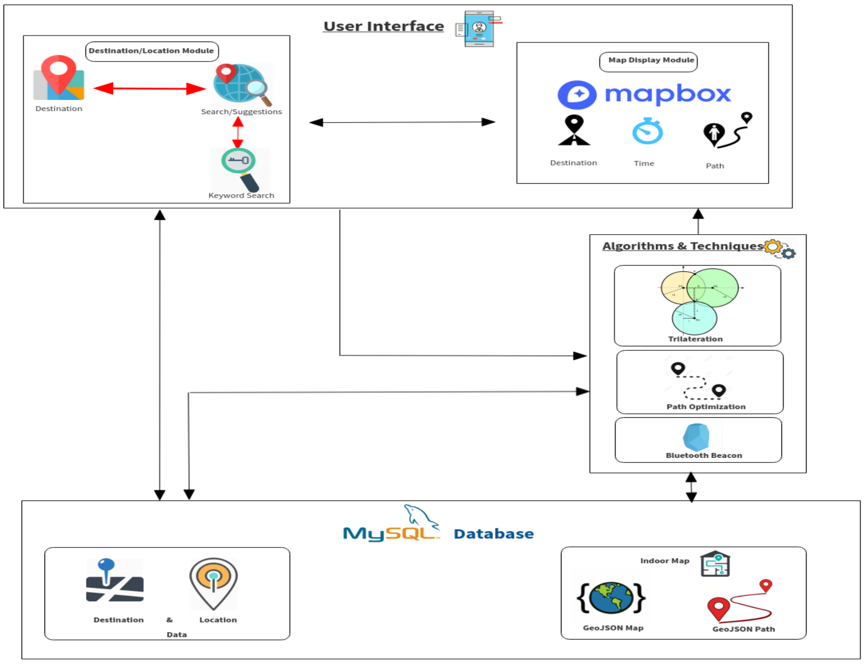


FIGURE 2.1: System Over View

2.1.3 Overview

There has been an upward trend in the requirement of indoor positioning systems as people spend a lot of time in indoor places, its a concern now for people and service providers to get exact indoor positioning information.Nowadays location predicated techniques are utilized in various fields such as traffic navigation, map accommodations, health-care ,manufacturing, and airports.There are many technologies to get indoor location information like Wifi,Bluetooth,Radio Frequency Identification.Regardless the importance of IPS there is no a standard principle for IPS techniques.Thus,this proposed project will focus on improving the performance of indoor positioning systems by enhancing its accuracy. This document introduces "Movers a mobile application that supports indoor localization which will help users to find their desired places faster and also find the shortest path to it. Movers will be focusing on improving the indoor localization by using both Wifi access points and Bluetooth beacons in order to achieve better accuracy that will be reflected to the customer while navigating.

Our system consists of three components:

The user interface,algorithms, techniques, and database. The user interface consists of a destination list module and a map module which allows the user to input or search for his desired destinations and view the map respectively.The search results access the trilateration technique in order to locate the user indoor location then allow him to put his desired destination and this data is processed by path optimization algorithms in order to give a shortest path to the user from his indoor location to the destination. The database component contains destination information and Indoor floor plan modules. The saved info modules interact with the keyword search by gathering the destination information and their respective location. The Indoor floor plan modules provide information to the path optimization algorithm to generate maps and locations of products.

2.1.4 Business Context

There has been an upward trend in the requirement of indoor positioning[1] systems as people spend a lot of time in indoor places, its a concern now for people and service providers to get exact indoor positioning information.Nowadays location predicated techniques are utilized in various fields such as traffic navigation, map accommodations, health-care ,manufacturing, and airports.There are many technologies to get indoor location information like Wifi,Bluetooth,Radio Frequency Identification. Regardless the importance of IPS there is no a standard principle for IPS techniques.Thus,this proposed project will focus on improving the performance of indoor positioning systems by enhancing its accuracy and which can be integrated with many various fields that are mentioned above.

2.2 General Description

2.2.1 Product Functions

Indoor Positioning System (IPS) will be used by a lot of sectors more than particular individuals[2]; it will be used in:

1. Hospitals and medical sector:
    - for patients including indoor navigation, reminders and services.

- for visitors including the building navigation and map of the place.
- tracking of mobile medical devices
- integration into hospital information system

2. Trade fairs and congresses:
   - Details about exhibitors, products and events based on navigation.
   - Inter-modal and parking information.
   - location exhibition stand staff.
3. Office:
   - For access control.
   - visitor and invitation management.
   - Asset tracking.
   - Support a facility of management.
   - It may support theft protection.
4. Parking:
   - optimization of occupancy rate through user navigation and reservation.
   - Car finder.
   - preparation for future changes in parking sector (autonomous mobility).
   - people will find free parking space faster.
5. Super markets and malls:
   - 2D/3D maps including shops,products,..etc.
   - Sales promotion at the POS (point of sale); (couponing, location based ads,push notifications).
6. Transportation:
   - passengers app including inter-modal traffic routing,delay alarm.
   - security relevant tracking, including alerts.
   - Location based marketing.
7. Industry:

- Asset tracking (forklift,goods,robots,..)
- Personal tracking.
- Definable alerts.
- Integration into existing ERP systems (enterprise resources planning Erp software).

2.2.2 Similar System Information

- Any place (Launched on the app store) [14].
- Hybrid Indoor Positioning With Wi-Fi and Bluetooth: Architecture and Performance.

2.2.3 User Characteristics

User: Must have basic knowledge in using Android mobile devices.

Admin: Must have good knowledge in using web applications to control the system and using android mobiles.

2.2.4 User Problem Statement

Enhancing the accuracy of Indoor localization that can be integrated with many market applications such as retail supermarkets to offer several services to world-wide clients and users.

2.2.5 User Objectives

The user objective is to have a guidance to make the user find his targeted destination in an optimal time. The application will have a user interface that contains a database with search suggestions that allow users to input destinations they want to reach. A map, with an optimal path and suggested time required to traverse path, will be displayed to guide the customer to retrieve their required destination.

1. Real time detection of indoor location.
2. Classifying the indoor position.
3. Interesting Pop up messages to view notifications.
4. Tracking users and recommending them.

2.2.6 General Constraints

1. Google Maps.
2. IPS accuracy (Real time update).
3. Easy navigation.
4. Business owners may provide their buildings with beacons.
5. Mobile application applicable for android mobile devices only.

2.3 Functional Requirements

2.3.1 User - class 1

2.3.1.1 FR1

-Title: Locate GPS.

-Description: The user locates himself globally and sees building location on map.

-Input: Users latitude and longitude

-Output: The user location on Google maps.

-Pre-conditions: None

-Post-condition: Screen updated with current user global position.

-Dependencies: None.

2.3.1.2 FR2

-Title: Search for building

-Description: user search for a certain building on Google maps.

-Action: Retrieves information about the building registered in the system from the database.

-Input: Building name

-Output: The building location on Google maps.

-Pre-conditions: Building registered in the system by the admin.

-Post-condition: Desired building shown on Google maps.

-Dependencies: FR15.

2.3.1.3 FR3

-Title: Load Floor plan

-Description: Load the floor plan of a desired building and load it to the users screen.

-Action: Retrieves the buildings floor plan registered in the system from the database.

-Input: Building location

-Output: View the floor plan

-Pre-conditions: Building registered and its respective floor plan uploaded by admin

-Post-condition: Desired Floor plan is loaded to the user from the database.

-Dependencies: FR1, FR19.

2.3.1.4 FR4

-Title: List Buildings

-DESC: List all Buildings that were added by the admin in the system.

-Input: Added building name.

-Action: Retrieves all added buildings in database.

-Output: view all added buildings.

-Pre-Condition: admin add building to the database.

-Post-Condition: list all building available.

-DEP: FR15.

2.3.1.5 FR5

-Title: Locate Indoor Position.

-DESC: Determines the users current indoor location in the building on the floor plan.

-Input: Sensors Readings.

-Action: Retrieves sensors readings registered in the system from the database.

-Output: Real-time estimated indoor position of user on floor plan as a point.

-Pre-condition: Floor plan loaded and sensors readings are recorded previously.

-Post-Condition: An indication on floor plan to current user position.

-DEP: FR1, FR3, FR9.

2.3.1.6 FR6

-Title: Start navigation

-DESC: Generate a route on floor plan between two POIs.

-Action: Two routes will be drawn between the starting point and the end point

-Input: POI1 (Start point) , POI2 (End Point).

-Output: Navigation starts and a guided route is drawn, and updated.

-Pre-condition: Building Floor plan saved in database with POIs added and sensors already available.

-Post-condition: generate a path route to the user from his indoor location or starting POI to his destination.

-DEP: FR5, FR19.

2.3.1.7 FR7

-Title: Search for destinations

-DESC: Search for the users destinations.

-Input: Name.

-Action: Views all rooms in the building.

-Output: List all rooms

-Pre-Condition: rooms saved and marked in the building

-Post-Condition: None.

-DEP: FR19.

2.3.1.8 FR8

-Title: Show notification

-DESC: Shows specific notification according to the specific user indoor location

-Action: Check Database for location and shows respective notification if available and notifies user.

-Input: User Position

-Output: A dialog is previewed to show notification.

-Pre-Condition: Notification setupped .

-Post-Condition: The screen is updated to the user to see notification.

-DEP: FR3.

2.3.1.9 FR9

-Title: load beacon map

-DESC: Load the beacon map of a desired room and load it to the users screen.

-Input: User indoor Location.

-Action: Retrieves the beacon map registered in the system from the database.

-Output:view beacon map of a certain room.

-Pre-Condition: the beacon map is loaded to the user .

-Post-Condition: Desired beacon map is loaded to the user from the database.

-DEP: FR10.

2.3.2 Admin - Class 2

2.3.2.1 FR10

-Title: Register Beacons.

-DESC: admin will register beacons to the room.

-Input: Beacon UUID.

-Action: Add beacon details.

-Output: Beacons Details added to database.

-Pre-Condition: Scan for Beacons.

-Post-Condition: Beacons are registered successfully and saved in database and assigned to a building.

-DEP: None.

2.3.2.2 FR11

-Title: Add notification

-DESC: Assigns notifications to the users or guests to the business site.

-Input: Name, Description, image, Mark on floor Plan (X and Y points on floor plan).

-Action: X and Y points on floor plan searched in database and respective notifications are retrieved.

-Output: Confirmation message or error message if something went wrong upon assigning the notification.

-Pre-Condition: the floor plan is loaded to the business owner.

-Post-Condition: Database is updated with new notification based on X and Y points on floor plan.

-DEP: FR20.

2.3.2.3 FR12

-Title: Delete notification

-DESC: delete notifications to the users or guests from the business site.

-Input: Name, Description, image, Mark on floor Plan (X and Y points on floor plan).

-Action: X and Y points on floor plan searched in database and respective notifications are deleted.

-Output: Confirmation message or error message if something went wrong upon deleting the notification.

-Pre-Condition: the floor plan is loaded.

-Post-Condition: Database is updated with new notification based on X and Y points on floor plan.

-DEP: FR11.

2.3.2.4 FR13

-Title: Edit notification

-DESC: Edit notifications of the users or guests from the business site.

-Input: Name, Description, image, Mark on floor Plan (X and Y points on floor plan).

-Action: X and Y points on floor plan searched in database and respective notifications are retrieved and edited.

-Output: Confirmation message or error message if something went wrong upon assigning the notification.

-Pre-Condition: the floor plan is loaded to the business owner.

-Post-Condition: Database is updated with new notification based on X and Y points on floor plan.

-DEP: FR11.

2.3.2.5 FR14

-Title: Locate GPS

-Description: The user locates himself and determine the building location.

-action: Retrieve latitude and longitude location from GPS and show it on Google maps.

-Input: Latitude, Longitude.

-Output: The user location on the GPS

Pre-conditions: None

-Post-condition: Get user GPS location on Google map.

-Dependencies: None

2.3.2.6 FR15

-Title: Add building.

-Description: Marks a building on Google map.

-action: Save buildings latitude and longitude on Google map.

-Input: Code, Name, Description, publicity, geojson file

-Output: Confirmation message or error message if something went wrong upon adding the building on the system.

-Pre-conditions: None.

-Post-condition: Building saved in database.

-Dependencies: None.

2.3.2.7 FR16

-Title: Delete building

-Description: Deletes a building on Google map.

-action: Deletes buildings latitude and longitude on Google map.

-Input: Building Name.

-Output: Confirmation message or error message if something went wrong upon deleting the building on the system.

-Pre-conditions: At least one building is registered in the database.

-Post-condition: changes are saved in database and on Google maps.

-Dependencies: FR15.

2.3.2.8 FR17

-Title: Edit building

-Description: Edit certain building on Google map.

-action: Edit buildings information such as: name, code, description or publicity.

-Input: Building Name.

-Output: Confirmation message or error message if something went wrong upon editing the building on the system.

-Pre-conditions: At least one building is registered in the database.

-Post-condition: changes are saved in the database.

-Dependencies: FR15.

2.3.2.9 FR18

-Title: List buildings

-Description: Shows all or a certain building on Google map.

-action: Retrieves information about the building registered in the system from the database.

-Input: Building Name. -Output: All buildings registered in the system and their information is previewed.

-Pre-conditions: At least one building is registered in the database.

-Post-condition: None.

-Dependencies: FR15.

2.3.2.10 FR19

-Title: Upload building Floor plan.

-Description: Upload floor plan for certain building for indoor localization.

-action: Save Floor plans of buildings that registered in the system to the database.

-Input: geojson file.

-Output: Confirmation message or error message if something went wrong upon uploading the floor plan of the building from the system.

-Pre-conditions: At least one building is registered in the database.

-Post-condition: Database updated with new buildings information.

-Dependencies: FR15.

2.3.2.11 FR20

-Title: Upload beacon map .

-Description: Upload beacon map for certain room for indoor localization.

-action: Save Floor plans of buildings that registered in the system to the database.

-Input: geojson file.

-Output: Confirmation message or error message if something went wrong upon uploading the floor plan of the building from the system.

-Pre-conditions: At least one building is registered in the database.

-Post-condition: Database updated with new buildings information.

-Dependencies: FR15, FR10.

