ZİRVE UNIVERSITY

WLAN-based Indoor Navigation

by

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ABSTRACT

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Location information services evolved from the advent of computing and information services. It refers to any technique that will be used to return the information regarding position of an object in a real time and with relative accuracy. The information can be used to solve many location service related requests, or serve as safety instruction to the user, or help user to locate a particular object from similar objects or aids the person in knowing weather related information etc. Many techniques were developed to cater these services depending of their applications and the technology behind. Some of the major sensor techniques like GPS (Global Positioning System), Bluetooth, Infrared, EM waves, IEEE 802 (WLAN) and GSM (Global System of Mobile) all can provide real time positioning with different accuracy. Among these systems, GPS were earliest and widely accepted to use globally by civilian positioning system with accuracy around 6-12m. GPS has drawbacks of not functioning in an indoor environment, low functionality in a densely environment and many other things. These and many other things prevented GPS to be accepted as indoor positioning system. With these, many techniques have been started gaining attention of the researchers in order to solve this problem of GPS, especially by seeing how positioning services change how people navigate. Among these systems, WLAN techniques have

been widely accepted due to many factors; no additional cost required and is deployed in most of the buildings than other infrastructure considered and many more.

The objective of this research is to examine how possible it is to develop an Application in Android platform using existing WLAN infrastructure that can return position of a user inside a building. There are many researches going on, on how to improve key parts of the technique, especially database generation and location algorithms which both played parts in improving accuracy of the system. The project has tested in a single floor with different databases generated at different time and with different granulity.

Keywords: Fingerprinting, Indoor Positioning System (IPS), fingerprinting database, Global Positioning System (GPS), WLAN.

ÖZET

BAŞLIK

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Turkish Abstract

Yer bilgi servisleri hesaplamali bilgisayar ve bilgi servislerinin gelişmesiyle ortaya çıkmıştır. Bu servisler gerçek zamanlı olarak ve göreli doğruluk ile bir nesnenin konumu ile ilgili bilgiler; döndürmek için kullanıl maktadir. Konum bilsiler ile ilgili istekleri çözmek, kullanıcılara güvenlik talimatları sağlamak, veya benzer nesnelerden özel nesneleri bulmak, veya hava durumu gibi bilgiler ile insanlara yardımcı olmak icin kullanilabilir.. Uygulamalara ve teknolojiye bağlı olan bu servisleri sağlamak için bircok teknik geliştirilmiştir. GPS (Küresel Konum Belirleme Sistemi), Bluetooth, kızılötesi, elektromanyetik dalgalar, IEEE 802 (WLAN) ve GSM (Küresel Mobil Sistem) sibi teknikler farklı doğrulukta gerçek zamanlı konumlama sağlayabilmektedir. Bu sistemler arasında GPS en yeni ve doğruluk oranı 6-12m olan sivil konumlama sistemi tarafından kabul görmüş bir sistemdir.

GPS sisteminin kapalı mekanlarda ve yoğun ortamlarda çalışmama gibi eksik-

leri bulunmaktadır. Bu ve bunun gibi sebeplerden dolayı kapalı mekanlarda GPS kabul görmemektedir. GPS sisteminin problemini çözmek için bununla beraber, birçok teknik araştırmacıların ilgisini çekmeye başlamıştır. Özellikle, kişilerin yer değişikliğine göre GPS sisteminin nasıl değiştiğini göz önüne alan araştırmalar ilgi çekmiştir. Bu sistemler arasında, kablosuz yerel alan ağları teknikleri talep edilen fazladan maliyet bulunmamasıdan, bir çok binada kullanılmasından dolayı kabul edilmektedir.

Bu araştırmanın amacı kablosuz yerel ağ kullanan Android platformunda geliştirilen bina içerisinde kullanıcının pozisyonunu belirten uygulamanın nasıl geliştirileceği hakkında inceleme yapmaktır. Özellikle sistemin doğruluğunun artması üzerinde rol oynayan veri tabanı üretimi ve lokasyon algoritmaları içeren tekniklerin ana kısımlarının nasıl geliştirileceğine dair bir çok araştırma bulunmaktadır. Bu calisma farklı zamanlarda ve içeriklerde üretilen veri tabanları ile bina katinda test edilmiştir.

Anahtar Kelimeler: Parmak izi kaydetme, Kapalı mekan konum belirleme sistemi (IPS), Parmak izi veri tabanı, Küresel konumlama sistemi(GPS), WLAN.

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1. INTRODUCTION

1.1. Background and Motivation

GPS (Global Positioning System) is a household name whenever we taught about location services. The first satellite of GPS system was launched in 1978 with the sole intention of military aids, missile launching and many operations. It has precise timing module and surpassed first satellite that was launched (Transit 1964) which has no timing module aboard. Some events that were not connected with military persuaded US and its allies to reconsidered the only military functions of GPS system, which led to then US President Reagan in 1984 to partly succumbed GPS services for civilian and commercial services, but left some algorithmic errors of around 100m. This prompted commercial companies to start using services for many purposes but at accuracy lower than that of military which increased cost of services for commercial services. It was in May 2000, that President Clinton ordered the scrambled channel be fully released for commercial services, this paved way for a new era of full utilization of the system and to the positioning technology.

With the growing competition on GPS from other commercial companies, the technology got world wide recognition and many scientists and engineers ventured into improving the system for civilian purposes. It was on this moment another lead has been opened which has shown that work has to be done in order to make the GPS to function in other spaces like indoor, due to many reasons that will be discussed fully in this text later. This development gives rise to what is called now Indoor Positioning System (IPS).

Scientists uses many techniques to calculate the position of an object in indoor environment and many technologies have been tested and applied. Systems like Bluetooth, RFID, UWB, Infrared, Assisted-GPS (AGPS) and WiFi have been used together with the techniques to determine the position of object in indoor, but still no single technology has been considered as effective as GPS is in outdoors.

The only system that scientists so far considered efficient is WiFi infrastructure that is already pre-installed in many buildings and is growing in coverage than all other systems mentioned above. Also it is already installed for another purpose reduces the additional cost of installing another hardware in the environment. Many techniques are used with the WiFi, but Fingerprinting proved to be more considered in the system.

Fingerprinting technique of WiFi is the best so far in terms of accuracy. Now the research focus on how to improve the technique to be globally acceptable based on accuracy and technology. Improvement on database generation and algorithms are the key leading the research presently.

1.2. Challenges of Fingerprinting Technique

The system would use fingerprinting method to determine location inside a building with improvement in accuracy and burden reduction of database. The fingerprinting method uses database which is been created by obtaining signal strength of each point (fingerprint) and uses that information to return the position in a map of the building.

Some of the challenges of this method are as follows;

Firstly, signal propagation in indoor environment is complex to predict due to many obstacles present, which resulted due to unwanted phenomena like refraction, reflection, delay etc. trying to predict the signal is tedious and uncertain. Secondly, position of human in the building or their movement also affects the signal strength at all the time and at different frequency. The blockage of direct line of sight between transmitter and receiver can greatly affect the signal propagation. Thirdly, interference from many signals operating at the same frequency with the WLAN, like microwave ovens, Bluetooth, wireless signal transmitters and mobile phones all can affect the signals. Database generation has to be performed many times in order to remove unstable access points which also greatly affect the performance of the system. The target of the thesis is to design a system that can reduce these challenges to the

minimum level.

1.3. Thesis Structure

Chapter One covers introduction of the topic of indoor positioning system and some of the drawbacks of the GPS (Global positioning system). The major challenges of fingerprinting technique which is the accepted technique in a short range indoor positioning base has been briefly discussed. Chapter two deals with Literature review of topic, it started with describing the reasons why GPS is not considered as indoor positioning systems, then go on to discussed some of the sensor technologies in positioning systems and their shortcomings. Standards of wireless LAN communication have been discussed briefly in the same chapter and radio signal propagation in indoor have been discussed also. On the same chapter, positioning techniques have been discussed and Fingerprinting technique which was employed in the project has been elaborated further. Chapter three explained the methodology employed in carrying out the design, experiment and software part of the project. Chapter Four reveals the result obtained in the experiment of chapter three. Discussions and conclusions have been put together in the final chapter which is Chapter Five.

2. LITERATURE REVIEW

2.1. Introduction

2.2. The Reasons Why GPS is Not Functioning Well in Indoors

The recent development of internet network coverage and cellular networks help in improvement of research about location based system (LBSs). The mobile devices that operate within these networks like Smartphones, Laptops and PDAs (Personal Digital Assistants) can be able to utilize location-based systems to determine the position of their users or locate an object which is relevant to them. Many applications on these devices rely on LBSs for their operations, therefore, maintaining the positions of their users in real-time, accuracy and efficiency is very essential.

GPS (Global Positioning System) and cellular network based systems (GSM or 4G) are among the common methods employed by many devices to locate or navigate a user anywhere in the globe. A GPS navigation device is a device that receives (GPS) signals to determine the device's location on Earth. These systems return the location or navigation in outdoors, also because of the wider space of navigable area, the accuracy of between 6m to 12m is acceptable with 95 percent of time [1]. They normally malfunction in human densely areas and indoors, due to signal being hindered from direct line-of-sight (LOS) with the receiver, by buildings or roofing. Depending on the nature of the materials being used and its volume, the signal can be reflected, delayed, absorbed or even when it eventually penetrate through the medium it may be attenuated to the level that it is either undecipherable or weak [1]. When considering outdoor positioning, the accuracy of 10-12m is normally enough compared with the overall spaces available for the navigation. This accuracy (12m) is totally insufficient in indoors, which may result into locating a user in different rooms, office or even floor (depending on the test-bed). The desirable accuracy of indoor positioning will be around 1-2m at this stage, which GPS can not provide. Another drawback of

GPS in indoors is unpredictable nature of radio signal in indoor, this will require many complex mathematics to predict and is yet to be solved. This unpredictable conditions will eventually result into deviation from the actual location of the user [2]. The high power demand of any GPS receiver make the system not desirable, which result into cost increment of the devices. Temperature and humidity also affect the radio signal indoors and human density greatly disrupt signal propagation [3]. Another consideration of the GPS service is, since it requires line-of-sight before it perform well, in an area with a taller buildings or mountains, the accuracy should not be above 6m in order to return likely location or tracking in a car or road generally.

With the present need of location-based services with the high precision and the availability of many alternative technologies, there is a need of finding the best system that can perform better than the present ones, in terms of accuracy and to be able to integrate the systems together (GPS-enhanced and indoor).

2.3. Other Positioning Techniques Overview

The applications of indoor navigation is always increasing together with the demand of finding the cost-effective and accurate techniques, these make it among the hot areas of research in this decade. Many researchers have come up with many methods to implement the indoor navigation, but the major shortcomings are; the objects that block the line-of-sight communication with the receiver which result in the reflection or attenuation of the signal, the hardware needed, environmental factors (humidity, temperature etc) and human activity are among the obstacles that are affecting their continue operations [3]. The indoor navigation techniques are many but the general criteria were selected and discussed their merits and shortcomings briefly.

2.3.1. Global Positioning System

Global Positioning System (GPS) or its Differential Global Positioning system is at present, among the successful outdoor positioning technologies available [4]. Despite

its tremendous success in outdoors, the performance in indoors is very poor or even not acceptable. Despite these drawbacks, many researchers and commercial companies have tried to come up with the idea of utilizing it in indoors or combine with other technologies to yield a better result. SnapTrack, A Qualcomm company has come up with another relevant technology with the original GPS that yield a positioning accuracy of 5-50m in indoors. The system uses original server with the help of GPS sensor in the receiver to locate the positions. They called the system Assisted Global Positioning System (A-GPS) [1]. Another method that uses pseudolite-based positioning system. The system uses the same technology with the GPS and the satisfactory experimental results show that the Root Mean Square (RMS) accuracy is 1 mm(1σ) horizontally and 2 mm(1σ) vertically and the RMS dynamic error is 5.6 mm(1σ) horizontally and 15 mm(1σ) vertically [5]. With all the development in the GPS system, the accuracy in indoor is still not as expected, the cost is still far higher than any of the methods discussed so far. The best idea is integrating the technology to the existing ones by the same owners or partnership.

