Indoor Positioning Techniques using RSSI from Wireless Networks

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Declaration

It is hereby declared that

1. The thesis submitted is our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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Abstract

The whole world is familiar with the Global Positioning System or GPS which can identify the exact position of any object with the help of satellites. Yet GPS signals are not available indoors. To overcome this, Indoor Positioning System(IPS) is used which enables us to locate objects inside an indoor environment. Our goal is to build an Indoor Positioning System by estimating the location using Received Signal Strength Indication (RSSI) through wireless networks. The proposed model will determine the position of wireless devices in a room. We took the RSSI values as coordinates and specific reference points at every two meters making the room into a grid. The RSSI values on the reference point are measured. The position of the wireless devices will be estimated from the reference points using the trilateration method and the ITU indoor path loss model.
With the aforementioned process, we calculated the position using the ITU indoor path loss model and trilateration. Using the ITU indoor path loss model our mean error was 1.01166m and while using trilateration it was 1.22m.

Keywords: Indoor Positioning, WiFi, RSSI, Trilateration, ITU

Dedication

We would like to dedicate this paper to the Almighty, our family and friends.

Acknowledgement

To begin with, we want to offer our gratitude towards the Almighty Allah who helped us to overcome all the hurdles and we completed our thesis.

We are extremely grateful to our Supervisor, Dr. Amitabha Chakrabarty and our faculty member Md. Rayhan Kabir. Without their constant support and guidance, we could not have completed our thesis.

Lastly, we are thankful to our parents for their unconditional support and prayers that we are at the end of our graduation.

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Nomenclature

The next list describes several symbols & abbreviation that will be later used within the body of the document

AP Access Point

BLE Bluetooth Low Energy

CSI Channel State Information

GPS Global Positioning System

IoT Internet of Things

IPS Indoor Positioning System

IR Infrared

ITU The International Telecommunication Union

LOS Line Of Sight

RFID Radio Frequency Identification

RSSI Received Signal Strength Indicator

UWB Ultra-Wide Band

WLAN Wireless Local Area Network

Chapter 1

Introduction

1.1 Overview

Location based services have become a fundamental part of our lives with the extensive use of wireless networks. In fact, GPS is the most used location services out there that we use in our everyday life. GPS is a positioning system based on satellites that gives accurate position and time of users. But as soon as we enter a building, GPS signals face loss due to the building structure. The connection gets weak as the user enters the building. Thus to use location services indoors, Indoor Positioning System is used.

An indoor Positioning system is like a GPS for the indoor environment. It lets us locate an object, people or IoT devices inside buildings or any facilities. The different technologies used for indoor positioning are proximity based system [1][2], Wi-Fi based system [3], infrared systems and many others. Although Wi-Fi based system is the most researched one, our work is mainly on the Wi-Fi based system. Wi-fi based indoor positioning system gives fairly two to five meters accuracy.

Among all the technologies for indoor positioning (IPS), Wi-Fi is preferred because no new hardware is required for the environment setup and is available in public places which can be used for our purpose without any complications. Wi-Fi based positioning system gives comparatively higher accuracy. We are using Received Signal Strength Indication (RSSI) to determine the position by calculating the distance.

In Wi-Fi system, many methods are used to find the location. Trilateration is one of the methods used in wireless networks. Using the trilateration method we can compute the approximate position by taking three reference points. Taking the distance from the reference point to a mobile user as the radius and drawing circles from reference points, we would get the actual position where the circles intersect [4]. In the trilateration method, there should be at least three reference points to compute the distance.

In addition to the trilateration method, ITU indoor path loss model is applied to find the path loss inside the room or the building [5]. The path loss of the signals takes place due to various interference. Building structure, walls, furniture, electronic devices, number of people inside the building and so on contributes to path loss of signals. During signal propagation, the signal wave reflects due to obstruction from objects of larger dimension and some part of the wave signal gets absorbed by the object [6]. As a result, RSSI values fluctuate causing a loss of signal wavelength. Moreover, when RSSI fluctuates, distance estimation is not accurate. To determine this signal path loss ITU indoor path loss model is used.

1.2 Objective

The main objective of our research is to create an indoor positioning system through a minimal approach using existing technology. Indoor positioning systems need to be very light and dynamic so that it can run on any environment. Most of the indoor positioning systems have been deployed in an ideal space without any interference. Our objective will be deploying it in a crowded environment with people and other network interferences.

Secondly, we would like to bring down the overall cost of an indoor positioning system so that it can be implemented easily in any environment. Our system can be implemented using only three routers placed in three corners of an environment. In this way, we can minimize the number of APs as well.

Thirdly, implement the solution in such a way that businesses can easily adapt to the system. Our system will only use the RSSI so the APs can also be used for other purposes as well. As a result, utilizing it for multiple purposes. More importantly, the APs can be from existing infrastructure which can decrease the burden of spending extra money.

1.3 Motivation

The world is consistently advancing. Technology has achieved great advancement in this sector and there are yet necessities for an integrated ready solution for indoor positioning which lacks reliability. Our main motivation is to contribute to the sector of indoor localization based on Wi-Fi infrastructure in a dynamic environment. We wanted to implement a system using Wireless Access Points and using its network features to provide reliable location related data.

There are many articles [7], [8], [9] that gave overviews on various existing technology scopes for implementing IPS such as Ultrasound, Infrared (IR), Wireless local area network (WLAN), Radio Frequency identification (RFID), Bluetooth, magnetic signals, Ultra Wide band (UWB), audible sound and vision analysis. A number of indoor positioning systems have been established using the aforementioned technologies by different organizations and research groups. Each system utilizes any of the existing positioning technologies to take advantage of the technology.

1.4 Contribution

The purpose of our research is to contribute in the field of indoor positioning by increasing the accuracies of the positions. We have tried to minimize the error and to some extent we have done quite a progress. Our whole contribution towards the whole thesis has been described below in bullet points.

- We have implemented our indoor positioning system in a crowded environment where there were lot of interferences such as cellphones, computers, laptops, etc. With all these interferences, we were able to achieve quite a satisfactory result.
- RSSI values were calculated during the scene analysis process by taking the average of three different iteration to get a precise calculation.
- Most of the existing indoor positioning system or researches usually contains one algorithm. However, we have implemented two different algorithms (ITU Path Loss Model and Trilateration) together to increase the accuracy.
- Our research was conducted on two rooms separately. Later we were able to merge the coordinates of both the rooms. By merging, we can easily find coordinates of one room from the other. This was quite an achievement.
- Most importantly, we were enable to increase the accuracy through our research work. It was minimized to a distance of an average of 1.22m.

