TARGET LOCALIZATION AND CLASSIFICATION IN HABITAT MONITORING USING WSN

Project report submitted in partial fulfillment of the requirement for the degree of Bachelor of Technology

in

Computer Science and Engineering/Information Technology

By

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Candidate's Declaration

I hereby declare that the work presented in this report entitled **"Target localization and Classification in Habitat Monitoring using Wireless Sensor Networks"** in partial fulfillment of the requirements for the award of the degree of **Bachelor of Technology** in **Computer Science and Engineering/Information Technology** submitted in the department of Computer Science & Engineering and Information Technology**,** Jaypee University of Information Technology Waknaghat is an authentic record of my own work carried out over a period from August 2015 to June 2016 under the supervision of **Dr. Yashwant Singh** (Assistant Professor) (Senior Grade) Computer Science & Engineering.

The matter embodied in the report has not been submitted for the award of any other degree or diploma.

(Signature)
Mohinder Kaur Sidhu (123208)

This is to certify that the above statement made by the candidate is true to the best of my knowledge.

(Supervisor Signature)
Dr. Yashwant Singh
Assistant Professor (Senior Grade)
Computer Science & Engineering
Date

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Computer Science And Engineering

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Abstract

In past few years Wireless Sensor Networks have got large engrossment from the researchers as well as the scientific society. With their extensive application in almost every field, the hunt for measures to take advantage of the sensors in the most beneficiary way has begun. In this review paper we shall discuss about the relevance of wireless sensor networks in the area of localization. A wide variety of sensors have been deployed in the spectrum of wireless sensor networks to scale various types of habitats in the challenging scenarios. The rush to look out for cost-efficient, energy-efficient and accurate sensors and sensor algorithms is keeping the researchers on their toes. We have tried our best to go through the existing algorithms and after weighing their pros and cons carefully using the metrics such as the cost associated, the energy efficiency, complexity of the hardware and the software involved we have finally selected one algorithm and implemented it. Further we have proposed some changes in the algorithm and implemented the modified algorithm.

Chapter-1 INTRODUCTION

1.1 Introduction

Recent advancements made in wireless communication, along with development in digital electronics and analogue devices have given us sensor nodes that are efficient,communicate untethered in short distances and collaborate as a group low cost, low power and communicate untethered in short distances and collaborate as a group [1].

1.1.1 Introduction to Wireless Sensor Networks

A wireless sensor network (WSN) comprises of spatially distributed autonomous sensors which invigilate physical or environmental conditions such as temperature, sound, pressure etc. and then collectively collect , manipulate and send their data through the network to the destination. Wireless sensor network nodes are involved in faster and larger deployments due to the aggrandizing of heavy and power-hungry data collection impedimenta with lighter and smaller devices. Arrays constituting of large number of wireless sensor nodes are now possible, hence enabling scientific studies that aren't achievable with trivial instrumentation [2]. The WSN is made up of nodes which may number up to hundreds or thousands. These nodes are connected to sensors which typically have components such as: radio transceiver, a micro controller and a battery as shown in Figure 1.

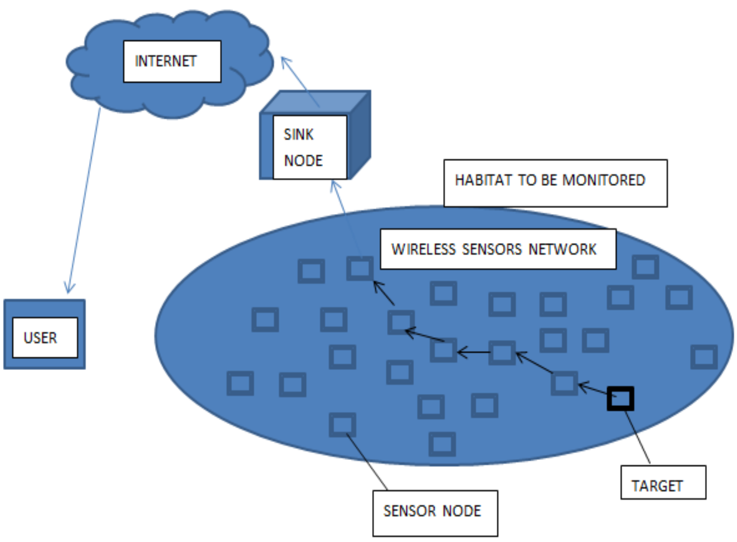

Figure 1.1.1 Wireless Sensor Networks basic architecture

1.1.2 Basic Architecture of WSN nodes

Usually sensor nodes used in wireless sensor networks have both hardware as well as software nodes. In terms of hardware the sensor nodes generally consist of various parts such as processors along with radio-transceiver sensors as well as power unit. The softwares which are typically used for sensor nodes are Contiki, Tinyos, and Nano Rk. In the following section, we shall discuss the hardware components very briefly:

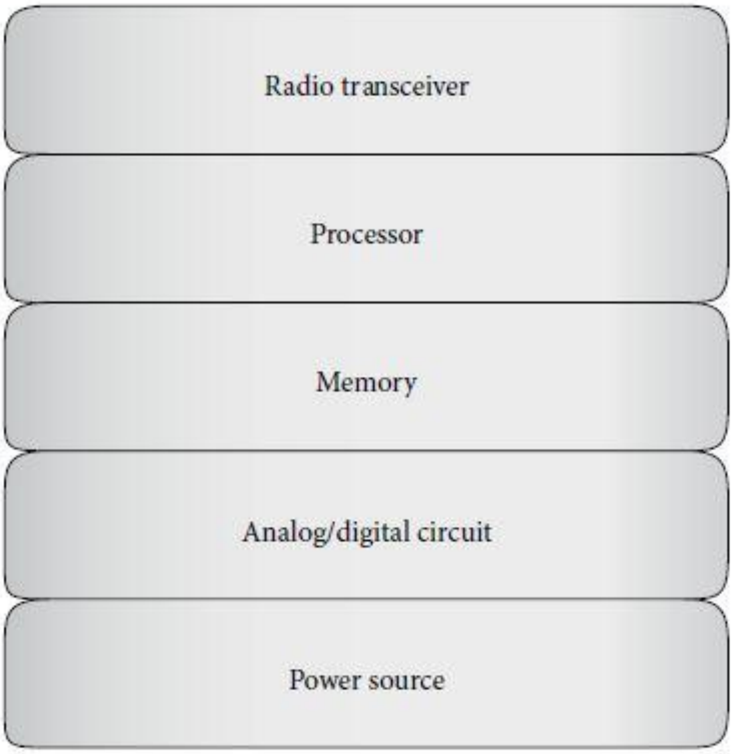

Figure 1.1.2 Basic hardware architecture of a sensor node

- **Sensor:**

The first being the sensor part.On the basis of the type of signals generated the sensors nodes can be categorized into two categories namely: digital sensors and other one analogsensors. Analog sensors are the ones which produce data that is in continuous form or in a wave form. This data is further that converted into human readable formafter being processed by the processing unit Digital sensors in contrast to this directly generate data in discrete or digital form. This data is directly sent to the processor for further processing after being converted into the processor friendly form.

- **Microprocessor**

Next we come to the microprocessors where various types of embedded memory that are used for processing data. The memory is integrated on same circuit as input/output devices. The data is initially stored in random-access memory (RAM) before sending it, while operating system of sensor nodes is stored in read-only memory (ROM). Microprocessors of sensor nodes namely tiny CPUs since they take care of the CPU speed, voltage, and power consumption. Generally most of the sensors operations run at low CPU speed. To save the energy and make the wireless sensor networks energy efficient, sensors stay in sleep mode most of the time. When the processor is in sleep mode does not mean it is not consuming any power. This is because when in the sleep mode, the processor is still involved in other activities like time synchronization

- **Transceiver**

Since after sensing the physical conditions in the environment around them the sensor nodes may have to send and receive data from other neighbouring nodes or the cluster head thus they also require a built in transceiver for the same. The transceiver is used to receive and sends data to other sensor nodes. In most of the cases radio frequency is used to connect sensors with other nodes. Data transmission is a costly affair since major energy consumption is done by transceiver during the data transmission that is while sending the data. In fact receiving data also consumes almost equal energy as much as is used in while sending the data. In order to maximize the energy efficiency of the wireless sensor network and hence increase the lifetime of the network there are four operational modes at which the transceivers can work, which are sleep, idle, receive, and send. These are explained as follows:

- Sleep mode

  Whenever the nodes turn off their communication modules or devices so that there is no more transmission and reception of data packets the node is said to be in the sleep mode. However the nodes can still listen to data frames in the sleep mode. This is called as the listening stage of sleep mode. The node remains in sleep mode and shifts to active mode whenever it listens to data frame.
- Active mode

  The next mode is the active mode. The active mode is the one in which data is transmitted normally. In this phase the communication device of the node are completely active, as a result it can both receive data as well as transmit data.

- Dormant mode

  Next we come to the dormant mode which is also a sub category of sleep modes. In this stage, sensor nodes operate or run on low-power mode and stay in the same mode for pre-decided amount of time. The sensor nodes then rediscovers the networks before startingcommunication. Whenever they go back to awake or active mode from dormant mode.

- **Power Unit**

Coming to the most prominent part of the sensor node is the power unit. Needless to saysensor node is absolutely inefficient to perform any operation or do any work without this unit. The lifetime of the senor node is defined by its power unit.