2.3.2. Radio Frequency Identification (RFID)

RFID is a means of sending and retrieving data through electromagnetic transmission by an RF compatible Integrated circuit [1]. The system have many components; RF readers, RF tags and communication protocol. RF reader always reads the data emits from the tags, this help in positioning system. Some tags can emit the signal to some tens of meters (Active tags) while others only emit between 1-2m (passive tags) [6]. The positioning accuracy of the system is good, but the major setback is the cost of installing tags and readers, and finding the right protocol and radio frequency to which they can communicate without interference.

2.3.3. Bluetooth

Bluetooth is another wireless technology standard of exchanging data and information within short range (ISM Band 2400-2480 MHz) and in Wireless Personal Area Networks. It received recognition because of its high speed data rate transfer, high

security, low power consumption, low cost and smaller in size [7]. Many techniques have been proposed and tested for using Bluetooth technology in indoor navigation, some provide efficient system but are either expensive or required fixed installation of infrastructure. Their problems of latency delay also prevent its usage in real time positioning and the whole system being portable, can be carried along by the users which prevent its better application as real time location system.

2.3.4. UWB (Ultra Wide Band)

This technology is employed and considered better than Narrow band RF because of its ability to mitigate the effect of multipath propagation which is among the leading problems in indoor navigation. The technique is essentially good and provides accuracy of less than (20cm) with 90 percent of the time [8]. The major drawback is the incorporation of many transmitters in the building in spaces of few centimeters which make it expensive and demand high power consumption, though the issues of power consumption has been reduced by [8].

2.3.5. Ultrasound Technology

Ultrasound technology is another method that helps in finding indoor positioning. The system utilize pulses that is been emitted to measure the distances between receiver and transmitter, or directly measure distances between the measuring device and an obstacle such as wall [9]. There are many approaches of measurements; The receiver and transmitter could be installed on the navigation devices or the receiver to be distributed evenly in the area (walls and ceiling), then the positioning can be obtained using trilateration techniques using the time of flight of the transmitted signal by the navigation device [10]. This system is expensive due to pre-installation of the transmitters in the area, and the sound waves can not penetrate through walls which renders the general efficiency of the ultrasound system in indoors low and also there is inherent weakness due to the presence of environment noise.

2.3.6. Infrared

Infrared wavelength are longer that of visible light but shorter than terahertz radiation. The range of frequency wavelength is between 430 THz down to 300 GHz. Normally the rays are not visible to eyes which make them less disturbing than the other rays, they are normally the type of rays that emit from thermal radiation above room temperature. There are about three different positioning technology architectures based on infrared; Active beacon, Imaging (using natural radiation) and artificial light sources. But, in spite of all the techniques being developed, they all have common problem of requiring line of sight for it to function which renders it inefficient in indoors. Another problem of infrared technology is; its short range coverage, this can limit the general performance of the system [1]. These two drawbacks does not match with the basic requirement of indoor navigation system.

2.3.7. WLAN Network

WLAN technology is now advancing in coverage and availability. WLAN is a standard that is operating at 2.4GHz, usually available in residential, hospital or commercial area (ISM). The coverage of WLAN is between 50-100m and surpass that of Infrared or Bluetooth. Cost of infrastructure and pre-installation of equipment are virtually zero if WLAN is to be used as navigation techniques, since all the required infrastructures are already installed. These advantages are among the reasons why WLAN is considered at present to be one of the best method to yield location services. There are many methods employed in indoor navigation using WLAN with variable accuracy and latency, the best among them is Fingerprinting using RSS (Received Signal Strength) and has accuracy between 3-30m with moderate latency. The other methods are ToA, TDoA and AoA are less employed due to higher latency and difficulties of angle measurement.

2.4. WLAN (IEEE 802.11) Standards and Its Measurement

WLAN (Wireless Local Area Network) as its name reveals, can be defined as LAN without wires or cords. Understanding WLAN is essential due to the growing coverage that the technology is gaining together with the portable devices that are also increasing. The system comprises with many cells (Base Service Sets BSS) that are controlled connectivity by (Access Point). It has many advantages from uninterrupted mobility to the inexpensiveness of the system, these make the technology acceptable and research on increasing data rates, bandwidth and reducing interference are in progress [11].

There are different technologies available in WLAN, depending on the need, bandwidth utilized, data rates and the area of application. Technology standards that are being explored in communication are:

a. IEEE 802.11 b. HiperLAN/2 c. Bluetooth d. HomeRF

2.4.1. IEEE 802.11

This technology enjoy wider support in industry, enterprise, home or even public WLAN needs. It was set up by Institute of Electrical and Electronics Engineers in 1997. They include;

2.4.1.1. IEEE 802.11. This standard transmits data at 1-2 Mbps and uses both two spread spectrum methods, and operate in 2.4 GHz.

2.4.1.2. IEEE 802.11a. This standard is high speed physical layer that also transmit on 5 GHz and have higher data transmission rate up to 54 Mbps. This has the advantage of no interference from any channel or signal unlike those that operate in 2.4 GHz.

2.4.1.3. IEEE 802.11b. This standard is high speed physical layer on 2.4 GHz that transmit data from 1, 2, 5.5 to 11 Mbps. It uses direct sequence modulation techniques for its modulation. This standard is currently being choose by many companies in deploying wireless LAN.

2.4.1.4. IEEE 802.11g. This standard is meant to deal with high speed needs that works on 2.4 GHz bandwidth with data rate up to 54 Mbps using Orthogonal Frequency Division Multiplexing.

2.4.1.5. IEEE 802.11n. This standard has been developed to work on both 2.4GHz and 5GHz and has data rates between 50Mbps and 600Mbps. It incorporates MIMO antenna.

Table 2.1. Shows 802.11 standards and their frequency ranges

Standard	Frequency Supported	Maximum Bandwidth	Channels	Radio Bandwidth
802.11a	5GHz	54Mbps	23 (24)	20MHz
802.11b	2.4GHz	11Mbps	14	22MHz
802.11g	2.4GHz	54Mbps	14	20MHz
802.11n	GHz & 5GHz	150Mbps (Per Stream)	11 & 23	20 or 40MHz

2.4.2. HiperLAN/2 (HIGH PERFORMANCE RADIO LOCAL AREA NETWORK)

ETSI came up with four different standards that would maintain typical nature of wireless network by giving uninterrupted services and interchangeability from different locations. The standards was initialized in 1991 and launched in 1996 [11]. The main idea behind it is to provide basic networking infrastructure or ad-hoc wireless services within a radius of not greater than 50m. HiperLAN is compatible with traditional IEEE 802.11 but has higher data rate. It connects with end users by employing carrier sense multiple access protocol, and because of the different nature of data structures it uses isonchronous traffic in order to separate voices, videos or texts. HiperLAN/2 has been emerged in 2000 to provide high speed data rate up to 54Mbps in physical layer of

different networks like ATM, IP Networks, UTMS Backbone, Homes and offices [11]. It achieves this speed by employing Orthogonal Frequency Digital Multiplexing (OFDM), this technique is very essential especially in an area that is prone to many reflections or attenuation like offices. Other standards are summarized in the table below:

Table 2.2. Shows HiperLan Standards and their frequency

	HIPERLAN/1	HIPERLAN/2	HIPERACCESS	HIPERLINK
Description	Wireless Ethernet	Wireless ATM, UTMS	Wireless Local Hoop	Wireless Point to Point
Frequency Range	5 GHz	5 GHz	5 GHz	17 GHz
PHY Bit Rate	23.5 Mbps	6-54 Mbps	>25Mbps	>155Mbps

2.4.3. BLUETOOTH

Another industry based standard is called Bluetooth technology. It is based on short-range RF-based connectivity of portable devices of around 10 meters in range. With many electronic gadgets now available, it is serving as a cheapest way to communicate with neighboring devices, be it cell phone to cell phone, cell phone to computer etc. It was released in 1999 by Bluetooth Special Interest Group and operate at 2.45GHz for (ISM). The architectural element of the technology is called piconet and it consists of 8 devices (a master and 7 slaves). The master control communication by polling protocol, usually asynchronously at a rate of 721Kbps a master can transfer data and received on 57.6Kbps or 432.6Kbps in synchronous mode [11]. When many piconets connected together they form scatternet. The technology employs Frequency Hopping Spread Spectrum at its physical layer.

2.5. RF Signal Indoor Propagation

Radio Frequency propagates predictably in open spaces like free space, with least amount of loss and predictable polarization. Losses increase with increasing frequency in sea water, undergrounds or indoor environment, which lead to attenuation very

rapidly [12].

In indoor environments, with many obstructions like walls, furniture, humans and electronic gadgets; RF propagation is unpredictable and attenuated rapidly. The signal may be absorbed, penetrated, reflected, refracted or even diffracted to the surrounding and resulted into multipath or fading effect when passes through any physical obstruction [13]. The propagation of RF does not depend on only with transmission rates or power, but with the response of the receiver to effects mentioned above (multipath or fading) which varies from products to another [13]. Some others may function efficiently and cope with all the effects than the other. Antenna is another factor that can affect the propagation, tilting or any positional change may change the result of received signal strength [13]. For us to understand the effect of RF propagation in indoors clearly, we have to fully understand these mechanisms; Reflection, Diffraction and Scattering [14].

Reflection is a phenomenon that occurs when transmitted signal impacts on an objects that have higher dimension than it is wavelength. Usually, some of the signal may penetrate through the object and some may be reflected back to the transmitted medium. Objects like walls, tables or ceiling can cause reflection in office environment. Surfaces with sharp regularities tend to produce a bend from the transmitted signal when they obstruct it, we called it Diffraction. The diffraction can occur in a Line of sight position or Non Line of sight positions. Having many smaller objects with smaller sizes than the transmitted signal in a medium can cause scattering of the signal. Objects like grasses, smaller objects causes scattering.

The combined effect of these mechanisms causes multipath i.e signal reaching receiver antenna at different time and range. It can be constructive or destructive [12]. Destructive multipath can cause severely rapid attenuation and result in producing distorted version of the original signal. Many factors can contribute in these effects,

depending on materials being used, signal frequency, thickness of the objects and angle of incident and many more [13]. This is the reason why researchers are yet to come up with generalized model in determining propagation in indoor environment. Because, attenuation and path loss is always unique in the type of objects and other factors.

2.6. Positioning Techniques

The positioning techniques can be broadly categorized based on the techniques they employed in obtaining positioning information. Some techniques are based on cell-id (predefined demarcation) to find position, Some techniques are based on the relative quantities from a reference points/beacons and others based on the either employing external image of the area or certain information on the position.

2.6.1. Connectivity Based Method (Proximity Detection)

As the name implies, this technique involves demarcating areas (cells) and putting detectors (beacons) in each area. The target object positioning could be returned by detecting them with those beacons [1]. If a beacon detect an object, then that object will be in a cell/area of that beacon, but if more than one beacon detect an object, then the beacon that returns the highest signal will be returned as the target cell. Though, the technique is simpler to implement, but it only gives symbolic relative location positioning not absolute or relative positioning. For example, if the positioning application is room-based, then rooms will be considered cells. The accuracy of the technique is based on the number of detectors being deployed in the cells or the range of the signal from each beacon. Many systems like GSM (cell-id), IR (Infrared technology), RFID (Radio Frequency Identification) or bluetooth can be applied in this technique [1].

