SELF LOCALIZATION WITHOUT GPS AID

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Declaration of Originality

We, Abdul Rehman, Hassaan Ahmad Qureshi and Wajih Ullah Naaim declare that this thesis is our original work. It has not been submitted in any form for another degree or diploma at any other university or institute. Information derived from the published and unpublished work of others has been acknowledged in the text and a list of references is given in the end.

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Certificate of Approval

This is to certify that the work contained in this thesis entitled

"Self-Localization without GPS Aid"

Was carried out by

Abdul Rehman, Hassaan Ahmad Qureshi & Wajih Ullah Naaim

Under my supervision and that in my opinion, it is fully adequate, in scope and quality, for the degree of B.S. Electrical Engineering.

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Signature: ________________________

Head, Department of Electrical Engineering

Stamp:

To my Parents

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1 - Introduction

1.1 Localization

Localization is the process of determining the physical position of a person/unit. The most popular localization scheme in use nowadays is the Global Positioning System (GPS). The GPS makes use of an array of 24 satellites in determining the position of any object across the globe with higher accuracies of around ±1 m (subject to constraints). The receiver locks onto 3 or 4 signals and then uses TOA (Time of Arrival) and TDOA (Time Distance of Arrival) techniques to determine distance of transmitting satellites. After that Multi-lateration or triangulation algorithms are used to figure out its 3D position on earth's surface.

Apart from the US GPS system, other countries have come up with their own positioning systems the reason for which solely is less reliance on the GPS system which can be disabled in times of conflict and wars. Among these, the most notable are the Russian GLONASS, the European GALILEO and the Chinese Compass Navigation System. None of these boast the same the same accuracy and precision as the US GPS system nonetheless they provide an important alternative for these countries.

It is because of this reason that localization through GPS although accurate and precise must not always be relied upon as it can be disabled/jammed or tampered with by using advanced equipment. An alternative method is therefore researched upon extensively and has led to several solutions, one of which is the use of Wireless Sensor networks.

1.1.1 Wireless Sensor networks

Wireless sensor networks are fast becoming hugely popular for many applications in various civilian and military paradigms because of their flexibility and easy accessibility. With the minimal need for infrastructure development, WSNs exploit the sensor nodes and radio communication to achieve many tasks like tracking, monitoring, disaster relief and surveillance to name a few. [6]

Out of these tracking or collaborative localization schemes find their maximum applications. The ever growing demand of wireless connectivity means that conventional localization which involves absolute positioning by using signals from a satellite may need to be overlooked for easier and cheap methods. In hostile environments especially those faced by military forces in non-friendly zones, GPS scrambling is indeed a real threat to inhibit or handicap the enemy tracking units and their mobility. For such cases wires sensor networks provide a better alternative to carry out large monitoring, encompassing greater areas. [7]These could further be divided as

1.1.2 Range based schemes

These implement localization by using angle or distance measurements between node pairs. The required information is collected by augmenting the nodes with a hardware such as a transceiver for distance measurements or directional antennas for angle of arrival measurements. We use an anchor based approach whose location in the network is known and may be treated as a reference from which all calculations are to be carried out. [5]

1.1.3 Range free Schemes

Range free schemes implement localization by relying on proximity information. Positions are calculated by communications between adjoining nodes. It may even use an anchor free approach in which because no anchor node as a reference is present, the algorithm generates relative maps that assist in geographical routing and tracking.

Although range based schemes are known to be more accurate but they tend to be more complex then range free schemes. For the purpose of this project range based algorithm are selected keeping in view their better accuracies which is essential for any tracking or localization systems. [5]

1.2 Defining the Problem

In the absence of GPS, localization issue gets a lot of importance. Various methods of positioning and tracking are there such as Ultrasonic sensors, laser rangers and inertial sensors like accelerometer and gyroscopes. But the expensive infrastructure development leads to the conclusion that a more cheap method of signal strength indication should be used to get the task at hand done. Range based schemes have many different methods to accomplish localization. They are

1.2.1 Angle of Arrival

AOA techniques require the knowledge of angles of the incoming signals from various emitters. The information of the incoming angles is obtained by use of an array of multiple directional arrays. One of the shortcoming of AoA techniques is its susceptibility to multipath signals. [7]

1.2.2 Time difference of Arrival

TDoA technique does not previous knowledge of the transmitted signals but it is important for all the transmitting and receiving nodes to have synchronized clock to make use of difference measurements to accomplish localization. It requires the use of expensive equipment to achieve sync in all nodes which makes it not an efficient solution for the problem at hand. [7]

1.2.3 Time of Arrival

ToA techniques require information like phase and amplitude of the transmitted signals. Transmit time of the signals is required to calculate the total time of flight which is then used in localization. [7]

1.2.4 Received Signal Strength Indication

RSSi method has become the most favorable option since it does not require expensive equipment to achieve synchronization in the modules and no priori information about the signal is required. However it is significantly dependent on different terrains and therefore needs to be mapped for different scenarios separately.

1.3 Objectives

To design and implement a jamming resilient self-localization system in the absence of GPS, following tasks are accomplished

1. Understanding existing methods of localization and their shortcomings.
2. Selecting the most suitable technique i.e. RSSi, TOA, TDoA etc. by analyzing their pros and cons
3. Identifying the hardware (transceivers) that will assist in localization.
4. Designing and implementation of the anchor and the mobile nodes.
5. Establishing communication protocol between the modules by using C programming.

6. Applying fingerprinting and multi-lateration techniques by using MATLAB.
7. Ensuring jamming resilience by incorporating a frequency hopping protocol.
8. Ensuring correct operation of system by field testing and validation.
9. Demonstrating the localization by displaying it on a Radio Map designed using LABView/JavaScript.

1.4 Overview of Remainder of the Report

Chapter 2 discusses the existing methods for the selected Range based schemes. Various approaches are discussed analyzing their effectiveness and weakness in different terrains. Difference between Large and Short scale models along with the selected positioning algorithm is described in detail.

Chapter 3 is about implementation of the system. It describes the selected hardware, its programming to make them as nodes and the algorithms and protocols used to remotely read data that will lead to localization of a unit. It also explains the use of MATLAB in applying the multi-lateration techniques and neural networks to pinpoint location of the body

Chapter 4 explains the testing of Nodes in real time and the plots of data obtained to be transformed into meaningful conclusions. And the serial communication protocols to import the coordinates to a JAVA script environment to be displayed on a Radio map.

Chapter 5 is about the tests carried out to check the validity of the established system (transceivers, communication and mapping) is discussed.

2 – Literature Survey

Considering the great amount of research done in addressing this issue, many models have been presented before this work. Bearing in mind that the Range based case which has been selected for this project, a brief glance of the models is given below.

2.1 RF propagation Models

RF schemes have to encounter these complications to overcome before they can be used for localization purposes

- Radio waves experience energy loss (Signal Strength) on the way from the source (Transmitter) to the destination (Receiver).
- Amount of loss is characterized by many a factors such as frequency of transmission, Reflection, Diffraction, Scattering and alike during its way.
- Modeling a propagation channel involves gathering a sufficient amount of samples in the field, where the system has to be deployed, as analytical solutions are usually unable to take care of all the local parameters.

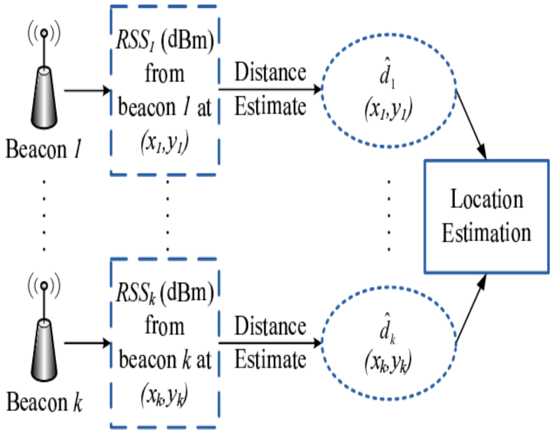


Figure 2-1: Location Estimating Scheme

To address this issue, various RF propagation models are developed which provide both analytical as well as empirical models. RF propagation models generally characterize two aspects of RF propagation:

- Large scale propagation model
- Small scale Propagation model

2.1.1 Large scale propagation model

These models take care of average signal strength over many signal samples from transmitter to the receiver. Some of the analytical models for large-scale propagation are as follows:

- Friis Free Space Path Loss Model
- Two Ray Ground Reflection Model
- Log-Distance Path Loss Model with Shadowing

2.1.2 Small scale Propagation model

These models predict the rapid fluctuations in the signal strength over small distances or that occur in short intervals of time.