Chapter 2

Literature Review

There has been quite a number of researches to address the indoor positioning system. All the research varies from technologies and techniques. This chapter will focus on previous works and research related to indoor positioning system.

2.1 Positioning Techniques

There are many techniques that have been used in order to pinpoint the position or simply put, localize the position. Some of the most important ones have been described below.

2.1.1 Trilateration

Trilateration is a process where the position of an object is determined from its distance from three reference points or access points. [3] This method is widely used but mostly it is used in RSSI methods where the reference points are usually the Wireless Access Points with pre-determined coordinates. The distance is measured

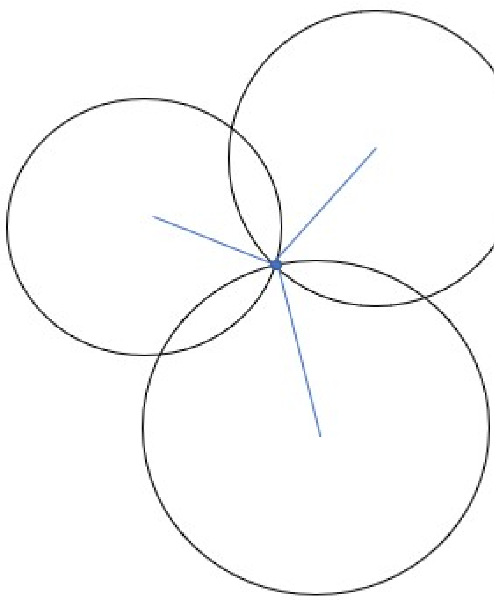

Figure 2.1: A visual representation of the Trilateration method

with the help of signal strength and considering it as a radius of a circle is drawn around the wireless AP. While doing it will all the access points, the circle intersects with each other and that is the required position. However, it should be noted that the number of access points actually increases the accuracy while using it with WiFi technologies. [10]

2.1.2 Triangulation

Triangulation method usually uses the basic properties of trigonometry and geometry. In this process, a position is determined by forming triangles to the point from known points. Triangulation has two parts – lateration and angulation. Calculating the distance from reference points is known as lateration. And, angulation refers to calculating the angle to a certain position from reference points.[11] In addition, this technique uses the angles from angulation method and their corresponding distance from at least two reference points to find their intersecting point which is estimated as the localized required position. [1]

2.1.3 Fingerprinting

Localization systems based on fingerprinting usually require the analysis of the environment beforehand. It requires a survey of the environment where the fingerprints are collected for later use [12]. Another name of this process is Scene Analysis. The required position of the device can be found from the similarity between environments or scenes [13] . It is the unique collection of characteristics of a scene. This method is usually carried out in two stages – i) Training Stage and ii) Tracking Stage.

At first, different measurements of RSSI are taken during an offline stage which is the training stage. Later it is used to train to the system. Once the system starts working or deployed, the online measurements from a definite point is taken into contrast with the offline measurements to calculate the user location precisely. This step is called the tracking phase. Fingerprinting method is usually done by the collection of RSSI or CSI. [14] There are a many algorithm that are used in the tracking stage to match the offline measurements with the online measurement. Few of the widely used algorithms are -

i. Probabilistic Method
i. Artificial Neural Network
ii. k-Nearest Neighbor (kNN)
iii. Support Vector Machine (SVM)

2.1.4 Proximity Based Localization

The process through which the distance between the user and Point of Interest (PoI) is measured or calculated is known as proximity-based localization. This method is heavily based on radio frequency. In proximity-based localization principle, many fixed antennas are placed around the environment where this technique will be used. When a user comes near one of the antennas with a device (usually IoT device), the device is recognized and the antenna which is at the closest is considered to be its location. When a device is connected or recognized by multiple antennas then the antenna receiving the strongest signal will be considered as the location of the device. [1] [2]

2.1.5 Device Based Localization

Device based Localization (DBL) is another important process for IPS. This process is dependent on the devices as the name suggested. Here, the user device uses some nodes or anchor nodes to estimate or calculate the required location. The primary use of this system is in the navigation system. This method assists the user in navigation around any space or environment. [15]

2.1.6 BLE Localization

Bluetooth is a radio technology for wireless data transmission that can be used to transmit data over short distances. With the help of this technology data can be exchanged between mobile phones as well as computers. Everyday appliances such as wireless speakers, keyboards or mice can also be connected. The rate of data transfer is usually lower than that of USB. In addition to classic Bluetooth, a newer technology has been developed, which is known as Bluetooth Low Energy (BLE). It usually has the same range as the normal Bluetooth which is between 10 and 30 meters. [16] This network technology is also used particularly for indoor positioning. For this procedure, Beacons are needed. Beacons are battery operated BLE devices which is based on a transmitter-receiver principle. They are a small device that sends out signals in a radius of 10-30 meters. They can accurately measure or determine a position up to 3 meters. BLE beacons can be used in both client-based as well as server-based applications. [16] [17] However, if beacons are installed in such an environment where there are lots of Wi-Fi signals, interference can occur because they both share the same frequency range (2.4 GHz). [18]

2.1.7 Infrared Based Localization

Infrared (IR) based location system uses light waves to determine the position. In this system IR receivers are placed everywhere inside the building. The IR tags receive light pulses and IR receiver reads the data. IR based system is easy to install because of the easy availability and easy maintenance. However, it cannot pass through opaque interferences and requires line of sight which makes it difficult to apply in complex indoor environments. [19] [20]

2.1.8 Radio Frequency Based Localization

Radio frequency based localization uses electromagnetic waves which can penetrate through opaque structures. Radio frequency identification (RFID) has RFID tags, receiver and data processing system [21]. RF based system covers a wide area since it used electromagnetic waves. However, RFID is difficult to maintain because all the receivers need different tags. In addition, interference with various radio frequencies is possible which will give inaccurate position.

2.2 Free Space Path Loss Model

Free space path loss is the loss of signal strength due to line-of-sight (LOS) in free space where there is no obstruction to cause reflection or diffraction [22]. Although, Free space path loss model cannot be directly applied to indoor propagation, it is required to calculate the path loss for a close-in reference distance [6]. For LOS in free space environment, free space path loss model gives path loss measurement as a function of T-R separation where transmitter and receiver are in line-of-sight [23]. However, free space path loss model is not sufficient for transmission inside buildings because of multiple interference.

Chapter 3

Proposed System and Implementation

3.1 Proposed System

In our model, we aim to measure the distance and the accurate position of wireless devices from RSSI values collected from wireless networks using two methods; ITU indoor path loss model and Trilateration. Here, we used raspberry pi 3 to calculate the RSSI values.

