Smart Phone Based Indoor Environment Awareness System

Ain-ul-noor Fatima
National Textile University
anfatimakhan@yahoo.com

Umar Farooq
National Textile University
ufrajput@gmail.com

Muhammad Asif Habib
National Textile University
drasif@ntu.edu.pk

***Abstract*— The Global Positioning System (GPS) is highly reliable and accurate when used outdoors. Due to unavailability of GPS in an indoor environment, many other alternative techniques are proposed for indoor localization. But most of this system required an infrastructure and great installation cost. Due to these problems Wi-Fi based approach got a great attention. The goal of this paper is to build an application using the Wi-Fi-based approach with the specific focus on fingerprinting-based localization technique for the Android mobile device. The application is useful for three purposes, First is the navigation in a building, second is targeted advertisement where Ads will be pushed to targeted clients and third is emergency alert message will be sent to the user device in an emergency case in a building. A Smart Phone Application is built to facilitate a group of different people and businesses. This paper also presents the comparison between different indoor localization techniques and discusses the working of application that provides the indoor environmental awareness to the user with location-based information inside buildings. The accuracy of actual and expected location estimation is also discussed in this paper.**

Keywords*— *Global Positioning System; Indoor Positioning System; Wi-Fi based Approach; Fingerprinting Method; Indoor Positioning; Navigation; Geo-fencing; Agile software Development; Android Application.

I. INTRODUCTION

GPS, which stands for Global Positioning System, is the only system today able to show you your exact position on the Earth anytime, in any weather, anywhere. There are many applications of GPS such as navigation, target tracking, search and rescue, mapping, find lost vehicles etc. [1]. GPS has two fundamental laws: They don't work indoors. They only really operate in two dimensions. Outdoors, navigation relies for the most part on GPS, whose accuracy ranges from 1 to 10 meters. Indoors, because of attenuation and scattering, GPS falls apart. And even outdoors, GPS is vertically challenged; it's about one third as accurate at pinpointing your elevation as it is at telling where you are on the ground. Localization refers to locate a person or object in an area, helping a person to navigate and to reach a specific location. Localization can be sub-divided into two categories i.e. one is Indoor Localization and other is Outdoor Localization. To find a location in outdoor environment GPS can be used to track and manage assets, transport navigation, and guidance etc.[1]. While Indoor localization can be stated as any system which provides a nearly exact position in a closed structure i.e. in a building, airport, and shopping malls etc. It is quite easy to find an outdoor location with GPS (Global Positioning System) using Smart Phones, Tablets and many other Devices[2]. GPS works well in the outdoor environment, however, it is great to challenge to find the indoor location because of GPS failure due to its inability to work in non-line of sight and irregular signal propagation, due to indoor obstacles like walls, roofs etc.

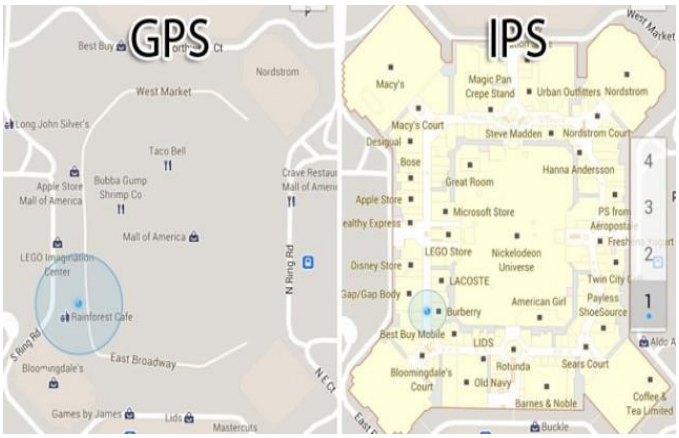

Figure 1: Difference between GPS and IPS Environment

This paper presents the Indoor Localization Using Wi-Fi to find one's own location. The idea is to develop a Smart Phone Application on the basis of this system to facilitate a group of different people and businesses e.g. providing targeted advertisements to people who are in the range of some certain shop in an indoor environment. This application will also be helpful to locate specific places e.g. coffee shop in an airport or in a shopping mall etc. And another purpose is, a message will be sent to user side in an emergency situation in a building. This application has a very broad scope in a large indoor environment. As we know in such environment people have to face a lot of difficulties to find their location and to

search nearest places. Anyone having a smartphone can use our app. A person who is not well aware of places in a building will need this app to reach his required location. Moreover, he/she can also find his current locality using this app and can get related advertisements while shopping etc. And when an emergency situation will come like in case of terrorism, blast in a building a message will be displayed on an app for users[3].