Small-scale models are related to multipath fading and moving obstructions. It causes great variations within a half wavelength or so.

This type of fading is approximated by using Rayleigh, Ricean, or similar fading statistics.

Rayleigh Model for Multipath fading	Ricean Model for Multipath fading
Line Of Sight component is present in the signal	No direct line-of-sight component is present.

Table 2-1: Small Scale models

Remarks

Large-scale' loss determine the average power level of the signal while multipath fading and shadowing result into a distribution around that average. (Sort of a bell curve)

2.1.3 Empirical Models

Besides the analytical models mentioned earlier, empirical path loss models have also been developed for different terrains, weather and foliage conditions. Some commonly used models in wireless communication are mentioned as follows:

COST 231-HATA MODEL

It is a practically more usable version of Okumura-Hata model that can be modified to be used for small, medium and large cities. [9]

FOLIAGE MODEL

There also exists empirical models for foliage attenuation especially in high wind conditions and for different seasons. Quite a many studies have been done for different frequency bands.

All the analytical models discussed above have some environment dependent factors such as **path loss exponent** which is of immense importance when it comes to prediction of signal attenuation. So, in our next phase of the project, we'll be taking field measurements to tune the propagation models with the environments in which the systems has to be deployed and finding the model parameters.

2.2 Finger Printing Method

For the scenarios in which more accuracy is required, a lot of field measurements are taken and are stored in a database. This is the offline phase. In the online phase, runtime values are compared to stored values are the current position is estimated.

To reduce no. of such hectic field measurements, some measurements are taken and then interpolation is used with the help of propagation models discussed above.

This is an objective of our next project phase.

2.3 Positioning Algorithm

2.3.1 Trilateration

In geometry, trilateration is the process of determining absolute or relative locations of points by measurement of distances, using the geometry of circles, spheres or triangles.

In addition to its interest as a geometric problem, trilateration does have practical applications in surveying and navigation, including global positioning systems (GPS).

We are using trilateration to get coordinates from out distances estimates. Distance formula is used to get the relative coordinates of the receiver using the distances from each transmitter and solving the distance equation for each case.

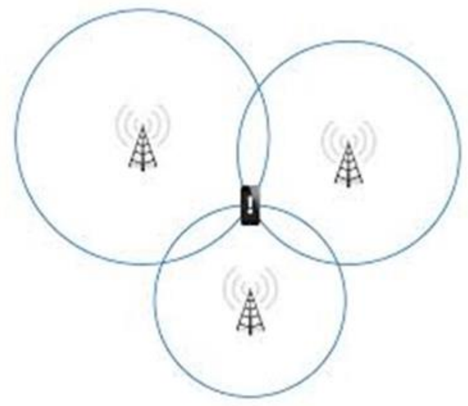


Figure 2-2: Trilateration

IMPROVING THE POSITION ESTIMATE

Using the trilateration, the coordinates we'll get are subject to the errors in distance estimate. So to minimize this error we used weighted positioning algorithm.

CIRCULAR POSITIONING ALGORITHM

The idea here is **to minimize the sum of squared errors** in all the estimated distances measured between nodes using the *Distance formula.*

$$\varepsilon = \sum_{i=1}^{N} \left(\sqrt{(x_i - x)^2 + (y_i - y)^2} - d_i \right)^2$$

Here (x_i, y_i) is the position of the *ith* transmitter and is well-known beforehand, whereas, *di* is the estimated distance (so much noise out there) of receiver from the *ith* transmitter. All we need is an initial guess about (x,y) and then use some optimization method like "Gradient Descent" to find the *minima* **iteratively.**

WEIGHTED CIRCULAR POSITIONING ALGORITHM

It uses the same circular algorithm, but with different weights for each measurement. The motivation here is that the reading closer to the transmitter are likely to be more accurate as compared to the one which are taken at a distance away from the transmitter. Method is the same too. An initial guess. Iterative in nature. But performance is far better than the non-weighted circular algorithm.

2.4 Jamming Resilience

One of the major reasons for the decision to establish less reliance on GPS is because of jamming issues.

SCHEME

When the mobile transceiver is not able to receive packets from the beacon transceiver, the mobile transceiver will change its frequency after some specified waiting time. The beacon transceiver on not listening back from the mobile transceiver will also change its frequency according to a pre-agreed sequence-a pseudorandom sequence, which is hardwired in both transceivers' microcontrollers.

2.4.1 Frequency Hopping

It is a method of transmitting radio signals by rapidly switching a carrier among many frequency channels, using a pseudorandom sequence known to both transmitter and receiver

Each of these techniques employs pseudorandom number sequences — created using pseudorandom number generators — to determine *and* control the spreading pattern of the signal across the allocated bandwidth.

The Transceiver we are using has the built-in FHSS capability. It has programmable registers to set the frequency step size.

Add	R/W	Function	D7	D6	D5	D4	D3	D2	D1	D0	POR Def.
79	R/W	Frequency Hopping Channel Select	Fhch[7]	Fhch[6]	Fhch[5]	Fhch[4]	Fhch[3]	Fhch[2]	Fhch[1]	Fhch[0]	00h
7A	R/W	Frequency Hopping Step Size	Fhch[7]	Fhch[6]	Fhch[5]	Fhch[4]	Fhch[3]	Fhch[2]	Fhch[1]	Fhch[0]	00h

Table 2-2: FHSS Programmable Registers

For the pre decided over determined system consisting of 5 modules, 5 setups of each of the following are prepared

- Arduino
- Transceiver
- Battery

3.1.1 Si4432 RF transceiver

An Si4432 Transceiver is to be used which is to be programmed by an Arduino development board.

The Si4432 is a 100% CMOS ISM wireless transceiver with continuous frequency tuning over the complete 240–930 MHz band. The wide operating voltage range of 1.8–3.6 V and low current consumption makes the Si4432 and ideal solution for battery powered applications.

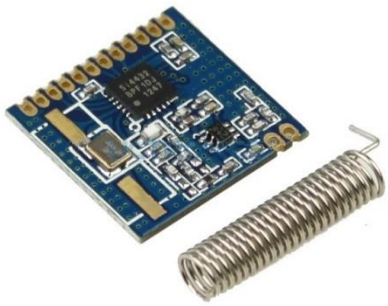


Figure 3-3: Si4432 Transceiver

Why Si4432?

The reasons for selecting this transceiver are multifold. With a great number of transceivers at our disposal, Si4432 was selected keeping in mind its range, maximum resolution and economic aspects which were all rather favorable considering the scope of project. On top of that, other features included

Frequency Range	240–930 MHz
Sensitivity	118 dBm
Max Output Power	+20 dBm (Configurable from +11 to +20 dBm)
Digital RSSI Resolution	±0.5dB per bit
Frequency Hopping Capability	

Why Arduino UNO?

In the beginning separate microcontroller development boards were prepared but due to several hardware malfunctions, its reliability were far from satisfaction. In order to fix that, Arduino UNOs were incorporated in the project to take care of all these shortcomings. Another major reason for its use was its ability to enable the user to make use of many if features with considerable ease, some of which are

- USB connectivity
- SPI interface
- Periphery ports.

3.2 Programming

Arduino UNO board was programmed using Arduino development environment. The Arduino development environment contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions, and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them.

Arduino connects with Si4432 via SPI port. Si4432 needs to be programmed at start up. Si442 have total 126 8-bit configuration registers and one 64 byte FIFO Access register.

Firstly Si4432 is programmed to use FSK modulation, read/write data to FIFO, and frequency is set differently for each node. Setup for each node is same except frequency. But the operation cycle of beacons nodes is different from Mobile node.