2.6.2. Triangulation (Lateration or Angulation)

This techniques involve finding position of an object relative to some reference points. The relative quantity can either be angle, distance or signal strength. The geometric property of triangle is used in determining the positioning of the object [1].

2.6.2.1. Angle of Arrival (AoA) Angulation Method. Two or more reference points A and B from Fig. 2.1 can be used to measure the angles of arrival which signal from them is received by the target object. The intersection of these lines (x) from Fig. 2.1 of bearing is the position of the object, which can be obtained by geometric relationship of the lines. Highly directional antenna is required for determining the direction or angles, which is another drawback in terms of cost of implementation of the system. The systems accuracy can be increased by increasing the number of referenced points but its function is limited to only outdoor because of multipath propagation of indoor environment which greatly affect the directional information [1].

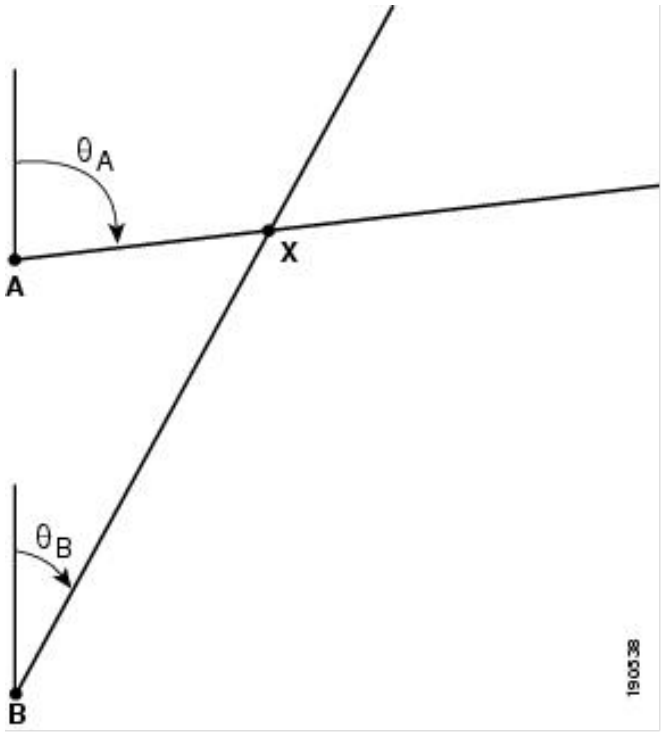

Figure 2.1. Angle of Arrival demonstration [1]

2.6.2.2. Time of Arrival (ToA) Lateration Method. Having accurate time measurement and signal propagation speed, the distance and positioning can be returned. This is the main idea behind this technique. At least three reference points are needed, and the accurate time synchronization instrument/server is also needed. The object will transmit time stamp signal(s) to those reference points and the transmitted and

received time will be recorded. Using the recorded time and signal propagation speed, the distances r1, r2 and r3 from Fig. 2.1 can be calculated, which is the radius of the circle between an object and the reference points s1, s2 and s3. The position where all the circles intersect (x) from Fig. 2.1 is the required position of the object. The major drawback of this technique is requiring another server for time synchronization.

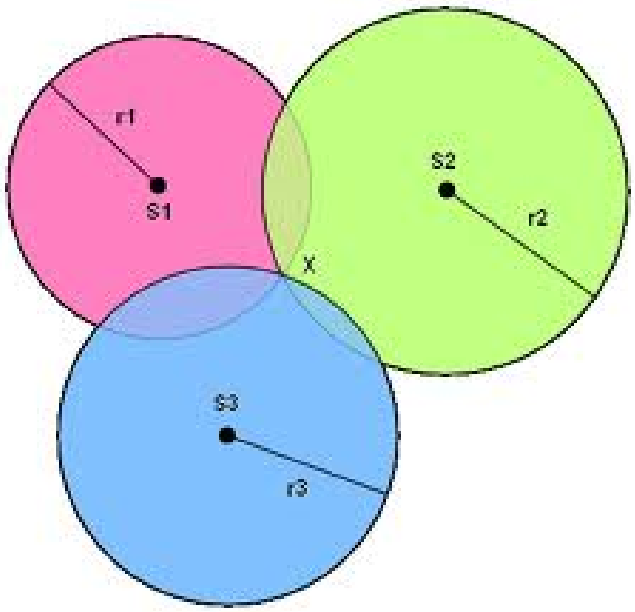

Figure 2.2. Time of Arrival demonstration

2.6.2.3. Time Difference of Arrival (TDOA) Lateration Method. In this technique, the differences in time of signal arrival at different measuring units instead of absolute time in ToA is calculated [15]. The range is constant between two points and transmitter lies on a hyperbolic curve which is obtained by the fact that two or more stations/beacons transmit signal to a single point. The range equation will be obtained as hyperbolic equation with (x,y and z) as the unknown positions of the target object. It can be calculated by regression to find iterative algorithm method [1]. The timing measurement here is made only on receiver terminal which reduce burden of synchronization. Correlation of time of more than two receivers will yield many hyperbolic curves and intersect at a target position [1]. Fig. 2.3 shows how the technique finds the position of an object. R1, R2 and R3 are three transmitters/satellites/access points. Their time

of synchronization are T1, T2 and T3 respectively. The hyperbola H12 is obtained using timing correlation between R1 and R2, and hyperbola H23 using R2 and R3. The intersections of these two hyperbola is the likely location of the object.

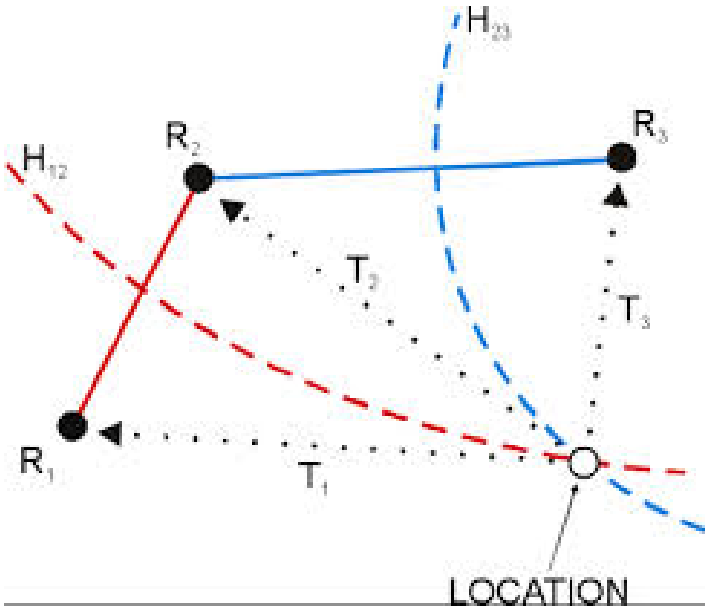

Figure 2.3. Time Difference of Arrival Demonstration [1]

2.6.2.4. Round Trip Time (RTT) Lateraton Method. Unlike TOA, this will require only one time measurement at a single node, and the round trip time can be calculated which will determine the position of the object. The technique solves many problem of ToA methods but also has its drawbacks, many latency may arise due to changing time in a consecutive readings [16].

2.6.2.5. Received Signal Strength Indication (RSSI) Method. This technique involves the use of signal power and received signal strength indicator to calculate signal propagation path loss. The distance can be returned by using path loss, which can be two or three measurement at a time. The major problem of the system is environmental factors can easily change the signal propagation , like multipath and fading effect etc [17].

2.6.2.6. Fingerprinting Method. With the idea of RSSI, another method which uses the signal strength is developed. The technique involves recording signal strength of each point (reference point) and save it as a database, and then use the database in finding the position of each phase. It involves offline (recording the fingerprint) and online (finding location). The technique solve many problems, from multipath, fading to additional cost of antenna or time synchronization effect etc.

2.6.3. Map Matching Method

Another alternative way of installing additional hardware is called Map matching. Where an electronic map is being used to obtain real positioning information regarding moving objects or vehicles [15]. The technique uses topological pattern, pattern recognition or fuzzy analysis.

2.6.4. Dead Reckoning Method

There are methods that estimate the positioning based on the previous known position or based on relative speed over a known time [15].

2.7. Details of Fingerprinting Techniques

All the techniques discussed so far, are good with their advantages usually based on accuracy or deployment. But, they have some demerits of either size, complexity or cost which make them unfeasible in indoors or specifically in a mobile device.

The fingerprinting technique is employed to work with the Wi-Fi infrastructures that are already deployed in the environment for another purpose. These infrastructures will be used to measure the received signal strength of a position, the idea is to find the static RSS of each location. At a certain time, the RSS is dynamic due to multipath propagation nature of indoor environment and fading effects. Also, movement of people tend to influence the values of RSS, so during office hours in a building with

many movement of people the signal has deviation of around (3-5dBm). Therefore, one has to device a means of obtaining average value of these signals over a giving period of time and to obtain a range which serve as deviation value with that RSS.

The technique involves two phases, offline training phase and online determination phase. During training phase, each reference points have a unique set of Access Points that their RSS will be received at that position. The received Signal strength (RSS) is the measure of the power of the signal that has been transmitted from the transmitter (Access Point) to the receiver (mobile device) in our case. These access points together with their MAC addresses and signal strengths value (in dBm) will be recorded and stored in the database. The test bed area will be overlaid with grid points in order to know the coordinates of each reference point. The size of each grid determines the granularity of the system, which translates to the accuracy of the system. The higher the granularity is, the higher the accuracy of the system is. More reference points per test bed, means less granularity and the accuracy is high [18]. Depending on the nature of the system, changing the physical layout of the area or position of the access points alters the training database [19].

Online determination phase involves the client (mobile user) receives RSS at every position in the area from Access Points that are within this range. It then sends the data collected (RSS + MAC) to the server which can be standalone or main server. The server searches through the training database for any match of the vector collected using any positioning algorithms and returns the likeliest location of the client.
The recent development in research in this particular technique arises because of the advantages it has over other indoor positioning techniques. In spite of its advantages, there are some key areas that require enhancing or simplification, one of these areas is generating database; as explained in the last paragraph, database generation is the most difficult and crucial part of the technique, though it reduces the chances of multipath propagation effect. The contemporary way is getting RSS at different time and obtains the average value which is saved in the database [20], which reduces the un-

wanted access points that may be presented during the process without taking into account the directional effect that may result. Reference [21] indicates the effect of direction in the receiver antenna which improve the training phase by taking antenna direction into consideration. Another method based on kriging that improves accuracy of database generation and workload has been developed by [22], that utilizes granularity of around 2-3m in the test and achieved better result than the contemporary method.

Online phase also uses positioning algorithms to locate the client, there are some researches on how to improve original algorithms or come up with another ones that may either simplify the execution time or accuracy. Some of the algorithms are discussed in the next chapter.

3. METHODOLOGY

The aim of this chapter is to describe extensively the methods employed in conducting the project. It has started by describing how database is generated and stored in the software part, then moved to discuss some of the algorithms used in location determination.

The software part has been built on Android application, which have been developed using java programming language and Extensible Markup Language (XML) for interfacing and layout designs. We use Eclipse as integrated environment which have many in-built libraries in it.

3.1. Site Surveying and Database Generation

The experiment has been conducted at the wing of fourth floor of Engineering building of Zirve University. Figure 3.1 shows the test area, 28 reference points with 3m distance were chosen. Insidder 3.0 software has been used for the recording signal strength of each reference points. It records Signal Strengths, SSID with their unique MAC addresses at a given range of time. This uniqueness is important in distinguishing two reference points, which is the main objective of using fingerprinting algorithm.