2.4 Interface Requirements

2.4.1 User Interfaces

2.4.1.1 GUI

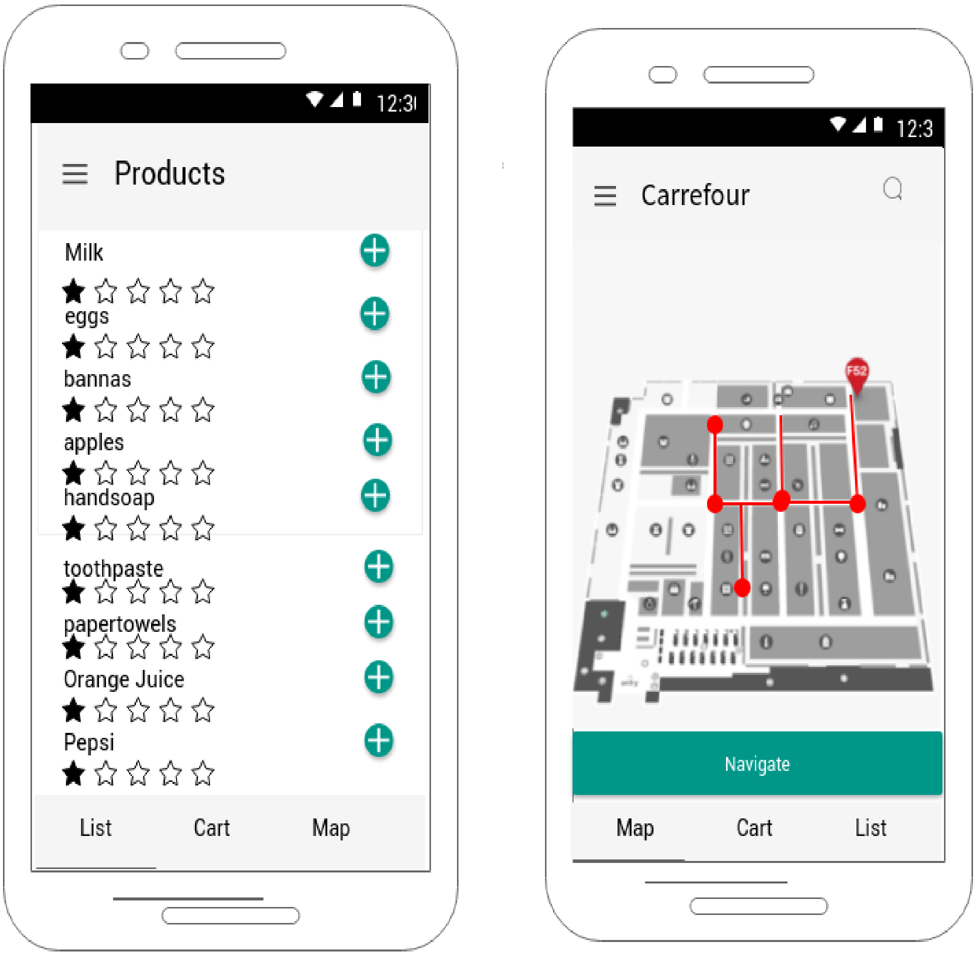


FIGURE 2.2: user GUI

2.4.1.2 API

1. Google Maps API
2. Estimote SDK

2.4.1.3 Diagnostics or ROM

Estimote Location Beacons:

1. Identification (Hardware revision):

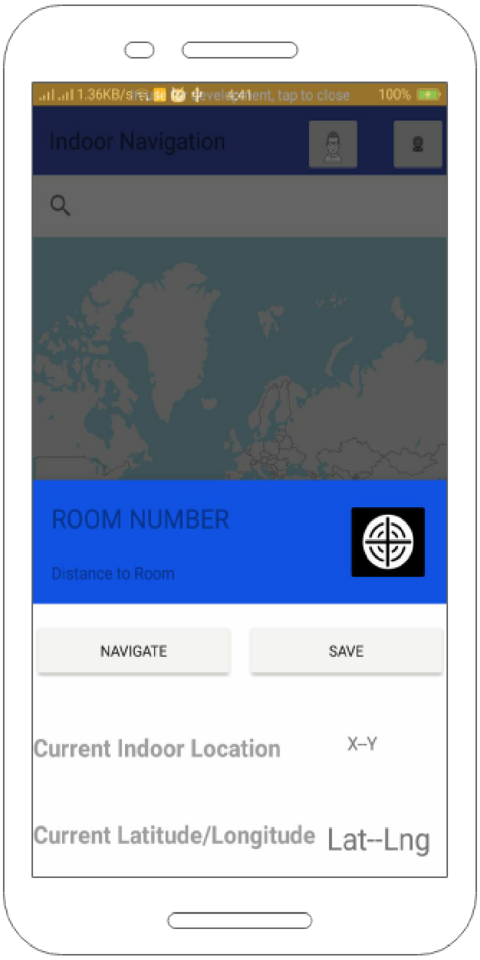


FIGURE 2.3: user GUI

- F3.3

2. MCU:

- Bluetooth SoC
- ARM Cortex-M4 32-bit processor with FPU
- 64 MHz Core speed
- 512 kB Flash memory
- 64 kB RAM memory

3. Radio: 2.4 GHz transceiver:

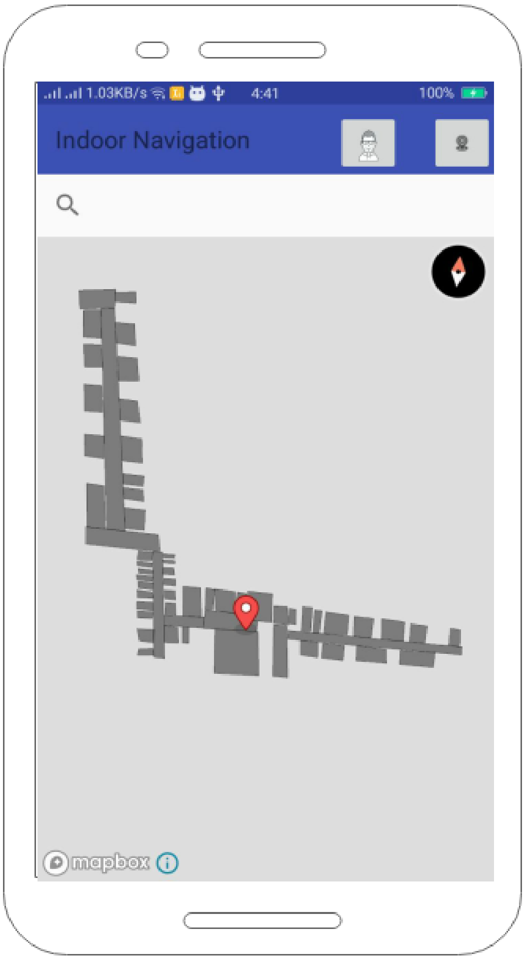


FIGURE 2.4: user GUI

- Bluetooth 4.2 LE standard
- Range: up to 200 meters (650 feet)
- Output Power: -20 to +4 dBm in 4 dB steps, Whisper mode -40 dBm, "Long range mode" +10 dBm

4. Sensitivity:

- -96 dBm
- Frequency range: 2400 MHz to 2483.5 MHz
- No. of channels: 40
- Adjacent channel separation: 2 MHz

- Modulation: GFSK (FHSS)
- Antenna: PCB Meander, Monopole
- Antenna Gain: 0 dBi Over-the-air data rate: 1 Mbps (2 Mbps supported)

5. Sensors:
   - Motion sensor (3-axis)
   - Temperature sensor
   - Ambient Light sensor
   - Magnetometer (3-axis)
   - Pressure sensor
   - EEPROM Memory 1 Mb
   - RTC clock
6. Additional features: GPIO NFC
7. Power Supply:
   - 4 x CR2477 3.0V lithium primary cell battery (replaceable)
   - High efficient Step-Down DC-DC converter
8. Environmental Specification: Operating Temperature:
   - 0C to 60C (32F to 140F)
   - Storage Temperature (recommended): 15C to 30C (59F to 86F)
   - Relative Humidity (operating): 20
   - Relative Humidity (storage): 10
9. Materials:
   - non-ammable
   - enclosure: silicone
   - adhesive layer: double-sided adhesive tape
10. Size and Weight:
    - Length: 62.7 mm (2.47 inches)

- Width: 41.2 mm (1.62 inches)
- Height: 23.6 mm (0.93 inches)
- Weight: 67g (2.36 ounces)

Signal characteristics and the way beacons communicate with mobile devices (received data [signals] from beacons): [15]

1. Broadcasting Power: Broadcasting Power (or Transmit Power) is the power with which the beacon broadcasts its signal. In Estimote Beacons, you can change it with the Estimote SDK, the Cloud interface, or the app. The value ranges from -40 dBm to +4 dBm.
2. Advertising Interval: Beacons do not broadcast constantly. They blink instead. Advertising Interval describes the time between each blink. Just as with Broadcasting Power, Advertising Interval on beacons can be adjusted with Estimote SDK, Cloud, and the app.
3. RSSI: RSSI stands for Received Signal Strength Indicator. It is the strength of the beacon's signal as seen on the receiving device, e.g. a smartphone. The signal strength depends on distance and Broadcasting Power value. At maximum Broadcasting Power (+4 dBm) the RSSI ranges from -26 (a few inches) to -100 (40-50 m distance).
4. Measured Power: Measured Power is a factory-calibrated, read-only constant which indicates what's the expected RSSI at a distance of 1 meter to the beacon. Combined with RSSI, it allows you to estimate the distance between the device and the beacon.
5. Proximity zones: allows you to establish your own proximity zones with a code and enable interactions when a user enters or leaves each zone.

2.4.2 Hardware Interfaces

1. Wifi Router

2. Estimote Location Beacons.

   A small location-based technology device that transmits a signal using Bluetooth Low Energy (range of up to 70 meters).

2.4.3 Communications Interfaces

2.5 Performance Requirements

- The system must be capabl of collecting different sensors readings (wifi and beacons)

-send and updates the indoor position

- The actual average error should be less than 1.5 meters.

2.6 Design Constraints

2.6.1 Standards Compliance

- Mobile smart phone that should be connected to Wi-Fi or Bluetooth to connect with beacons
- Wireless Ethernet IEEE 802.11 (Wi-Fi)
- BLE based technology using Estimote beacon devices

2.6.2 Hardware Limitations

- Wifi Routers should be used.
- Beacons may be used.
- Mobile phone should be android based.
- Mobile phone should support Bluetooth feature.
- Mobile phone must be connected on WIFI.
- Mobile phone may have inertial motion sensors.

2.7 Other non-functional attributes

2.7.1 Accuracy

-The whole system work is depended on accuracy. The system should provide high accuracy. It will determine the exact indoor location of the user, tracking employees in a system and start navigation between two points in a building.
-FR Dependent on this: FR1, FR5, FR14, FR6, FR9, FR19.

2.7.2 Performance and Speed:

-Description: The IPS must be interactive. Data sent such as users location needs to be sent with very high speed as it must be updated on real-time. Also its needed in order to upload the floor-plan of the building for the wanted building, show notifications to the user, and allow the business owner to track his employees with no delay. .
-FR Dependent on this: FR4, FR6, FR3, FR7, FR9, FR8, FR2.

2.7.3 Re-usability

-Description: The system is designed as component packages, that existing components could be reused in new applications. In the prepossessing the system can scan the signals of the Wi-Fi/beacons, the signal is added to filters to improve its accuracy to return RSS values to determine the users location; the system uses the GPS to locate the building location and to view the floor plan if exists.
-FR Dependent on this: FR1, FR3, FR5, FR34, FR41, FR36, FR15, FR19, FR8, FR11.

2.7.4 Maintainability

-Description: The system is designed in MVC design Pattern in order to make the least effort if any changes appeared in the future. As the MVC divides the system into three inter connected parts. This is done to separate internal representations of information from the ways information is presented to, and accepted from, the user. It allows for efficient code reuse and parallel development.

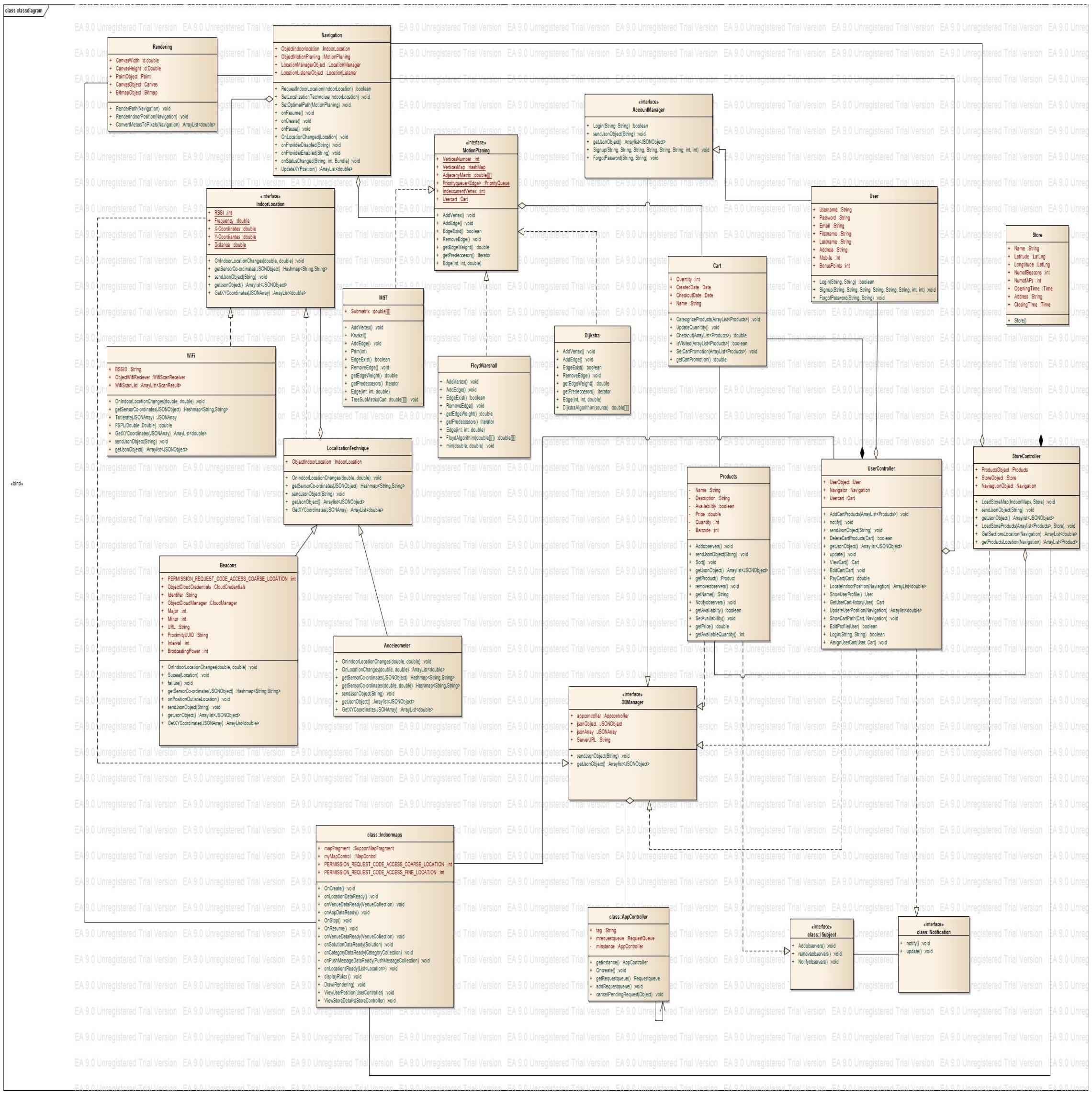


Figure 2.5: Class Diagram

FR Dependent on this: FR2, FR4, FR7, FR15, FR16, FR17, FR19, FR20.