1.1.3 Working structure

Now we shall discuss the conventional working structure of any wireless sensor network. In a typical network operation every node samples the incoming data and then stores it in the node memory which the local flash memory that is usually embedded in every node since these days we prefer to go for in-situ computations. These nodes are also capable of transmitting periodic messages to inform their status or in order to achieve synchronization with other nodes. Whenever a node detects an interesting event occurring in its environment, it routes the message via other nodes to the base station which is usually a remote database centre. In some other cases where the clustering protocol might have been followed, in that case all the nodes sense the data and after initial manipulation collectively send the data to the cluster head. After this the various cluster heads collect and combine their data and pass it to the server for the purpose of further calculations or storage. These nodes may be placed in the area to be monitored in any fashion. However, extracting high quality and very reliable data from a wireless sensor network is pretty much a difficult task for two primary reasons. First one being that the radio links are usually very much prone to loss, error and are frequently asymmetrical. Second one being that theclock rates vary across the network due to low-cost crystal oscillators on these nodes which have low tolerances. This leads to issues in synchronization amongst the nods in the Wireless Sensor Network and hence effects the results. Large amount of research is focused on addressing these challenges.

1.1.4 Deployment of nodes

The next aspect related to wireless sensor networks is the deployment of the nodes. The nodes are placed or deployed in away so as to achieve the basic necessities that is Quality of service and quantity of service. Depending on the Quality or Quantity of service desired along with keeping in mind the economic considerations as well as the application, one of the several basic network topologies may be adopted. Further the nodes may also be placed in an ad-hoc manner. This usually happens in the case of wireless sensor networks, since the nodes are usually deployed to sense far off and wide areas, or the areas which are otherwise usually difficult to have access of. QoS can be achieved in any form such as by improvisingmessage due dates, bit error rates, packet loss, message delay, economic cost of transmission, transmission power, etc.

1.1.5 Application of WSN

The next evolutionary development is the coming of the smart environments. Just like in any other ingenious or impertinent organism, the smart environment too is highly reliable on the sensory data from the real world and how well it responds to this data. Sensory data is being continuously generated in the environment and may come from various typesof sources of different modalities in the distributed locations. However there are enormous challenges in this ranging from difficulty in detecting data in relevant quantities, hindrance in monitoring the environment and collecting data, complications in assessing and evaluating the collected information which is usually in heterogeneous form, muddle in creating meaningful user displays and arduousness in performing decision making and alarm functions. However Wireless Sensor Networks can be used to sense the environment and for initial stages of processing hierarchy normally referred to as in-site processing [3]. Wireless Sensor Networks have an ample range of applications attributing to their ability to adapt in different environments. They can be used to fetch data from the areas where otherwise it would have been very difficult if not impossible for humans to get the data and process it.

1.1.6 Introduction to Localization

One of the most prevalent applications of wireless sensor networks is localization. Localization refers to detecting a target in the vicinity of the wireless sensors.It is useful forcoverage, routing, location service, target tracking, and rescue since all f these require location information. It becomes indispensable when there is an uncertainty in the exact location of some fixed or mobile devices. In this report by localization we shall mean to monitor a habitat and try and identify the different species in that particular habitat. This is of great significance to the scientific society and the society as a whole. The reason behind the same being it enables us to know about the counter species we share our planet with. Especially there is a wide range of possible applications of source localization methods [4]. While intruder localization, habitat monitoring and vehicle or aircraft localization can be considered as outdoor application. On the other hand tracking the human speakers can be considered as indoor application. Further in underwater environment, localization is extensively used to find the position of varioussea animals and on voyage ships. There are numerous ways which can be used to estimate the source location: energy-based, angle of arrival (AOA) [5], time difference of arrival (TDOA) [6]. Being quite an inexpensive approach, as compared to others energy-based method is an attractive method because it requires low hardware configuration. Single-source further can be categorized into: energy decay model-based localization algorithm and the other being model-independent localization algorithms.

The usage of wireless sensor networks has eased this task further because it has enabled to get an access to the areas which otherwise were not possible for the mankind to scale manually. Localization is still one of the latest and impressive fields, with new algorithms, hardware, and applicationscontinuously being developed at a febrile pace; however it is really hard to say which of these techniques and hardware will be prevalent in the end [7]. A variety of different algorithms are available which can be used to monitor all types of natural environments. But still no algorithm is a clear favourite across the spectrum. The reason for the same being the certain parameters and trade-offs associated with all the algorithms. Every algorithm comes with its own pros and cons. While some algorithms guarantee high accuracy others guarantee high energy efficiency with a little compromise on the former parameter. Whereas there are some algorithms which attract the researchers on account of their easiness to apply and implement or may be with their easiness to scale over time. Still there are some algorithms which provide us robustness and fault tolerance which again is of utmost importance as repeated deployment and implementation of algorithms due to failures can be both challenging and financially exhausting. Hence to find an appropriate algorithm while settling with beneficiary and intelligent trade-offs is the need of the hour in the technology of wireless sensor networks.

Some other applications of wireless sensor networks apart from Habitat and ecosystem monitoring are Civil structural health monitoring- the nodes deployed in the structures are used to check periodically the health, tension, stress and various other characteristics to determine and make sure that the building is safe and secure for the presiders , Seismic monitoring- the deployed nodes measure the seismic parameters after the calamities , Logistics and telematics- they find an application in tracking, Precision Agriculture- the deployment of the nodes tells us precisely in which part of the land the fertilisers are actually needed thus helping us to cut on the fertiliser costs, Industrial process monitoring- wireless sensor nodes can be used for various industrial process monitoring right from the evaluation of the raw material to the production to the delivery process, Machines efficiency and fault monitoring- deployment of nodes helps to ensure that various parts of the machines are working efficiently and in case of any fault they help us to find out the area of defect, Perimeter security and surveillance- nodes can be deployed for the surveillance of buildings, army etc. to detect any intruders or accidents etc. and their integration with their devices can help us to raise alarms, Automated building- the fanning out of sensor nodes in buildings can be used to automate the buildings in terms of temperature control, turning off the lights, shutting of doors and windows etc. Apart from these wireless sensor nodes are extremely being used in all the smart objects.Their miniaturized sizes allow them to be deployed almost anywhere .

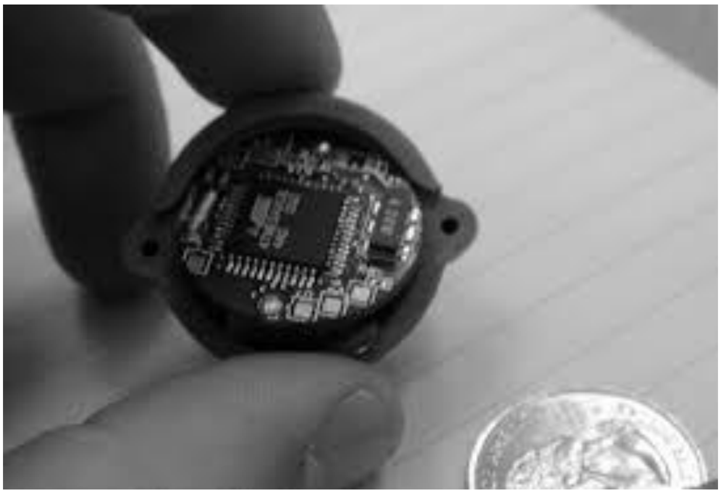

Figure 1.1.3 An illustration to show the size of a wireless network sensor node[Source: internet]

1.1.7 Advantage of WSN

The best part about wireless sensor networks is that their network can be incrementally expanded and increased by simply adding more nodes to the existing network (controlled by the scalability factor) – no rework or complex configuration is required. Along with reducing the costs drastically, the wireless sensor networks also have the property to adapt dynamically to the ever and continuously changing environment. Adaptation mechanisms help the network to respond to any kind of changes which may occur in network topologies or can cause the network to shift between drastically different modes of operation.

1.2 **Problem Statement**

As mentioned earlier localization is one the of the most pertinent applications of the wireless sensor networks. By localization we mean to detect a target in the vicinity of th wireless sensor networks. Localization is becoming one of the most sighted after application, the reason behind the same being its extensive advantage in keeping scrutinized check in the environment. In pour project we extend the use of localization to do habitat monitoring. That is we use it to detect different types of species in the habitat where we deploy our wireless sensor network. This project holds great leverage not just to the scientific society but entire mankind as a whole since it will help us to know about the species we share our planet with. Further with the increased rate at which the species are getting extinct, this approach of using wireless senor networks to do localization will help us to track them down, wherever they are even in the most intense of places where it is not otherwise possible for humans to pan the area and get information of quality good enough or in quantity large enough so as to deduce significant and relevant results. Thus in a way this project will help us to track down and safe guard whatever is left from the fast paced extinction of the fauna. One another aspect related to localization in habitat monitoring is the wide and large number of constraints that have to be taken care of. Some of them namely being the energy constraints, the lifetime of the network, the deployment topology and the robustness. There is a need to strike an absolute trade-off between these constraints so as to fetch the maximum advantage out of the network that we deploy. One way to do this can be to merge different types of algorithms each of which individually provide desired characteristics and then implement them and obtain all of the desired characteristics. This approach helps us to take advantage of the pros associated with a variety of algorithms. Further the methodology adopted here in this project can also be implemented for indoor localization with little or no modification.