It will be applicable to following scenarios and some of them are discussed below.

i. Railway Stations
ii. Airports
iii. Exhibitions
iv. Shopping Malls
v. Offices and Enterprises
vi. Museums

i. Museums

With the help of that map, the user can easily reach some specific location in that building e.g. the user is in a museum, user wants to visit picture gallery, but he/she doesn't know that where the picture gallery is, so the user can query in the application where the way to reach that gallery will be displayed to that user and user can also search nearby places.

ii. Shopping Malls

This application will be used for targeted advertisement in any Shopping malls, where ads will be pushed to targeted clients. E.g. a person is inside a shopping mall, he/she searches for sales on some shoe brand, in the result of that search all advertisement for that brand will be displayed to that user.

Three main ideas are implemented and discussed in this paper.

A. Navigation in a building
B. Geo-fencing
C. Emergency Case

A. Navigation in a Building

The basic idea behind this application is to help those people who are not aware of some certain place e.g. an airport, or a shopping mall or a university campus etc. The people who have installed this application on his/her smartphone can easily locate places in the building. Simply he/she will have to run the application where his/her estimated location will be displayed on an indoor map of that building.

With the help of that map, the user can easily reach some specific location in that building e.g. the user is in a museum, user wants to visit picture gallery, but he/she doesn't know that where the picture gallery is, so the user can query in the application where the way to reach that gallery will be displayed to that user. And the user can also search nearby places.

B. Targeted Advertisements

This application will be used for targeted advertisement in an indoor environment, where ads will be pushed to targeted clients. E.g. a person is inside a shopping mall, he/she searches for sales on some shoe brand, in the result of that search all advertisement for that brand will be displayed to that user.

C. Emergency case

This application will be useful for an emergency situation in an indoor environment, in this situation; an alert message will be displayed to the user on the app. For example, in case of terrorism etc.

II. LITERATURE REVIEW

This section covers the details of previously worked on localization and there are some methods used for indoor localization. Indoor Positioning System (IPS) is playing a vital role in the modern era[4]. A location-based service is an information service which can be accessed using mobile devices. Besides the applications of navigation and mapping, the location's information can also be used for geometric based social network or another type of entertainment.

IPS uses real time geodata from a mobile device to provide information[5]. There exist many location-based services e.g. check in at restaurants, shopping malls, advertisement of different products in the certain area. There exist several ways to use IPS such as in Store/Shopping Mall Locator, using these services a customer can easily find the nearest store or a shopping mall in his/her area. In Product Marketing, many companies used these services to market their products by pushing ads to individuals within the same geographic location. It can also be used to deliver ads or some offers to their potential users. And it helps in traveling, IPS can help the user about the roadmap to reach a specific location. And there can be many more uses of Location Based Services.

There are many existing techniques which are being used for indoor localization. Some of them are stated as follows.

i. Camera-Based Indoor Localization.
ii. Infrared and Bluetooth and ZigBee Based Approaches.
iii. Radio Frequency Identification (RFID) based Indoor Localization.
iv. High Sensitive GNSS (Global Navigation Satellite System).
v. Wireless Based Approach i.e. Wi-Fi.