The microcontroller had to be programmed in two ways, one for the transmitter’s point of view or the beacon node and the other from the mobile nodes point of view. There is a significant change in the protocol of the tasks to be accomplished for both entities which are pictorially shown

3.2.1 Mobile Node Operation Cycle:

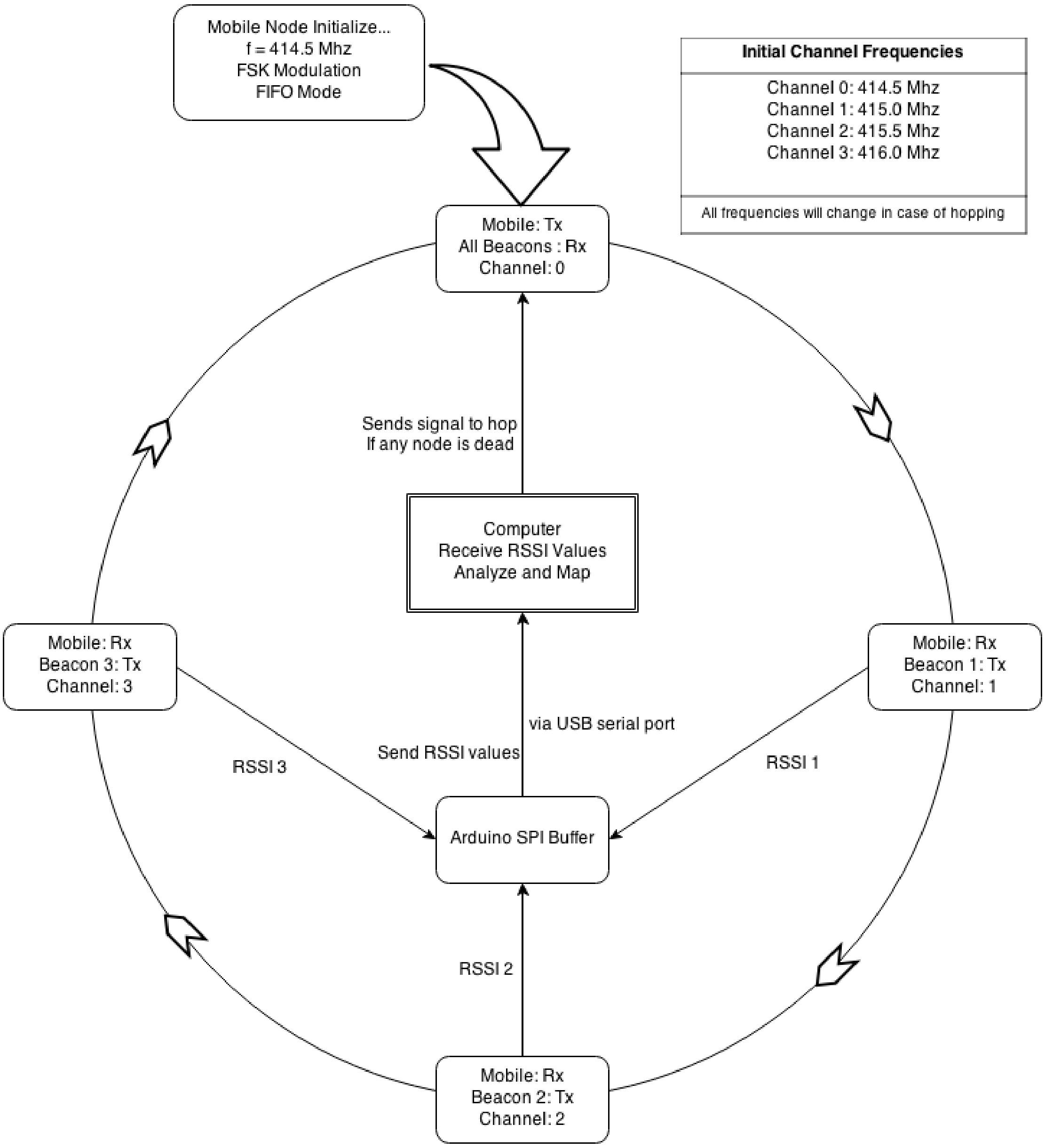


Figure 3-5 : Mobile Node Operation Cycle

3.2.2 Beacon Node Operation Cycle:

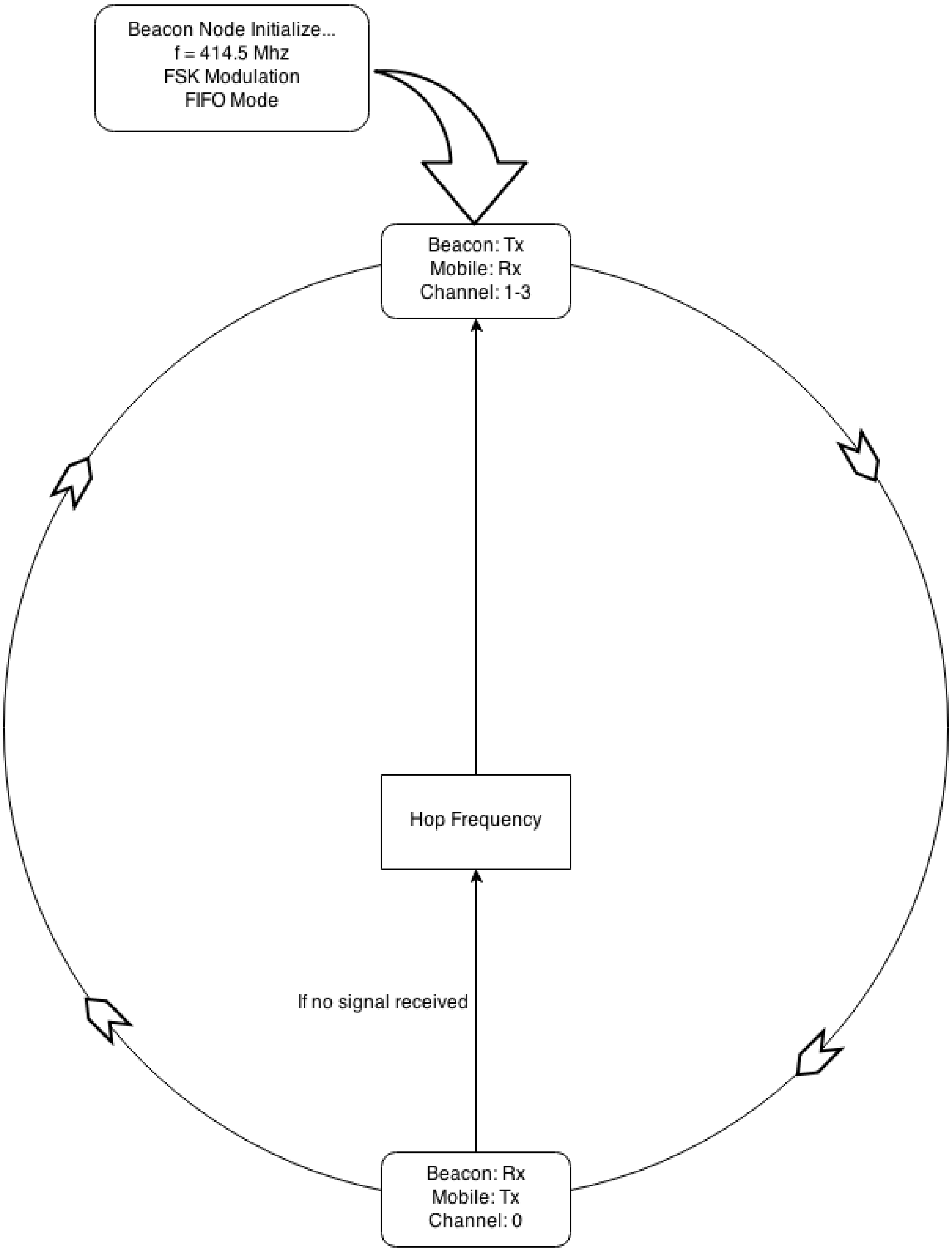


Figure 3-6 : Beacon Node Operation Cycle

3.3 Sensor Network Implementation

3.3.1 Beacon Nodes Placement

In this project, we have used 3 transmitter nodes that will act as beacons. They are placed in triangular geometry. This geometry is selected in order to get good coverage for all nodes without any directional ambiguity as will be in the case of three receivers in nearly co-linear configuration.