2.8 Preliminary Object-Oriented Domain Analysis

2.8.1 Inheritance Relationships

2.8.2 Class descriptions

2.8.2.1 Class name

Building

Admin

sensors

2.8.2.2 List of Sub classes

Beacons

Floor

Indoor position

POI

2.8.2.3 interfaces

Motion Planning

2.8.2.4 Purpose

Building: Handles buildings info.

Admin: Handles all business owners and buildings in the system.

Sensors: Handles signals detection and classification to classify the indoor position.

Beacons: Handles beacons information and notifications.

Floor: Handles the floor-plan images of the building.

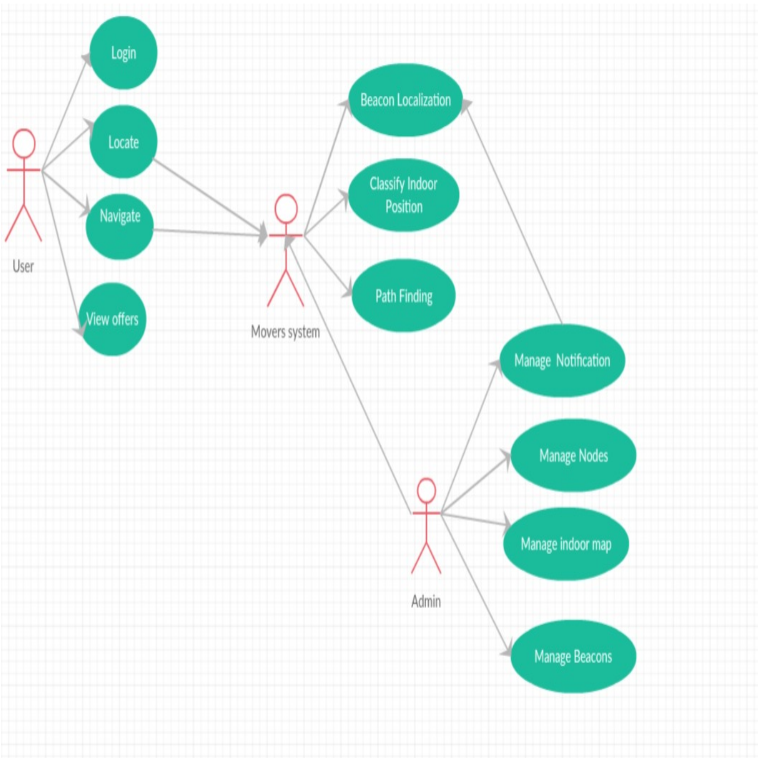
POI: A unique marker on the floor plan to indicate point of interests on certain indoor locations.

2.8.2.5 Collaborations

Sensors: is used by class buildings in order to indicate that each building has different sensors and is composed of indoor position class to indicate that each sensor has a specific indoor location.

Admin: Uses business controller and buildings controller in order to control the business owners and buildings in a system.

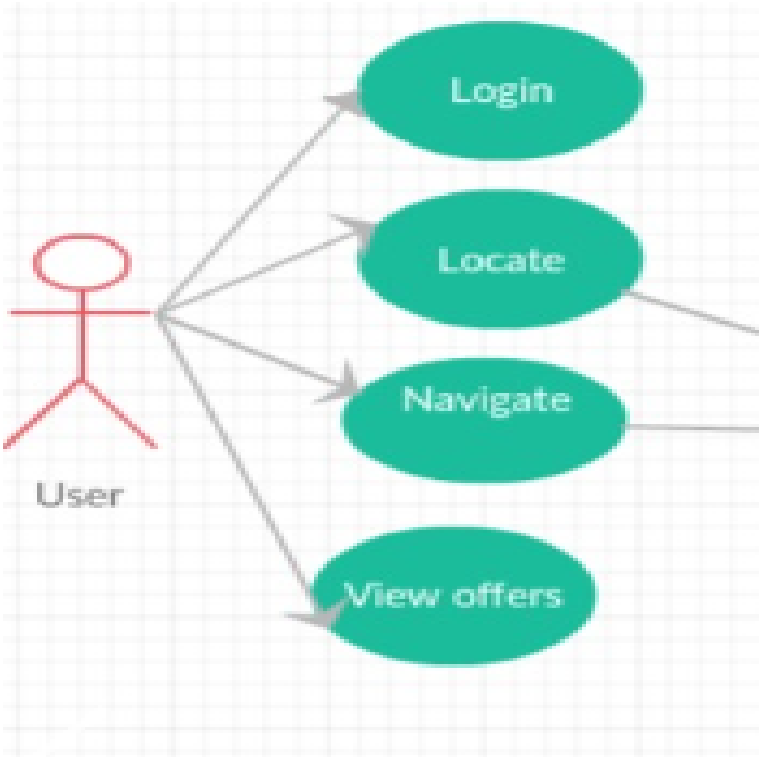
Floors: Has POI that indicates certain marker on certain floors.



2.8.3 Scenarios

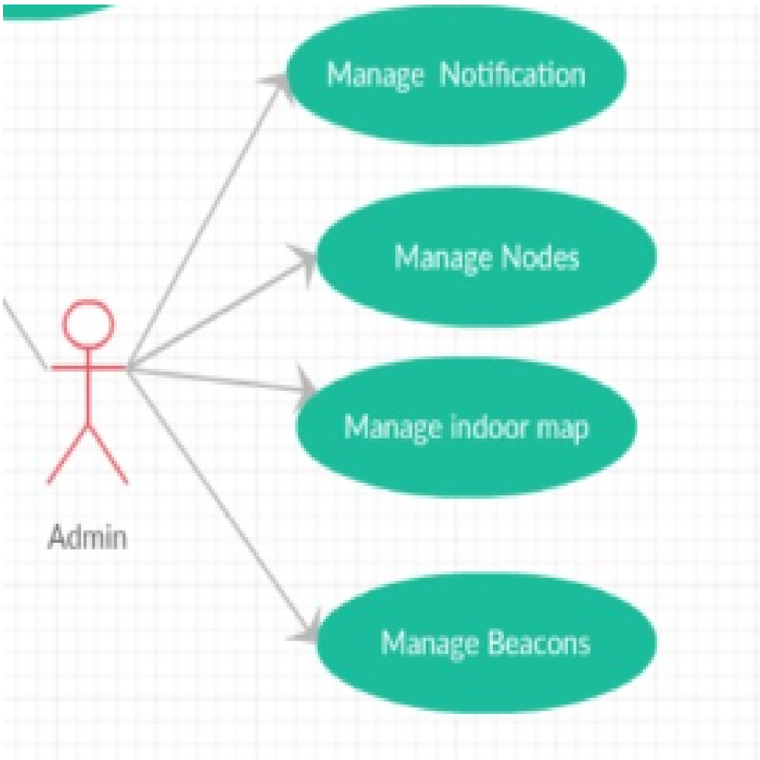
Here will be illustrated some of the scenarios that are shown in the systems use case diagram.

2.8.3.1 Scenario 1: User Locating Indoor position and Shopping



The user included this scenario is a normal user to the system. This scenario will allow the user to log in and then locate him self on Google maps using GPS location to find a respective indoor place near his global position,then accordingly the map of the indoor place will be loaded from the server and the indoor position will be updated on the map.The user then can start choosing his destinations and the system will optimize the shortest route for him to navigate inside the indoor place to assist him. The user may get notification shown on his device.Moreover when the user reaches his destination a beacon map will open if exists to allow the user to locate himself inside a room to enhance the accuracy.

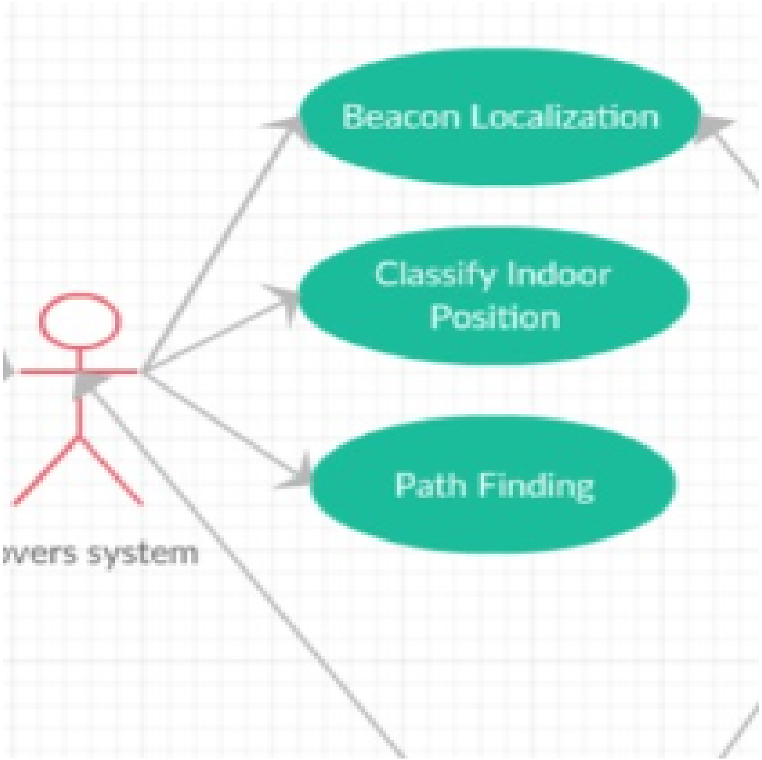
2.8.3.2 Scenario 2: Admin Controlling the system



The user included in this scenario is the admin. The admin is the one who controls the whole system, as he is going to do the following:

1. Add,edit,delete and list all the floor plan maps.
2. Managing the rooms position which will be placed on the nodes.
3. Add,edit,delete and list the stores.
4. Uploading at least one map for each indoor .
5. Add,edit,delete and list notifications that will be shown to the users.
6. Add,edit,delete,search and list all used beacons

2.8.3.3 Scenario 3 - Detecting and Classifying sensors reading to generate an indoor position



The system will detect the user indoor position by trilateration approach. This position will be displayed on the map that is visible to the user. As the user reaches a place has a beacon map the system will open the map and locate the user inside it that will enhance the accuracy. Moreover, the list of destinations that the user chooses will be optimized by an optimized shortest route that the user must follow in order to navigate reach his destinations. The proposed system will support the orientation of the user using IMU sensors.

2.9 Preliminary Schedule Adjusted

2.10 Preliminary Budget Adjusted

- COST: 4493 LE

	Enter Your deadline as start and end date	20/08/17	26/06/18
	Information gathering	20/08/17	30/08/17
	Survey and proposal	01/09/17	25/09/17
	Proposal Presentation	26/09/17	16/10/17
	SRS writing and presentation	17/10/17	10/11/17
	SDD writing and presentation	11/11/17	20/01/18
	Implementing GUI design	21/01/18	01/02/18
	Designing Database	02/02/18	15/02/18
	Implementing Application	16/02/18	31/05/18
	Validating and testing	01/06/18	25/06/18
	Final Presentation	26/06/18	26/06/18

FIGURE 2.6: Time plan Table.

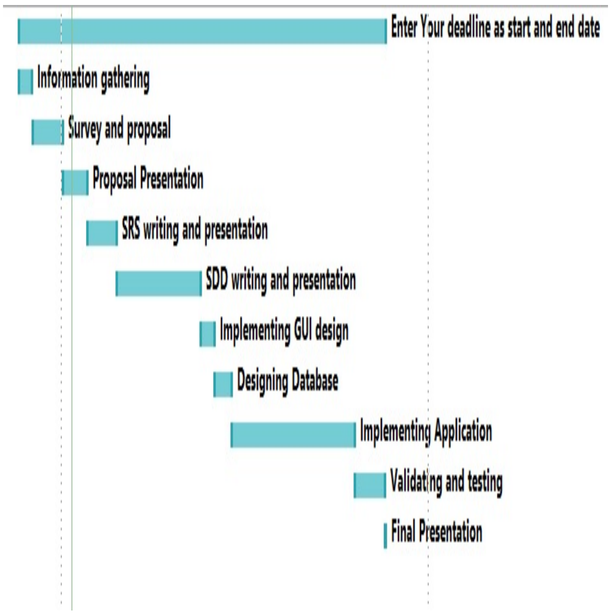


FIGURE 2.7: Gant chart.

2.11 Appendices

2.11.1 Definitions, Acronyms, Abbreviations

-Definitions:

- Bluetooth beacons: are hardware transmitters - a class of Bluetooth low energy (BLE) devices that broadcast their identifier to nearby portable electronic devices.

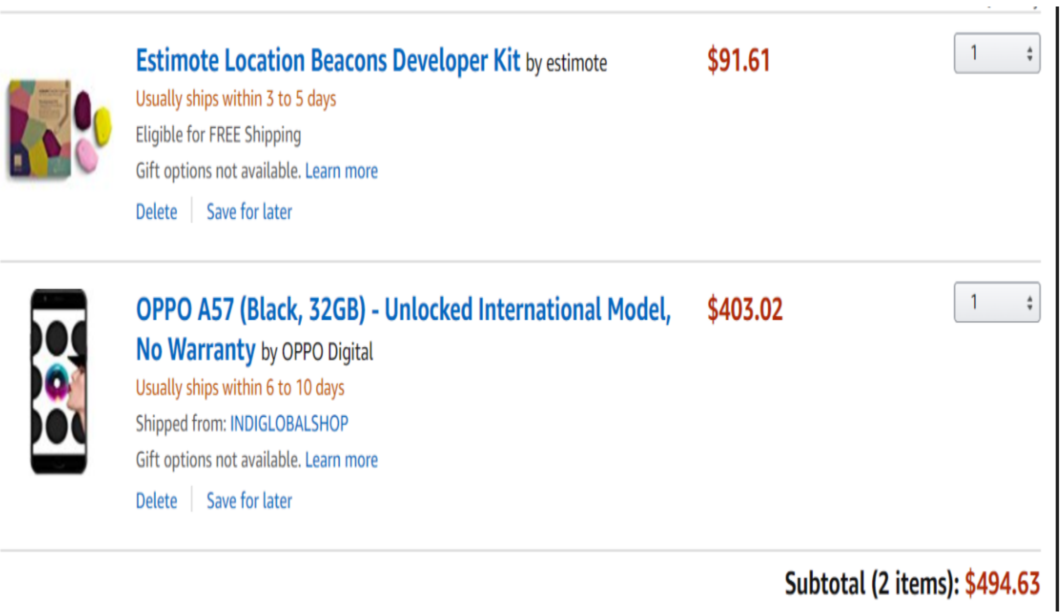


FIGURE 2.8: Budget

The technology enables smartphones, tablets and other devices to perform actions when in close proximity to a beacon.