There are some limitations to this system. These techniques are heavily related to hardware devices i.e. Bluetooth, Infrared, RFID and Wi-Fi Access Points. As some hardware such as Bluetooth and RFID leads to a higher accuracy of

localization, but they are quite expensive and suffers from lower scalability. The WIFI based approach seems a better choice because of its wider availability, lower cost and easy deployment[6]. Moreover, the mobile phones have already such interfaces which are used to scan Wi-Fi access points, some of them are:

A. Localization using Wi-Fi Approach
B. RFID-Based
C. Bluetooth-Based

A. *Localization using Wi-Fi Approach*

Due to unavailability of GPS in an indoor environment, many other alternative techniques are proposed for indoor localization. But most of this system required an infrastructure and great installation cost[1]. Due to these problems Wi-Fi based approach got a great attention. As compared to other techniques, the Wi-Fi-based solution has many advantages including the availability of infrastructure, low cost, signal stability and easy installation.[6]

B. *RFID-Based*

Indoor positioning systems (IPSs) locate objects in closed structures such as office buildings, hospitals, stores, factories, and warehouses, where Global Positioning System devices generally do not work. This paper presents a standalone IPS using radio frequency identification (RFID) technology[4].

The concept is based on an object carrying an RFID reader module, which reads low-cost passive tags installed next to the object path. It has two tags:[6] The power source of a passive tag is provided by the reader. When a radio signal is sent from a reader when the tag enters the signal field of the reader, it will be powered on by the signal, the reader then captures the ID and data from the tag and sends this information to the host computer[7]. The principles of an active RFID system are slightly different from a passive system as shown in Figure 2. An active RFID system usually uses active RFID tags (with a battery built in) and each tag periodically transmits its data which may contain identification and other application-specific information such as location, price, color, and date of purchase.

C. *Bluetooth-Based*

Bluetooth has emerged as a viable choice of technology in indoor positioning systems due to the increase in the number of Bluetooth-enabled devices over the last decade.[8] Bluetooth was initially developed as a cable replacement technology but properties such as low cost and high availability have led to the development of several indoor positioning systems relying on Bluetooth signals.

Previous system comparisons for IPS is given below in table 1.

RFID Based	**Bluetooth Based**	**Wi-Fi Based**
Using RFID	Using Bluetooth	Using Wi-Fi
It reads low-cost tags	High cost	Low cost
Required an Infrastructure	It also requires an infrastructure	Signal stability and availability of infrastructure
Great Installation Cost	Have great installation cost	Easy installation

Table 1: Comparison of Different Techniques used for IPS

III. METHODOLOGY AND TOOLS

This section gives the details of methodology that is used for our system.

A. *Extreme Programming*

We are going to use Extreme Programming to complete this project. The main reasons to choose this methodology are as under.

i. The purpose of XP is to create quality programs in short time.
ii. XP tends to work best for small to medium size development efforts in environments that have frequent specification changes and where near-instant communication is possible
iii. It supports increment development through the small release of the system.
iv. It supports customer involvement through continuous engagement in the development team.
v. It embraces the changes through regular releases of the system.
vi. It maintains simplicity by constant refactoring that improves code quality[9].

The platform used for this system is Android Studio, in java programing language. Hardware tools include Wi-Fi access points and Android mobile device.

IV. THE PROPOSED SCHEME

Hence there exists many techniques to achieve the functionality of indoor localization, but we are going to use Wi-Fi-based approach due to the wide availability of Wi-Fi access points in a building. There exist two major methods of the indoor localization using WLAN, i.e. Model-based approach and fingerprint-based[10]. We will use the Fingerprint-based methodology to achieve our target. The

most indoor system adopted the fingerprint method as the basis of location estimation. The basic idea is to collect the features of the scene from the nearest signature at every location in the interested areas and then making a fingerprint database. Figure 2 shows the method of fingerprint approach.