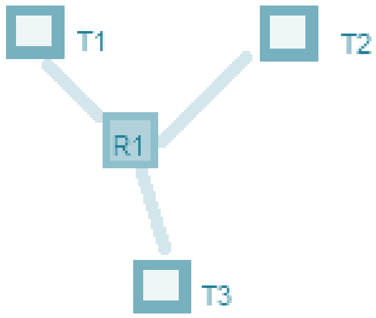


Figure 3-7: Beacon Nodes Placement

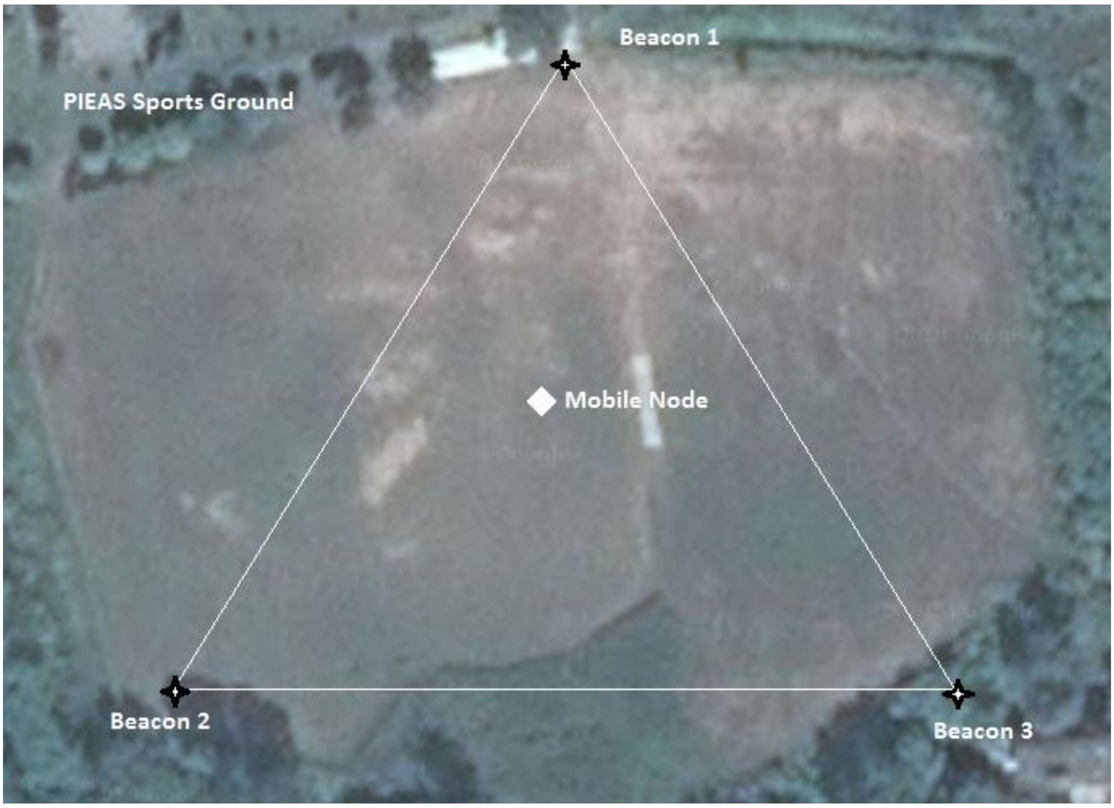


Figure 3-8 : Field Test Site

3.4 Data Collection

Following procedures are carried out to obtain the data for processing in order to meet the requirements.

3.4.1 Cumulative moving average

As RSSI values are collected in Real-time, the average RSSI value, at a certain distance, need to be corrected with addition of each new RSSI value.

Doing this helps smoothen the random fluctuations in the RSSI values. Also, it reduces the effect of strong alleviation in RSSI values due to any moving obstruction that blocks the path between transmitter and the receiver nodes.

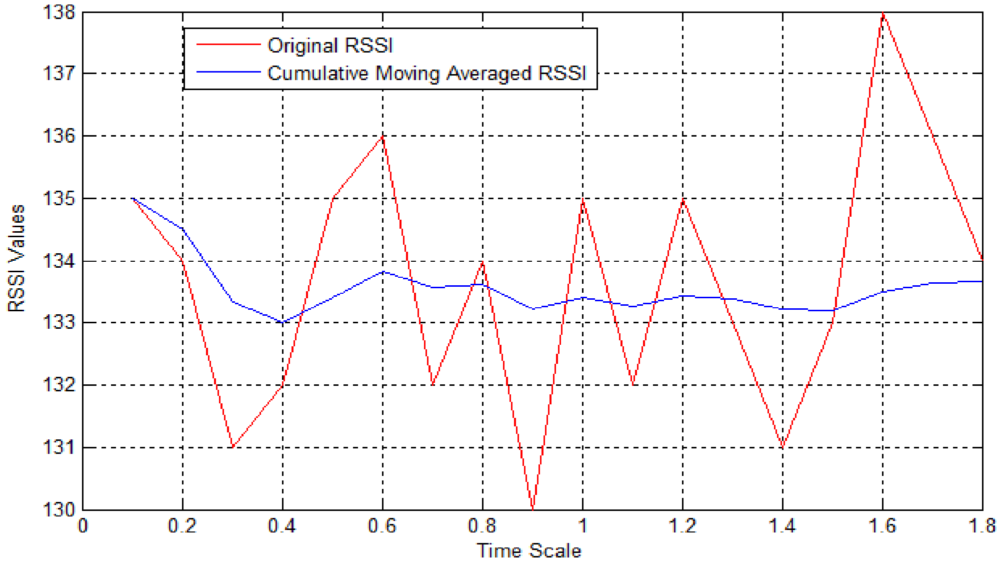


Figure 3-9: Averaged RSSi

3.4.2 Selectivity of Real-time RSSI values

The selection of RSSI values to be included in the database depends on the fact that how deviated they are from the mean of values taken already e.g. the third RSSI value taken is compared with the average of the two previous values; and if their difference is greater than (about thrice the standard deviation in our experimentation) otherwise they are included and the new average is calculated.

About twenty RSSI values are taken at each distance radius. Taking cumulative average at each new reading, the final average value is stored as the fingerprint for that particular distance.

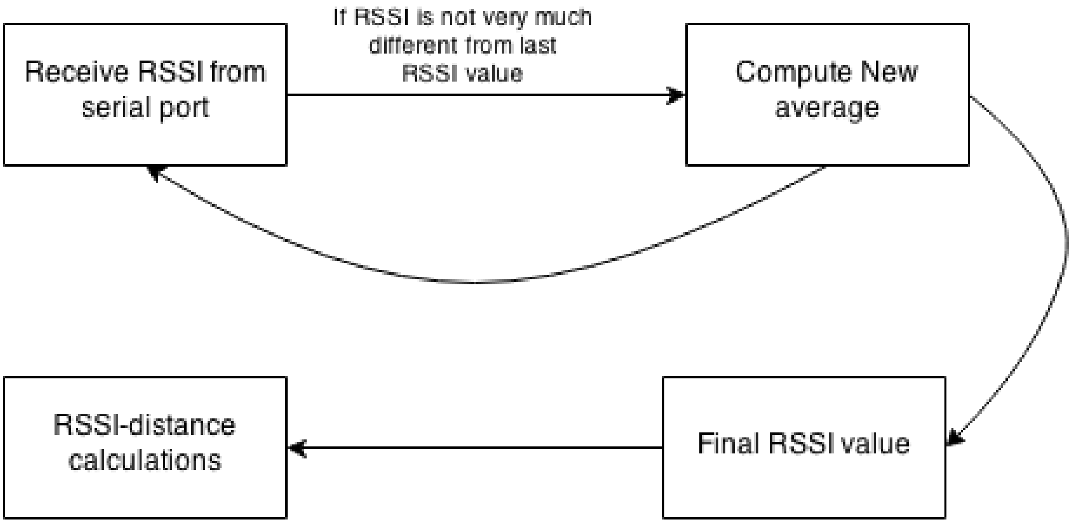


Figure 3-10 : RSSi Selectivity

3.4.3 RSSI VS Distance plots

RSSI values obtained from each of the three beacon nodes are first averaged and then plotted against distance. Slight differences between the curves of each node are the result of some hardware level differences like battery levels and temperature of RF transceiver chips.

On the y-axis, RSSI values are plotted. The RF transceiver Si4432 used in this project outputs the signal power as an 8-bit value form 0-255. Though strength values greater than 210 saturates its buffer and no variation can thus be detected above this signal strength level.