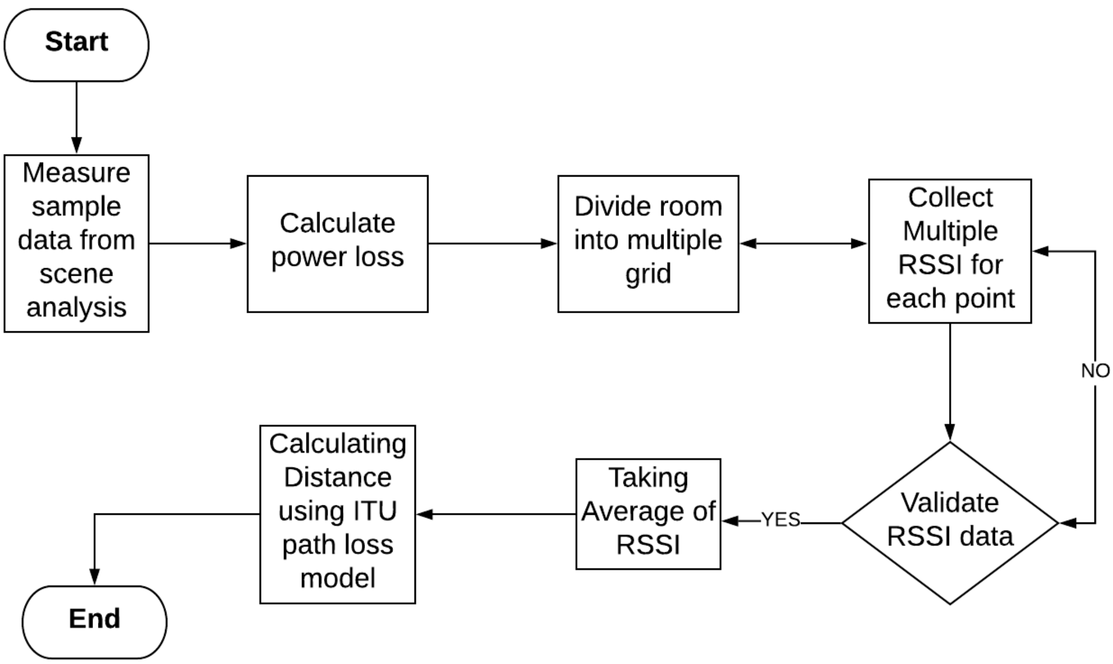

Figure 3.1: Distance calculation from RSSI values using ITU indoor path loss model

In the flowchart given in Figure 3.1, initially sample data are measured from the scene analysis. After taking sample data, power loss coefficient is calculated. Considering the room into a grid, multiple RSSI values are noted on multiple points. Then the average RSSI value is taken and the distance is calculated using ITU indoor path loss model.

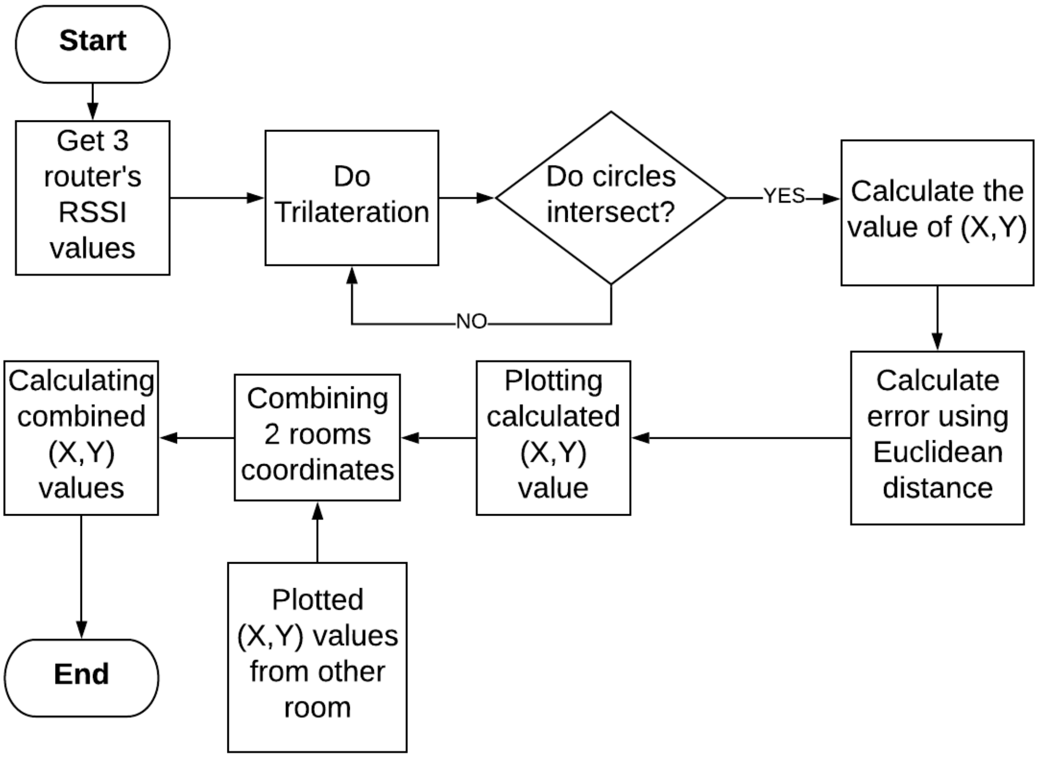

Figure 3.2: Distance calculation using Trilateration and merging two rooms

In the flowchart given in Figure 3.2, RSSI values of a position is collected from three routers. After taking the RSSI values, Trilateration has been done in order to find the intersecting points of the circles. Then the values (x,y) coordinates has been calculated. Euclidean distance has been calculated to find the error after plotting the x,y. Later two rooms are merged together with the (x, y) values from both the rooms.

3.2 Experimental Setup

Devices used:

- 2 x TP Link WR845N 300Mbps Wireless-N-Router
- 1 x Tenda F3 300Mbps Wi-Fi Router
- 1 x Raspberry Pi 3 Model B+

The three routers were used to create three Acess Points which was positioned in such a way in the rooms that they formed a triangle. Figure 3.3 and Figure 3.4 is the visual representation of how the routers were placed in room 1 and room 2 respectively. R1, R2 and R3 respectively mean Router 1, Router 2 and Router 3. The raspberry pi was used to collect the RSSI values in different points of grid which was later sent to our local server to create the database of scence analysis.