1.3 Objectives

The objectives intended to make this project a success are as follows:

- To study about the wireless sensor networks and realise the importance and the application of localization by making an extensive survey on the existing literature.
- To implement TDOAand NIRAA algorithms of localization using Matlab and Java.
- To propose a new algorithm for localization.
- To analyse the proposed algorithm with TDOA and NIRAA.

1.4 Methodology

A gantt chart depicting our working through the course of fulfilment of this project is as follows:

	Task Name	Start Date	End Date	Duration
1	**Literature Survey**	**07/26/15**	**12/31/15**	**115d**
2	Study papers on WSN	07/26/15	09/30/15	49d
3	Study papers on Localization	10/01/15	11/30/15	43d
4	Write a review paper	12/01/15	12/31/15	23d
5	**implementation**	**01/15/16**	**03/30/16**	**54d**
6	select an algorithm	01/15/16	01/29/16	11d
7	Iimplement the algorithm	02/01/16	03/30/16	43d
8	**Propose changes in algorithm**	**03/15/16**	**05/13/16**	**44d**
9	Do metric analysis of algorithm	03/15/16	03/31/16	13d
10	**Implementation-II**	**04/01/16**	**05/13/16**	**31d**
11	Implement proposed algorithm	04/01/16	05/13/16	31d
12				
13				
14				
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17				
18				

Figure 1.4.1: The scheduling of the tasks and objectives through the project completion

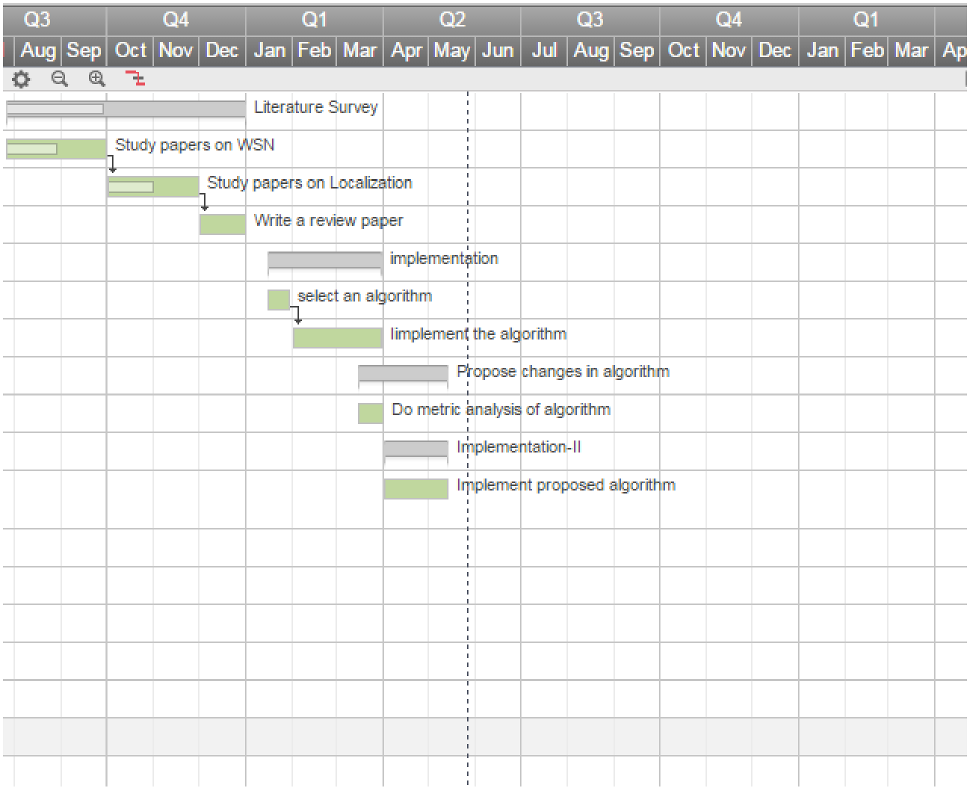

Figure 1.4.2 : Gantt chart to depict the flow of the work throughout the project

The methodology adopted to fulfil this project on time without any compromise in the efficiency aimed is as follows:

- We began by going through extensive literature survey. Since wireless sensor networks is one of the latest and the most trending topics in technology as a result there is stupendous amount of literature available for the same. We began by understanding about the basics of wireless sensor networks that is their need to the scientific committee and the society, their advantage over other existing technologies, the basic architecture of wireless sensor networks and also the typical working style of wireless sensor architecture. Next we studied about localization and its advantages. We studied numerous papers on localization using wireless sensor networks, various types of localization and their advantage to the society by studying about their applications in real life scenario.During this we also learned about the wide range of the existing algorithms and the pros and cons associated to each of them. We realised how a single algorithm can not fit into the all time favourite spectrum since there are advantages as well as disadvantages associated with each algorithm. Some of them may provide accuracy but may not have a good and long enough lifetime, another one may have larger lifetime but may not be scale able. Yet another one may be not be robust. Thus there is a consistent striation to strike a balance amongst these metrics and choose one algorithm which provides the maximum benefits along with accurate results. Also during this phase we wrote a review paper on the existing algorithms.

- Thus after undergoing extensive literature survey next we selected one algorithm out of the numerous existing algorithms that is time difference of arrival. The reason behind the same being that it provided the maximum accuracy and had maximum shelf life. Thus compromising on the fact that it's implementation is slightly costlier than others we cinched to adopt this algorithm since it provided maximum accuracy and served our purpose fruitfully. We implemented the algorithm in the Matlab. After this implementation we began looking for the modifications that can be made in this algorithm so as to improve the efficiency and reduce the cost.

- Finally we learned about how to go further with the modifications in the algorithm. We did it by adopting Neighbour Informed Rate Adaptable Algorithm and merging it with Time Difference Of Arrival. This helped us to cut out on the energy expenses. Reason behind the same being that NIRAA allows us to allot operational modes to the nodes and hence helps in conserving energy. Hence we finally implemented the modified Algorithm using JAVA.

1.5 Organization of Report

- Chapter 1

Chapter 1 consists of introduction to the various aspects related to our project along with the promulgation of the problem statement followed by the objectives aimed by our project, the methodology that has been adopted to attain these objectives.

- Chapter 2

Chapter 2 consists of the literature survey that is the study of the related information that has been done in lieu of this project.

- Chapter 3

Chapter 3 comprises of the System Development where we discuss the technologies used, the system requirement specifications and the proposed algorithm.

- Chapter 4

Chapter 4 contains the performance analysis of the implemented algorithm where we discuss the simulation scenario along with the input and output.

- Chapter 5

Finally in chapter 5 we present the conclusion and the future perspectives.

Chapter-2 LITERATURE SURVEY

2.1 Introduction to Wireless sensor Networks

Being the trending topic of research amongst the masses, clearly there exists a large amount of literature on the wireless sensor networks. A brief review about the literature survey done in lieu of this project is given hence follows. Generally in such monitoring applications the network scans the physical environment and tries to detect any changes in it which usually are the physical parameters such as temperature or humidity or pressure or ambient light or movement or may be the presence of any foreign object or particle for the purpose of target tracking. For this purpose the information about the location of both the phenomenon and the sensing nodes is necessary [8] for tracking and correlation purposes.

2.2 Introduction to Localization

First of all we shall try to mathematically define the problem statement as given in [9]. It demonstrates the problem as, say we have a wireless sensor network which comprises of *n* nodes where each has a range of communication extending up to *r*. Further say we have a squared sensor field which is two dimensional denoted by *Q*. To avoid any computational complexities it considers a communication link that is symmetric; that is, for any two nodes u and v,the signal strength w with which u reaches v is same with which v is capable of reaching u. Henceforth they represent the network by the Euclidean graph G= (V, E) with the following properties:

•V= {v1 , v2, …, vn} represents the set of sensor nodes.

•⟨i, j⟩∈ E if vi reaches vj; that is, this implies that thedistance between vi and vjshould beless than r.

•w(e) ≤ris where the weight of edge e= ⟨i, j⟩, the distance between vi and vj

Now the problem is to do localization using these nodes.

Being one of the most trending and versatile section there has been development of algorithms at a very fiery pace as a result we have a large number of algorithms for the same. These existing algorithms can be differentiated into two categories: first is Range based algorithms, where the point-to-point distance or angle information is required and second is the Range free algorithms, where no distance or angle measurement between nodes is required.

2.3 Range-Based Algorithms

Range-based localization [10] generally assumes that the distance between the nodes can be accurately measured by making use of special and extensive ranging hardware. But there are two very major issues related with range-based algorithms which are: (1) the localization accuracy is very largely and adversely affected by the ranging noise; (2) the localization robustness may badly harmed by the collinearity of the critical node sets which can produce unanticipated flip ambiguities. The very extensive previous research done in this aspect still does not resolves these issues especially for patch merging, a powerful tool to localize sparse sensor networks. Another critical issue for range-based localization is the existence of outliers in raw data (i.e. distance measurements and anchor positions) which strongly deviate from their true values. These outliers can severely degrade localization accuracy and need to be rejected. The two major inadequacies of the previous studies are (1) but totally neglecting the patch merging instead focusing only on adding an outlier rejection ability to multilateration; (2) neglecting outlier anchors and rejecting only the outlier distances but. The reason behind the same being that it is convenient to neglect outlier anchors which are more difficult to remove, because outlier anchors may collude by declaring positions in the same coordinate frame.