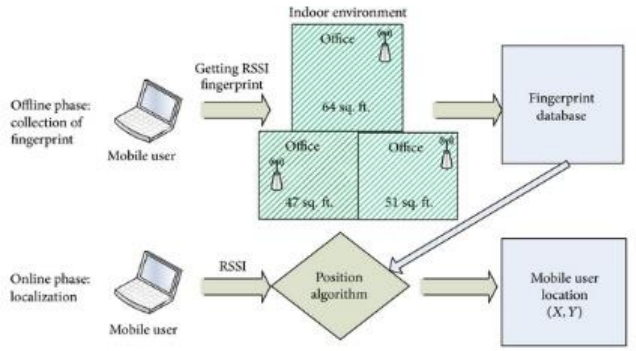

Figure 2: Fingerprinting based Positioning

The fingerprint does not require specialized hardware. It may be implemented totally in software which reduces complexity and cost. It consists of two main phases. Phase 1 is called the calibration phases, training or offline phase, the second phase is the online or localization phase[11]. In offline phase, maps for fingerprinting is set up for site survey where the positioning is supposed to work. In online phase, position algorithm is applied to get the user location for user side. The fingerprint-based approach focuses on-site survey to estimate location from knows reference points. The basic idea behind this is to manually get RSSI (Received Signal Strength Indicator)[12] values as the signatures (fingerprints) at many locations within the required area. These fingerprints will be stored in the database. When the user wants to know its location, he/she will query from an application. The application will take the sample fingerprints from surrounding location and then it will estimate the location using similar values of that fingerprint.

The Architectural design can be called the 'solution phase' of the life cycle because it defines the software in terms of the major software components and interfaces. The 'Architectural Design' covers all the requirements as it establishes the framework of software to find the AP Location Estimation. Figure 1 shows the details of purposed work through the architectural diagram.

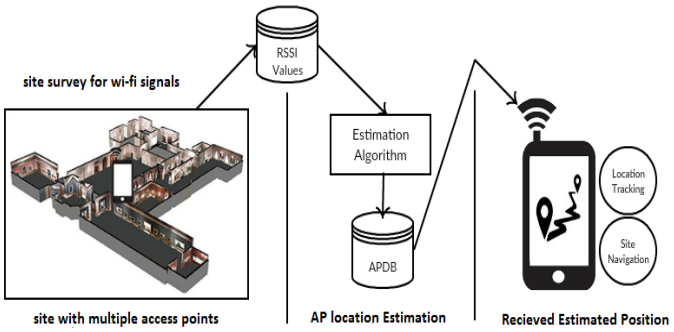

Figure 3: Architectural Diagram

V. SYSTEM DESIGN

This application is used in three ways through admin, shopkeepers, and users. How this application used by admin, shopkeeper and users are given below and the working of the system is defined through data flow and deployment diagrams.

A. Admin

i. Admin should be able to login into the system.
ii. Admin will be able to upload a floor plan of the building.
iii. Admin will be able to modify the location and modify site details.
iv. The admin or surveyor will able to update location database after site survey.
v. The admin will add the shop and add details of the shop then assign to the shopkeeper.
vi. Admin will be able to set or stop emergency situation.
vii. Admin will be able to calibrate map, and allow AP's for scanning and can update the list of AP's.
viii. Admin will able to check or update visitor's graph.

B. Visitors

i. The user should be able to view his/her location.
ii. User shall be able to search nearby places.
iii. User shall be able to find directories.
iv. The user will be able to see an advertisement on his/her mobile phone.
v. The user will be able to see an emergency notification on his/her phone.

C. Shop Keepers

i. The shopkeeper can register for this application.
ii. The shopkeeper will login into the system.
iii. Shopkeepers should be allowed to upload their advertisement to this app's server.
iv. Shopkeepers can modify shop details.
v. Shopkeepers can modify Ads and can change settings of ads, display status that is on or off,

e.g. in case of on the ads will display to the user.

A. Data Flow Diagram (DFD)

A DFD represents how data is processed by the system in terms of input and output. It shows the flow of information means where data comes from where to go and how it gets stored. Below figures represent the flow of information and where data is stored for Admin, shopkeeper, and user. [13] DFD for admin, user and shopkeeper are shown below.