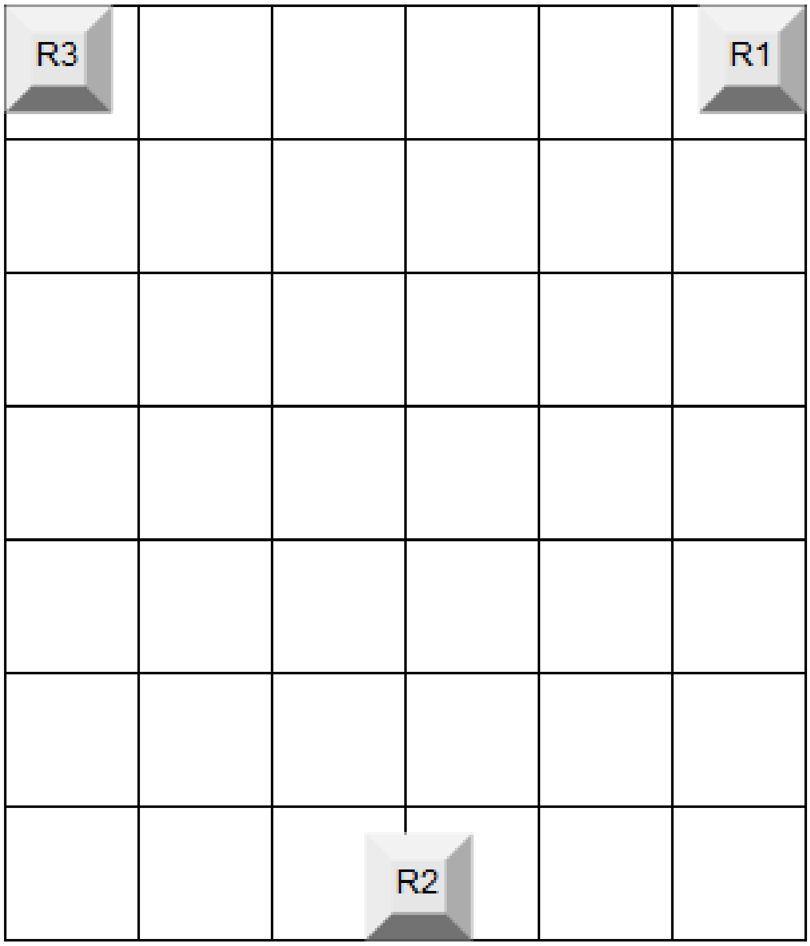

Figure 3.3: Experimental grid setup of routers for Room 1

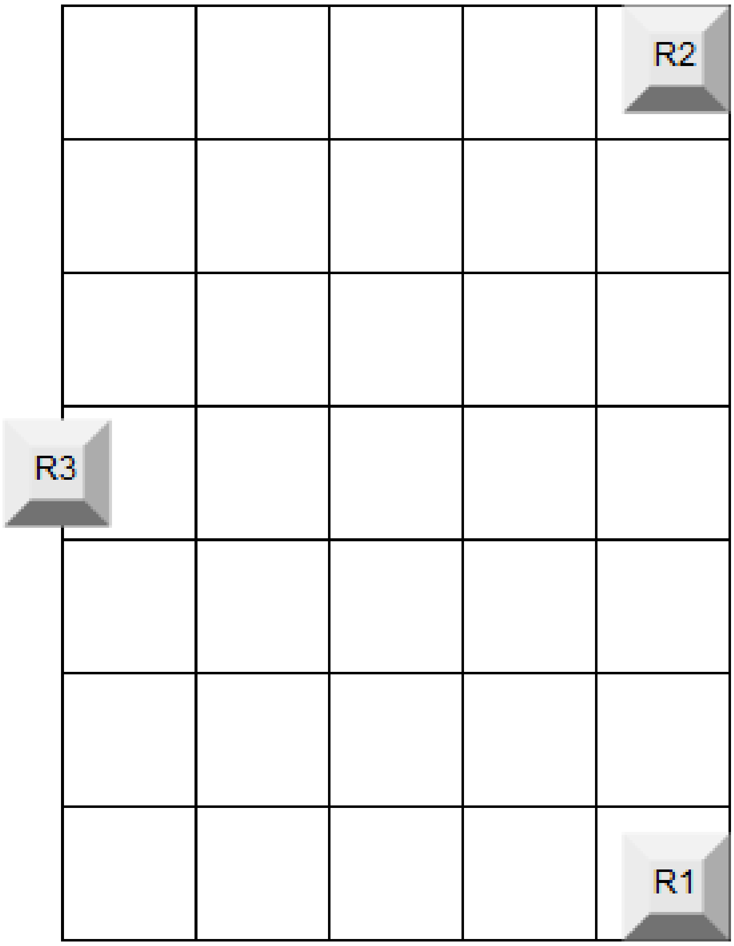

Figure 3.4: Experimental grid setup of routers for Room 2

3.3 System Implementation

3.3.1 Data collection and Scene analysis

We considered two rooms for our scene analysis. For each room, three Access Points, that is, routers are placed at three corners forming a triangle. In the first room, two routers were installed 7 meters apart on top left and right corners and another router was installed at the mid bottom. For the second room, two routers at top right and bottom left corners 9 meters apart and another at mid left. A visual representation of the rooms are given in Figure 3.5 and 3.6. Each room is divided into grid and RSSI values are calculated for different points on the grid. We measure RSSI using python script on raspberry pi. Three RSSI values for each point are noted and then the average value is considered.

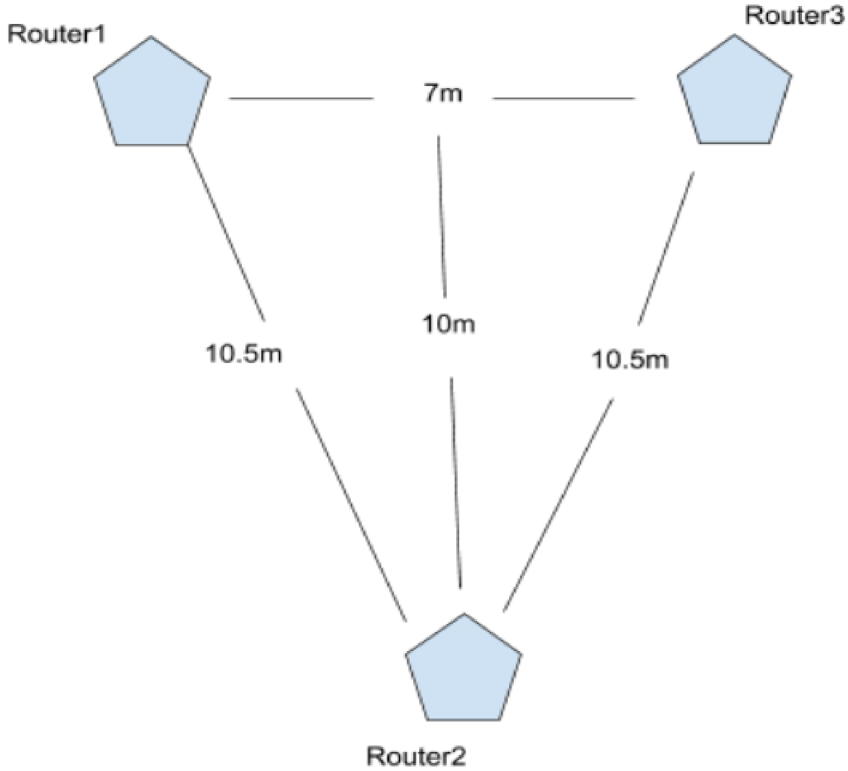

Figure 3.5: Router setup of first room.