The most classic methods in the category of range based algorithms to assess the indoor location are time of arrival (TOA) followed by time difference of arrival (TDOA) and angle of arrival (AOA), as well as received signal strength (RSS). TOA is used to measure travel times of signals between nodes. TDOA on the other hand does localization by measuring the difference between the time between signals' arrival at anchor nodes and unknown node. This method generally achieves high ranging accuracy, but has an associated disadvantage since it requires some extra hardware and also it consumes relatively more energy. Another hardly expensive approach that requires relatively low configuration and energy is RSS which uses path loss attenuation with distanceto establish the mathematical model on the basis of [11]. The distance between the beacon node and unknown node can be obtained through the above three measurement methods. These algorithms are explained in keen detail later on in this chapter.

2.4 Range-Free Algorithms

Even though the high accuracy of the range-based algorithms is highly desirable still they are not very convenient and much accepted algorithms as far as wireless sensor networks are concerned. As it can be clearly seen in the problems related to range based algorithms mentioned above, we can deduct that ranging in wireless sensor networks is a difficult option. There are many reasons behind the same. Beginning with the hardware costs which is tremendous in case of range based algorithms. Further the energy expenditure involved in these algorithms is again very high. Along with this, the form factor and the limited range all are very difficult compromises to be made in the field of wireless sensor networks where energy efficiency and the ability to use the sensor network far and wide is one of the primary priorities. Also it is very difficult to anticipatenominal priced, capricious and devices constrained by the resources make use of range-based localization solutions.

As a result many range-free solutions have been recommended to combat the limitations of the range-based localization schemes. These solutions estimate the location of sensor nodes by, either, exploiting the sensing efficacies possessed by each sensor node or by exploiting the radio connectivity information among neighbouring nodes.

Due to the very different characteristics of these two approaches, the range-free localization schemes are generally categorized into two categories namely: anchor-based schemes these are the ones which conjecture the presence of sensor nodes in the network that have judgement about their location and anchor-free schemes, which do not require any special sensor nodes for localization. There is a requirement of high-cost custom hardware on each sensor node is to a large extent eliminated by range-free localization schemes. Very large calibration costs become necessary in anchor-based localization schemes because characteristics of the radio propagation maychange over.

2.4.1 Anchor Based Solutions

The anchor based solutions can be explained as follows: in this case we represent the location of a sensor node in a coordinate system. In any 2D space, we can make use of three anchor nodes to uniquely figure out a coordinate system. However in case of 3D space, there are at least four anchor nodes are required. Hence forth we discuss several range-free localization schemes which deducts proximity to a set of anchor nodes by making use of radio connectivity.

- **Centroid Approach**

  This scheme was suggestedby Bulusu in [12]. The main idea behind this approach is to consider the anchor nodes, located at (Xi , Yi), as point masses mi and to find the centre of gravity (centroid) of all these masses. An little illustration in Figure 2.1.1, shows the working of the Centroid scheme where a sensor node Nk is within communication range to four anchor nodes, A1...A4. The node Nk localizes itself to the centroid of the quadrilateral A1A2A3A4 (for the case of a quadrilateral, the centroid is at the point of intersection of the bimedians - the lines connecting the middle points of opposite sides).

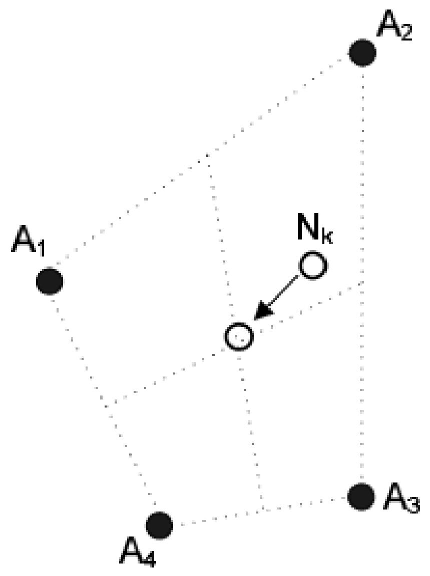

Figure 2.4.1.1 Centroid Localization- node $N_k$localizes to the centroid of the $A_1A_2A_3A_4$ Quadrilateral [11]

- **APIT [13]**

This is methodology is an area-based methodology. It makes an assumption that there is a stunted number of nodes, which know their location called anchors, which are equipped with transmitters that are high-powered and hence enable them to calculate location. Generally the GPS mechanism is used for this purpose. APIT uses beacons from these anchors, to implement a novel area-based approach by isolating the environment into triangular regions between anchor node to perform location estimation. We can use different combinations of anchors so that thearea in which a node resides can be reduced, and hence provide a good location estimate.

Algorithm 1 APIT

Receive location beacons (X_i, Y_i) from N anchors;
$InsideSet = \emptyset$;
for each triangle $T_i \in \binom{N}{3}$ triangles **do**
    if Point-In-Triangle-Test (T_i) == TRUE **then**
        $InsideSet = InsideSet \bigcup T_i$;
    end if
end for
Estimated Position = CenterOfGravity($\bigcap T_i \in InsideSet$);

Figure 2.4.1.2 APIT algorithm [11]

- **SerLoc**

  SeRLoc [14] is yet another algorithm which does based on the area a range-free localization. The authors in this case speculate that there are two types of nodes: first one being the normal nodes and second one being locators or commonly called the anchor. Normal nodes are equipped with antennas which are omnidirectional, while locators are equipped with directionally sectored antennas and their locations of locators are establishedbefore hand. On the basis of the information disseminated by the locators SeRLoc, a sensor estimates it location. The algorithm for the same is as follows:

Receive beacons from locators; each beacon contains the position of locator and the angles of sector boundary.
Find four values: $(X_{min}, Y_{min}, X_{max}, Y_{max})$ among all the locator positions heard.
Set the search area as the rectangle $(X_{min} - R, Y_{min} - R, X_{max} + R, Y_{max} + R)$, where R is the radio range.
Partition the search area into grids.
for each beacon received **do**
    Increase the value of a grid point by one if this grid point is within the sector defined in this beacon.
end for
Estimated Position = CenterOfGravity(the grid points with the largest values)

Figure 2.4.1.3 SeRLoc Algorithm [11]

- **Gradient Algorithm**

  In the Gradient scheme, put forward by Nagpal et al. in [15], the anchor node infers its distance from the anchor by initiating a gradient that self-propagates and allows a sensor node. The sensor node figures out its location by usingmultilateration after and needs to estimate distance to three nodes for the same.

  The steps followed in the Gradient algorithm are as follows:

  - Each anchor node Ai transfuses a flood of the network by repoting everywhere a data frame containing its position along with counter whoseinitial value is set to one.
  - Track of the shortest path is maintained by each sensor node Nj (namely the count of of radio hop, hj,Ai) to an anchor Ai fwhich had sent a beacon. To obtain distance estimate between sensor node and the anchor node , we use: dji = hj,Aidhop where hop is the estimated Euclidian distance covered by one radio hop.
  - After this coordinates are computed by every node in such a way we are able to minimize the total error. The general sources of error in the Gradient scheme are: incorrect or wrong estimations of one-hop distance , and the multilateration procedure.

- **Ad-Hoc Positioning System**

  The Ad-Hoc Positioning System (APS) is almost similar to the gradient method and was put forward by Niculescu and Nath [16]. It calculates the distances to known anchors (a set of anchors is assumed to be present in the WSN) by using hop-by-hop mechanism. After a sensor node has obtained estimate distance to three or more anchors, it improves its location estimation by employing a multilateration (similar with that of GPS). The only major difference between Ad-Hoc positioning system and the gradient approach lies in how a sensor node Nj estimates its distance to an anchor Ai.

  The steps which are followed in the APS localization scheme algorithm are the following:

  - Each anchor node Ai sets the initial value of the counter to one and initiates a flood of the network by sending everywhere a packet which contains its position.
  - Track of the shortest path is kept by each sensor node Nj (namely number of radio hop counts, hj,Ai) to an anchor Ai which had earlier sent it a

beacon. In [16] the four methods proposed by the authors which can be used for propagating the distances from anchors to sensor nodes: first is DV-Hop, second one DV-Distance, third Euclidian andfinally Coordinate. There is no ranging assumed in this method.

- After having finished obtaining the distances to other nodesA computes distances to other anchors, it computes a correction factor ci (the estimated 1 radio hop Euclidian distance), which it propagates in the network. It uses controlled flooding, to propagate the corrections i.e., after a node receives and forwards the first correction, it will stop forwarding subsequent corrections.
- To solve the non-linear system of equations we use a least square method.

- **Probability Grid**

  This method is almost similar to DV- hop algorithm. This method is generally employed in the cases where the topology applied is grid before hand.