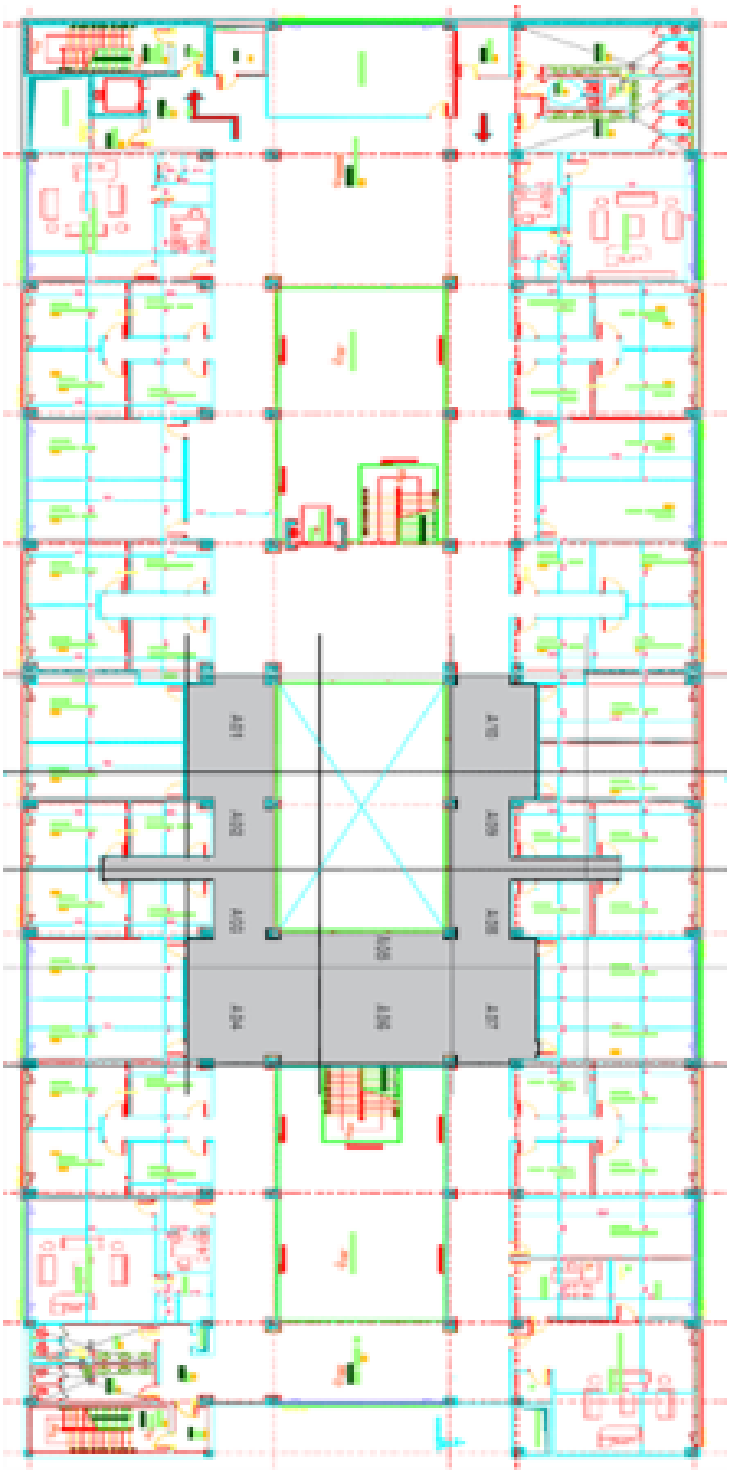

Figure 3.1. A Fourth floor plan with shaded area as a test bed

3.1.1. Reference Points

The recording has been taken at each reference point about 20 different readings at 3-5 seconds interval. The first five readings have been recorded with the computer to face North, then West with another five readings, then South also and lastly East making 20 readings at each point. These procedure is important in order to fish out any unwanted signal or access point and also to view vividly the effect of antenna direction which is influencing signal propagation. These readings have been averaged as a single reading of each reference point and saved as one file. Also for the weaker signals, it is important to filter them in order not to disrupt the positioning system. As you can see, any signal lower than (-80dBm) is not present. These signals, even if you leave them, there is strong likelihood they might not appear in the next reading.

3.2. Signal Variation With Time

Table 3.1 shows how values of received signals is changing with time at each direction. The access point has MAC address as C8:CB:B8:FC:E1:70. At any given time, the signal strength is changing, this is very crucial in deciding the range values that is going to be assigned in the database. Because, the client device can access any of the signal values below, and failure to detect it in the algorithm is a total failure of the system. That is reason why we have tried to widen the range so any value can fall within its range. For this single signal within short range of time varies from -51dBm up to -77 dBm. This clearly shows how effective the range will be in constructing algorithm.

3.3. Fingerprinting Algorithm

The fingerprinting methodology on this project is Nearest Neighbor, which is built based on the fact that indoor radio signal is varying with time. This is the main reason to take readings many times and create variance of the data. Our database generation is considered all the directions in order to cover more information regarding each location.

Table 3.1. Shows the sample of reading of a reference point

NAME	SIGNAL STRENGTH	NAME	SIGNAL STRENGTH
A009 E	-51	A009 S	-54
A009 E	-69	A009 S	-66
A009 E	-71	A009 S	-70
A009 E	-69	A009 S	-63
A009 E	-71	A009 S	-70
T. A009 E	-66	T. A009 S	-65
A009 W	-75	A009 N	-71
A009 W	-72	A009 N	-62
A009 W	-77	A009 N	-67
A009 W	-77	A009 N	-66
A009 W	0	A009 N	-53
T. A009 W	-75	T. A009 N	-64

The algorithm:

1. Pick the signal with device within the shortest possible time.

2. Take the range (±n dBm) and find its correspondence for the picked signal.

3. Compare the signals with the database values.

4. Count number of information that matches. 5. Return the location information of the reference point with the highest match.

6. If there are more than one matches, return their locations both.

3.3.1. Algorithm Elaborated

3.3.1.1. Pick the Signal. The device which its location to be found sniffs the signal strength from any nearby Access Points. The signals sample are shown in Table 3.2;

3.3.1.2. Take the Range (± n dBm). In our case, n= ±6 dBm. The new values search through the database with the range as shown in Table 3.3;

Table 3.2. Shows the sample of signal sniffed by device

SSID	MAC ADDRESS	SIGNAL STRENGTH
ZirveUniversity	c8:cb:b8:fc:e1:70	-73
ZirveUniversity	64:31:50:ee:bf:71	-57
ZirveUniversity	c8:cb:b8:fc:e2:50	-76
ZirveUniversity	c8:cb:b8:fc:e5:10	-71
ZirveUniversity	64:31:50:ee:bf:61	-60
ZirveUniversity	c8:cb:b8:fc:e5:d0	-75

Table 3.3. Shows the sample of signal range

SSID	MAC ADDRESS	SSMax	SSMin
ZirveUniversity	c8:cb:b8:fc:e1:70	-67	-79
ZirveUniversity	64:31:50:ee:bf:71	-51	-63
ZirveUniversity	c8:cb:b8:fc:e2:50	-70	-82
ZirveUniversity	c8:cb:b8:fc:e5:10	-65	-77
ZirveUniversity	64:31:50:ee:bf:61	-54	-66
ZirveUniversity	c8:cb:b8:fc:e5:d0	-69	-81

3. The algorithm will search for any Access point that falls within SSMin and SSMax values and count it.

4. The one with the highest counts is likely be the location and its location information is returned.

3.4. Software Part

In order to build any application on android platform, it is required to install tools necessary that takes to the task area of the application;

ECLIPSE IDE: The first thing to download is Integrated Development Environment (IDE) it can be Eclipse or Netbeans. IDE will have all built in methods and classes in it, it is not required to manually put them all, IDE makes your job simpler

and easier. Fig. 3.2 shows a sample of Eclipse environment with java classes in it.

ANDROID SDK (Software Development Kit); this kit allows to be interacted with classes and methods that are specifically designed for android platform.

ANDROID VIRTUAL DEVICE (AVD): An application can be developed without original android phone or tablets. Then this virtual device will be set up as an emulator of the android device, which comes in handy in many platforms like phone or tablets. Once available, we can develop, test and run an android application in our system can be developed.

Android platform development constitutes of three major parts that is required to be known extensively before starting anything, these things are: Java, XML and android Manifest.

JAVA PROGRAMMING ENVIRONMENT: This is the eclipse environment that allows to run java classes and methods. It is area where actual java code is built and execute. It holds main package of the application, classes and codes. In eclipse, it usually resides in src folder.

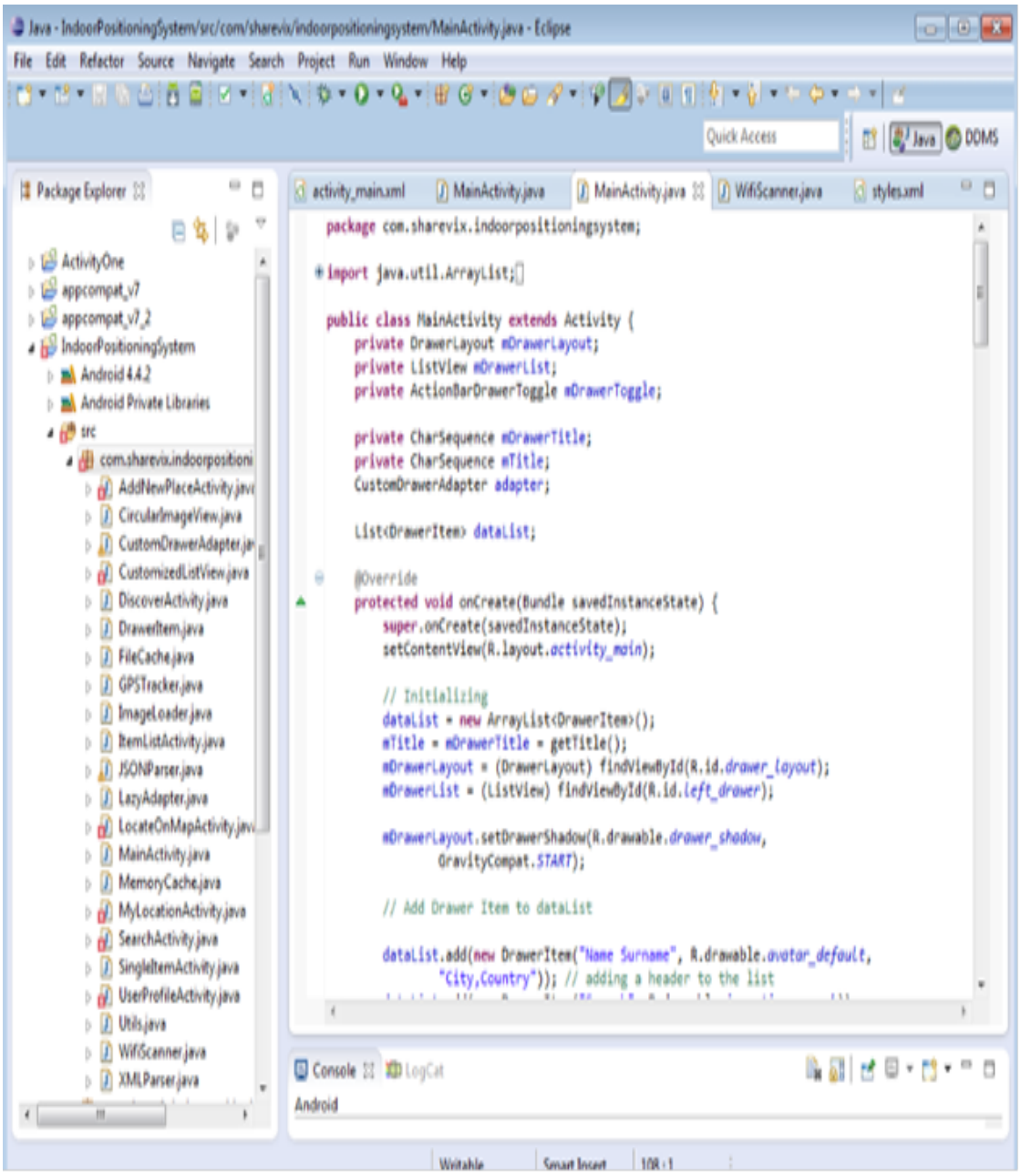

Figure 3.2. Eclipse development environment showing java codes

At the left hand of the screen, there is a field called package explorer where all the application are listed. The src folder is with red mark in it, inside it there are many java classes all with .java to indicate they are java files. The main code is java window, in it all the methods are written and executed in the console.