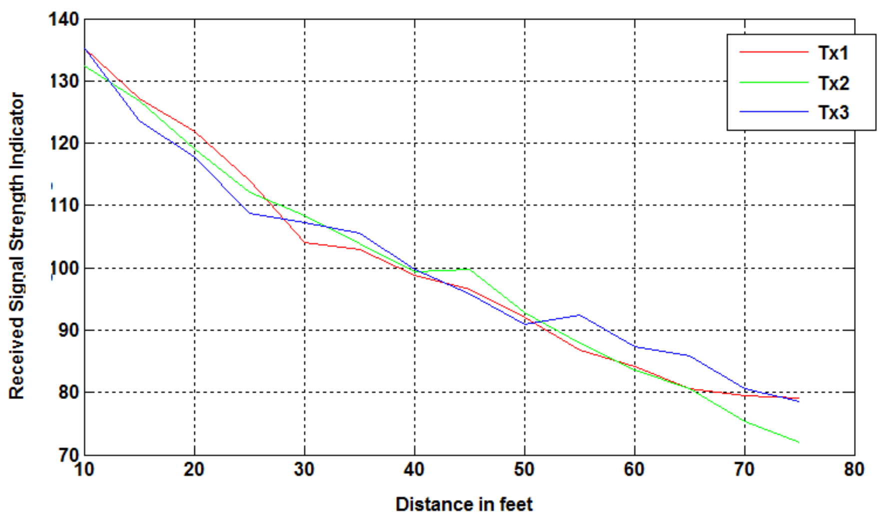


Figure 3-3-11 : RSSi vs Distance

The variation or spread of the RSSI values obtained at a distance from the beacon node can be visualized form the plot below which contain complete RSSI values i.e. before averaging.

This 'stream' of data values also enables us to visualize the range of possible distance values for a certain RSSI attained.

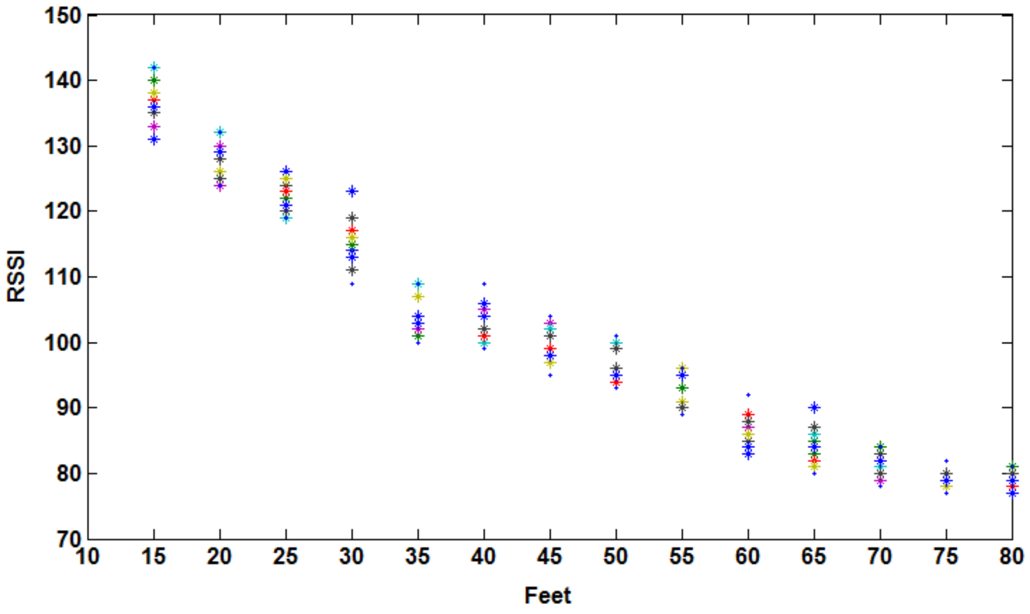


Figure 3-3-12: RSSI value Spread

3.5 Algorithms and Protocol

3.5.1 Protocol for Node Reading

Mobile node sets its frequency to the channel to listen at, then RSSI of special node is read.

Code:

```
for(int k=1; k<=3; k++)
{

 hop_ch(channel[0]);     //Mobile Tx frequency
 tx_data();
 tx_data();
 tx_data();            // Mobile Transmits Data
 tx_data();
```

```
   hop_ch(channel[k]);    // set frequency for node k = 1,2,3


   while((rssi_rcvd[k]<2)&&(no_sig_count<rx_tries))
   {
   digitalWrite(leds[k], HIGH);
   rssi_rcvd[k] = rx_data();  }     //Read RSSI while receiving

   digitalWrite(leds[k], LOW);

   if(no_sig_count>=rx_tries)  //If No signal for many tries
   {
        no_sig_count = 0;
        channel_dead[k] = HIGH;     //Set channel as dead channel
}

   if(read_data[0] == 0x20)   //Read FIFO first byte
   {                          //which is the Transmission power in db
     power[k] = 20;           //Get the Transmitted Power by Beacon
   }
   else if(read_data[0] == 0x14)
   {
      power[k] = 14;
   }
    else
    {
      power[k] = 0;
    }


  Serial.print("\n");
  Serial.print("#");
  Serial.print(k);            //Print Node Number to serial port
  Serial.print(".");
  Serial.print(rssi_rcvd[k]); //Print RSSI to serial port
  Serial.print(".");
  Serial.print(power[k]);     //Print Transmitted power by Beacon
  Serial.print("<<");

 }
```

3.5.2 Protocol for Frequency Hopping

```
if((channel_dead[1]==HIGH)||(channel_dead[2]==HIGH)||(channel_dead[3]==HIGH)||(chan
nel_dead[4]==HIGH))
{
 Serial.print("\nHopping Now\n");
 for(int onp = 1; onp<=4; onp++)
 {
 if(channel_dead[onp]==HIGH)
 {
  Serial.print("\nHopping for node:\n");
  Serial.print(onp, DEC);
  hop_func(onp);
 }
 }}
```

3.6 MATLAB Implementation

3.6.1 Finger Print Classification

There are several methods available which have been utilized to achieve the required objectives. They are classified as

Ensemble learning

In ensemble learning, multiple algorithms are combined together to achieve better prediction performance as compared to that achieved with individual algorithms.

Bootstrap aggregating (bagging)

In Bootstrap aggregating technique each different model or algorithm used, has equal weightage in the overall result. They vote independently for a certain outcome and that outcome is selected in the ensemble who gets majority vote.

Random forest is one of the ensemble learning algorithm in which each individual algorithm is random decision tree and they are combined together with bagging to achieve very high classification accuracy.

MATLAB Class

`B = TreeBagger(NTrees,X,Y)` creates an ensemble `B` of ‘`N`’ decision trees for predicting response `Y` as a function of predictors `X`. By default `TreeBagger` builds an ensemble of classification trees.

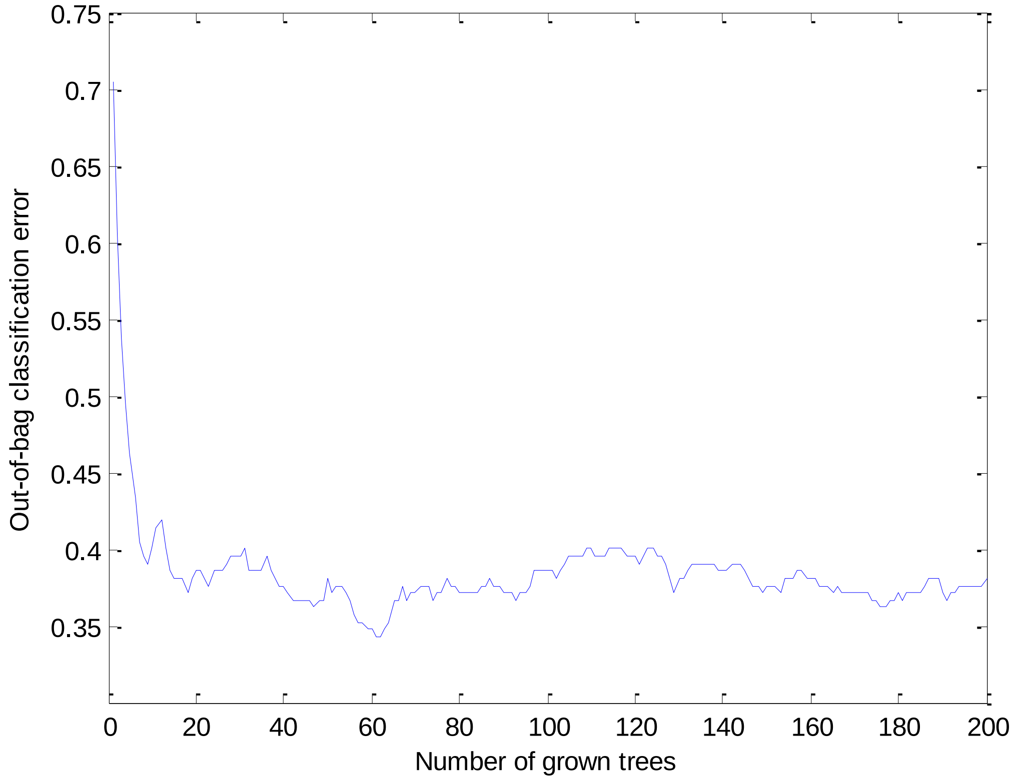


Figure 3-13 : Classification Error

K-Nearest Neighbors

The RSSI value from each beacon node is compared with averaged RSSI values of each distance. K values, (3 in our case), which are closest to the newly received RSSI value are chosen from the fingerprinting database and their corresponding distance values are averaged out to give the distance for the RSSI value obtained in real time.