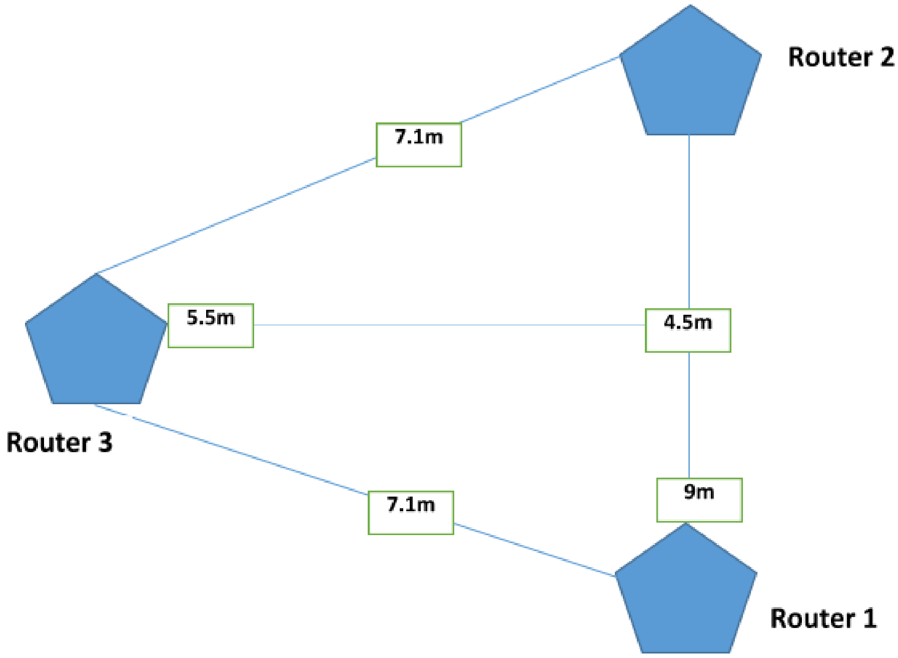

Figure 3.6: Router setup of second room.

3.3.2 ITU Indoor Path Loss Model

To overcome the signal path loss due to room architecture and other interferences we use ITU indoor path loss model. The equation for measuring path loss is given in Equation 3.1 [5]

$$P_t - P_{rssi} = 20log10(f) + Nlog10(d) + Lf(n) - 28dB \quad (3.1)$$

Where,
P_t = transmitted signal strength.
P_{rssi}= received signal strength,
f = frequency 2.4 GHz
N = power loss coefficient
$Lf(n)$ = floor penetration loss
n= difference of the floor between transmitter and receiver [n=0 for our experiment because the rooms were on the same floor] [24][25]
d= the distance.

P_t is given as 19-20 dbm at the product datasheet [26]. Power loss coefficient from our sample data is 28-32. However, the values in this equation varies from environment to environment because of the difference in frequencies, floor differences and different materials in the environment.

3.3.3 Trilateration

The RSSI values calculated from the routers are converted into distance using the distance Equation 3.2, 3.3 and 3.4. The unknown point would be (x, y) and known points would be $(x_1, y_1), (x_2, y_2)$ and (x_3, y_3).

$$(x - x_1)^2 + (y - y_1)^2 = r_1^2 \tag{3.2}$$

$$(x - x_2)^2 + (y - y_2)^2 = r_2^2 \tag{3.3}$$

$$(x - x_3)^2 + (y - y_3)^2 = r_3^2 \tag{3.4}$$

After trilateration the intersecting point of the three circles is considered as exact position of the wireless device. To calculate the error between calculated coordinates and the actual coordinates we use Euclidean distance formula given is Equation 3.5, 3.6 and 3.7.

$$\sqrt{(x - x_1)^2 + (y - y_1)^2} = r_1 \tag{3.5}$$

$$\sqrt{(x - x_2)^2 + (y - y_2)^2} = r_2 \tag{3.6}$$

$$\sqrt{(x - x_3)^2 + (y - y_3)^2} = r_3 \tag{3.7}$$

The coordinates of two rooms are merged together so that the position can be estimated anywhere on the whole floor. To calculate the new coordinates Equation 3.8 and 3.9 are used.

$$x^* = (1 - x) \tag{3.8}$$

$$y^* = (y + 6.5) \tag{3.9}$$

The wall thickness between the two rooms is 1 meter for which $1 - x$ is used and the length of the 1st room is 6.5 meters more than the second.

Chapter 4

Result Analysis

This section of the paper contains the collected data from both the rooms of our research. Followed by the analysis of the data that we got from scene analysis and comparing it with the calculated data from RSSI with ITU and Trilateration. Our data collection was done on two rooms in different segments and lastly the two rooms are merged to get a map of the whole floor.

4.1 Actual vs ITU Indoor Path Loss Model

Specific points	Router 1			Router 2			Router 3		
	Actual	RSSI dis.	Errors	Actual	RSSI dis.	Errors	Actual	RSSI dis.	Errors
1	5	5.5	0.50	10.112	11.06	0.95	2	3	1.00
2	3	3.37	0.37	10.012	10.27	0.26	4	5.56	1.56
3	1	1.2	0.20	10.3	11.5	1.20	6	7.5	1.50
4	5.385	5.15	0.23	8.139	8.16	0.03	2.828	3.79	0.97
5	3.606	3.12	0.48	8.016	7.49	0.52	4.721	5.45	0.73
6	2.236	3.83	1.60	8.382	8.77	0.39	6.325	7.49	1.17
7	6.403	5.33	1.07	6.185	6.22	0.04	4.472	5.33	0.86
8	5	5.79	0.79	6.021	5.33	0.69	5.656	6.28	0.63
9	4.123	3.53	0.59	6.5	4.16	2.34	7.211	8.16	0.95
10	7.81	7.41	0.40	4.272	3.53	0.74	6.325	10.28	3.96
11	6.708	6.03	0.67	4.031	4.16	0.13	7.211	11.98	4.77
12	6.082	6.55	0.47	4.416	4.16	0.25	7.211	11.98	0.00
13	9.433	9.52	0.09	2.5	1.62	0.88	8.485	11.17	2.04
14	8.544	8.04	0.50	2.061	2.54	0.48	8.246	10.28	0.58
15	8.062	9.52	1.46	3.201	2.58	0.62	8.944	9.52	2.94
16	11.18	9.52	1.66	1.5	1.62	0.12	10	12.94	2.75
17	10.44	9.48	0.96	0.5	0.47	0.03	10.77	10	0.49
18	10.049	9.52	0.52	2.5	1.39	1.11	11.661	10.28	1.38