1. DFD for Admin

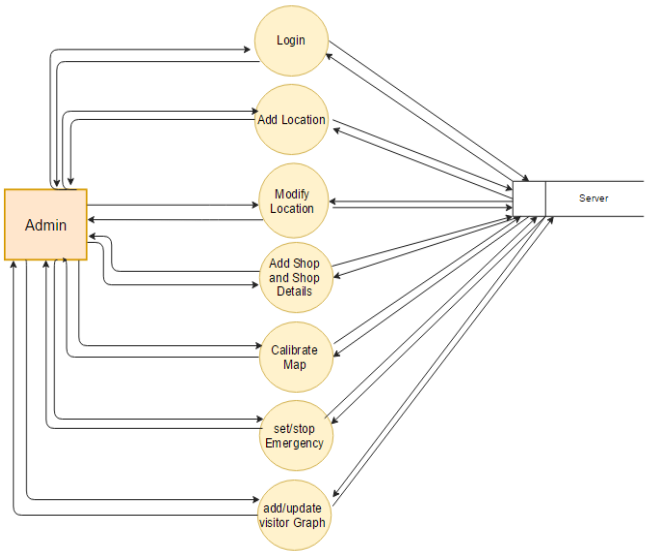

Figure 4: DFD for Admin

2. DFD for Shopkeeper

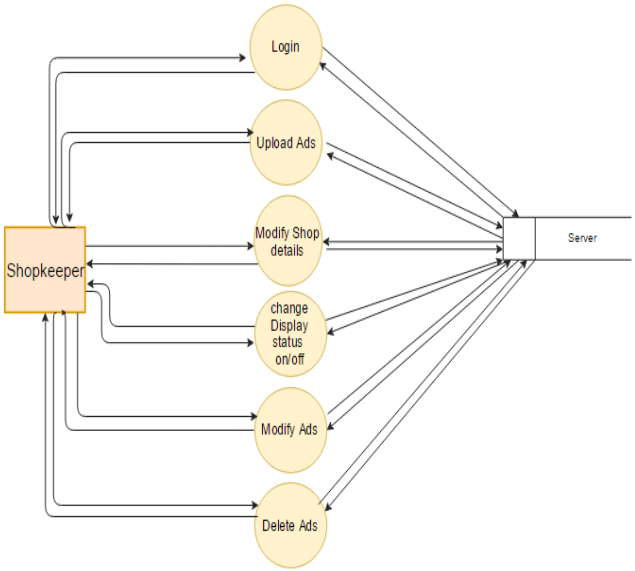

Figure 5: DFD for Shopkeeper

3. DFD for visitors

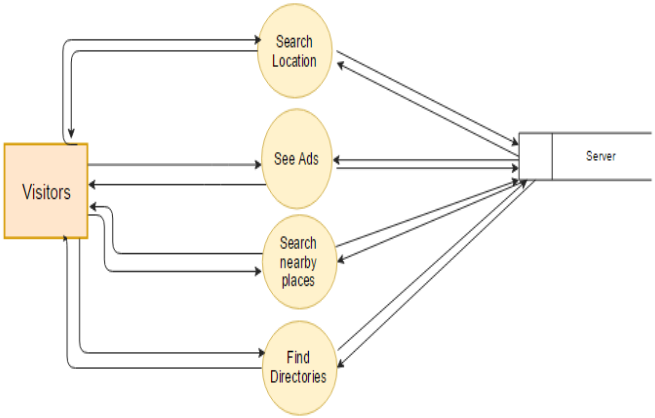

Figure 6: DFD for Visitors

B. Deployment Diagram

It shows the configuration of run-time processing nodes and components that live on them. It used to visualize the physical components of the system where software components will be deployed. Here, the hardware components include the AP's, Mobile device and server. [13]

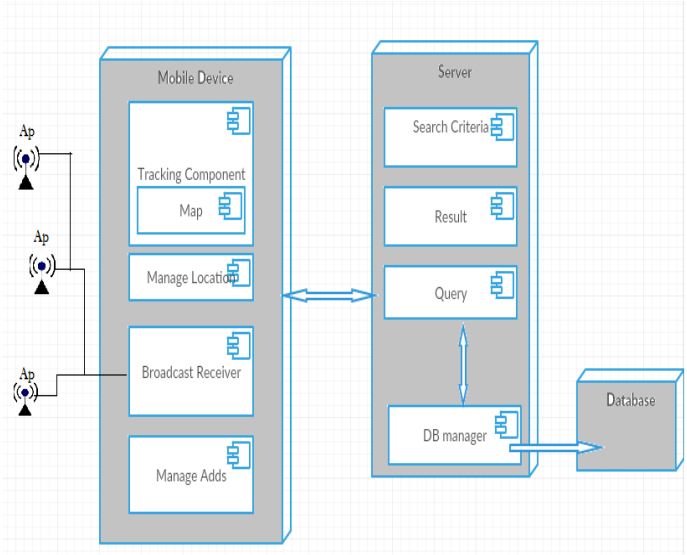

Figure 7: Deployment Diagram

VI. IMPLEMENTATION AND DISCUSSION

This section will cover the implementation results and discussion about the application. Results are displayed in the form of screenshots to understand the working of this application.