$$\boldsymbol{D}_{\textbf{Newly read RSSI value}} = \frac{\mathbf{1}}{\mathbf{3}}(\boldsymbol{D}_{NR1} + \boldsymbol{D}_{NR2} + \boldsymbol{D}_{NR3} + \boldsymbol{D}_{NR4})$$

$where\ D_{NRk}$ are the K- Nearest distance readings corresponding to the nearest RSSI values.

3.6.2 Curve Fitting

But the RSSI values that lies in-between the recorded values need also be incorporated in some way. For that we have fitted a curve in the data we collected. Using the regression technique, value of corresponding distances are found from this empirical relation.

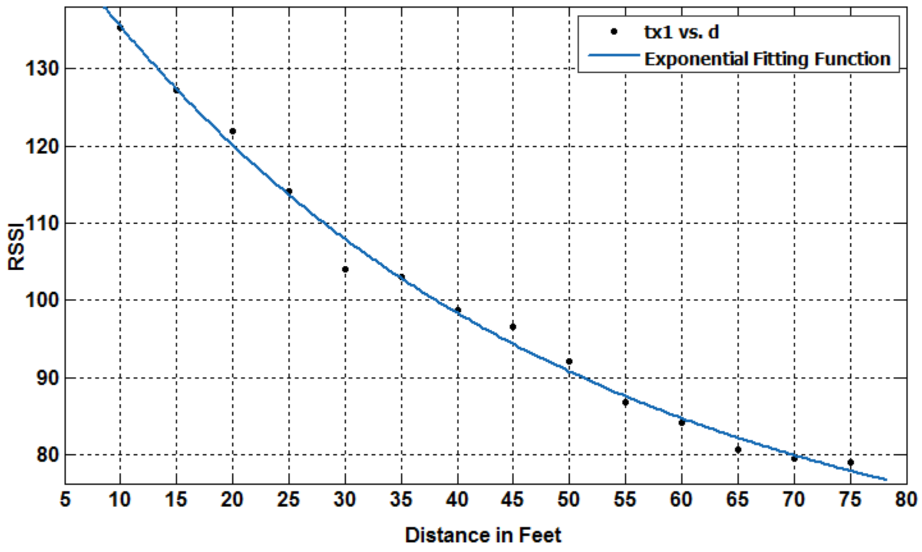


Figure 3-14: Curve Fitting

Fitting function

Exponential Function of degree 1

$$F(x) = a * e^{b*x}$$

Where x is normalized by mean 42.5 and standard deviation 20.92

And coefficients are: a = 98.62; b = -0.1845

Testing the Fit with new experimental data.

The exponential function of degree 1, that we have used, resulted in quite decent estimate of distance corresponding to the RSSI values that lie in-between for fingerprinted values.

The RMS error values is about 2.8feet which is quite acceptable because data available for fitting was just about sufficient.

Goodness of fit	
Sum of squares Error:	100.2
RMSE	2.89

Table 3-2: Goodness of Fit

After that, trilateration and circular positioning algorithms are used which have been previously discussed.

3.6.3 Obtaining the Least Square Solution

Solving the Trilateration expression is a matter of obtaining x and y coordinates of the mobile node with all the radial distances from the beacon nodes to the mobile node available at hand.

Trilateration with Least squares is performed to minimize the difference between the estimated position **($\hat{x}_0$, $\hat{y}_0$)** and the actual position **(x_0, y_0)** of the mobile node. This is a minimization problem and requires some iterative method to solve. We have chosen Gradient Descent due to the simplicity of its algorithm and the ease of implementation. To avoid getting the local minimum, least square solution must be obtained by running the algorithm several times with different initial points.

Gradient Descent

Gradient descent method is a way to find a local minimum of a function. The way it works is we start with an initial guess of the solution and we take the gradient of the function at that point. We step the solution in the negative direction of the gradient and we repeat the process. The algorithm will eventually converge where the gradient is zero (which correspond to a local minimum). It is a first-order algorithm because it take only the first derivative of the function.

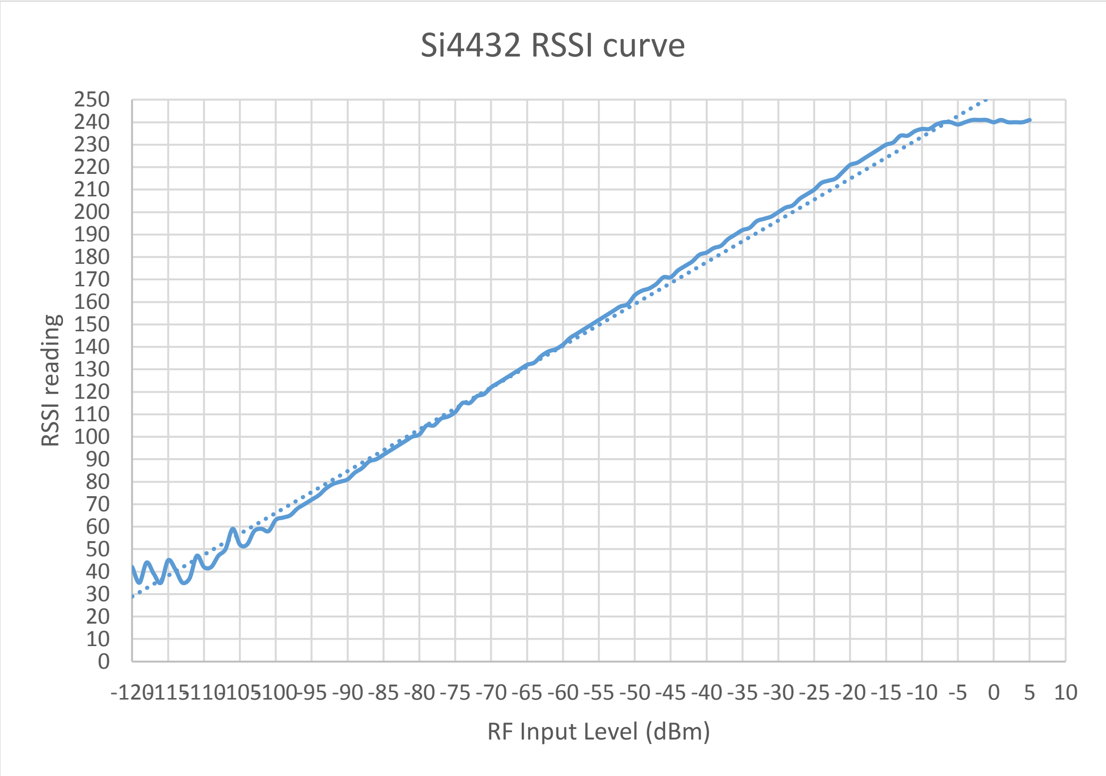
4 System Validation

4.1 Node testing

First step to take the readings from the transceiver used, was to make a relationship between the digital RSSI values it outputs and the corresponding power levels in dBm. We did extensive experimentation to get a curve that is shown below.

4.1.1 Obtaining the RSSI VS dBm Curve through Measurements

Measurements with RF transceiver Si4432 were taken in the field to determine an empirical relation between the strength value in dBm and RSSI which an 8-bit value. It can be seen that it is quite linear in most of the region of operation but gets saturated beyond -10dBm.