Table 4.1: User data from routers using ITU indoor path loss model for room 1.(in meters)

Specific points	Router 1			Router 2			Router 3		
	Actual	RSSI dis.	Error	Actual	RSSI dis	Error	Actual	RSSI dis.	Error
1	9.21	10.26	1.05	2	2.76	0.76	5.7	6.66	0.96
2	9.848	10.85	1.00	4	4.32	0.32	4.74	4.99	0.25
3	10.54	11.85	1.31	5.5	5.77	0.27	4.5	4.99	0.49
4	7.28	9.54	2.26	2.82	2.61	0.21	4.3	4.65	0.35
5	8.06	10.26	2.20	4.47	4.32	0.15	2.92	4.02	1.10
6	8.9	8.26	0.64	5.85	3.43	2.42	2.5	2.81	0.31
7	5.39	5.77	0.38	4.47	3.48	0.99	3.54	4.99	1.45
8	6.4	8.26	1.86	5.66	4.02	1.64	1.58	2.43	0.85
9	7.43	5.77	1.66	6.8	5.77	1.03	0.5	3.48	2.98
10	3.61	4.02	0.41	6.32	7.69	1.37	3.81	4.66	0.85
11	5	5.77	0.77	7.21	8.26	1.05	2.12	2.43	0.31
12	6.26	9.54	3.28	8.14	8.88	0.74	1.5	2.1	0.60
13	2.24	2.43	0.19	8.25	8.26	0.01	4.95	6.66	1.71
14	4.12	6.66	2.54	8.94	11.02	2.08	3.81	4.99	1.18
15	5.59	6.2	0.61	9.71	10.26	0.55	3.5	4.32	0.82

Table 4.2: Data from routers using ITU indoor path loss model for room 2.

In Table 4.1 and 4.2 the actual distances and the calculated distance from ITU indoor path loss model is shown for room 1 and room 2. The error has been calculated by taking the absolute values of the differences of Actual distance and RSSI distance. It fluctuates in some of the data due to various interference. The lowest error that we got from three routers is 0.03m for room 1 and 0.01m for room 2. On the other hand, the maximum error that we got is 4.77m for room 1 and 3.28m for room 2. The absolute mean error of room 1 for Router 1, Router 2 and Router 3 are 0.70m, 0.60m and 1.57m respectively and of room 2 are 1.34m, 0.91m and 0.95m respectively. The mean error for Router 3 of room 2 is high because some of the distance were less than 1 meter. Distance less than 2 meters does not give accurate RSSI value.

The absolute mean for room 1 with the routers combined is 0.95667m and for room 2 is 1.06667m. The combined mean for both the room is 1.01166m.

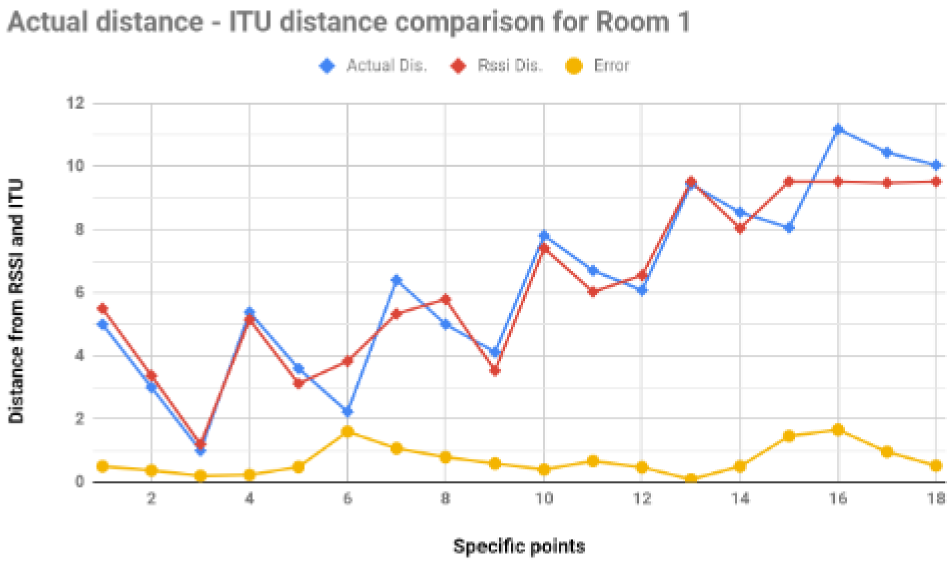

Figure 4.1: Actual distance vs ITU indoor path loss model for Room 1.

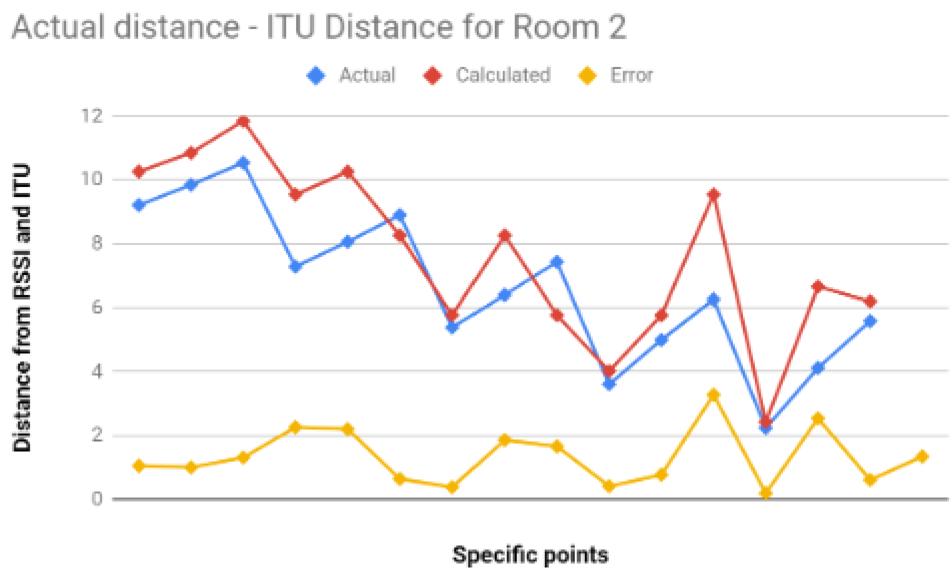

Figure 4.2: Actual distance vs ITU indoor path loss model for Room 2.