  The steps used for the localization scheme are mentioned hence follows:

  - Each anchor node Ai sets the initial value of the counter to one and starts a flood of the network by sending forth a packet which contains its position.
  - Track of the shortest path is maintained by each sensor node Nk(which is the numberof radio hop counts) to each of the anchors Al which had earlier sent beacons.
  - After distances to other anchors are obtained A_m computes a correction factor cm (the estimated radio range), and it propagates it through out the network.
  - After having received hop-count estimates to three or more anchor nodes, and a correction factor cm a sensor node Nk evaluates the probability of being located at any position in the grid (labeled (i, j)). For thispurpose we generally compute an expected hop count: λ = d(i,j),l/cm where d(i,j),l is the Euclidian distance between anchor Al and the point (i, j) being evaluated. It then computes the probability of it (node Nk) to be positioned at (i, j): pk,(i,j) = Y |A| l=1 P hk,l (i,j) where P hk,l (i,j) is the probability of node Nk, positioned at (i, j), to be hk,l hops from anchor Al .
  - Location that node $N_k$chooses is the one which is the position in the grid (i, j) with the maximum probability pk,(i,j) .

The observation made by the authors is that hk,l is a discrete random variable that represents the number of radio hops between one anchor and the point of interest, i.e. (i, j). To have one parameter λ (defined above) , to be narrow and skewed positively for small values of λ and become broader and relatively symmetric for larger values of λ are the main features that the distribution function for hk,l needs to exhibit.These requirements follow the intuition that for smaller values of the parameter λ (i.e., grid points closer to the anchor) the number of hops (call it τ) has a limited range of possible values with higher and higher values being less and less probable (positively skewed). As the distance between the anchor and the node increases (λ increases), the number of possibilities for the hop count (τ) increases and the distribution becomes bell-shaped, i.e., smaller and larger.DVhopalgorithm is explained in detail later on.

2.4.2 Anchor Free Algorithms

Anchor-free localization schemes generally tend to exploit the proximity to an event with a known location: a light event in [17] [18] or a nearby radio packet in [19]. All these schemes carry one common characteristic that is the complexity has now shifted from sensor to node to the central or a better and more sophisticated device, where complexity is the computation and the hardware required to get exact position or localization. Much higher accuracy can be obtained in localization in comparison to other anchor-based schemes merelyif we control well the spatio-temporal properties of the events which may be light packets or radio packets. Even though the anchor nodes are not typically vital or necessary for any of the hence forth given schemes, still their benefits for future perspective and betterment of the proposed schemescan not be ignored.

- **Spotlight**
  The basic idea behind Spotlight localization system [30] is to procreate events in a controlled fashion in the field where the sensor nodes are deployed. An event can be anything, for an instance let us tacit to be the light present in an area. Spatial information (i.e. location) with respect to the sensor node can be deduced easily by using the spatio-temporal properties of events which are generated along with the time when an event is anticipated by a sensor node. The localization process which makes use of these three functions can be explained as follows:
    - Events e(t) in the space A by a spotlight device for quite a period of time.

- The time at which is the sensor nodes detect the event during the event distribution is stored b the sensor nodes in form of a time sequence Ti = {ti1, ti2, ..., tin} .
- Once the event distribution has been done, detection time sequence is sent back by each senor node to the Spotlight device.
- Using the time sequence denoted by Ti and already calculated function denoted by E(t) the Spotlight device estimates the location of a sensor node i.

The basic spotlight structure is shown in figure 2.2.2.1

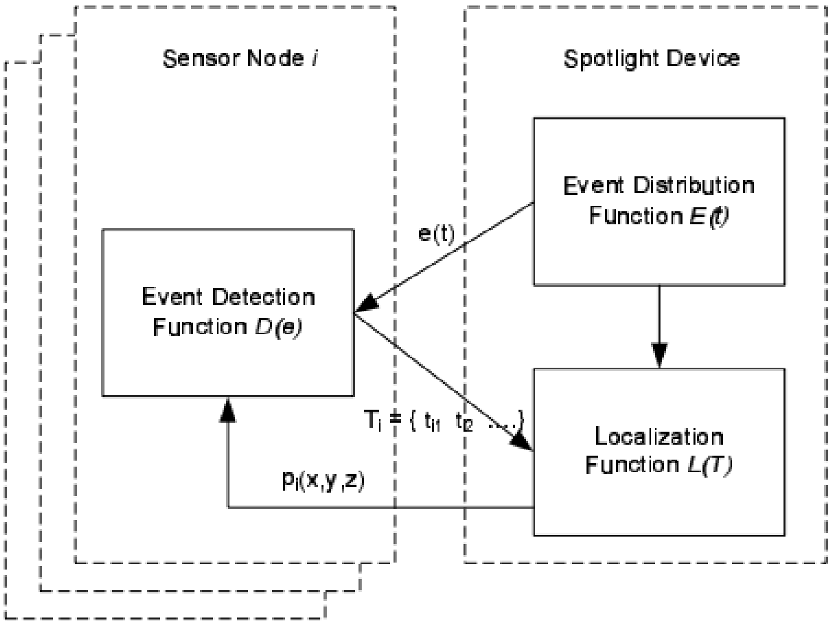

Figure 2.4.2.1 Spotlight System Architecture[11]

The event distribution function is one of the purport techniques used in spotlight system and there are three basic designs known for it, where each one has a different cost associated with it. These designs are explained as follows:

- Point Scan

  It is generally suitable for simple sensor systems that is whenever there is a set of nodes that are placed along a straight line (A = [0, l] ⊂R , in this case Point Scan EDF is applicable. The point events (e.g., light spots) are generated along this line with constant speed s, as shown in Figure 2.4.2.2. For all the events which were detected by a node the timestamp seti is Ti = {ti1}. The Event Distribution Function E(t) is as follows:

$$E(t) = \{p \mid p \in A, p = t * s\}[11]$$

where $t \in [0, l/s]$. The resulting localization function is as follows:

$$L(Ti) = E(ti1) = \{ti1 * s\}[11]$$

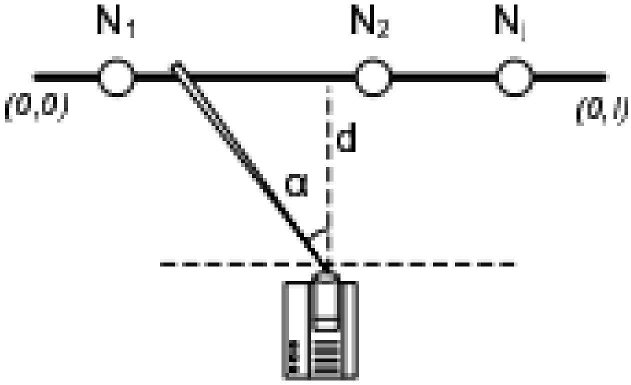

Figure 2.4.2.2 Point scan EDF implementation [11]

- Line Scan

  There are some devices which are capable of simultaneously generating entire line of all the events. One such example is a laser. These devices support Line Scan Event Distribution Function. For this we hereby assume that the sensor noes are placed in a two dimensional plane denoted by ($A = [l \times l] \subset R2$) and that the scanning speed is s $Ti = \{ti1, ti2\}$ refer to the set of timestamps of events detected by a node i is.

  The line scan EDF is depicted in figure 2.2.2.3 and is defined as:

$$Ex(t) = \{pk \mid k \in [0, l], pk = (t * s, k)\} \text{ for } t \in 0, l/s$$
$$Ey(t) = \{pk \mid k \in [0, l], pk = (k, t * s - l)\}$$
$$\text{For : } t \in l/s, 2l/s \text{ and } E(t) = Ex(t) \cup Ey(t).$$

  We can calculate the node locationby finding where the two event lines intersect, as shown in Figure 11. It can be defined in a more formal way as ollows:

$$L(Ti) = E(ti1) \cup E(ti2)$$

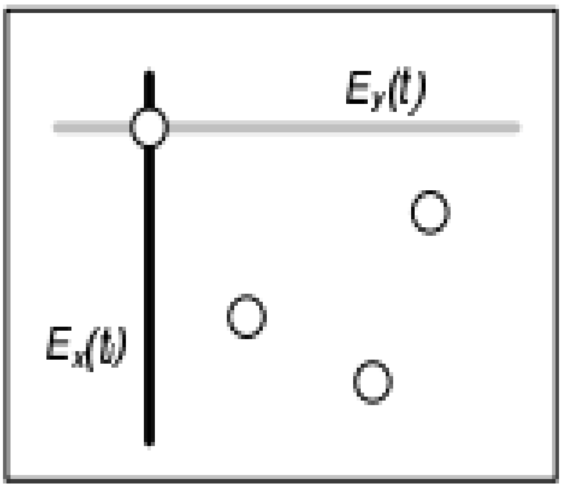

Figure 2.4.2.3 Line scan EDFimplementation[11]

- Area Cover

There are several devices which can generate events which can cover the entire area. An example of such devices is the light projectors. In such cases we prefer to implement the Area Cover EDF. The basic logic behind area cover EDF is to divide the spatial region *A*, where the sensor nodes are set out into partitions or multiple sections and then to each section assign a unique binary identifier, called code. Let us assume that we do localization in an area e ($A \in R2$). Each section Sk within A has a unique code k.