- is about your apps detecting theyre near areas of interest.
- Indoor Location: a navigation system used inside venues such as airports, museums, shopping malls and hospitals. An indoor positioning system (IPS) is the indoor counterpart to the global positioning system.
- Android Studio: an integrated development environment (IDE) for Android platform development.

-Acronyms:

- IPS: indoor positioning system.
- RSSI: Received Signal Strength Indicator.
- UUID: Short for Universally Unique IDentifier, UUID is a 128-bit value used for identification used in software construction.
- MVC: Model View Controller Design Pattern.
- SDK: Software Development Kit.
- FR: functional Requirement.

- POI: point of interests.

2.11.2 Collected material

Chapter 3

Software Design Document

3.1 Introduction

3.1.1 Purpose

The purpose of this document is to describe the implementation of Movers system which is designed for indoor navigation inside different retail's worldwide.This software specification document highlight and defines the functional requirement and how they work in order to give a software development team overall guidance to the architecture and design of the system. [16]

3.1.2 Scope

The proposed system is an indoor positioning system within a supermarket using both Bluetooth and Wifi.A navigation system that can provide positioning functionality which is beneficial to both customers and supermarkets. A system that will reduce the amount of time spent shopping for groceries in a large retail store by guiding a customer through an optimal and shortest path to travel in order to obtain their needed products.Moreover, movers is designed to support real time tracking and classifies customers and products inside a retail in order to give best recommendations for daily clients and help in managing the product's promotions thus that would increase the marketing strategy of the retail through the facility of indoor positioning. [17]

3.1.3 Overview

There has been an upward trend in the requirement of indoor positioning systems as people spend a lot of time in indoor places, its a concern now for people and service providers to get exact indoor positioning information.Nowadays location predicated techniques are utilized in various fields such as traffic navigation, map accommodations, health-care ,manufacturing, and airports.There are many technologies to get indoor location information like Wifi,Bluetooth,Radio Frequency Identification.[18] Regardless the importance of IPS there is no a standard principle for IPS techniques.Thus,this proposed project will focus on improving the performance of indoor positioning systems by enhancing its accuracy.This document introduces ”Movers” a mobile application that supports indoor localization within different retails worldwide to give customers a better navigating while shopping in order to find their products faster,take advantages of offers, promotions and optimize their shopping time through the application. Movers will be focusing on improving the indoor localization by using both Wifi access points and Bluetooth beacons in order to achieve better accuracy that will be reflected to the customer while navigating. [**?**]

3.1.4 Definitions and Acronyms

1. Android Studio - An integrated development environment (IDE) for Android platform development.[19]
2. Google Maps API - and API that allows using the google maps functionality elsewhere.[20]
3. MySQL - an open source relational database management system (RDBMS) based on Structured Query Language (SQL).
4. IPS - Indoor Positioning System.
5. FloydWarshall - An algorithm for finding shortest paths in a weighted graph,single execution of the algorithm will find the lengths (summed weights) of the shortest paths between all pairs of vertices.
6. A* - Algorithm that is used in path-finding and graph traversal, the process of plotting an efficiently directed path between multiple points.[21]

7. Estimote Indoor Location SDK.: locate users precisely, watch their real-time position on a floorplan, collect attendance data, or deliver way-finding instructions

8. Estimote Location Beacons: They are the next generation of beacons with several improvements compared to Proximity Beacons, including multiple packets support, enhanced conditional broadcasting, GPIO support, support for Indoor Location SDK, and improved battery life (up to 7 years). They even have a long range, up to 200 meters. They are the way to go for more complex deployments when more precise location information is needed. [22]

3.2 System Overview

Our system consists of three components.The user interface,algorithms, techniques, and database.The user interface consists of a shopping list module and a map module which allows the user to input or search for his desired products and view the map respectively.The search results access the trilateration technique in order to locate the user indoor location and each product sections and this data is processed by path optimization algorithms in order to give a shortest path to the user from his indoor location to the product. The database component contains Retail's inventory and Retail's floor plan modules. The Retail's inventory modules interact with the keyword search by gathering the product information and their respective location. The Retail's floor plan modules provide information to the path optimization algorithm to generate maps and locations of products.[14]

3.3 System Architecture

3.3.1 Architectural Design

The architecture diagram is based on Modelviewcontroller (MVC) it divides an application into three interconnected parts.

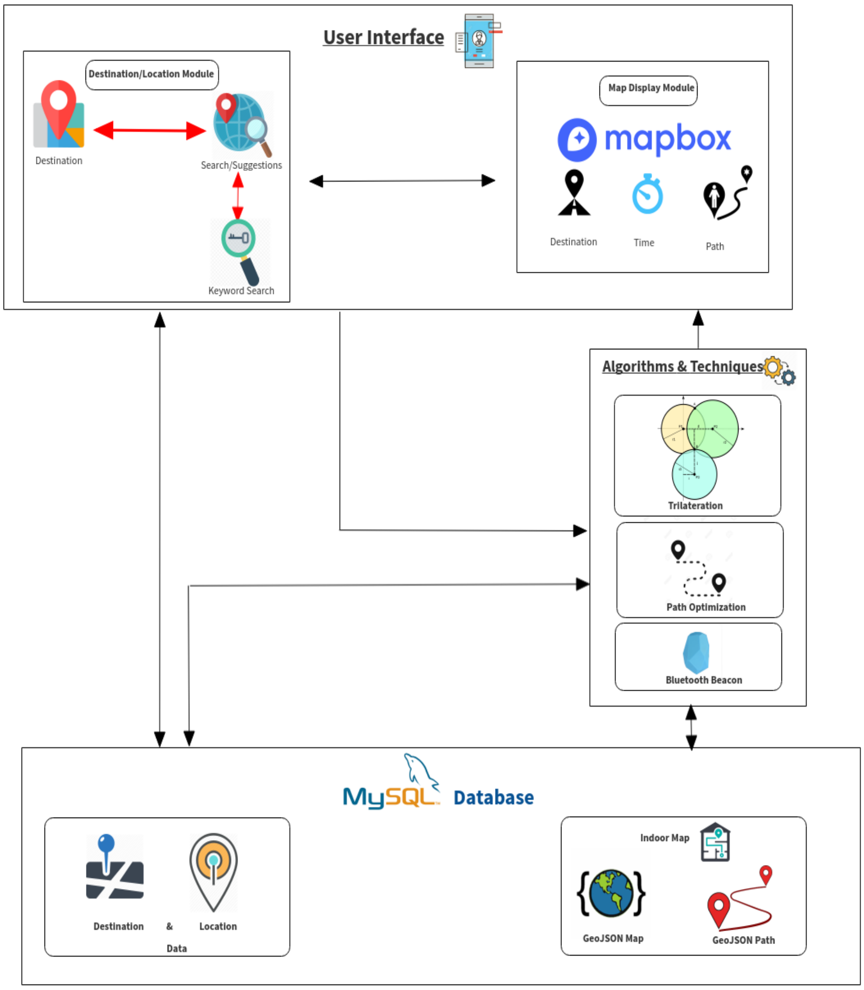


Figure 3.1: System Overview

3.3.1.1 View

A view is the representation of information,triggered by a controller's decision to present the data.It represents users interface here; it is divided into two interfaces. One is an admin web interface and one is mobile application interface for the user.

- Admin Interface: Consists of web screens that allow the admin to control the whole system:
  - Allow admin to login to the system.
  - Allows the admin to view the customers profiles to extract data from it to use it latter in products recommendations and offers.

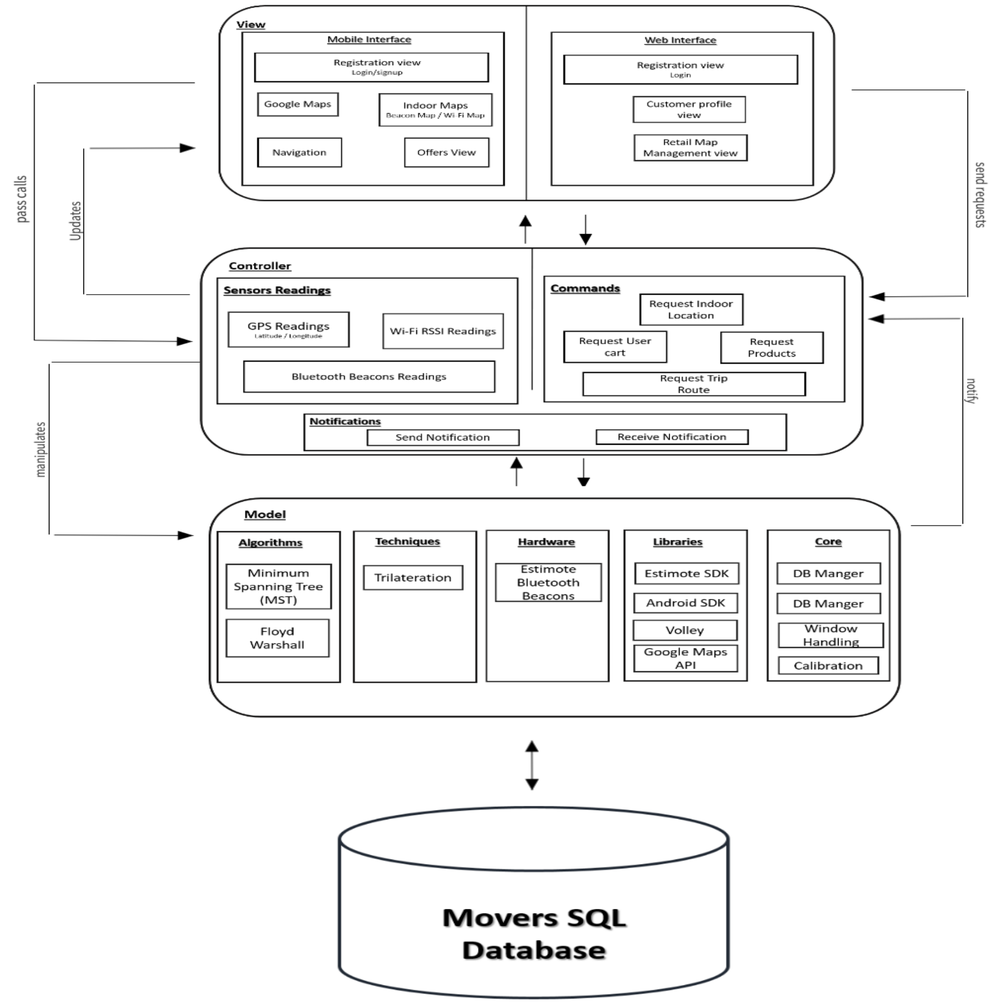


Figure 3.2: Architecture diagram

- View the indoor map (supermarket map) to track the user's position inside.
- View and control the retail map which shows the organization of products location in the supermarket in-case of any changes in the arrangement.
- Make the admin able of viewing a heat-map that shows places where crowd most centralize in the supermarket by customers.

- User Interface: Consists of android screens that:
  - Allows the user to sign-up/login.
  - Locate user's position globally.
  - Locate user's position inside the supermarket.

- User will choose his desired products.
- Help user to navigate through his products list in the minimized route.
- Provide him with products rating/recommendations based on his indoor location.

3.3.1.2 Model

The model is the central component of MVC pattern. It expresses the application's behavior in terms of the problem domain. It directly manages the data, logic and rules of the application.It is responsible for managing the data of the application by responding to the request from the view and, it also responds to instructions from the controller to update itself.

- Estimote SDK: it is the sdk of our used hardware device (estimote beacons) in order to use it in indoor localization to be presented on mobile app.
- Android SDK: Movers has an android based mobile application which is the users' interface; it is android platform, then it requires the Android SDK to be able to perform the functionalists on the android devices and use the sensors.
- Volley:it is used for interacting with the database.
- Google Maps API: Google Maps is a web mapping service developed by Google. It offers satellite imagery, street maps, 360 panoramic views of streets.

3.3.1.3 Controller

The controller accepts input and converts it to commands for the model or view, and it is responsible for responding to the user input and perform interactions on the data model objects, it also receives the input and validate it, then performs the operation that modifies the state of the data model.

The controller in Movers system combines between the model and the view, it handles the input data from the view that comes from the hardware devices like the WIFI RSSI reading and Bluetooth Beacons readings that is responsible to determine the user's indoor location, sends it to database and retrieves data from model and sends it to the view to preview the user indoor location and the shortest path.