Figure 4.1 and 4.2 are the graphical representations of data collected from room 1 and room 2 respectively. The specific reference points are considered along x-axis and distance calculated from RSSI and ITU indoor path loss are considered along y-axis. The error between RSSI and ITU indoor path loss model is plotted and shown in the graph.

The blue points represents the measured distance where as the red points represents the distance calculated from RSSI value.

If we compare the blue lines with the red lines we can find that there are negligible differences in some of the points. The yellow line represents the error which is pretty negligible except for few specific points.

4.2 Actual vs Trilateration

Specific Points	Actual Coordinates		Calculated Coordinates		Error
	X	Y	X1	Y1	
1	2	0	1.556	0.786	0.902736
2	4	0	3.64033	0.2637	0.445982
3	6	0	6.734	1.17	1.381179
4	2	2	2.26	2.026	0.261297
5	4	2	5.316	2.626	1.457303
6	6	2	5.188	1.3109	1.06499
7	2	4	3.284	3.821	1.296417
8	4	4	3.598	4.685	0.794247
9	6	4	4.93	3.567	1.154292
10	2	5.5	3.43	6.156	1.573288
11	4	5.5	4.5	6.25	0.901388
12	6	5.5	6.261	6.508	1.041242
13	2	7.5	3.072	8.671	1.587585
14	4	7.5	5.396	7.878	1.446271
15	6	7.5	6.532	9.5085	2.077762
16	2	9.5	2.156	8.195	1.314291
17	4	9.5	4.433	10.181	0.807001
18	6	9.5	5.23	9.354	0.783719

Table 4.3: Data from routers using trilateration method for room 1. (in meters)

Table 4.3 represents data from routers for room 1. The (x, y) coordinates are the actual position where as (x_1, y_1) are the calculated by trilateration method. The error has been calculated using Euclidean distance formula in equation 3.5. The lowest error is 0.261297m which is for point 4 and the maximum error is 2.077762m which is for point 15. The average distance error for this room is 1.13m.

Specific Points	Actual Coordinates		Calculated Coordinates		Error
	X	Y	X1	Y2	
1	2	0	2.6	0.95	1.12361
2	4	0	4.2	1.0033	1.02304
3	5.5	0	5.5844	1.45	1.452454
4	2	2	2.6549	0.1631	1.950153
5	4	2	4.30876	0.3113	1.716695
6	5.5	2	3.147	1.363	2.437699
7	2	4	1.03	3.323	1.18289
8	4	4	3.68	1.6	2.421239
9	5.5	4	3.611	4.5	1.954052
10	2	6	3.42	6.88	1.670569
11	4	6	5.17	6.44	1.25
12	5.5	6	8.01	3.824	3.321908
13	2	8	2.19	7.96	0.194165
14	4	8	6.65	8.8	2.768122
15	5.5	8	6.149	8.212	0.682748

Table 4.4: Data from routers using trilateration method for room 2. (in meters)

Table 4.4 represents data from routers for room 2. The (x, y) coordinates are the actual position where as (x_1, y_1) are the calculated by trilateration method. The error has been calculated using Euclidean distance formula in equation 3.5. The lowest error is 0.194165m for point 13 and the maximum error is 2.768122 for point 14. The average distance error for this room is 1.68m because the room had a lot of people and hence, the obstruction was more.

Specific points	Actual coordinates		Calculated coordinates		Errors
	X	Y	X1	Y1	
1	2	0	1.556	0.786	0.902736
2	4	0	3.64033	0.2637	0.445982
3	6	0	6.734	1.17	1.381179
4	2	2	2.26	2.026	0.261297
5	4	2	5.316	2.626	1.457303
6	6	2	5.188	1.3109	1.06499
7	2	4	3.284	3.821	1.296417
8	4	4	3.598	4.685	0.794247
9	6	4	4.93	3.567	1.154292
10	2	5.5	3.43	6.156	1.573288
11	4	5.5	4.5	6.25	0.901388
12	6	5.5	6.261	6.508	1.041242
13	2	7.5	3.072	8.671	1.587585
14	4	7.5	5.396	7.878	1.446271
15	6	7.5	6.532	9.5085	2.077762
16	2	9.5	2.156	8.195	1.314291
17	4	9.5	4.433	10.181	0.807001
18	6	9.5	5.23	9.354	0.783719
19	-1	6.5	-1.6	7.45	1.12361
20	-3	6.5	-3.2	7.5033	1.02304
21	-4.5	6.5	-4.5844	7.95	1.452454
22	-1	8.5	-1.6549	6.6631	1.950153
23	-3	8.5	-3.3087	6.8113	1.716695
24	-4.5	8.5	-2.147	7.863	2.437699
25	-1	10.5	-0.03	9.823	1.18289
26	-3	10.5	-2.68	8.1	2.421239
27	-4.5	10.5	-2.611	11	1.954052
28	-1	12.5	-2.42	13.38	1.670569
29	-3	12.5	-4.17	12.94	1.25
30	-4.5	12.5	-7.01	10.324	3.321908
31	-1	14.5	-1.19	14.46	0.194165
32	-3	14.5	-5.65	15.3	2.768122
33	-4.5	14.5	-5.149	14.712	0.682748

Table 4.5: Data from two rooms merged.

In Table 4.5, the coordinates are calculated from two rooms merged using Equation 3.4 and 3.5. The average error for the two rooms merged is 1.22m.