XML/LAYOUT: The second component is called layout folder which hosts Graphical User Interface (GUI) and XML format of it. Any activity (single page) of application has been built from here, like button it, editable text, written, pictures, media files etc all are made here, either using GUI or using xml formats.

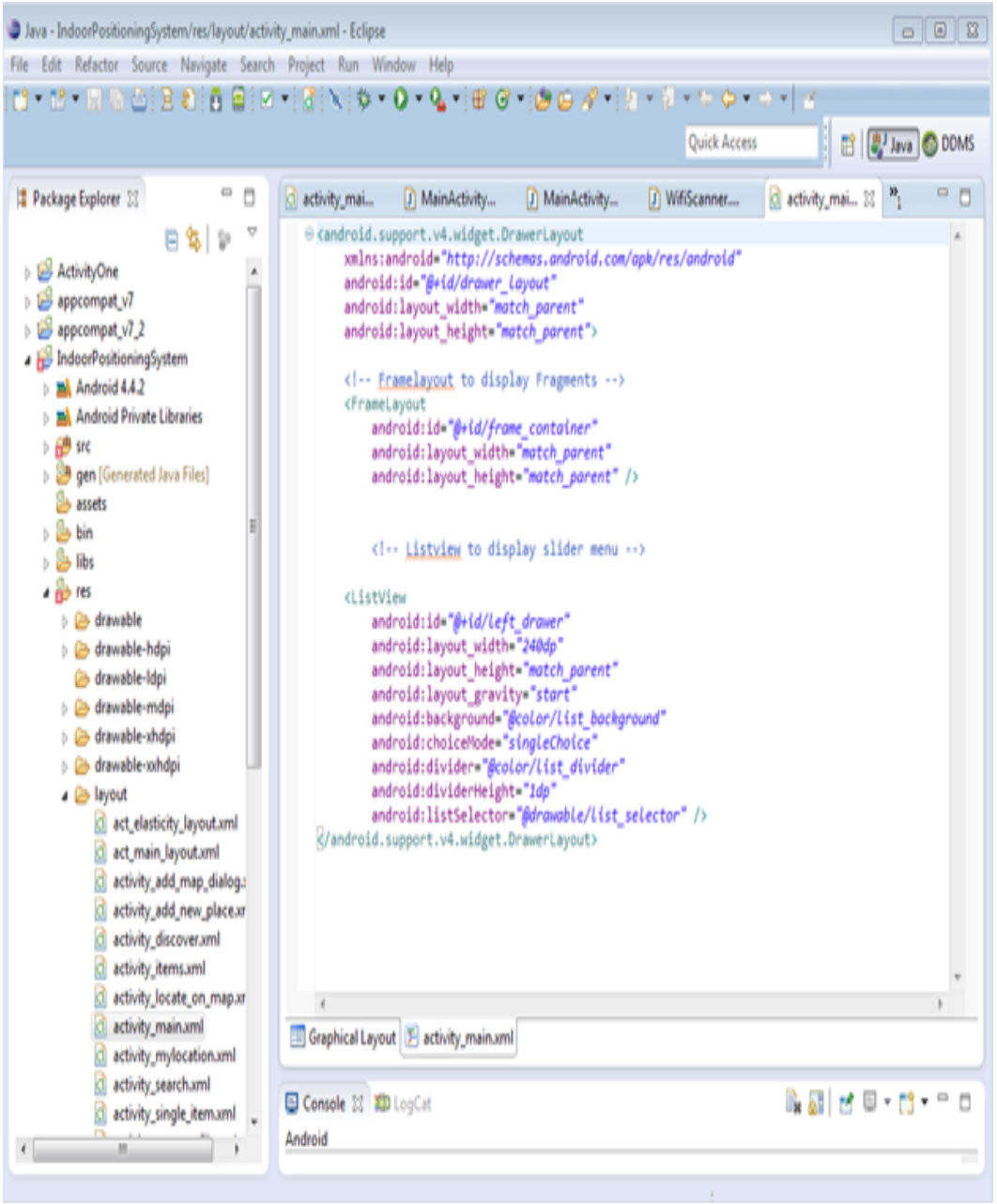

Figure 3.3. XML layout of the Activity

It is in this form that has been designed the activity size, height, gravity, back-

ground, color etc. Fig. 3.3 shows a sample XML codes in Eclipse environment.

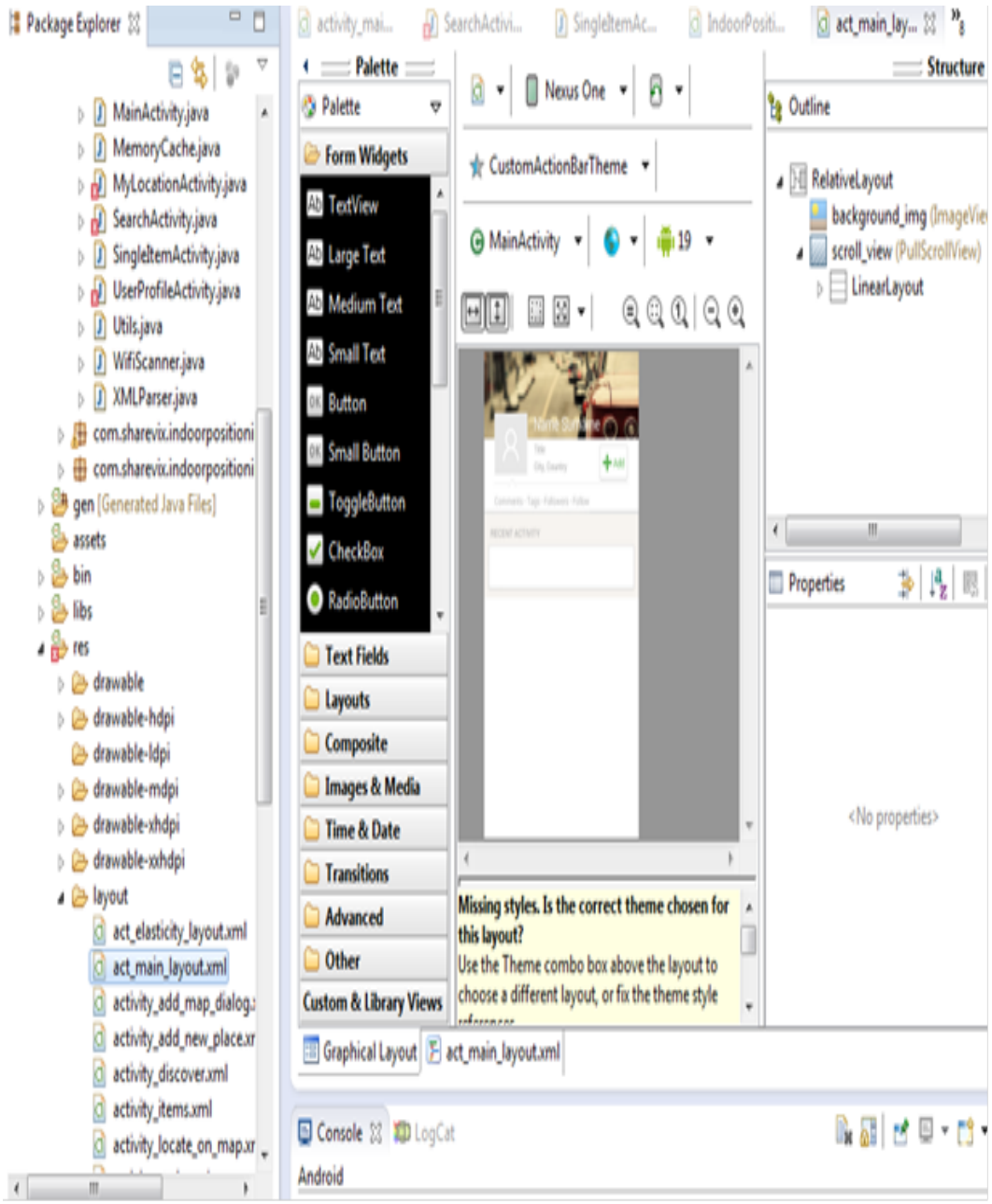

Figure 3.4. Graphical User Interface of the Layout

From here, the widget or many things depending on the projects can be dragged and dropped. But real calibration has to be done in xml format. XML/layout is in (res/layout/nameoftheacitivity.xml).

ANDROID MANIFEST: In this XML file, any activity to be added to the project must be declared here, any permission that is necessary to access third party services like accessing internet, sending text to another object, accessing pictures from album, GPS location etc must get the permission from android manifest. Fig. 3.5 shows a sample of Android Manifest in Eclipse environment.