a. *For Users Application*

This is the front/home page for user application. Here, the user can see directories they want. In the top left corner, the setting tab is given where the user can find directories, see the advertisement and other options are given to use this application.

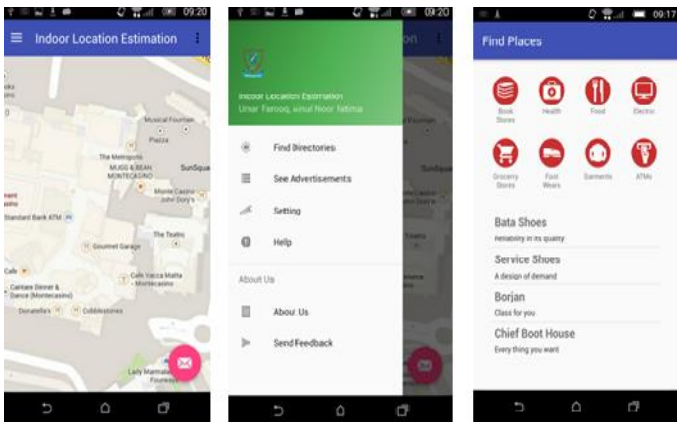

Figure 8: Home Page for User Application

a. *For Admin Panel Application*

This interface is used by admin and shopkeeper. Firstly, admin login into system and lead to admin page where they can start modifications according to their needs. Visitors graph is on top of the screen where we can see how many visitors in 4hours who use this application and visit the site. In site icon, the location will be added for example floor plan of the building.

Figure 9: Home Page for Admin & Shopkeeper

- Site Admin Panel/Icon

When site icon is used for modification then there are many options will displayed such as if we choose to add location then admin can add floor plan of the building, can modify, assign path and modify site details. After select add location, this page will open. Here you can enter site details. Enter location name, width, and length. Then click on the image to upload. After that map is added, then click on add location button.

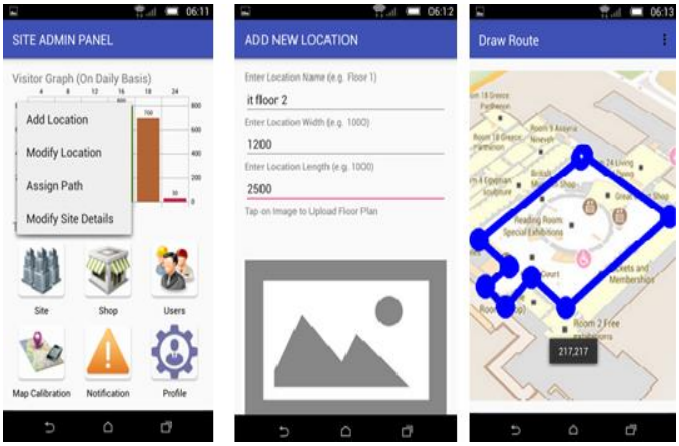

Figure 10: Site Admin Panel

- Shop Admin Panel/Icon

The shopkeeper can also modify shop/ad details. In the next interface, the shopkeeper can add shop details and can set the display status also which will show when we want to set the

ad to display for the user then it will on otherwise not displayed to the user.