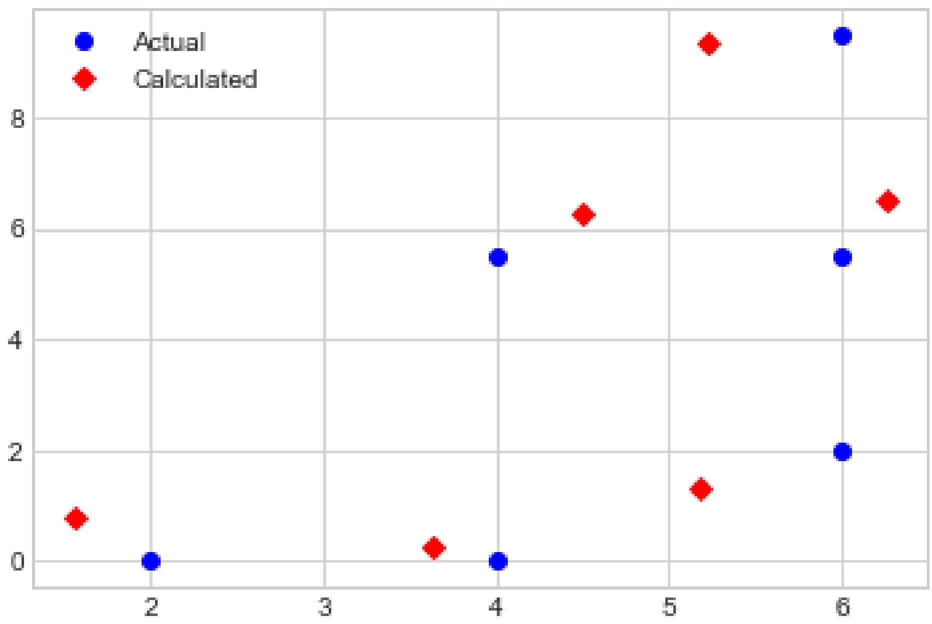

Figure 4.3: Actual Distance vs Calculated Distance in Room 1

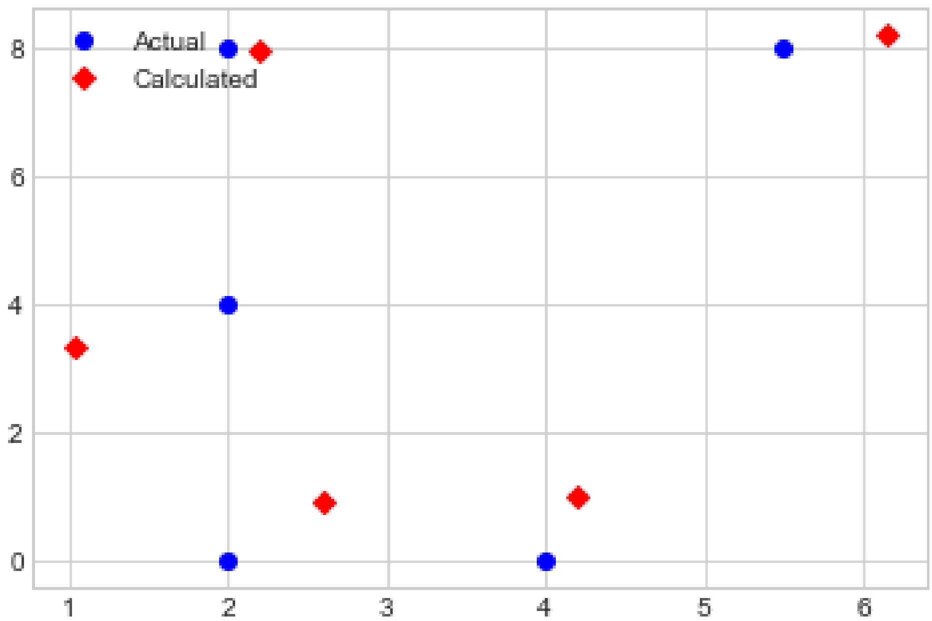

Figure 4.4: Actual Distance vs Calculated Distance in Room 2

In Figure 4.3 and 4.4, x-axis and y-axis represents the room in an euclidean geometric plane. Actual coordinates collected during scene analysis and the coordinates after applying trilateration are plotted in the scatter diagrams. Only a few number of coordinates has been plotted in order to graphically represent the differences between actual and calculated distances. Blue dots represent the actual distance and the red dots represents the calculated distance after calculating the distance using trilatertaion.

4.3 Comparative Analysis

In Table 4.6 we explained that in RFID system, it uses proximity and RSSI technique. It requires high power consumption also it is difficult very to integrate with other systems. Moreover, it can be unreliable for large scale implementation. In addition, if we use Bluetooth for positioning system it would require a large number of beacons which would be expensive. Also, the coverage area would be very low and the it can be easily catch interference from other devices. In Cellular Network approach, accuracy is very poor and unreliable. Also it would be very much congested system because of the number of devices available in a area. WiFi based indoor positioning system can be easily integrated using existing devices. It uses dynamic approach for different environments as a result it can be easily integrated with other different environments. Also, It works very efficiently for movable objects and we can combine different environments into one single environment for big areas.

Positioning Systems	Method of Measurement	Advantages	Disadvantages
RFID	Proximity, RSSI	a. Does not require LOS.	a. High power consumption.
		b. Penetrate objects	b. Difficult to integrate.
Bluetooth	Proximity, RSSI	a. Low power consumption	a. Low coverage area.
		b. It is available easily	b. High number of beacons required.
		c. Build in smart devices	c. Costly
Cellular Networks	RSSI	a. High Coverage area.	a. Low reliability.
		b. Mobile hardware can be used.	b. Very poor accuracy.
WiFi	RSSI	a. Use existing networks	a. Highly inaccurate for moveable objects.
		b. LOS is not required	b. Difficult for three dimensions
		c. Penetrate objects	

Table 4.6: Comparative analysis of some popular available technologies

Chapter 5

Conclusion and Future Scope

5.1 Conclusion

In conclusion, we can say that our proposed Indoor Positioning System model can estimate position of wireless devices with less error because using trilateration and ITU indoor path loss model we can compare and estimate the accurate position of the device since the actual values are collected from specific reference point. The mean absolute error derived from the merged room is 1.216072606, that is, approximately 1.22 meters. Moreover, looking for an object can be cumbersome and our model will work as a solution. On the other hand, our system can be installed in many places like hospitals, shopping malls and so on. As our system does not need any external setup any wireless device can be used, such as, raspberry pi which we used as an wireless device. Since GPS does not work indoors our model can be useful in navigation indoors.

5.2 Limitations

- First and the foremost limitation that we faced during our research was the collection of data during the scene-analysis phase. Manually collecting data multiple times in a single position was very challenging. We had to collect the data in peak hour when both the rooms were crowded.

- Secondly, during the collection of data, we had to face a lot of interference which hampered our data collection process to some extent. Since both the room were crowded and full of electronic devices; mainly cell-phones. The cellular network and the WiFi of the cells were interfering the RSSIs.

5.3 Future Scope

The future iteration of this paper includes combining both positioning system and mapping to take the system one step ahead. Implementation of the positioning system can be improved by introducing algorithms and model training such as kalman filter to the system. Also, an extended version of the system can be used for crowd handling, security, improved GPS accuracy. Moreover, it would also include a more extensive research on positioning which can be added as a module to an application for user guide in an isolated environment. Also, noise margin and signal loss can be reduced more effectively by adapting different devices.

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