The Area Cover EDF, with its steps shown in Figure 2.4.2.4 is then delineated as follows:

$$BIT(k, j) = \begin{cases} true & \text{if j th bit of k is 1 [11]} \\ false & \text{if j th bit of k is 0} \end{cases}$$

$$E(t) = \{p \mid p \in Sk, BIT(k, t) = true\}$$

and the localization algorithmcorresponding to this is:

$$L(Ti) = \{p \mid p = COG(Sk), BIT(k, t) = true \text{ if } t \in Ti , BIT(k, t) = false \text{ if } t \in T - Ti\}$$

wherecenter of gravity of Sk is denoted by COG(Sk).[11]

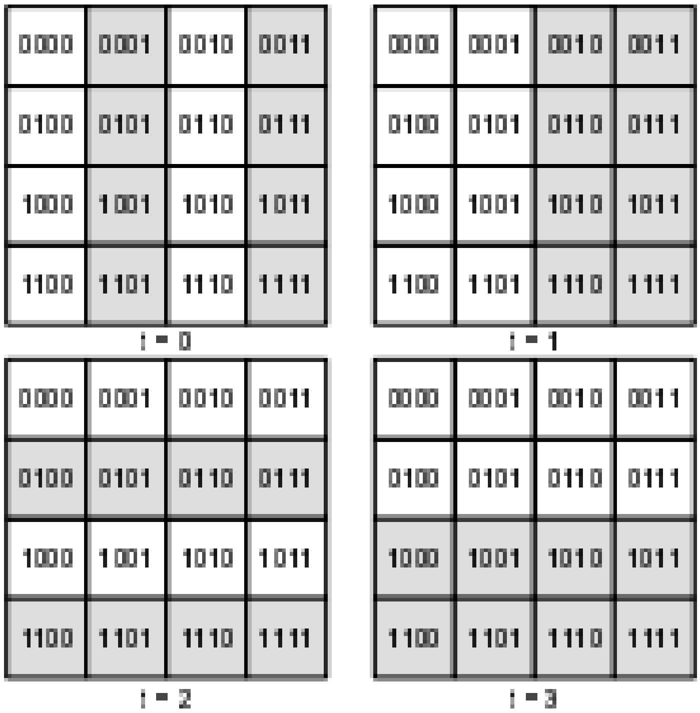

Figure 2.4.2.4 Implementation of area cover EDF [11]

- **Lighthouse**

Lighthouse [18] to an extent is quite similar to spotlight Localization System. It was proposed byR¨omer [18]. This methodologyutilises the free-space optical channel between a device which in this case is called lighthouse and the sensor nodes. It basically comprises of a parallel light beam of width b, which is emitted by an anchor A1 andafter a certain period it rotates. Tlight beam for a time periodtbeam, which is also depends on the distance d between the Lighthouse device and the sensor node by a sensor node N_k as follows:

$$d = b/\ 2\ \sin(\alpha 1/2) = b/\ 2\ \sin(\pi t_{beam}/t_{turn})$$

One can easilyfind out the distance from the sensor node and the lighthouse device dby using t_{beam} and knowing b and t_{turn},.A 3D location can be obtained byconstructing a device with three lights which are mutually perpendicular emitting Lighthouses. The main difficulty which was encountered by the authors while implementing the Lighthouse protocol is to make sure that the light beam is perfectly parallel (zero divergence), having a width b. Instead, we prefer to use two laser beams which are usually of bi and angle orientations βi ,γi and δii = 1, 2.

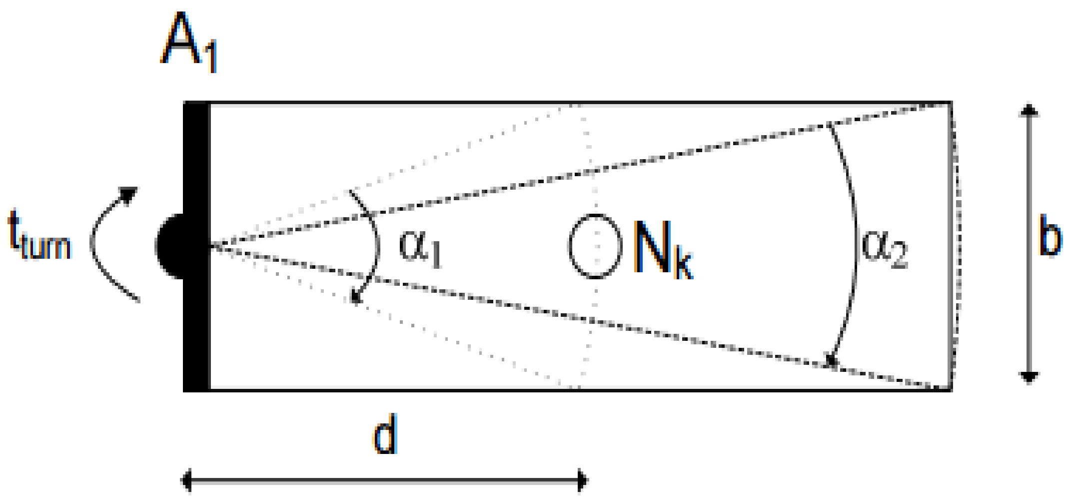

Figure 2.4.2.5 Using lighthouse scheme for localization [11]

- **Walking GPS**

Many a times Wireless sensor networks have envisioned as being used in unmanned aerial vehicles. Till date there have been many cases of manual deployment where the employed localization solutions make use ofan associated variant of the sensor node ID with precedent information of that ID's position in the field. In [19] a solution named Walking GPS has been proposed by the authors. In Walking GPSa GPS device carried by a deployer which may be a person or a device. This deployer periodically broadcasts its location. The location which isput forward by the GPS device is used by the sensor node which are deployed to infer there positions. The main advantages of this solutions are: it is pretty much simple, is quite cost effective in comparison to others and has very little overhead. Generally in the Walking GPS architecture we decouple the system into two software components: first one the GPS Mote and the second one Sensor Mote. The GPS Mote usually uses Mica2 mote to operate. The mote which is connected to a GPS device, gives the output that is its information about its location at definite time intervals. On the other hand the Sensor Mote component can be used to run on all types of sensor nodes which can be used in the network. This component deduces information about its location from the packets it receives which contain the location information GPS Mote had broadcasted. In this architecture all the complexity is imitated from the inter communication with the GPS device and is pushed to one particular node, the GPS Mote. This is basically so that size of the code and amount of memory used on the sensor node is decreased considerably. This decoupling makes a single GPS Mote pretty much plentiful for the localization of an entire sensor network, and thus helps in reducing the cost. A simpler design for the GPS Mote can be envisioned as the one which periodically broadcasts the actual GPS location which is collected from the GPS device. The Walking GPS system generally makes use of local Cartesian coordinate system so that overhead which occurs whenever the data that contains global GPS coordinates is exchanged, is reduced significantly. GPS mote performs the conversion between the coordinate system. A local coordinate system of reference is much more convenient for a WSN, than a global coordinate system. Experimental setup of a GPS walking system is shown in figure 2.2.2.7 where the nodes are set up in a grid form.

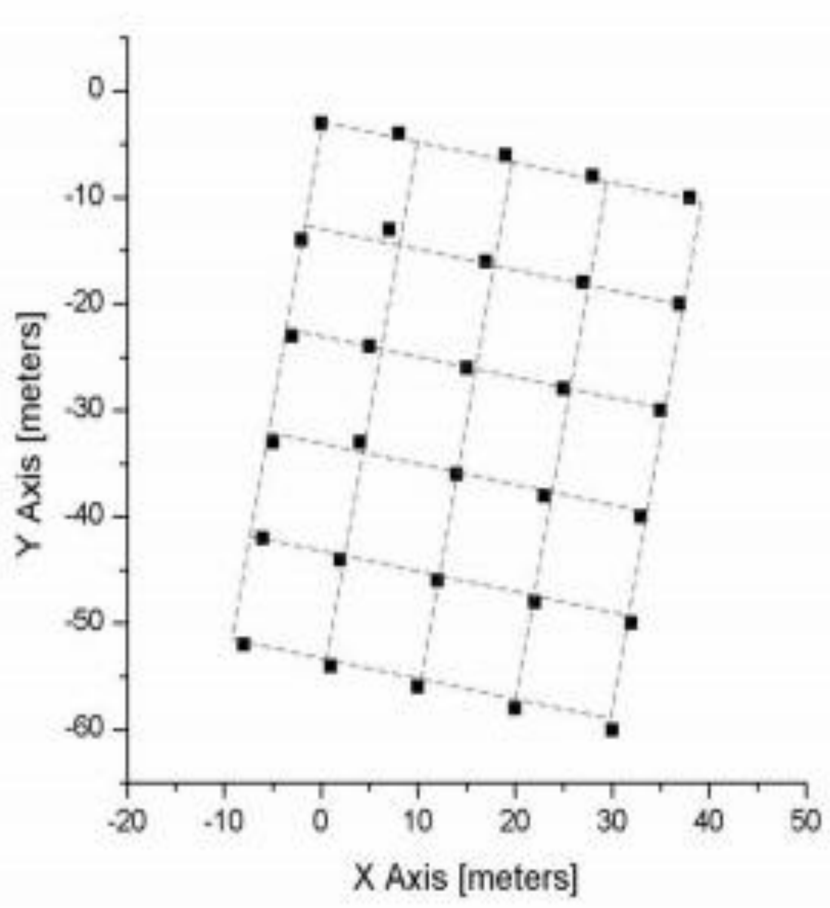

Figure 2.4.2.6Assessment of Walking GPS.Nodes setup in a grid.[11]

A simple flowchart depicting the categorization of various algorithms is shown in Figure 2.4.2.8