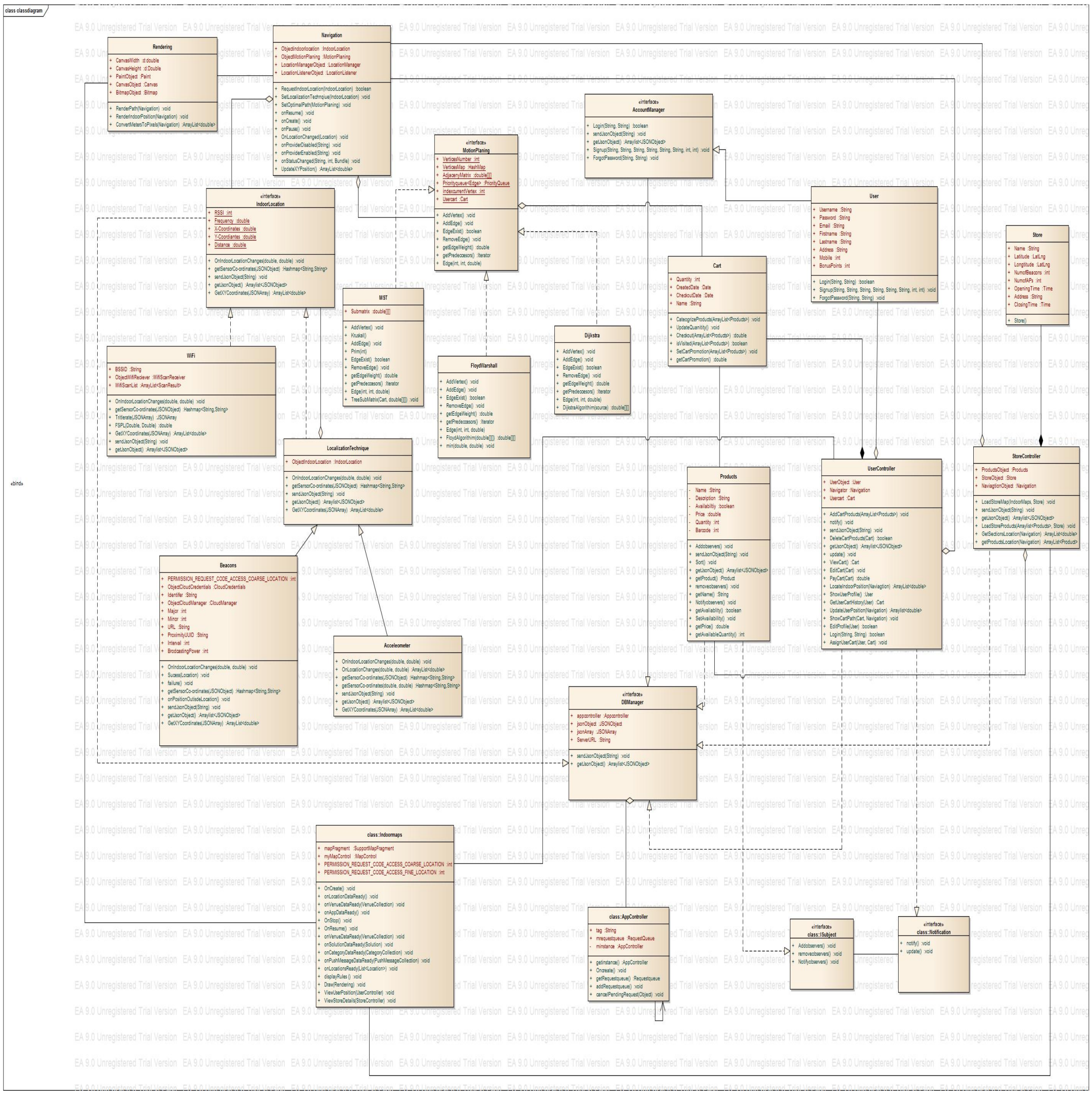


FIGURE 3.3: class diagram

3.3.2 Decomposition Description

3.3.2.1 class Diagram

3.3.3 Sequence Diagrams

3.3.3.1 Activity Diagram

3.3.4 Design Rationale

Since Movers is based on MVC, its architecture diagram is in the MVC form. MVC is the separation of Model, View and Controller classes. Main advantage of MVC architecture

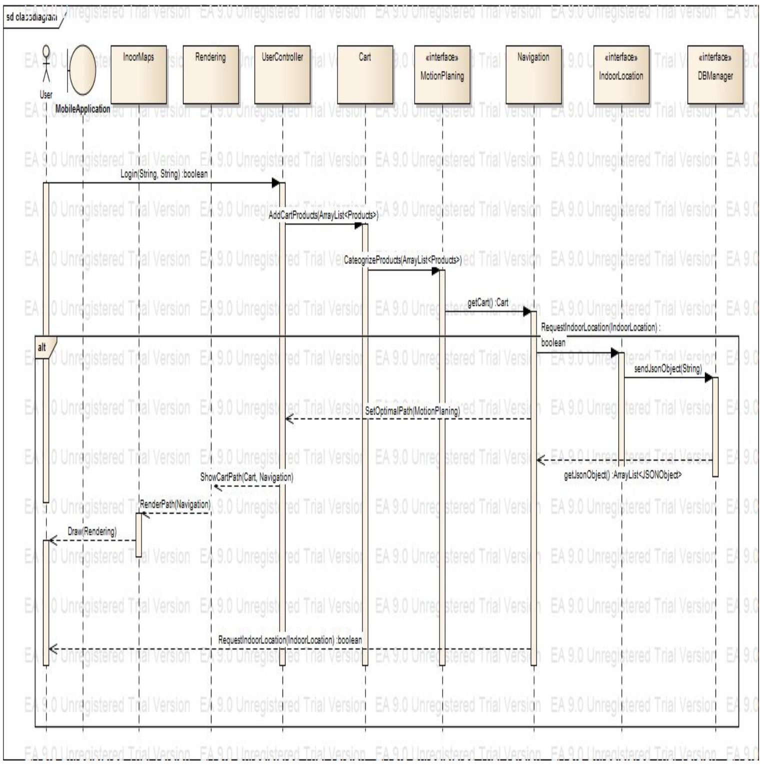


FIGURE 3.4: MotionSequence

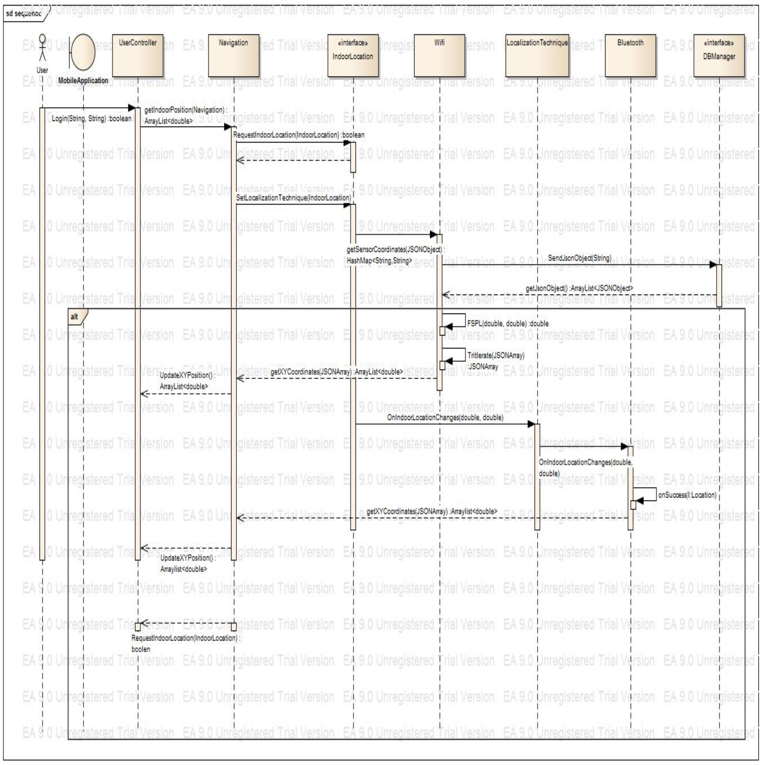


FIGURE 3.5: LocatingSequence

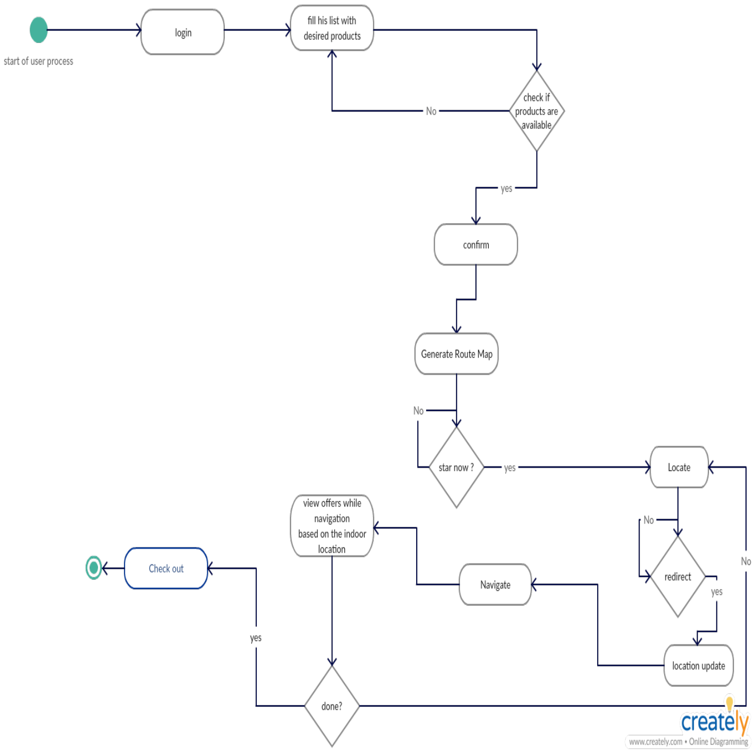


Figure 3.6: ActivityDiagram

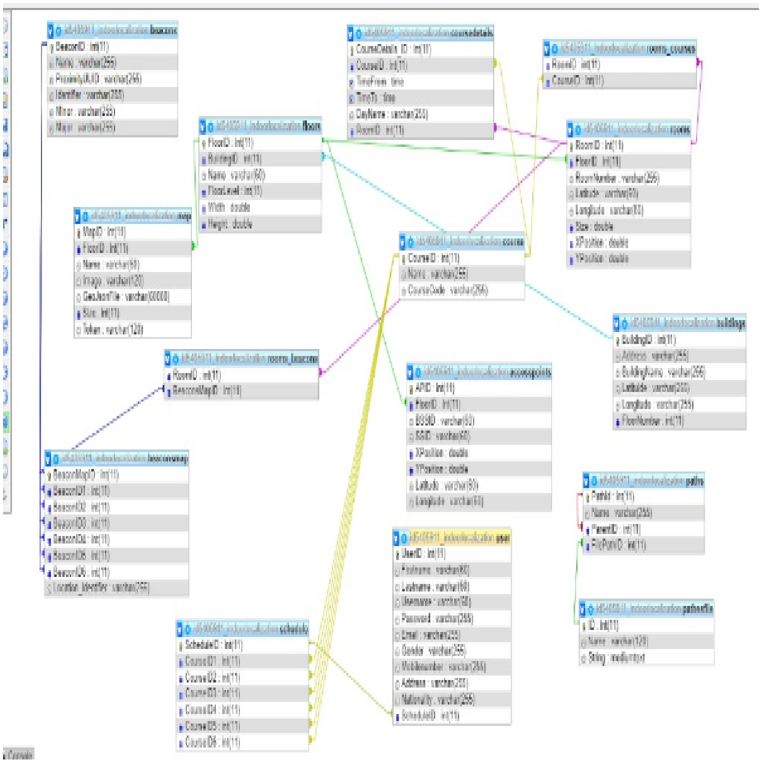


Figure 3.7: DataBase

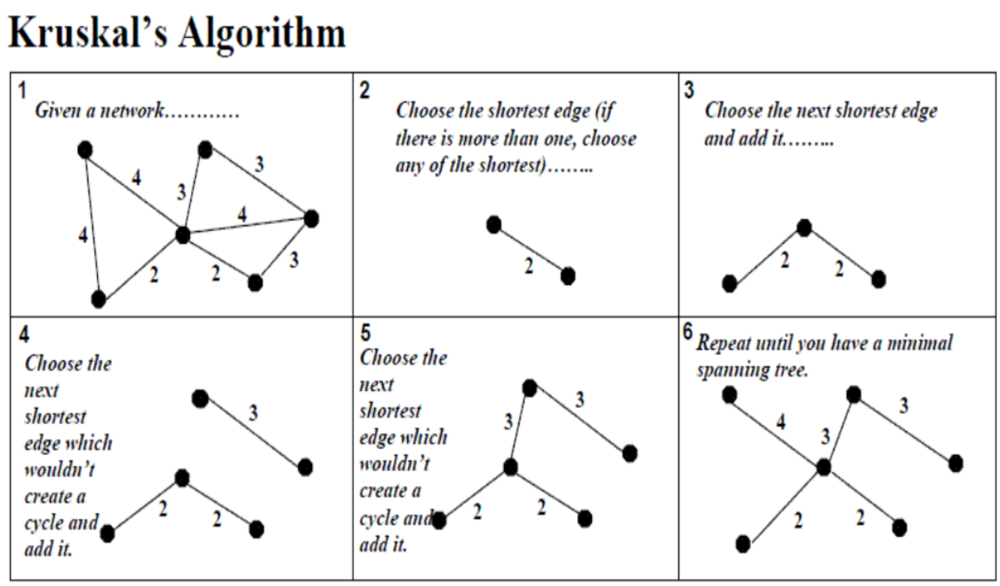


Figure 3.8: kruskal

is differentiating the layers of a project in Model,View and Controller for the Re-usability of code and better maintenance.[23]

3.4 Component design

3.4.1 Navigation Route Algorithms

3.4.1.1 A minimum spanning tree (MST)

A minimum spanning tree (MST) or minimum weight spanning tree is a subset of the edges of a connected, edge-weighted (un)directed graph that connects all the vertices together, without any cycles and with the minimum possible total edge weight. That is, it is a spanning tree whose sum of edge weights is as small as possible. More generally, any edge-weighted undirected graph (not necessarily connected) has a minimum spanning forest, which is a union of the minimum spanning trees for its connected components. Movers will use MST in order to find a navigation route along certain path which will be based on customer product list as the MST is the optimal solution to make the customer pass by all sections in the customers desired product list; there will be graph representing (sections of products) connected by this path to represent all sections.[24]

3.4.1.2 Floyd - Warhall

The Floyd-Warshall is an algorithm for finding shortest paths between a weighted graph with high-quality weights. Floyd-Warshall computes the shortest distances among each pair of vertices among the entered graph. The algorithm relies on the principle of dynamic programming; all possible paths between pairs of nodes are being compared and only keeps the shortest path found shortest Path (i, j, k) = min (shortest Path (i, j, k), shortest Path (i, k + 1, k) + shortest Path (k + 1, j, k)). Movers will use Floyd Warhall to find navigation route in pairs from a single source node to a single destination. [25]

- Movers will use two algorithms for path finding; the minimal spanning tree to find the optimal route which will pass by all sections in the customers list. Dijkstra will be used to find the rout between products in its section.
- For example, MST is responsible for finding route between (Frozen, beverages, electronics, dairy and cereals) sections but Floyd is responsible for finding route between soda, water and juice in the beverages section.