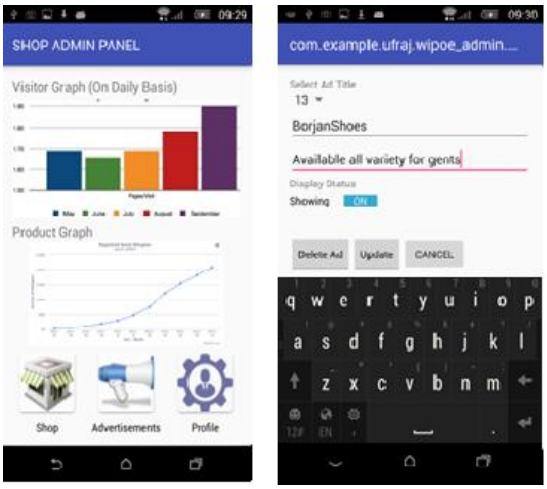

Figure 11: Shop Admin Panel

- Emergency icon/Notification

Emergency icon/Notification is used to set the emergency notification for a user device in case of an emergency in the building. Simply admin can set the notification title and enter a message and will post notification.

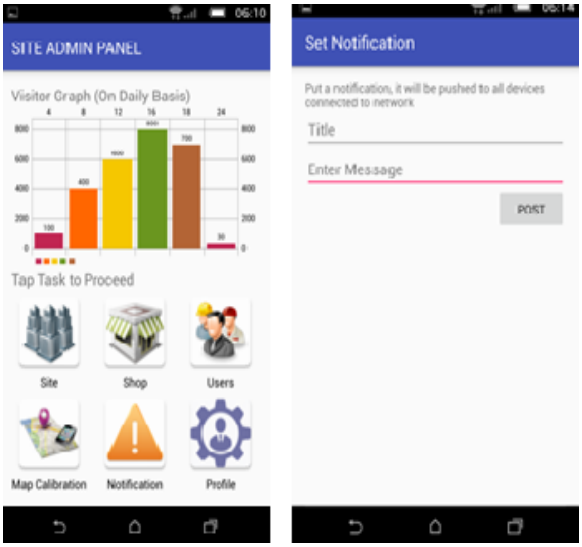

Figure 12: Shop Admin Panel

- Map Calibration Icon

Calibrate map is used to display all access points list will be available. We can select the access point to include in scanning and update those.

Figure 13: Access Points List/Map Calibration

VII. RESULTS

The test environment is shown in the picture below. The results were taken in an IT department of National Textile University Faisalabad, Pakistan. The map shows that there are 2 labs and faculty offices and access points with name AP1, AP2, AP3, and AP4 are shown. The navigation symbol and line are where results were taken. RSS data samples were taken over a period of time and used for estimation. Figure 14 shows the results of actual and expected outcomes.

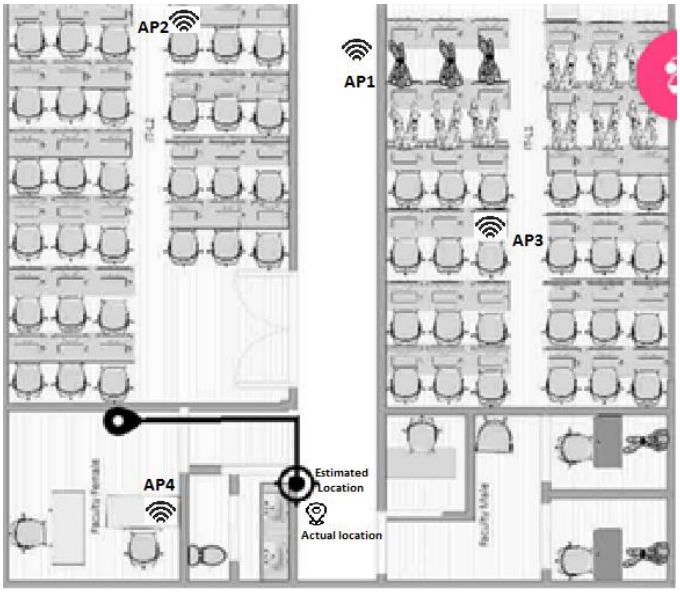

Figure 14: Map of IT Department Building

Table 3 shows the tracking result in a building with four access points. A number of AP's plays a major role in tacking the exact location. The relation between the number of Ap's and accuracy is significant More the Access points in the

building, more accuracy increased and error will be minimum. Less number of AP's in an area will lead to less number of RSSI values thereby low accuracy.