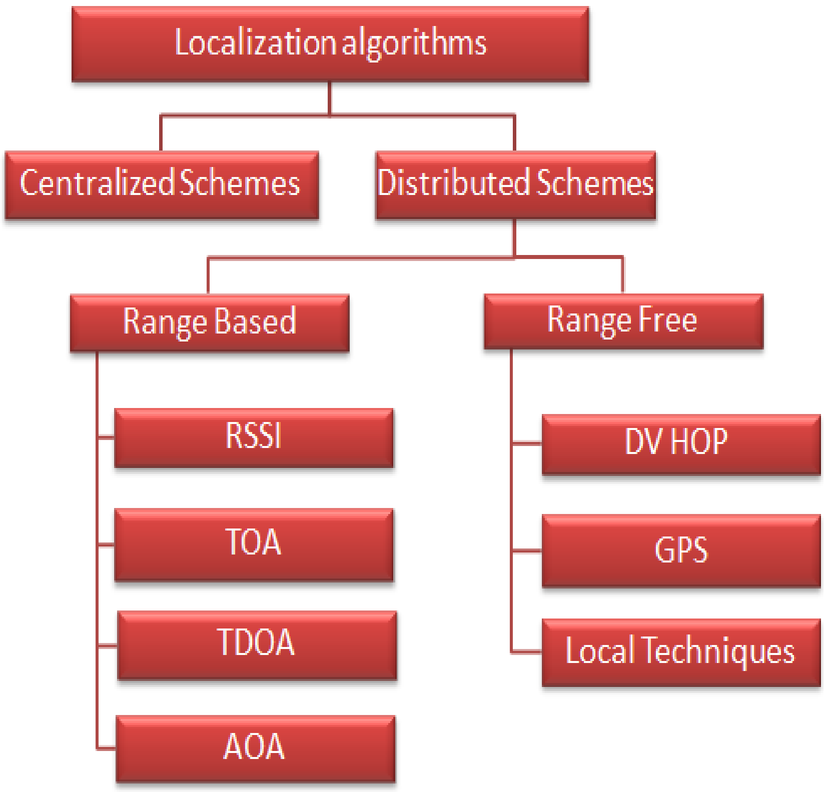

Figure 2.4.2.7 Flowchart to depict the categorization of various algorithms

Next we shall be discussing about various existing algorithms in detail along with their implementations and the associated pros and cons.

2.5 RSSI

The first localization algorithm that we shall be discussing is the signal strength indicator. This algorithm estimates the distance by comparing the signal strength at the node of the known location which had sent the signal with the signal strength received at the recipient signal. The ratio between these two signal strengths is then used to infer the distance between the nodes. Generally the deterioration in the signal strength is directly proportional to the square of the distance travelled by the signal. But this value becomes very difficult to be modelled mathematically since there may be many obstacles in the path of the signal and it becomes very complex to take all of these into account.

The correlation between RSSI (Received Signal Strength Indication)[20] values and distance is actually the basic of the various existing localizing and positioning schemes in wireless sensor networks. RSSI is pretty much apt for the nodes deployed in wireless sensor network whose power is limited since it has less communication overhead, lower implementation complexity, and lower cost. Currently, RSSI is implemented into 3 types of propagation model for WSN namely,free space model [21], 2-ray ground model [22] and log-normal shadowing model (LNSM) [23]. Both the first models are generally used for the purpose of application environment, whereas the last oneis used more for implementation of propagation model of general signal.

The principle behind the RSSI ranging lies in thecorrelation that lies between the power transmitted and the power received by wireless signals and the purview among nodes as explained earlier. This relationship is shown in equation 1. It shows the relationship betweenthepower that is received and the power that is transmitted by the wireless signal and the distance between the sending nodes and receiving nodes where the symbols have their usual meanings.

$$P_r = P_t \bullet \left(\frac{1}{d}\right)^n \quad [8] \qquad (1)$$

Next we taking 10 times the logarithm either sides on (1), then Equation (1) to transform it into Equation (2).

$$10\lg P_r = 10\lg P_t - 10n\lg d \qquad (2)$$

Equation (2) can be straightforward written as Equation (3) as follows:

$$P_R\left(dBm\right) = A - 10n\lg d \qquad (3)$$

From Equation (3), it is clear that the values of parameter A and parameter n can be used to figure out the correlation between the received signals strength and the distance the signal traversed.

To demonstrate the use of Received Signal Strength Indicator the authors have set up the field by using Micaz nodes as the preliminary hardware platform, which are wireless sensor nodes produced by For the experiment they have used two beacon nodes and a single base station node. These nodes rest on the ground. After this a location thirty meters in length and ten meters in width in the outdoor open space and another location fifteen meters in length and ten meters in width in form of an indoor hall was chosen. Data was collected by the transmission and reception of signals among the nodes. Beacon node 1 was made responsible for sending signals; beacon node 2 was responsible for receiving signals from beacon node 1 and then transmit the values to base station node; base station node is attached with a computer and is fettered for data reception and processing. Beacon node 2 was made to collect 100 signal valuesat each point which wasat a distance from the direction of beacon node 1 and then forwardthese values to the base station node. The base station node converted the values of the signal into another expression given by the formula:

$$RSSI(dB) = 10\lg\frac{P_t}{P_r}$$

and then passed the eventuality to the host computer. After the host system has received the data, it manipulates the data and calculates the average of for each distance point.

In the end it can be concluded that even though received signal strength indicator is one of the widely adopted algorithm due to its less expenditure and easy deployment still its large scale implementation is hindered by the fact that the results can be hugely affected by the presence of any obstacles in the channel of propagation.

2.6 Time of Arrival

In TOA, makes use of speed of wavelength and time of radio signals travelling between anchor node and unlocalized node is measured to estimate the location of unlocalized node [24]. It estimates the difference that lies from the Beacon to any other sensor node based on the time that is needed to traverse and the speed of the transmitted signal. [25] Since ToArelies tremendously on the exact time measurement at the receiver and transmitter, thus it is of utmost importance that synchronization be rendered. A GPS is the most basic example that uses ToA. As mentioned above to use ToA for estimating the range, a system needs to be synchronous, this in turn lead to the requirement of expensive hardware for precise clock synchronization. [26,27]

TOA or time of arrival in simple words can be defined as one-way proliferation time of the signal travelling between a source and a receiver.[28] This calls for all the source and all the recipients are synchronized very accuratelyto measure the TOA information. However if two way or round trip TOA is computed such an identical system is not needed. After the ToA is computed it is then multiplied with the a priori knowledge about the speed of propagation, usually denoted as c, to give the source and the receivers’ in between distance. Using simple geometry it can be easily judged that the measured TOA represents a circle where the centre of the circle lies on the receiver and the source necessarily lies on the circumference in a 2D space. Generally three or more such circles are rerieved from the noise free TOAs, which then result in a distinct intersection point which represents the source position and is as shown in Figure 2.6.1hence it can be concludedthat at least three sensors are required for two dimensional position estimate [29]. If the number of sensors is less than three this may lead to a case of no feasible solution since there is a possibility that there may not be any intersecting points. Hence, we can conclude that at least three sensors are necessary to deduce the intersection and these can be represented as a set of circular equations.

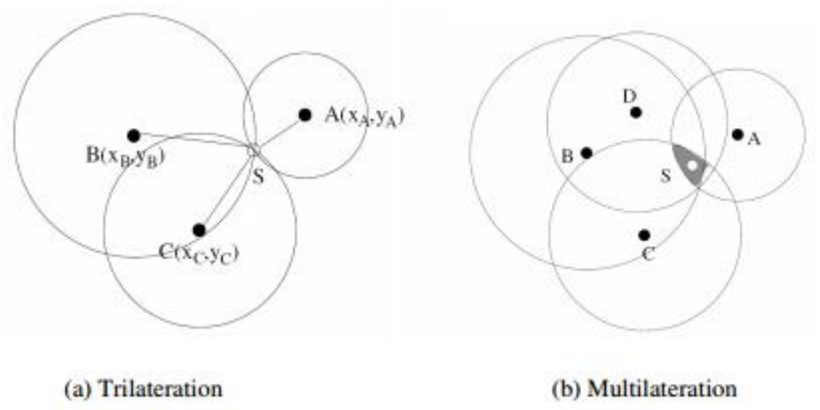

Figure 2.6.1: Geometrical representation of ToA Positioning System[28]

For the simulation purposes the authors have 2- Dimensional region with dimnsions 1100*1100 m^2, where the unknown source is assumed to be at position (x, y) = (200, 300), and the receivers are localised in coordinates at (0, 0), (0, 1000), (1000, 1000) and (1000, 0) respectively. The sensors are set up in a rectangular fieldin such a way that the source is encompassed by four receivers and is shown in Figure 2.6.2. It is also assumed that $\{n_{TOA}\ l\}$are zero-mean uncorrelated Gaussian process with variances $\{\sigma_{TOA}\}$ and zero- mean property indicates LOS transmission. The range error variance $\{\sigma_{TOA}\}$, is proportional to the square of the distance. The signal-to- noise-ratio (SNR) has been assumed to be 30dB. Hence forth the time of arrival algorithm is deployed in the manner as explained above.