3.4.2 Trilateration

We have chosen the tritleration technique to be able to locate a certain device in an indoor location.Trilateration method is used to determine the relative location of user by measuring distances using geometry.The distances are calculated using various signal measurement techniques such as Received Signal Strength(RSS), Time of Arrival (ToA), Time Difference of Arrival(TDoA).Atleast three wifi Aps are needed to form a circle equation:

$$(x - a_1)^2 + (y - b_1)^2 = r_1^2 \tag{3.1}$$

$$(x - a_2)^2 + (y - b_2)^2 = r_2^2 \tag{3.2}$$

$$(x - a_3)^2 + (y - b_3)^2 = r_3^2 \tag{3.3}$$

Subtracting three circles would give a linear equation which crosses their intersections in one point.Calculating the intersection of three of these linear equations gives the X value of the devices position in between the access points.Additionally this value can then be inserted in one of two linear equations to get the corresponding y-value.

$$x = \frac{[r_2^2 + a_1^2 + b_1^2 - r_1^2 - a_2^2 - b_2^2 - 2(b_1 - b_2)y]}{2(a_1 - a_2)} \tag{3.4}$$

y=

$$\left[\frac{(a_2 - a_1)(a_3^2 + b_3^2 - r_3^2) + (a_1 - a_3)(a_2^2 + b_2^2 - r_2^2) + (a_3 - a_2)(a_1^2 + b_1^2 - r_1^2)}{2[b_3(a_2 - a_1) + b_2(a_1 - a_3) + b_1(a_3 - a_2)]}\right] \tag{3.5}$$

The Trilateration technique is used in our system to locate users inside the retail.To give an enhanced accuracy of our indoor positioning system it supports the use of Bluetooth beacons between two shelves to give a better navigation experience to the user and navigate him to the certain destination that he chose. Here are the results below while testing and which showed that using Bluetooth and Wifi gives better accuracy. [26]

3.4.3 Estimote Location Bluetooth Beacons

Indoor Location is about replicating the GPS technology, but indoors, where theres no satellite coverage. Put up a whole bunch of Location Beacons throughout the space, and they will automatically map it out and create a floor plancourtesy of the UWB radio theyre equipped with, and Estimote Automapping technology. Android apps gain access to precise indoor (x,y) coordinates of the device. [**?**]

3.5 Human Interface Design

3.5.1 Overview of User Interface

Since there is a web interface for the admin, and an android based mobile application for the user; therefore, we have two different user interfaces.

- Admin Web Interface: The admin will be given his/her account to be able to log in. once logged in, he will have multiple options.Beacons screen which will allow

```
IndoorCloudManager cloudManager = new IndoorCloudManagerFactory().create(applicationConte
cloudManager.getLocation("my-kitchen", new CloudCallback<Location>() {
    @Override
    public void success(Location location) {
        // store the Location object for later,
        // you will need it to initialize the IndoorLocationManager!
        //
        // you can also pass it to IndoorLocationView to display a map:
        // indoorView = (IndoorLocationView) findViewById(R.id.indoor_view);
        // indoorView.setLocation(location);
    }

    @Override
    public void failure(EstimoteCloudException e) {
        // oops!
    }
});
```

FIGURE 3.9: beacons

him managing them. Also screen which will him managing the offers. screen that controls the nodes arrangement on the indoor map in case of any changes.

- User Android Application Interface: The user will be able to log in to his/her account and will be shown 2 screens one to choose his products list and the another is navigating.

3.5.2 Screen Images

3.5.2.1 User Mobile Application

3.5.2.2 Admin Web Application

3.5.3 Requirement Matrix

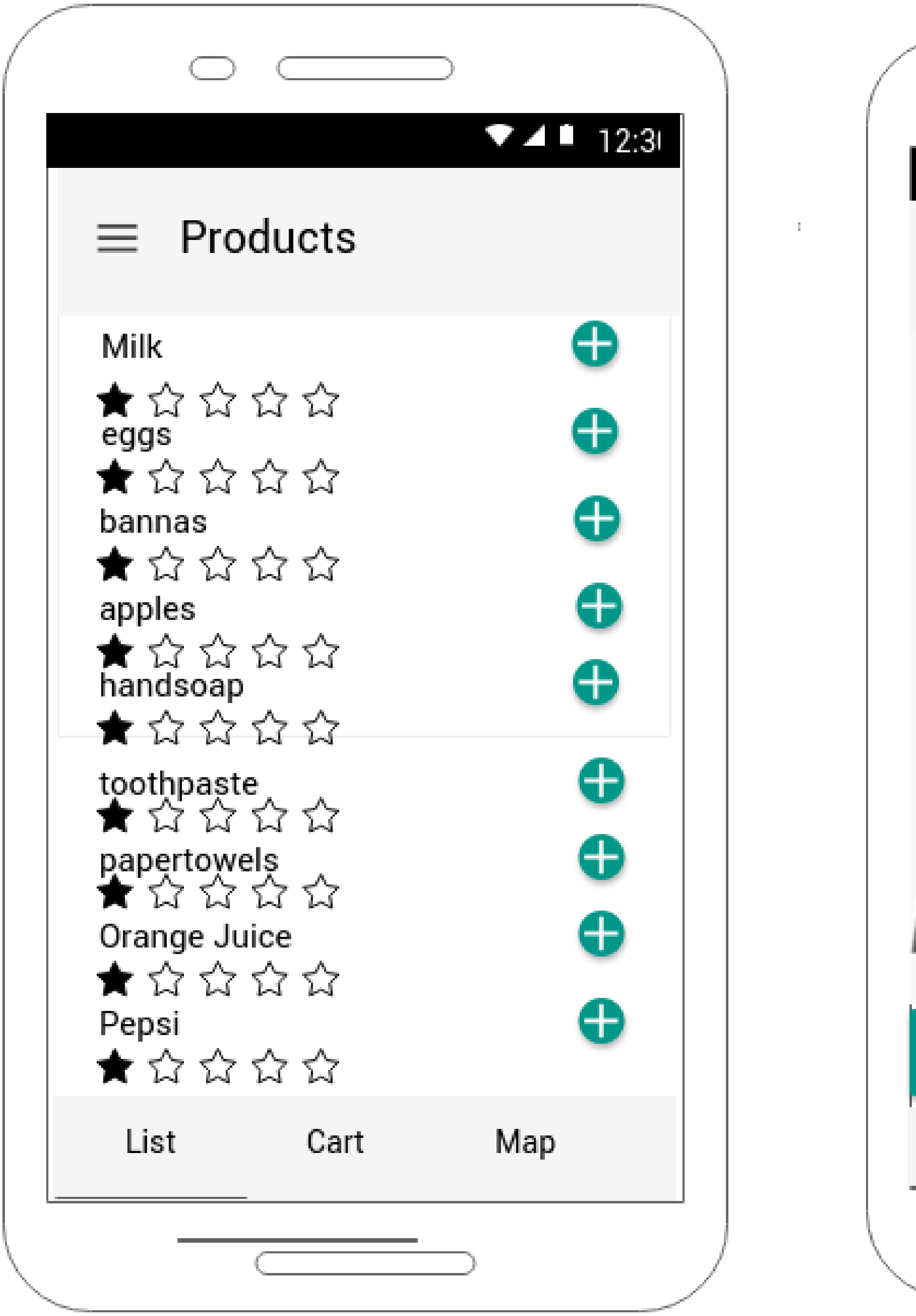


FIGURE 3.10: user GUI

Figure 3.11: Admin GUI

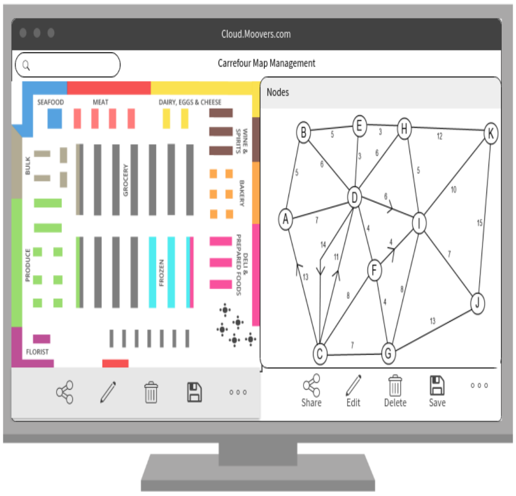
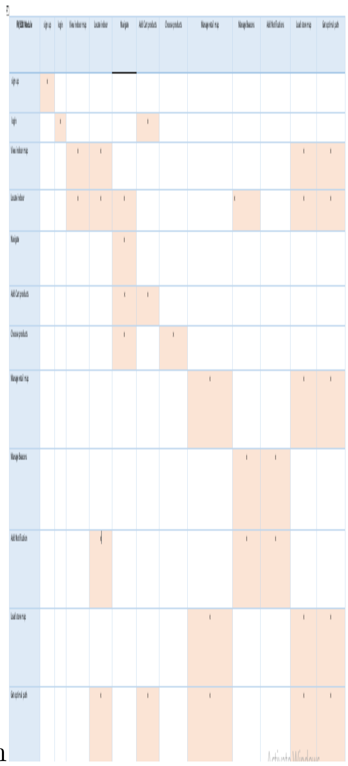


Figure 3.12: Admin GUI



m

Figure 3.13: Requirement matrix

Chapter 4

Evaluation

4.1 Introduction

After the system functionalities have been implemented, our system has been evaluated through 3 experiments to determine the accuracy. Briefly the experiments are as follows:

1. Comparative study between different algorithms and techniques.
2. The accuracy and performance of our system.
3. the user feedback.

4.2 Experiment 1

In this experiment, we are going to compare between the tritlateration technique and positioning by beacons in a single room.

4.2.1 Setup

In this experiment, a smartphone with Android operating system (version 6) is used as a positioning terminal and an experimental indoor site for a room with area of 12 m^2 the room covered by beacon as shown in figure 4.1 and for the same room has three WiFi access points (AP1, AP2, and AP3) and the experiment began by testing the positioning in the room by beacons once and by WI-FI tritlateration once.

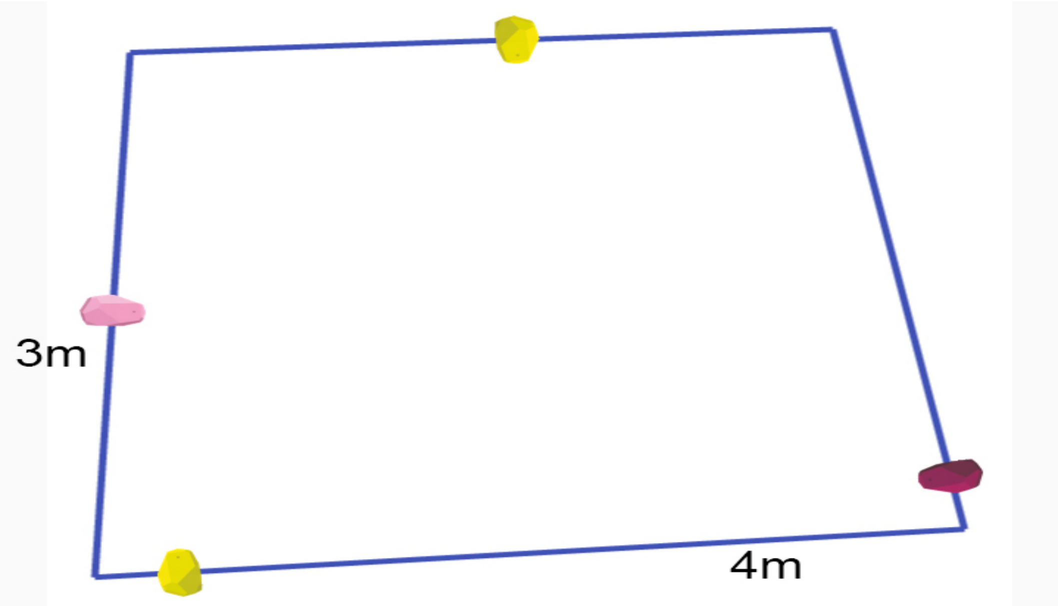


FIGURE 4.1: A room with Beacons installed

TABLE 4.1: Testing results using Wi-Fi with two meter average error

Test Points	Actual coordinates	Estimated coordinates	Error
1	(0.0 , 1.0)	(1.80 , 1.60)	1.99
2	(2.0 , 2.0)	(3.8 , 3.1)	2.11
3	(2.5 , 3.0)	(3.5 , 4.8)	2.05
4	(3.5 , 2.7)	(5.0 , 3.9)	1.92
5	(4.0 , 3.3)	(6.0 , 4.5)	2.33

TABLE 4.2: Testing results using Beacons with one meter average error

Test Point	Actual coordinates	test coordinates	actual error
1	(0.0 , 1.0)	(1.2 , 2.0)	1.5
2	(2.0 , 2.0)	(2.8 , 3.1)	1.3
3	(2.5 , 3.3)	(3.5 , 4.5)	1.6
4	(3.5 , 2.7)	(4.8 , 3.9)	1.7
5	(4.0 , 3.3)	(4.9 , 3.5)	1.0

4.2.2 Results

The results as shown in the tables 4.1 4.2 .

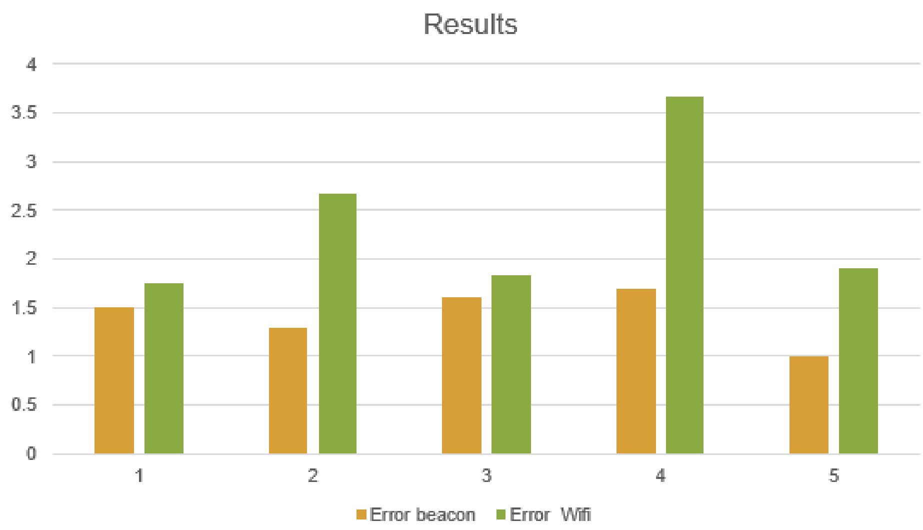


FIGURE 4.2: chart results

4.2.3 Discussion

From the figure 4.2 we conclude that we can get better accuracy by beacons than the wifi tritlateration in a single room, the average error of positioning by beacons was around one meter error while the average error of the wifi tritelation was around two meters.