	No of AP's used	Actual Location [X,Y]	Expected Location [X',Y']	Error
Ground Floor	4	[13,38]	[13,38]	0
	4	[7,6]	[5,6]	1.42
	4	[11,36]	[11,36]	0
	4	[14,7]	[12,10]	2.73
	3	[15,34]	[15,34]	0
	3	[10,3]	[10,1]	1.42
	3	[26,6]	[23,4]	2.73

Table 3: Estimation Results in Building

The accuracy of the application is tested in the computer department at ground floor. Accuracy depends on many factors such as a number of Ap's, Location of the AP's etc. keeping in view the above table accuracy of the position estimated is high in the proposed method compared to other methods. The application has been tested in multiple environments. The position of AP's should remain fixed for better results.

VIII. CONCLUSION AND FUTURE WORK

Localization has always been an issue, especially when a person is in an unknown building. Usually, the floor plan of the building is placed in the main entrance of the building which has mentioned all the places of the building. But it is quite difficult to remember that map. Usually, the user forgets location after covering some distance. This application is designed to fulfill that need of time. Indoor localization application using Wi-Fi-based approach to find users own location. A smartphone application is developed and discussed in this paper, on the basis of this system to facilitate a group of different peoples and many others. There are much current indoor localization or indoor positioning techniques but we used fingerprinting methodology because it gives better accuracy for estimation and accuracy of the positioning system can be further improved using multiple access points deployed in a system.

The future work includes the increase of the accuracy of estimation by using a better error calculation tool or algorithm.

IX. REFERENCES

[1] H. Thesis, "Indoor Positioning Technologies Habilitation Thesis," 2012.

[2] G. D. Bonde, "Finding Indoor Position of Person Using Wi-Fi & Smartphone : A Survey," *Int. J. Innov. Res. Sci. Technol.*, vol. 1, no. 8, pp. 202–207, 2015.

[3] Z. Farid, R. Nordin, and M. Ismail, "Recent advances in wireless indoor localization techniques and system," *J. Comput. Networks Commun.*, vol. 2013, 2013.

[4] G. Jekabsons, V. Kairish, and V. Zuravlyov, "An Analysis of Wi-Fi Based Indoor Positioning Accuracy," *Sci. J. Riga Tech. Univ. Comput. Sci.*, vol. 44, no. 1, pp. 131–137, 2011.

[5] P. Lin, Q. Li, Q. Fan, X. Gao, and S. Hu, "A real-time location-based services system using WiFi fingerprinting algorithm for safety risk assessment of workers in tunnels," *Math. Probl. Eng.*, vol. 2014, 2014.

[6] A. Matic, A. Popleteev, V. Osmani, and O. Mayora-Ibarra, "An Indoor Positioning System based on a WiFi router and FM beacons," *Analysis*, pp. 25–28, 2010.

[7] G. Jekabsons and V. Zuravlyovs, "Refining Wi-Fi Based Indoor Positioning," *Aict2010 - Appl. Inf. Commun. Technol. Proc. 4Th Int. Sci. Conf.*, pp. 87–94, 2010.

[8] S. L. Ting, S. K. Kwok, A. H. C. Tsang, and G. T. S. Ho, "The study on using passive RFID tags for indoor positioning," *Int. J. Eng. Bus. Manag.*, vol. 3, no. 1., pp. 9–15, 2011.

[9] D. Karlström, "Introducing Extreme Programming – An Experience Report," *Third Int. Conf. Extrem. Program. Agil. Process. Softw. Eng.*, pp. 24–29, 2002.

[10] M.-S. Choi and B. Jang, "An Accurate Fingerprinting based Indoor Positioning Algorithm," *Int. J. Appl. Eng. Res. ISSN*, vol. 12, no. 1, pp. 973–4562, 2017.

[11] A. Mukhopadhyay, P. S. Rajput, and S. Srirangarajan, "A Smartphone-based Indoor Localisation System Using FM and Wi-Fi Signals," pp. 1–5, 2017.

[12] D. Maduskar, "Open Access RSSI based adaptive indoor location tracker," pp. 0–7, 2017.

[13] O. Of, "On the Contribution of UML Diagrams to," *Engineering*, vol. 3, no. 1, pp. 143–156, 2004.