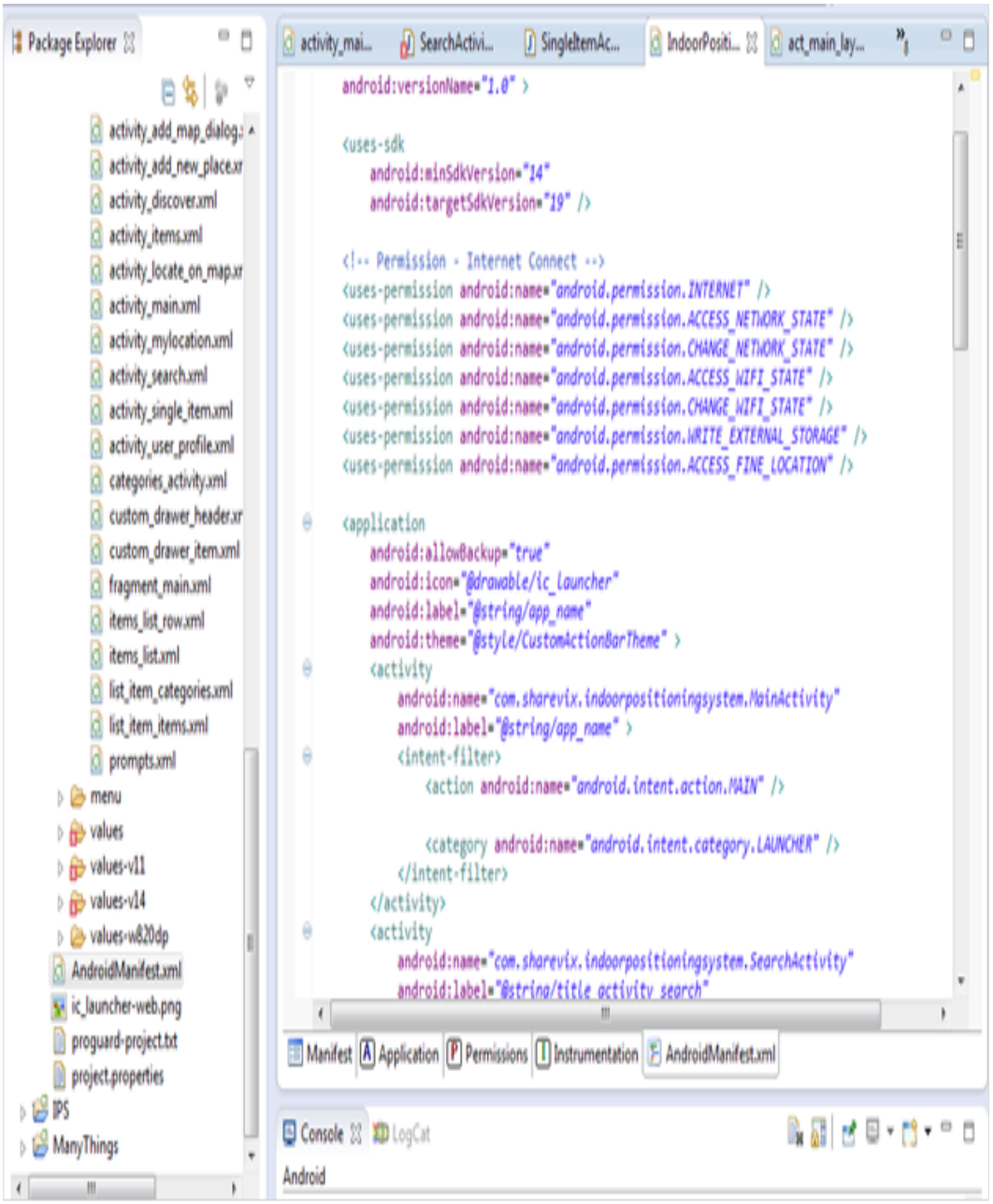

Figure 3.5. XML format of Android Manifest

At the main screen, the permissions that has been granted to the application are seen; Internet, access current network state, change network, write to external storage etc. all these were requested then granted here. Also in XML text format there is ¡activity, this started defining a new activity, in this case main activity with a name: "com.sharevix.indoorpositioningsystem.MainActivity" and declared it to be the main acticity, that is activity that will be launch at the first. The android manifest xml file is in package explorer beneath res folder.

3.5. Database Storage

For this project, remote server using PhpMyAdmin is utilized. Normally, if the database is fixed and small in size, standalone database is usually employed. But for flexible database, which has tendency to be increased, the remote server is the best suited. The database is consists of tables like location information and signals. These two tables are connected via their common fields. Normally, android can not connect directly to the remote server. A simple web service that will communicate to the server our requests and return to us the response using JSON format is created. The web service has been PHP, and our command or queries can be in this format and communicate to the server via that format.
Our algorithms and tables are all resided in the database, for security issues. The android part of this application will only receive signal strength from the access points. the received value passes to the server via PHP format and algorithms first receive the values and put the required range.

When the range is calculated, it then sends to the database as query that searches the whole database for any possible matching. When the matching is found after all the computations. it can return the location information of the reference point to the same query. This information send back to the android part.

The android part displays the information related to the place which has been

depicted from the database.

3.6. Adding Fingerprint

Part of the aim is to examine any possibility of improving the database generation, another class that automatically adds fingerprint to the database has been developed. Our algorithm has been tested with the new class to see effectiveness, despite the fact that signal strength is changing with time but the algorithm provides a way of maximizing searching range from calculated standard deviation. With higher range of values, the algorithm still can be able to return the likeliest location. Fig. 3.6 shows a sample of the class that adds the fingerprint.

Figure 3.6. A Class that Automatically Add a Fingerprint to the Database

This class has button, with editable string in it, that if fingerprint can not be find in the database the button pops up and ask you to add new place, by clicking the button, the location information automatically saves in the database. Next time, the location information of that position is returns in database. Fig. 3.7 shows a map view of the application in the phone, the shaded region is the tested area.

JSON parser is the class objects that lets you connect to the remote server and parse data into the server. In this application, PHP server were connected and data (signal strengths and location information) have been parsed to it. Fig. 3.8 shows a sample of JSON parser class of our application in Eclipse environment.

Fig. 3.9 shows a sample of class that locates a pin on the map by obtaining the location information. For any position, the location information that is return are coordinates of the fingerprint, this class moves the pin to the required coordinates on the map, depending on the pixels level of the map picture.

User profiles are the names of the location in strings, for any location, there are user information that displays on the screen if the system returns the location. Fig. 3.10 shows a user profile class of the application. Fig. 3.11 shows a GUI of the application that searches for the position in the application.