4.3 Experiment 2

In this experiment we test the wifi tritlateration for the whole indoor palce of an area 171 m^2

4.3.1 Setup

In this experiment, a smartphone with Android operating system (version 6) is used as a positioning terminal and an experimental indoor site of area 171 m^2. The site has three WiFi access points (AP1, AP2, and AP3) in which the access points AP1 and AP2 are installed in different rooms, while the access point AP3 is placed in the corridor as shown in Figure 4.3. As shown, the access points coordinates are (4.8 , 7.5), (5 , 2.5),

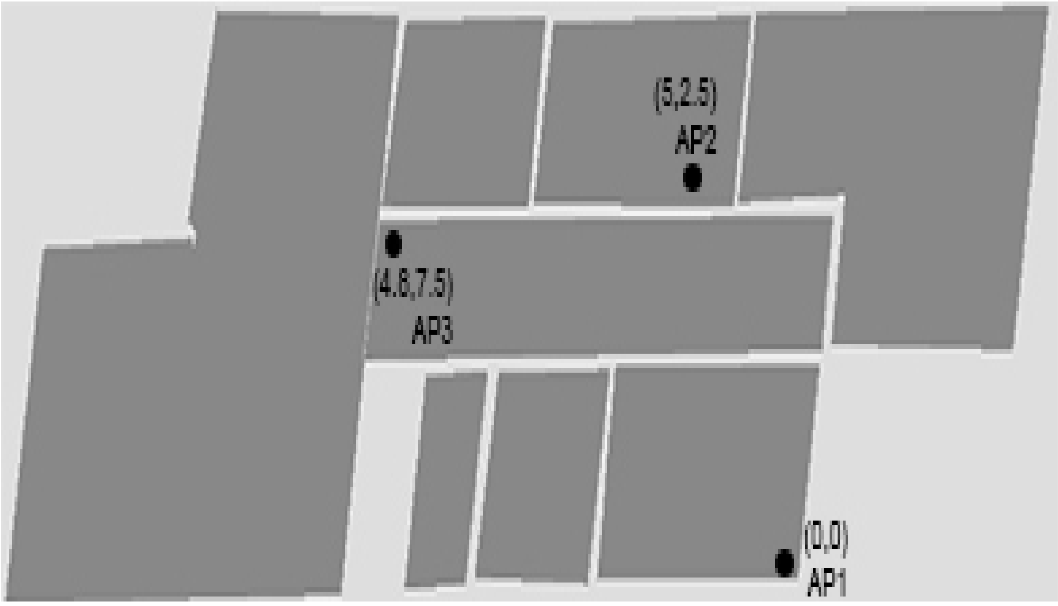


FIGURE 4.3: chart results

and(0 , 0) respectively. It should be noted that a Wi-Fi analyzer is used to monitor and record the signal strength of the access points.

Table 4.3: Experimental Results with tritlateration technique

Test Points	Actual coordinates	Estimated coordinates	Error
1	(2.50 ,1.10)	(1.60 , 2.60)	1.74
2	(4.25 , 4.20)	(6.60 , 5.50)	2.68
3	(5.50 , 6.30)	(6.70 , 7.90)	1.84
4	(6.40 , 9.10)	(7.20 , 12.7)	3.67
5	(7.90 , 11.1)	(10.2 , 13.0)	1.91
6	(8.80 , 10.2)	(9.70 , 11.4)	2.34
7	(9.20 , 12.5)	(8.10 , 11.7)	2.77
8	(9.50 , 14.7)	(8.60 , 13.1)	2.38
9	(9.80 , 11.1)	(10.5 , 11.9)	2.73
10	(9.60 , 15.3)	(9.00 , 14.8)	2.11

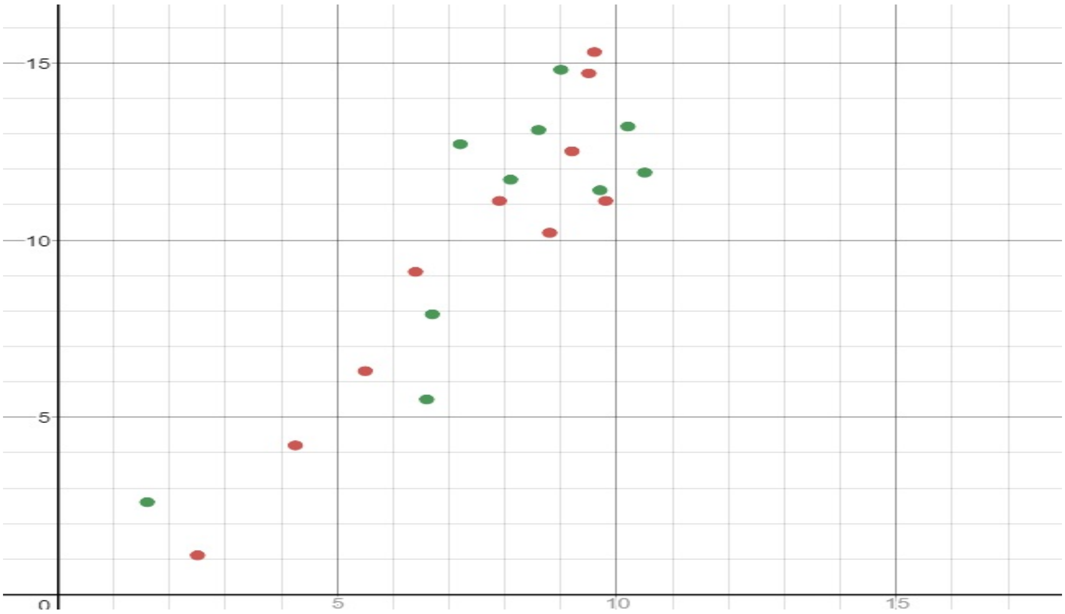


Figure 4.4: chart results

4.3.2 Results

It should be noted that a Wi-Fi analyzer is used to monitor and record the signal strength of the access points. The localization error obtained by the tritlateration technique is ranging from 2 to 4 meters. These results are affected by the indoor surroundings such as walls,obstacles, and gates between the access points. The red dots in Figure 4.4. Shows the actual position while the green dots shows the experimental results.

4.3.3 Discussion

As the experiment the average error we get is about 2.11m, which seems a huge error due to the surroundings which affects the signals of the wifi, and we can't also use the beacons for this whole space as it needs a huge number to cover this indoor space due to the high cost of the beacons. So the solution is a hybrid indoorlocalization system that uses Wi-Fi and BLE communication technologies. Uses partitioning criterion that combine low power communication technologies to achieve accurate indoor positioning. Wi-Fi tritleration method is used to get the position of users at indoor areas supported by wireless fidelity signal strengths and if the user exists within one of the indoor locations supported by BLE. This enabled the beacons to start the localization to achieve higher indoor positioning accuracies.

4.4 Experiment 3

This experiment was made to evaluate the system and to take the user feedback

4.4.1 Setup

- the experiment is done in our university to take the students feedback
-it takes place in the main building third floor
- 10 students tried the application
- Questionnaire to take the student feedback

4.4.2 Results

results shown in figures 4.5 4.6 4.7

4.4.3 Discussion

- we get a positive feedback from the students
- Integrating Wi-Fi and BLE communication technologies gives results show that the

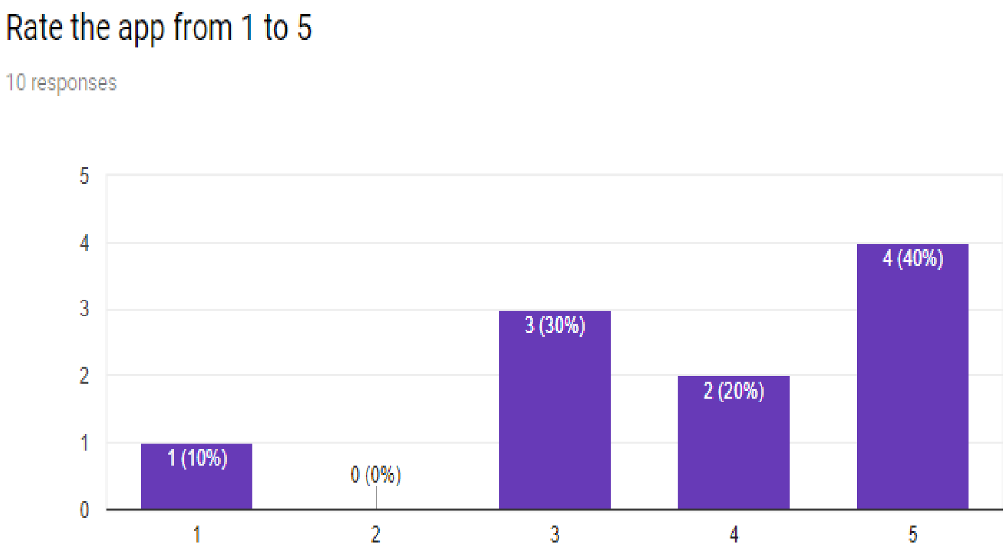


FIGURE 4.5: survey question 1

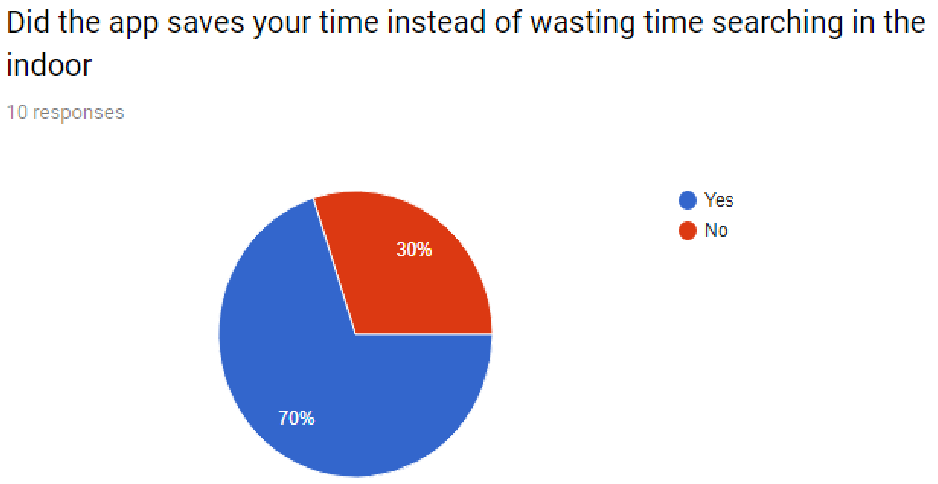


FIGURE 4.6: survey question 2

proposed system is inevitably provided lower average errors compared with other competitive indoor positioning systems.

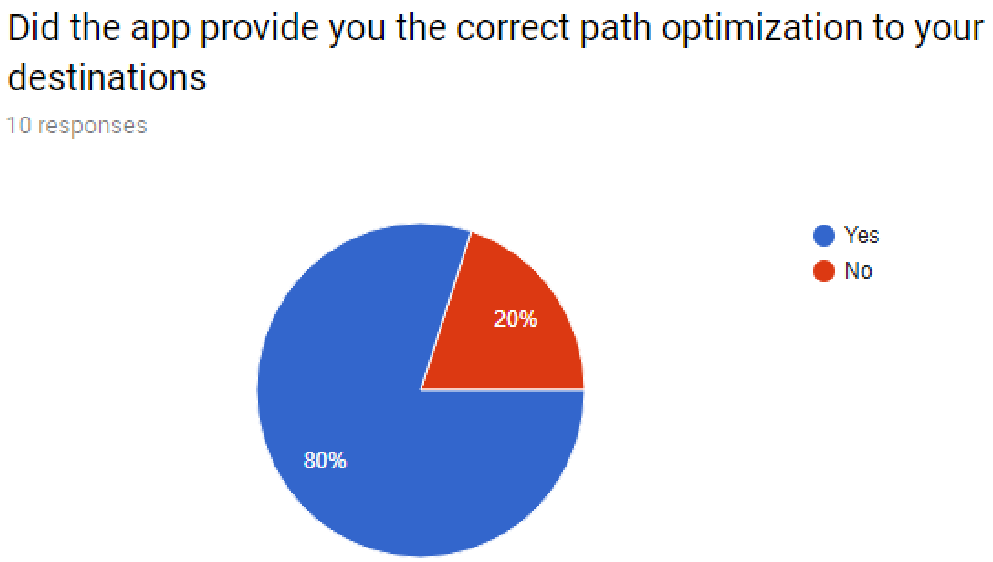


FIGURE 4.7: survey question 3

Chapter 5

Conclusion

5.1 Conclusion

Due to the shortage of accuracy and strength, Indoor Positioning System has been suffered from severe worldwide issues especially with the fast increase in transmission services and information. The goal is to boost the accuracy of indoor localization by exploiting the potential of various technologies offered. As demonstrated, we have proposed a hybrid indoor localization system that uses Wi-Fi and BLE communication technologies. As shown, the infrastructure of the proposed system uses s partitioning criterion that combine low power communication technologies to achieve accurate indoor positioning. In this context, Wi-Fi tritleration method is used to get the position of users at indoor areas supported by wireless fidelity signal strengths. This is employed to ascertain if the user exists within one of the indoor locations supported by BLE. This enabled the beacons to start the localization to achieve higher indoor positioning ac curacies. Experimental results show that the proposed system is inevitably provided lower average errors compared with other competitive indoor positioning systems[27].

5.2 Future work

Appendix A

An Appendix

Abstract

Due to the lack of accuracy and robustness, Indoor Positioning System has now become a major with huge concerns worldwide especially with the rapid increase in multimedia services and data. Therefore, there is a need to enhance the accuracy of indoor localization by exploiting the capability of the available technologies. In this paper, a hybrid indoor localization system that is based on Wi-Fi and Bluetooth Low Energy (BLE) communication technologies is proposed. The main infrastructure of the proposed system is to use Wi-Fi tritleration method to determine the position of users at indoor areas based on Wi-Fi signal strengths. Then, the position obtained by the Wi-Fi tritleration method is used to check whether the user exists within one of the indoor locations supported by BLE or not. This enables the localization process with beacons to get higher indoor positioning accuracy than Wi-Fi. Experimental results show that the proposed system can achieve average error of less than one meter compared with the existing indoor positioning systems. This vindicate the suitability and reliability of the proposed system.