Once we have got the RSSI value from each beacon node, we then compare them with the fingerprinting database we have developed in the offline phase.

For the in between RSSi values we use curve fitting function explained beforehand.

4.2 Simulation Results

We simulated how the number of beacons effected the position determination of the mobile node. In our simulations we estimate the average RMS error in the case of 3 and 4 beacon node placed in triangular and square geometry respectively. Gauss-Newton Method is used to solve the trilateration equation.

An assumption taken in while doing the simulation is that the accuracy of the distance measurement at reference locations is 90%, for instance the inaccuracy of a 1meter measured distance is around .1meter

4.2.1 With 3 Anchor Nodes in place

In the case of 3 Nodes, average estimated error comes out to be around 6.54meters.

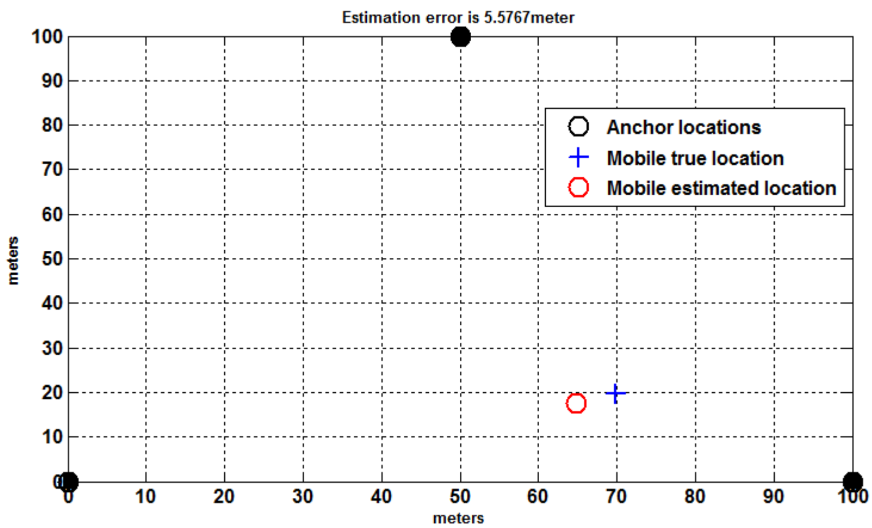
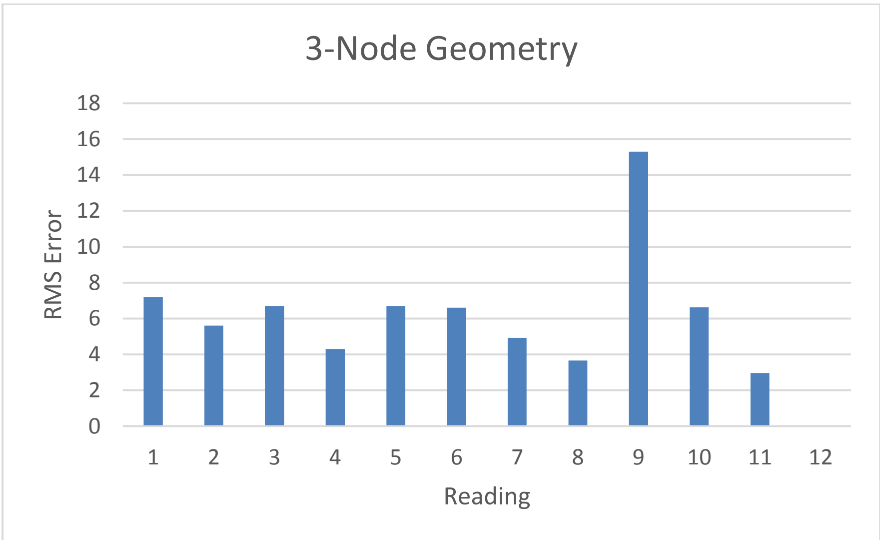


Figure 4-1 : 3 Anchor Node with Chart



4.2.2 With 4 Anchor Nodes in place

In the case of 3 Nodes, average estimated error comes out to be around 3.4 meters.

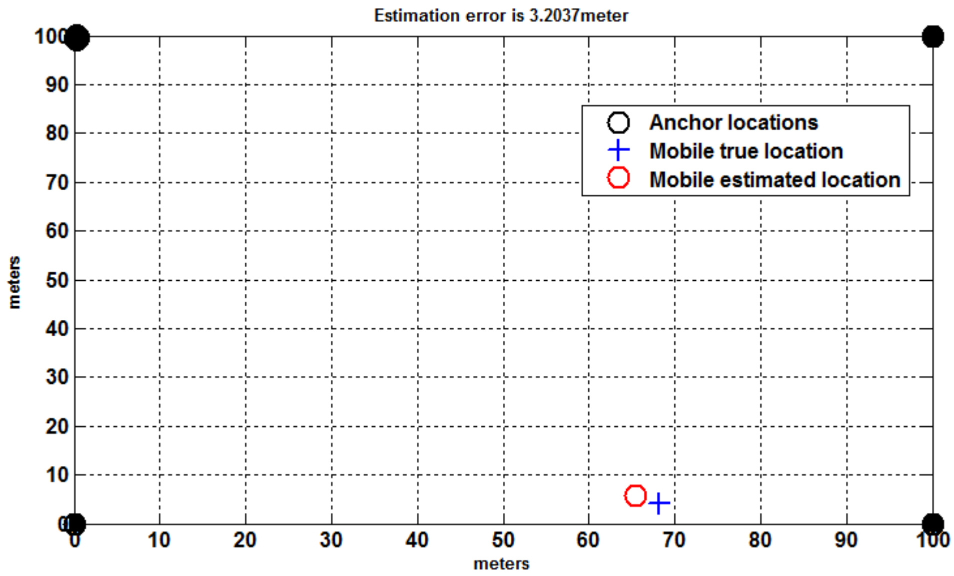
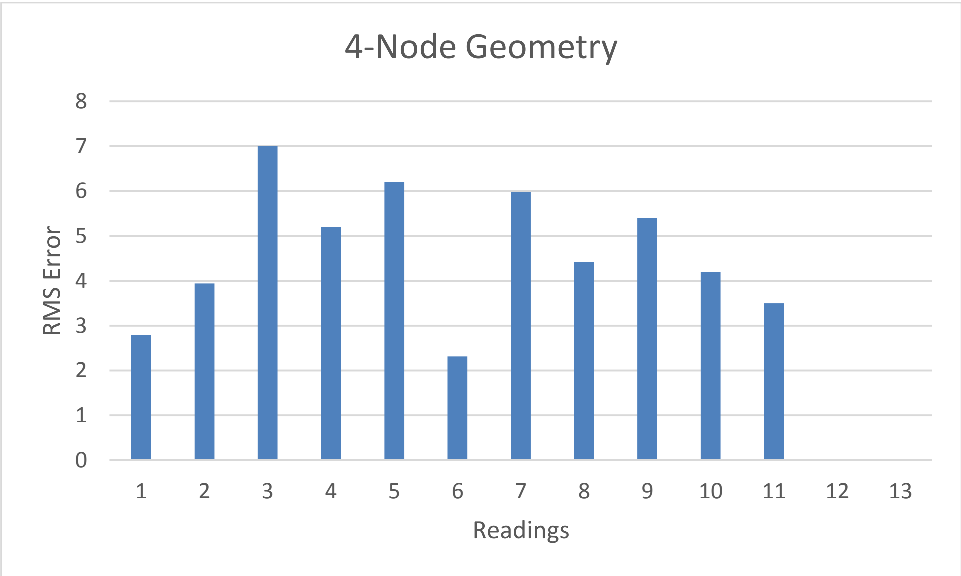


Figure 4-2 : 4 Anchor Nodes with Chart



4.3 Displaying position on Radio Map

After the RSSi to distance calculations have been completed and a pair of coordinates are calculated by the use of multi-lateration technique. A radio map is used to actively display the actual location of the mobile unit. A feature has also been used to ensure that the entire tracking i.e previous locations of the unit are kept displayed.

4.3.1 JavaScript Implementation

An environment is created using JAVA application that will serially take the coordinates and plot them on a prepared Radio map.