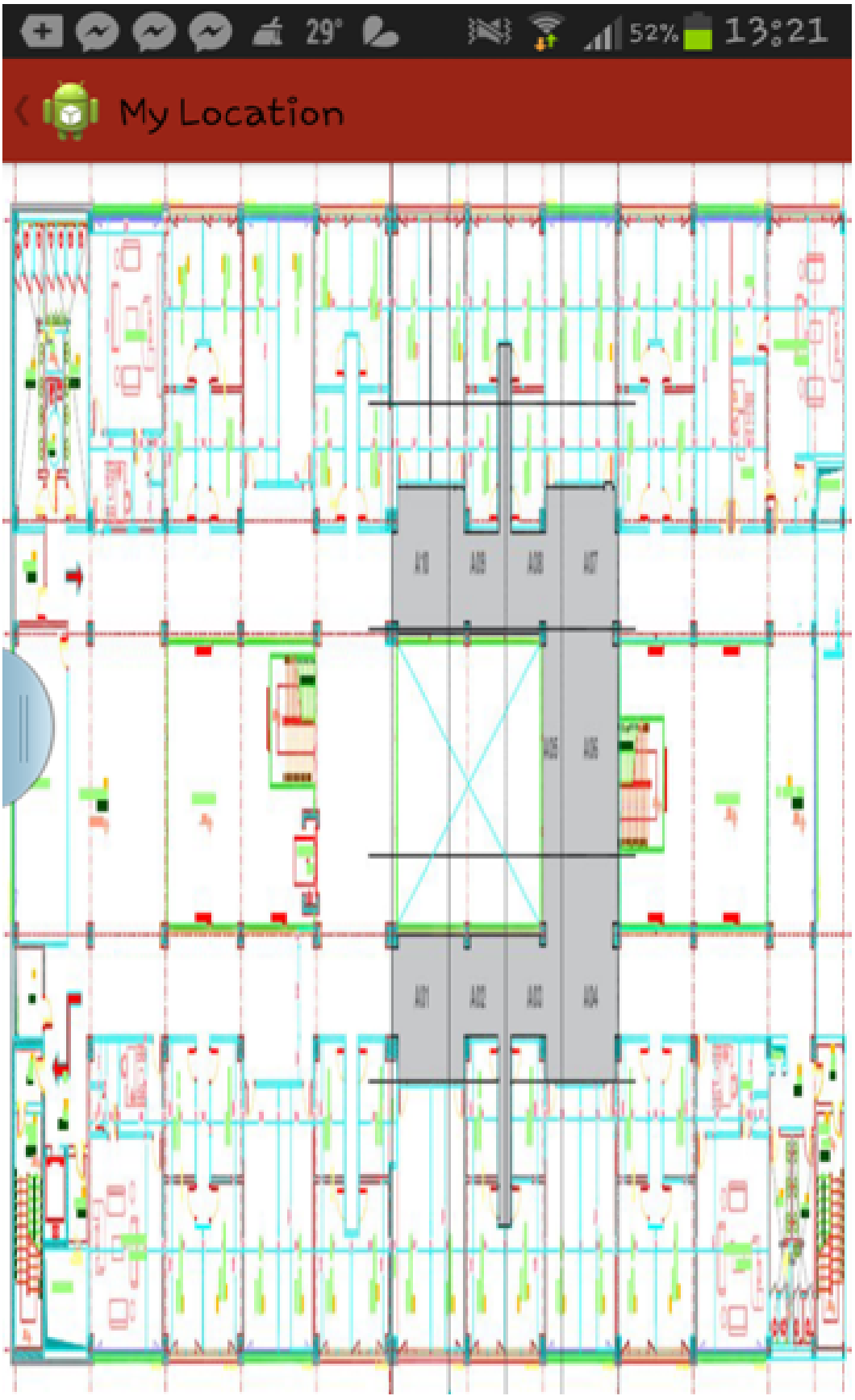

Figure 3.7. A View of the Map in the Application

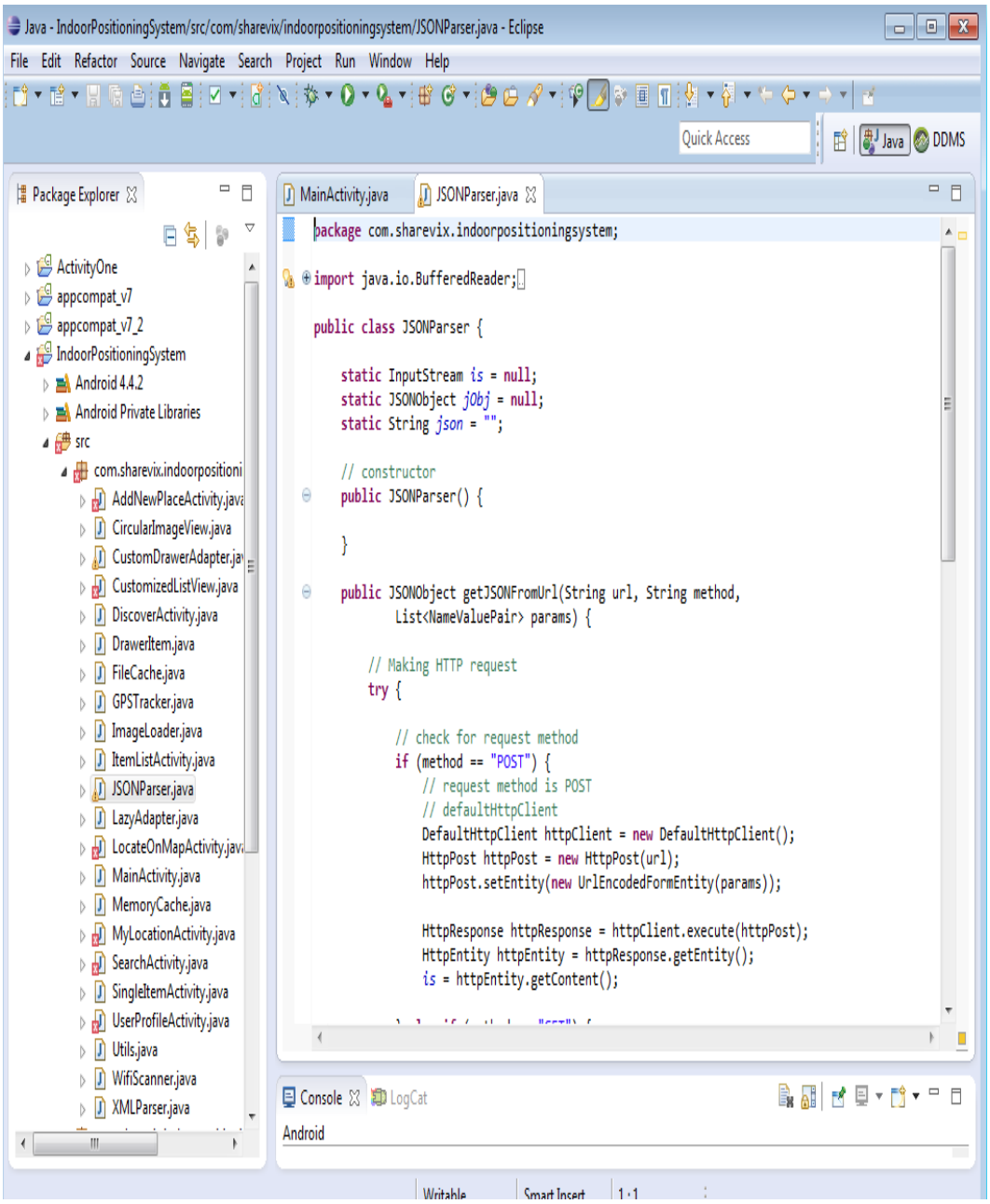

Figure 3.8. A View that shows json parser

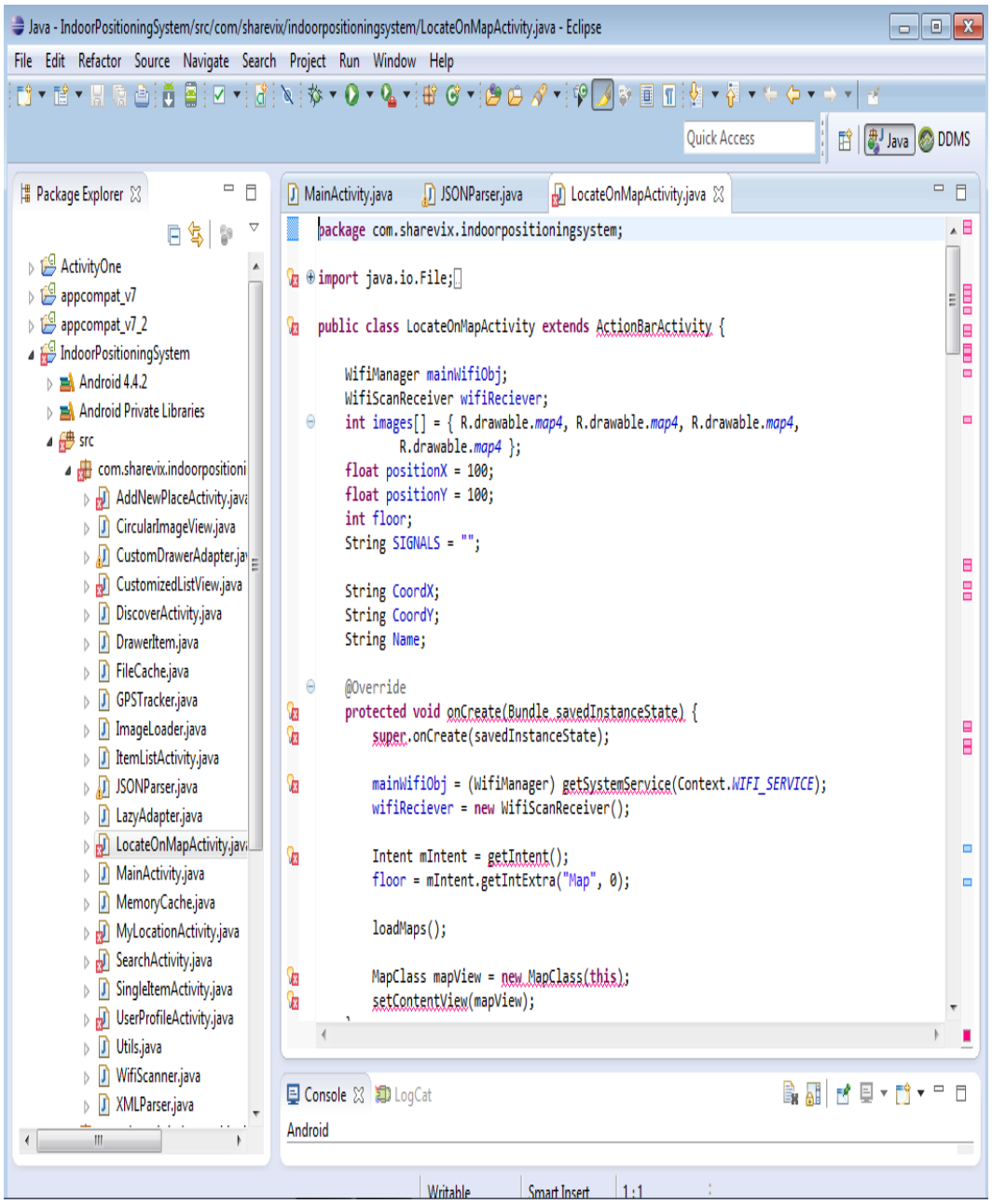

Figure 3.9. A Class that locate on map

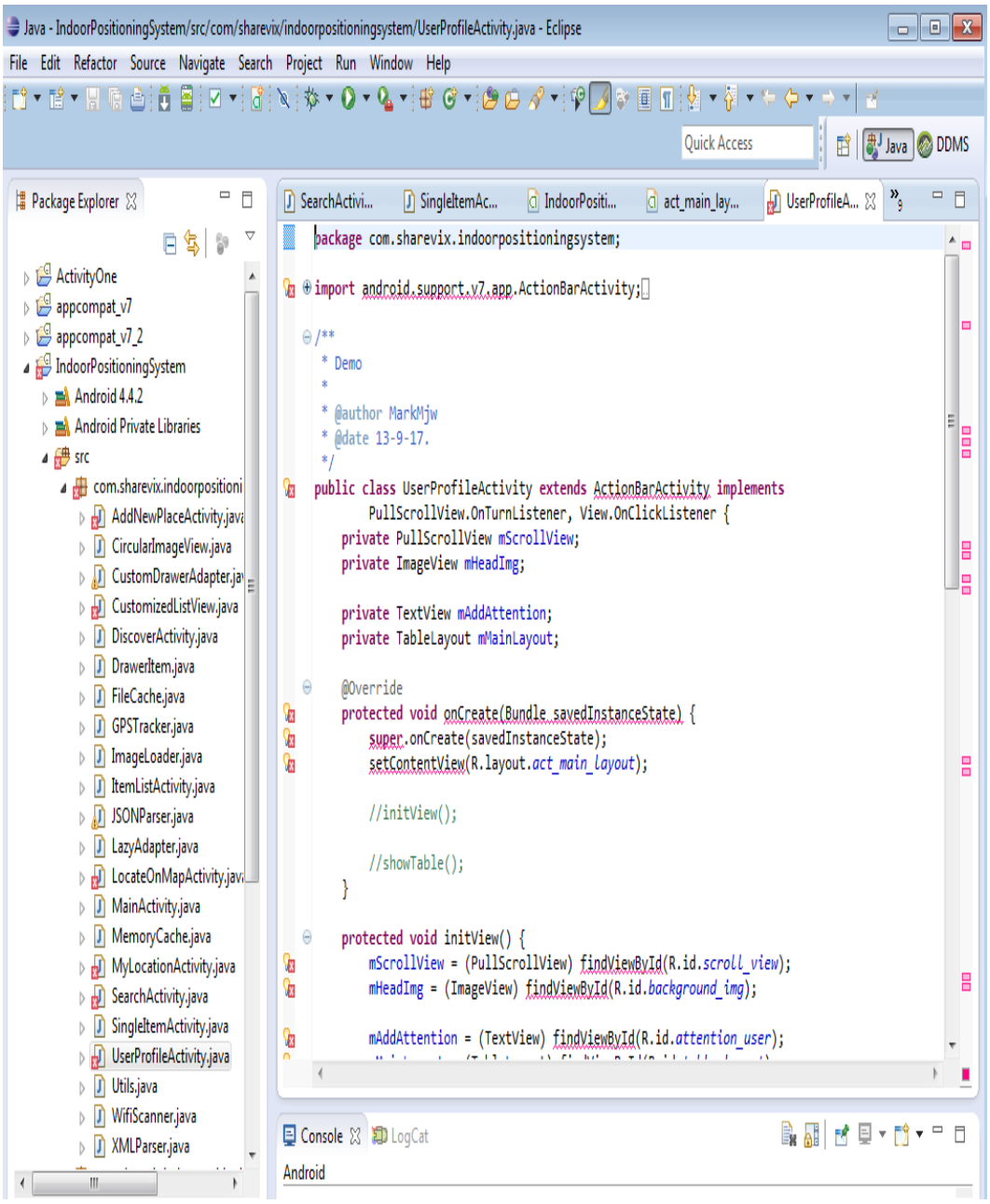

Figure 3.10. A Class that finds the profile of a user on a map

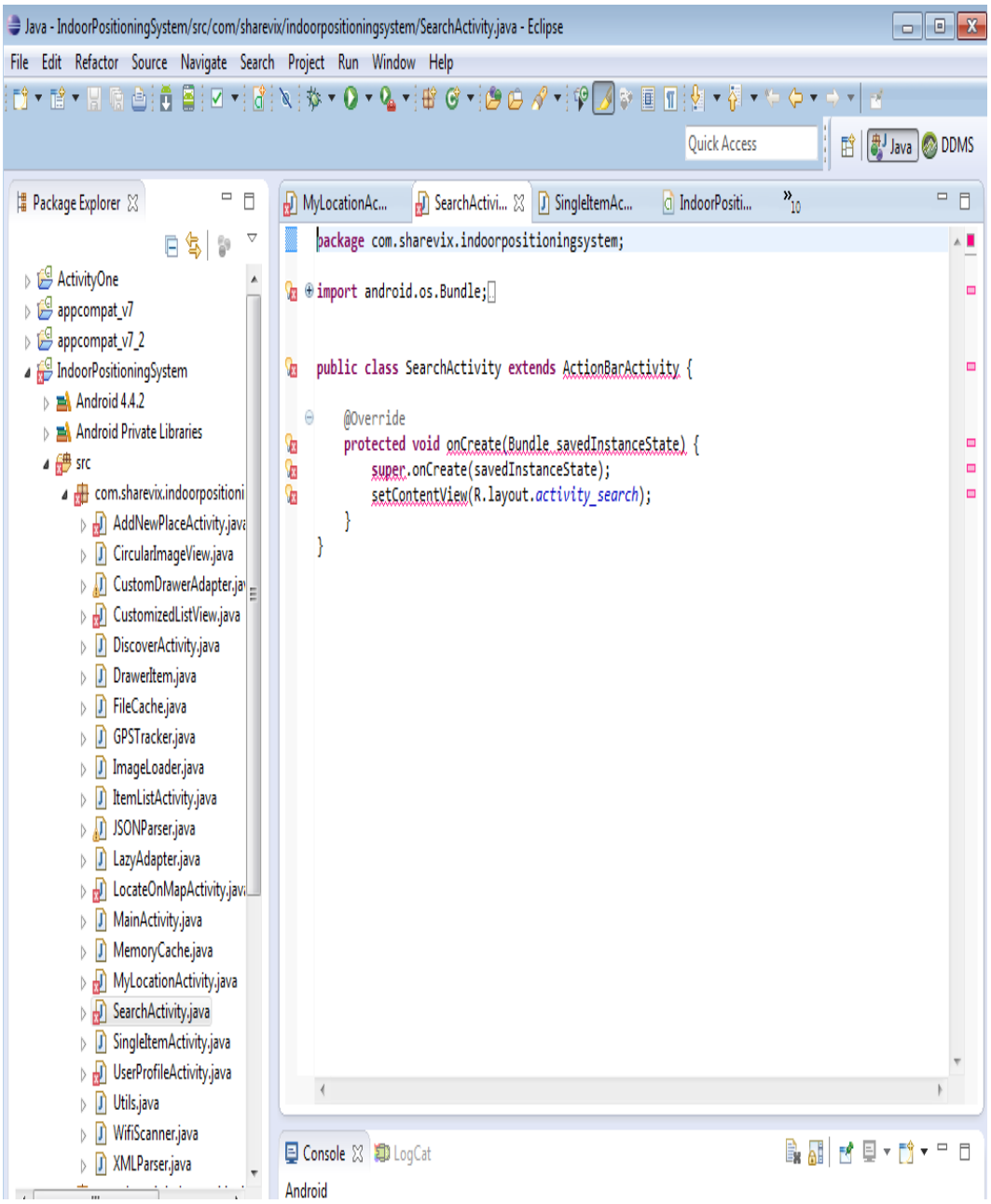

Figure 3.11. A Class that search for any fingerprint

4. EXPERIMENT AND EVALUATION

The aim of this chapter is to utilized the methodology and execute it in real time application using our methods.