Keywords: Indoor positioning, Localization, Wi-Fi trilateration, Beacons

A.1 1. Introduction

Indoor spatial awareness attracts attention from both industry and academia. The contribution of indoor based localization services is of particular importance as many of us spend considerable portions of their daily lives at indoor spaces. As an example, the indoor navigation service can help in guiding users in large shopping areas to provide them with better shopping services by required time needed. Moreover it can be used as alert service in airports to notify passengers of their flights and boarding gates to avoid any departure delays or missing. Indoor localization services are getting benefit from the availability of low cost and reliable technologies available such as ZigBee, Wi-Fi, Bluetooth, RFID and Ultra Wide Band (UWB) and other types of technology [1]. Among these technologies the targeting of both Wi-Fi and Bluetooth has major advantages because of their high efficiency [2][3]. Due to the signal attenuation when using Wi-Fi technology at indoor localizing, the shows primitive results of accuracy and requires high complex technology in order to improve the accuracy [4]. Due to the high cost of deploying beacons in large indoor spaces, Bluetooth low energy devices are only located in small areas in order to partition areas where Wi-Fi signals are weak due to the building infrastructures such as doors and walls. In this research we propose a hybrid indoor positioning system that employs both Wi-Fi and Bluetooth communication technologies. In this context, the proposed system uses Wi-Fi tritleration method to get the relative users location and further this result is used to check if the user is ranged within a BLE scope where beacons is used to enhance the accuracy of indoor localization [5].

The paper is organized as follows: section 2 describes the related work in indoor positioning, section 3 describes the system architecture of the proposed system along with the implementation details, while section 4 discusses the conducted experiments and shows the results obtained. Finally the paper is concluded in section 5.

A.2 2. Related Works

Indoor Positioning System Using Wi-Fi Bluetooth Low Energy Technology [6],Exploiting the feature of Wi-Fi signal detection from android smart-phones, they built an app for user positioning in indoor environment. For testing purposes, pre-installed Wi-Fi access points and Beacon devices based on Bluetooth Low Energy (BLE) technology are used for indoor positioning using classical RSSI based trilateration algorithm. In this context, a developed Android applications is used for indoor positioning. It is based on RSSI measurements for the pre-installed Wi-Fi access points which export to BLE based technology using Estimote beacon devices (or Eddystones). Eventually, a comparative study is carried out to examine the reliability and applicability of using Wi-Fi and BLE technology for indoor positioning. Experiments show that the use of Wi-Fi gives average accuracy of 77.59% and 88.41% for x-coordinate and y-coordinate respectively. When BLE technology is used, two different scan results are obtained. the first with average accuracy of 96.61% for x-coordinate and 66.10% for y-coordinate, while and the second scan with accuracy 81.5% for x-coordinate and 80.5% for y-coordinate. On average, the overall accuracy is 89.10% for x-coordinate and 73.3% for y-coordinate.

A.3 3. Proposed System

In this approach, we propose a system that uses Wi-Fi trilateration [4] technique integrated with Bluetooth beacons by partitioning to get an exact indoor position of the user, and then when the user enters his destinations the system provides a full optimal and shortest path to navigate the user to his destinations [7]. Our system consists of three components.The user interface,algorithms, techniques, and database.The user interface consists of a destination list module and a map module which allows the user to input or search for his desired destination and view the map respectively.The search results access the trilateration technique in order to locate the user indoor location and each product sections and this data is processed by path optimization algorithms [8] in order to give a shortest path to the user from his indoor location to the product. The database component contains Retail's inventory and Retail's floor plan modules. The Retail's inventory modules interact with the keyword search by gathering the product

Figure A.1: The proposed system infrastructure

information and their respective location. The Retail's floor plan modules provide information to the path optimization algorithm to generate maps and locations of products [9].

A.3.1 3.1 Positioning Algorithm

The trilateration algorithm is able to locate a certain device in an indoor location [4]. This is achieved by determining the relative location of the user by a geometrical distance measure. The distances are calculated using various signal measurement techniques such as Received Signal Strength (RSS), at least three Wi-Fi access points are needed to form a circular equations:

$$(x - a_1)^2 + (y - b_1)^2 = r_1^2 \tag{A.1}$$

$$(x - a_2)^2 + (y - b_2)^2 = r_2^2 \tag{A.2}$$

$$(x - a_3)^2 + (y - b_3)^2 = r_3^2 \tag{A.3}$$

where the r_i is the distance between the device and the access point i and is calculated by the free space pass loss(FSPL) as follows:

$$\begin{aligned} FSPL(db) &= 10log_{10}((\frac{4\pi}{c}rf)^2) \\ &= 20log_{10}(\frac{4\pi}{c}rf) \\ &= 20log_{10}(r) + 20log_{10}(f) + 20log_{10}(\frac{4\pi}{c}) \\ &= 20log_{10}(r) + 20log_{10}(f) - 147.55 \end{aligned} \tag{A.4}$$

The distance (r) is calculated in Kilometers (KM) and the frequency (f) in GHz. If the distance is in meters and the frequency in MHZ, the used free space pass loss(FSPL) will be as follows

$$FSPL(db) = 20log_{10}(r) + 20log_{10}(f) - 27.55 \tag{A.5}$$

By solving the above equations, the relative location of the user can be obtained as follows:

$$x = \frac{[r_2^2 + a_1^2 + b_1^2 - r_1^2 - a_2^2 - b_2^2 - 2(b_1 - b_2)y]}{2(a_1 - a_2)} \tag{A.6}$$

y=

$$\left[\frac{(a_2 - a_1)(a_3^2 + b_3^2 - r_3^2) + (a_1 - a_3)(a_2^2 + b_2^2 - r_2^2) + (a_3 - a_2)(a_1^2 + b_1^2 - r_1^2)}{2[b_3(a_2 - a_1) + b_2(a_1 - a_3) + b_1(a_3 - a_2)]}\right] \tag{A.7}$$

Therefore, this relative users location is used by the system to check whether the user has entered a specific area that is supported by Bluetooth beacons to get the exact users indoor position.

A.3.2 3.2 Minimum Spanning Tree (MST)

A minimum spanning tree (MST) or minimum weight spanning tree is a subset of the edges of a connected, edge-weighted (un)directed graph that connects all the vertices together, without any cycles and with the minimum possible total edge weight. That is, it is a spanning tree whose sum of edge weights is as small as possible. More generally, any edge-weighted undirected graph (not necessarily connected) has a minimum spanning forest, which is a union of the minimum spanning trees for its connected components. Movers will use MST in order to find a navigation route along certain path which will be based on customer product list as the MST is the optimal solution to make the customer pass by all sections in the customers desired product list; there will be graph representing (sections of products) connected by this path to represent all sections [10].

Dijkstra algorithm is used to find the optimal rout between the users position and a single destination manually entered by the user.

A.3.3 3.3 Hardware components

- Mobile smart phone based on Android connected to Wi-Fi [11].
- Wireless Ethernet IEEE 802.11 (Wi-Fi) [12]

Figure A.2: A map with Beacons installed

- BLE based technology using Estimote beacon devices [14][15]

Indoor localization is about replicating the GPS technology but without satellite coverage. This can be achieved by installing a set of of location Beacons throughout the space which automatically map and create a floor plan of the UWB radio signal. In this paper, Estimote Location Beacons auto-mapping technology are used [13]. In addition, smartphones with android operating systems can gain access to precise indoor position with Cartesian coordinates [13][14]. The following points should be considered when using the Beacons:

- Broadcasting Power: Broadcasting Power (or Transmit Power) is the power with which the beacon broadcasts its signal. In Estimote Beacons, one can change the power with the Estimote Software Development Kit (SDK), the Cloud interface, or a developed application. The power value ranges from -40 dBm to +4 dBm.
- Advertising Interval: Beacons do not broadcast constantly. They blink instead. Advertising Interval describes the time between each blink. Just as with Broadcasting Power, Advertising Interval on beacons can be adjusted with Estimote SDK, Cloud, and the app.
- RSSI: RSSI stands for Received Signal Strength Indicator. It is the strength of the beacon's signal as seen on the receiving device, e.g. a smartphone. The signal strength depends on distance and Broadcasting Power value. At maximum Broadcasting Power (+4 dBm) the RSSI ranges from -26 (a few inches) to -100 (40-50 m distance).
- Measured Power: Measured Power is a factory-calibrated, read-only constant which indicates what's the expected RSSI at a distance of 1 meter to the beacon. Combined with RSSI, it allows you to estimate the distance between the device and the beacon.
- Proximity zones: allows you to establish your own proximity zones with a code and enable interactions when a user enters or leaves each zone.

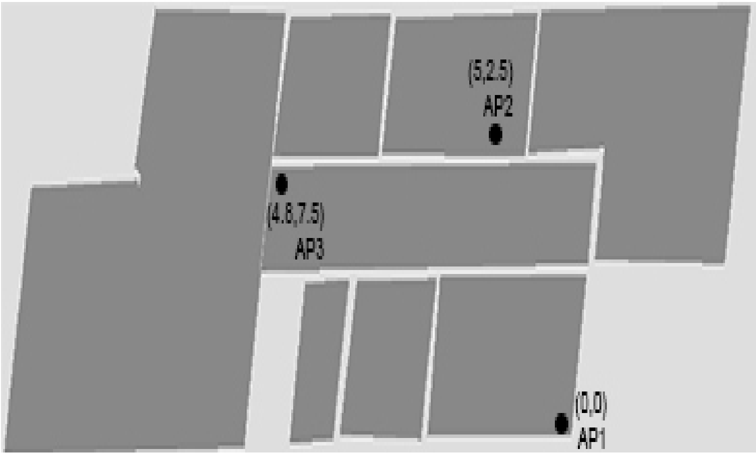


FIGURE A.3: Access Points Coordinates

A.4 4. Experiments And Results

A.4.1 Data collection and Localization using Wi-Fi Tritleration

In our experiments, a smartphone with Android operating system (version 6) is used as a positioning terminal and an experimental indoor site of area 171 m^2. The site has three Wi-Fi access points (AP1, AP2, and AP3) in which the access points AP1 and AP2 are installed in different rooms, while the access point AP3 is placed in the corridor as shown in Figure 3. As shown, the access points coordinates are (4.8 , 7.5), (5 , 2.5), and (0 , 0) respectively. It should be noted that a Wi-Fi analyzer is used to monitor and record the signal strength of the access points. The localization error obtained by the tritlateration technique is ranging from 2 to 4 meters. These results are affected by the indoor surroundings such as walls, obstacles, and gates between the access points. The red dots in Figure 4. Shows the actual position while the green dots shows the experimental results. the average error is 2.411m.

A.4.2 3.5 Proposed Data collection and Localization

Similar experiments are carried out with the same setup for a room with area of 12 m^2 covered with beacons as shown in Figure 5. The results collected from the previous test

Table A.1: Experimental Results with tritleration technique

Test Points	Actual coordinates	Estimated coordinates	Error
1	(2.50 ,1.10)	(1.60 , 2.60)	1.74
2	(4.25 , 4.20)	(6.60 , 5.50)	2.68
3	(5.50 , 6.30)	(6.70 , 7.90)	1.84
4	(6.40 , 9.10)	(7.20 , 12.7)	3.67
5	(7.90 , 11.1)	(10.2 , 13.0)	1.91
6	(8.80 , 10.2)	(9.70 , 11.4)	2.34
7	(9.20 , 12.5)	(8.10 , 11.7)	2.77
8	(9.50 , 14.7)	(8.60 , 13.1)	2.38
9	(9.80 , 11.1)	(10.5 , 11.9)	2.73
10	(9.60 , 15.3)	(9.00 , 14.8)	2.11

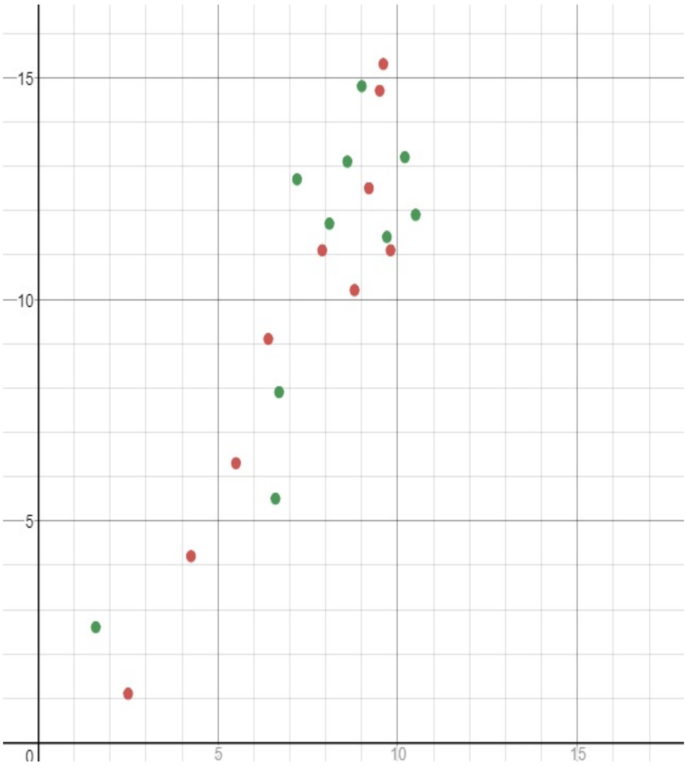


Figure A.4: Tritleration Results

Figure A.5: A room with Beacons installed

has helped in detecting the region in which the beacons are placed inside the room and the below test compares between localization of Wi-Fi Tritleration and Bluetooth inside the room.

Table A.2: Testing results using Wi-Fi with two meter average error

Test Points	Actual coordinates	Estimated coordinates	Error
1	(0.0 , 1.0)	(1.80 , 1.60)	1.99
2	(2.0 , 2.0)	(3.8 , 3.1)	2.11
3	(2.5 , 3.0)	(3.5 , 4.8)	2.05
4	(3.5 , 2.7)	(5.0 , 3.9)	1.92
5	(4.0 , 3.3)	(6.0 , 4.5)	2.33

Table A.3: Testing results using Beacons with one meter average error

Test Point	Actual coordinates	test coordinates	actual error
1	(0.0 , 1.0)	(1.2 , 2.0)	1.5
2	(2.0 , 2.0)	(2.8 , 3.1)	1.3
3	(2.5 , 3.3)	(3.5 , 4.5)	1.6
4	(3.5 , 2.7)	(4.8 , 3.9)	1.7
5	(4.0 , 3.3)	(4.9 , 3.5)	1.0

A.5 5. Conclusion

Due to the shortage of accuracy and strength, Indoor Positioning System has been suffered from severe worldwide issues especially with the fast increase in transmission services and information. The goal is to boost the accuracy of indoor localization by exploiting the potential of various technologies offered. As demonstrated, we have proposed a hybrid indoor localization system that uses Wi-Fi and BLE communication technologies. As shown, the infrastructure of the proposed system uses s partitioning criterion that combine low power communication technologies to achieve accurate indoor positioning. In this context, Wi-Fi tritleration method is used to get the position of users at indoor areas supported by wireless fidelity signal strengths. This is employed to ascertain if the user exists within one of the indoor locations supported by BLE. This enabled the beacons to start the localization to achieve higher indoor positioning ac curacies. Experimental results show that the proposed system is inevitably provided lower average errors compared with other competitive indoor positioning systems.

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