The anchor nodes are clearly presnt near the corners whereas the mobile node can be observed near the center. This is prepared across a 100x100 (ft) terrain.

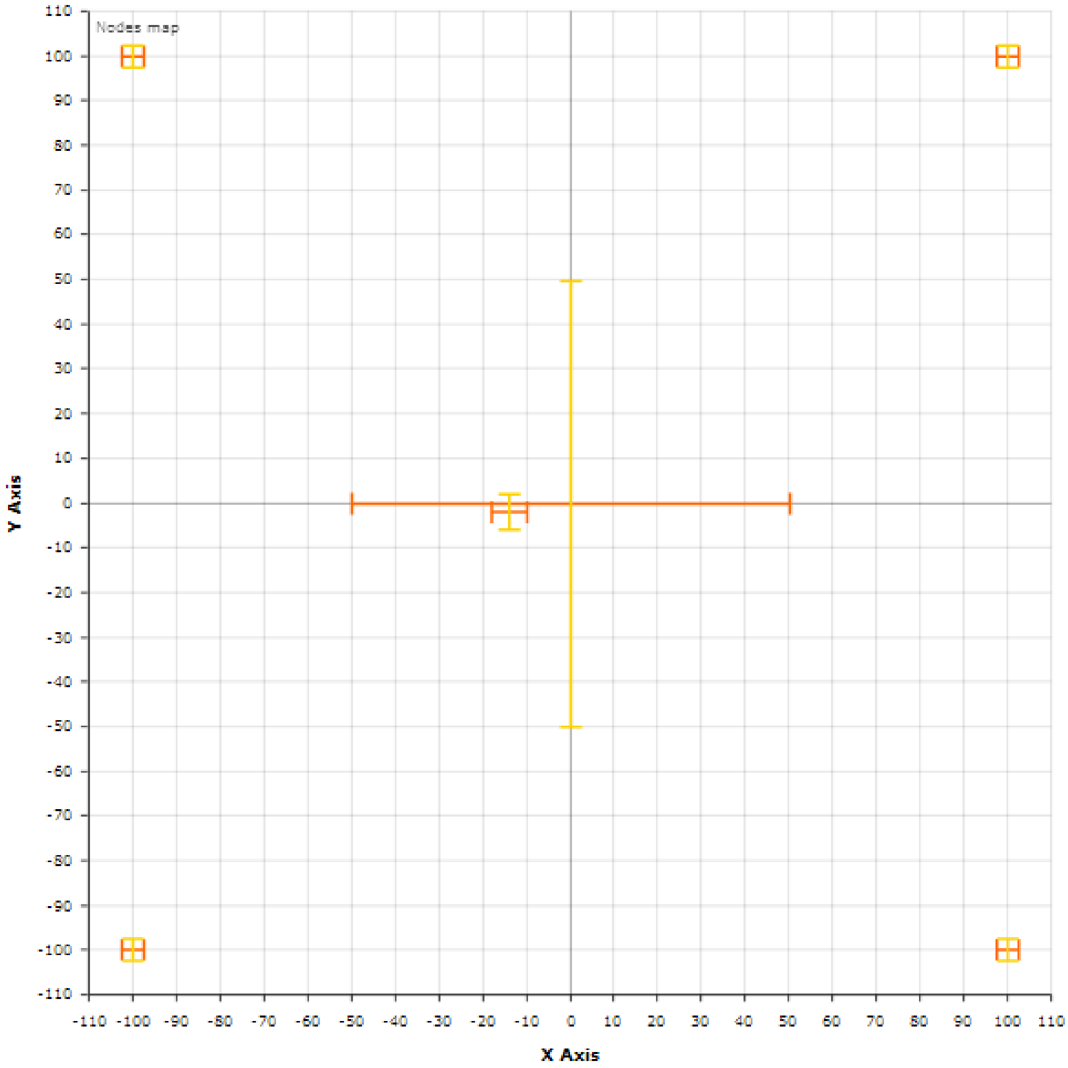


Figure 4-3: Radio Map

5 Results and Conclusions

Successful localization of the mobile unit was achieved albeit by some minimal fluctuations. The receiving node measured the incoming signals, processed them and then communicated them to Matlab for distance calculations.

5.1 MATLAB Results

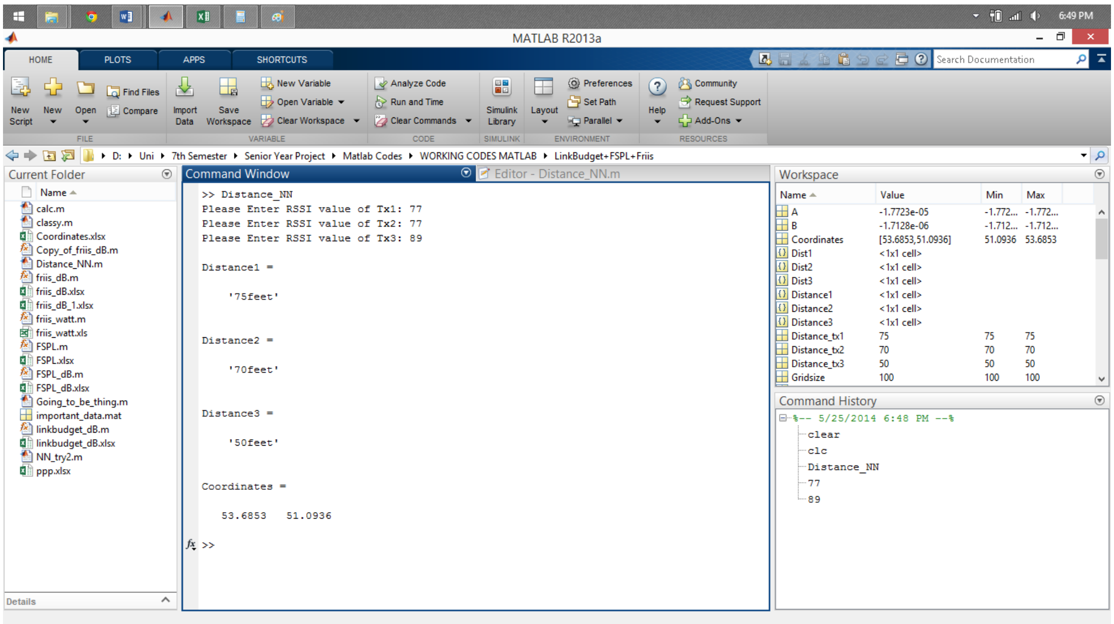


Figure 5-1 : Matlab Simulation

5.2 Applications

Localization without the need for GPS signals has many applications in the most diverse of scenarios. The advent of technology demands from a person to stay connected at all times. This is achieved only through the use of WSNs. These are therefore used in many applications like tracking, disaster relief, surveillance and a great source of information exchange while on the go.

5.3 Limitations

After thorough testing there were several intimidating factors which posed a problem for accurate determination of the results. The situation was rectified to greatest extent possible but it did prove to be a revelation about the effects of the smallest of details.

5.3.1 Effect of Height

The range of our modules was severely affected by their height from the surface of ground. The power levels decreased significantly within 100 feet. It severely compromised the range capability of the designed hardware. This shortcoming was overcome by performing the testing at added height.

5.3.2 Effect of Battery Levels

Different battery levels at modules led to transmission of signals at slightly changed power levels. This non uniformity in the signals poses several problems of its own. Since a relation had to be established with the distance and power, therefore the differences led to unreliable relationship.

5.3.3 Mismatch between RF nodes

Although the transmitter claims to send a signal at a predefined level yet there always are cases where the slightest mismatch or failure in detection of a preamble led to

5.3.4 Tiresome Offline Measurements

Since this technique requires extensive interpolation to relate the power and distance readings, visit of fields were carried out to map the extensive terrains to help in making a protocol relating decreasing power trends.

5.4 Future improvements

RF transceiver that is the heart of our project has an 8-bit RSSI but its buffer saturates on receiving about -10dBm. As beacons nodes can transmit up to +20dBm, quite a span of power levels is just wasted. Better and newer RF transceiver like Si446x can enhance the resolution as well as the range of operation.

RF transceiver with high hopping rate can improve the efficiency of the hopping protocol we have developed. Higher hopping rate can decrease the delay when receivers and transmitters switches to different channels and tunes to them. Especially if the mobile vehicle is on the go with higher speed then the receiver has to listen to all the beacon nodes pretty quickly.

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