4.1. Experiment Setup

The project has been conducted on fourth floor of the Engineering building of Zirve University, Gaziantep, Turkey. 28 reference points with 3 m between them have been chosen. At each reference point, Signal strength together with MAC Address and Location information has been recorded using inSsider 3.0 software.
The targeted accuracy is room-based or office-based level based on 6m range accuracy between each reference points.

Directional information of the device antenna has been considered, new database generation method have been tested . For each direction, five readings have been recorded at interval of 3-5 seconds each, making 20 readings at each reference point. The average of each reading has been obtained after filtering out unstable signals and unwanted access points. In order to expand the effectiveness of the experiment, the readings have been taken in different hours and days. Fig. 3.1 shows the picture of the tested area.

4.2. Experiment Testing

Because of the changes in the database generation, the standard deviation has been increased to pave rooms for the wider range of selection. Our experiment hav been focused on improving the database together with the standard deviation in the algorithm.
The first database (ddbaseThree) has been created using 3m spacing between reference points . The second database (ddbaseSix) has been constructed using 6m spacing

between reference points. The third database (ndbase) has been constructed by not considering directional effect of the device. The algorithm has been evaluated with different values of n. The first value is 3, which is normal value if there is no directional consideration, while the second value is 6 using our calculated value.

4.2.1. Testing

The application has been tested, about 20 different tests have been conducted with two different values of n.

These cases have been considered in the testing;

- The application returns the exact location.
- Or returned at the one location below or above the exact location.
- Or two below or above the current location.
- Or returned at the more than three locations from the current position.

4.2.1.1. Testing of ndbase. In this case, the algorithmSix and algorithmThree have been tested with the ndbase (database without considering directional effect). The room-based accuracy of the application have been examined and the effect of standard deviation. Fig. 4.1 shows the result of the two algorithms with the ndbase database.

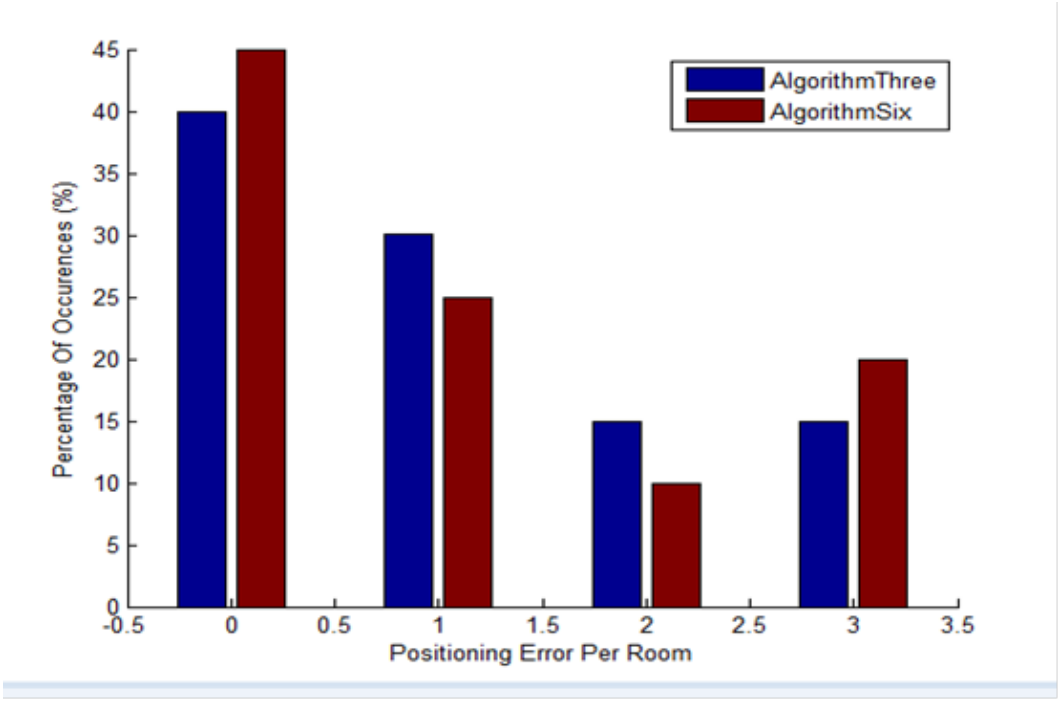

Figure 4.1. Accuracy of the ndbase with the two algorithms

4.2.1.2. Testing of ddbaseThree. In this testing, the directional database which has been constructed firstly have been tested with our algorithms. This testing has given us insight on how effective changing the range values of standard deviation is with respect to the accuracy and time. Fig. 4.2 shows the results of the ddbaseThree with the two algorithms.

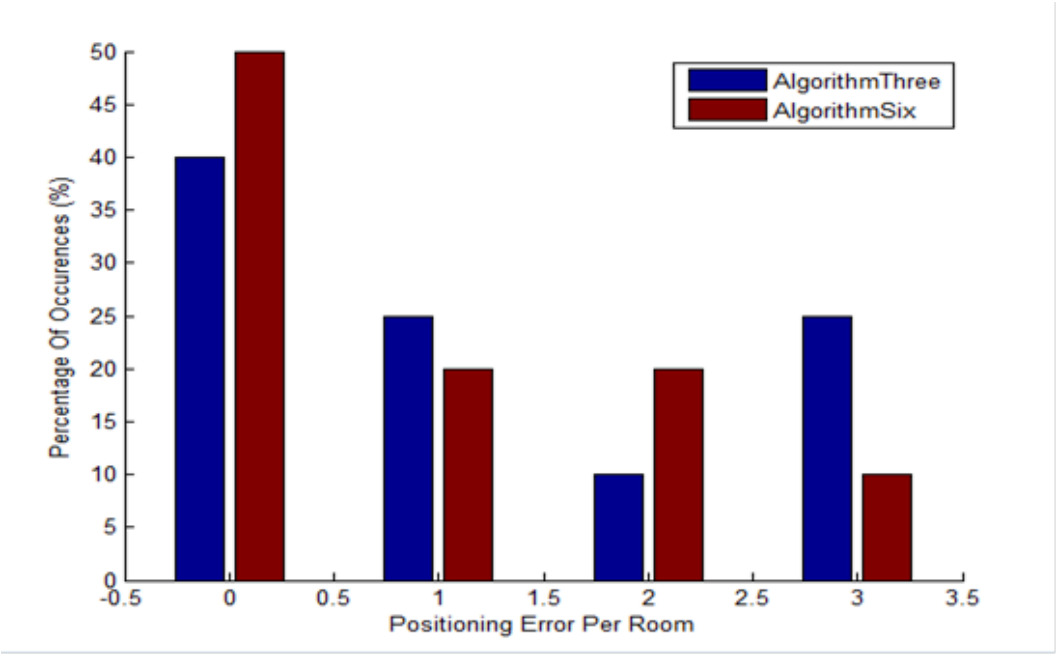

Figure 4.2. Accuracy of the ddbaseThree with the two algorithms

4.2.1.3. Testing of ddbaseSix. : In this case, the directional database has been reduced to half, the effect of time reduction to the overall accuracy of the system and room based accuracy with the directional database have been tested. Fig. 4.3 shows the results of the two algorithms with the ddbaseSix.

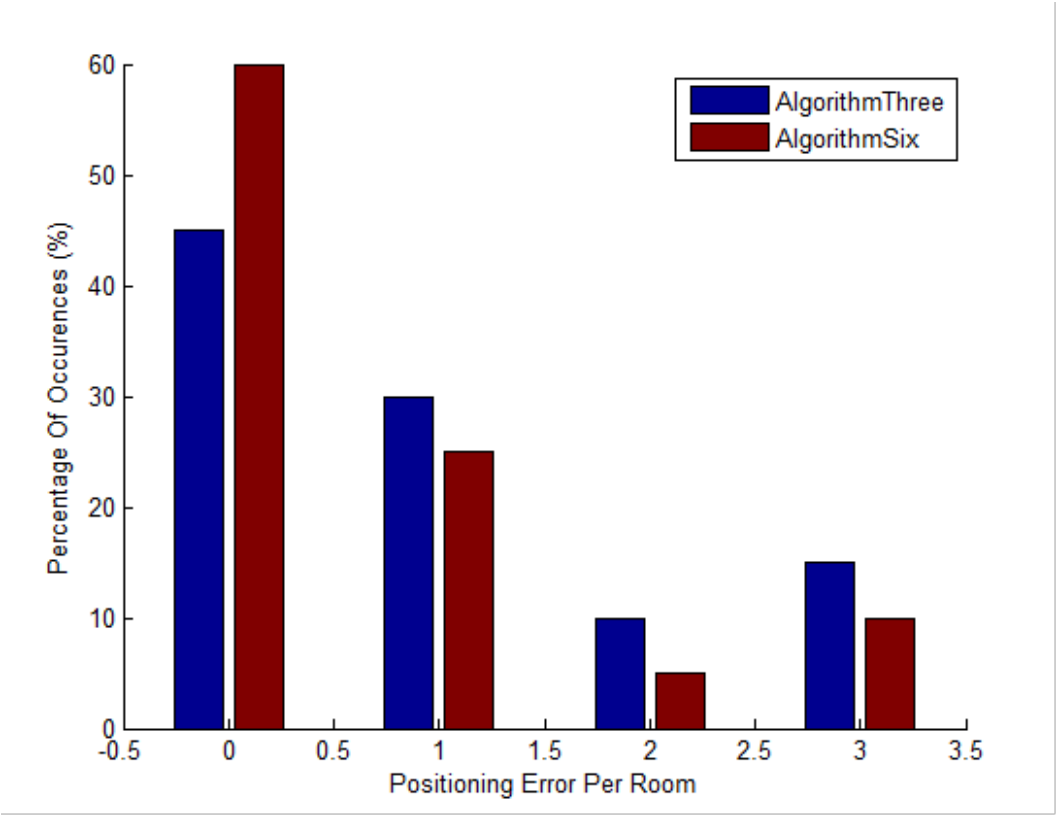

Figure 4.3. Accuracy of the ddbaseSix with the two algorithms

4.2.1.4. Results. The algorithmSix has recorded about 50 percent of the testing correctly against 40 percent in algorithmThree.

In figure 4.2: algorithmSix has recorded 60 percent against 45 percent of the algorithmThree. Also shows that directional consideration is important in database generation.

Also, it clearly indicates that with the directional database, it is better to consider the standard deviation of the wider range, in room-based accuracy.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The aim of this project is to examine the possibility of using WiFi infrastructure to find the location of an object indoors. The software has been designed using java programming tools in android platform. Fingerprinting technique has been employed in the application by generating a database in a remote server. Conventional nearest neighbor algorithm has been used for positioning algorithm part and considered directional effect of antenna during database generation, this enhanced the accuracy of the database consequently location algorithm. The effect of directional information have been investigated during training phase using three different database depicted from original database and by varying the standard deviation of the database. The result shows that it is better to consider directional information during training phase of the system.

5.2. Recommendation

For a future research, it is paramount to consider all other basic algorithms of fingerprinting technique to see the effect of directional information. Also it is important to come up with the way on which database generation will be reduced. It is better to use wider range of standard deviation in room based accuracy method because it gives better accuracy.

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