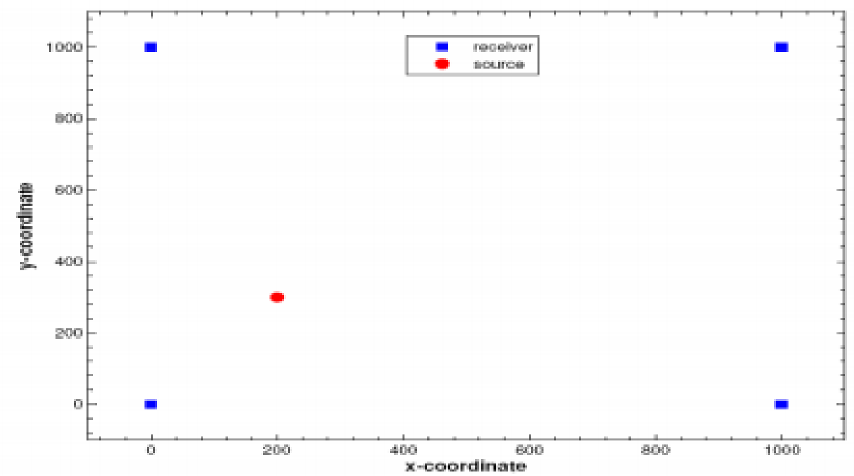

Figure 2.6.2 Position of source and receivers[28]

Thus we can say that using time of arrival for positioning and localization purposes holds great attraction attributing to the fact that it is easy to implement. But still its wide range implementation is avoided since it is not very feasible to obtain exact and accurate synchronization. This can lead to faulty results.

2.7 NIRAA

As we have discussed earlier, energy efficiency is one of the mostprominent issues involved in WSN designs, as a resultsetting the transmission rate of a sensor in an energy profitable manner is very important.[30]This algorithm focuses on the problem of virtuous transmission rate acclimation for various sensors in a WSN network while we are monitoring a moving event of interest. The basic idea behind the algorithm is to assign relative importance values to the sensor devices. For exampleif there is only one sensor node in a wireless sensor network, that is discerning an event, then naturally the relative importance of these node becomes higher than all other network nodes. As a result, larger snumber of resources shall be assigned to that node.

Basically since WSN nodes are equipped with a CPU which might be programmed as per the needs of the system they are set up for thus we try to exploit their capability to adjust themselves adaptively.

This algorithm is inspired by Hermes Middleware [31]. All the nodes in this architecture possess the ability to independently alter their data transmission rates. Let us say we have a sensor data transmission rate r assigned to it, thus this nodes wakes up every 1/r seconds, and samples the environment on which it is deployed and in case any measurements are sensed, it transmits them. Rest of the time, it saves energy by staying in the sleep mode. Typically, transmission range which is dictated by the overall network design considerations is denoted by < min, max > and beyond this range the nodes cannot adjust their transmission rates. The purpose of the lower bound is just to ensure network is operational and not to sense anything specific but to characterize damaged sensors from others. On the other hand upper bound increases network efficiency by avoiding unnecessary usage of power and radio bandwidth. This network is known as RateAdaptable Wireless Sensor Network (RA-WSN).

As per the proximity of the nodes to the events the transmission rates of nodes can be assigned whenever there is an event that occurs in the network. Clearlyin comparison to a node which is at a distance from the event, a node that is in proximity to an event will have superior priority. Further the importance of the nodes that are close to the event are more likely to be affected by the event in future in case of the event is a moving object (such as fire spreading).

As an example, in Figure 2.5.1, say an event occurs in the sensing range of n1,then its transmission rate increases since in this case n1 will naturally become relatively more paramountin comparison with other nodes whichdo not contain the event in their sensing rang. However n2 and n3 will transmit at the same lower transmission rate since they will not be able to detect the eventas the event is not in their range. Intuitively, n3 is more important than n2 since it is closer to n1's sensing range. Thus, there is more probability that n3 will sense the event sooner than n2, and further, n3 is expected to be attributed more resources than n2.

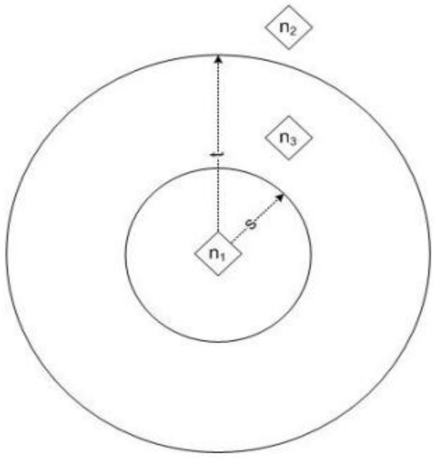

Figure 2.7.1 Transmission Range v/s Sensing Range[30]

This kind of information is generally used to estimate the importance of the evacuation zones and scheduling evacuation procedures for areas in case of fire spreading. Further we need to have exact knowledge about the positions of the nodes so that we can come up with an efficient transmission rate mechanism, and a localization mechanism to estimate the location and closeness of the nodes to the event. Inspite of a large number of mechanisms proposed for localization in WSNs, many of them are quite unattractive for this purpose due to poor reliability and low accuracy.

WSNs can be used to auditor the displacement of an object, say a car as in Figure 2.7.2. The sensors which are closer to the object are expected to transmit at a higher rate since they are more importantwhere the others' importance value is decide by the relative position to the event passing by.

This figure below demonstrates that the two nodes transmit frequency at a very high rate(marked with "H"), are the ones that are closest to the object ,three nodes that are of importance to the system in future, transmit with medium rate (marked with “M”) and all the others transmit with lower rate.

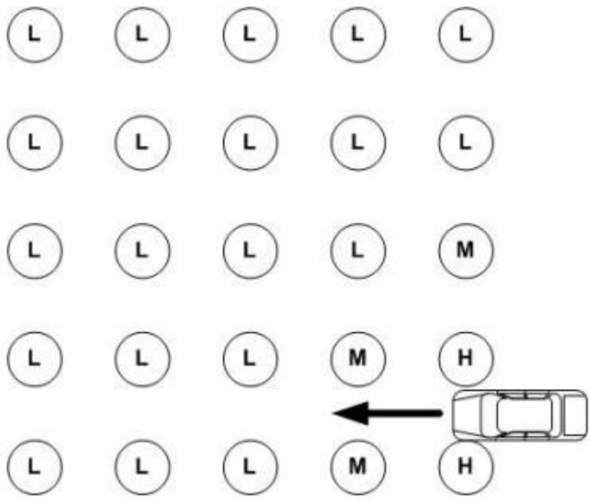

Figure 2.7.2 Monitoring a moving object using NIRAA in WSN[30]

The receptors that receive this message elevate themselves to an advanced transmission rate after a close node has detected an event and. Notice that a node that receives an EventDetected packet can be ascertaining the event itself, in which case it will extend its transmission rate to the maximum rate; otherwise transmission will be at a medium rate since it is not as important as the nodes that are detecting the event, but it is more significant than the nodes that are neither detecting the event nor have received the EventDetected messages. Algorithm 1 summarizes this mechanism.

```
if LocalEventDetected() then
    Rate = MAX
    AlertNeighbors()
else if NeighborAlertReceived() then
    Rate = MEDIUM
else
    Rate = LOW
end if
```

Figure 2.7.3 NIRAA Algorithm[30]

This algorithm performs very well for monitoring moving objects which are moving with low-to-medium velocity values and promises efficiency and quickness of high rate assignment with the cost of low rate assignment. But this algorithm may give no o inaccurate results when the object to be monitored is moving at a very fast pace. The reason behind the same being that in such a case the object traverses through the area to be sensed at a very high speed and as a result our network sensor is unable to capture it.

2.8 TDOA

Time Difference of Arrival (TDOA) can be used to address the problem of position estimation in a range of applications from WSN to electronic warfare positioning. [32] It forms a hyperbolic function by doing correlation analysis of the transmitted signal to two receivers. We can compute more hyperbolic functions, by making use of more than two receivers, which ideally intersect in one unique point.

The TDOA measurement is computed as follows:

I. A signal s(t) is transmitted by the sender which is delayed $\Gamma_i$by the time it reaches the receiver *i* according depending upon the distance between the sender and the receiver. The signal can either be a pilot from a an up link where the mobile's outright time is unknown, or it can be unknown, as is the case in electronic warfare. In either case, Γ_i cannot be computed.

2. Time delay Γ_i - $\Gamma_j$is provided by the correlation analysis corresponding to the path difference to receivers i and j

To get a further clear understanding, we first consider a hyperbola with the transverse axis aligned with y-axis with the characteristic equations, where *a* is the distance from the centre to either vertex, *b* is the length of perpendicular segment between each vertex and the asymptotes, and *c* is the distance from centre to the either focus points. For any point *P(x,y)* on either vertex, the absolute difference between the eccentricity $|d_2-d_1|$ is always equal to twice the distance between centre and the vertex. The proposed TDOA method works based on the presumption that target is located somewhere on the hyperbola, and uses the intersection of two or more hyperbolas to perform localization.

Consider a region where nodes $(N_1, N_2, N_3,..)$ are located at random locations $((x_1,y_1),(x_2,y_2),(x_3,y_3),..)$ as in Fig. 2. When the target initiates its search routine for sensor nodes in its vicinity, it marks the time of arrival of each node in its sensing radius as T_1, T_2, T_3,.. Once this information is obtained, target designates the node with lowest TOA as reference node, and draws hyperbolas between the reference nodes and three other nodes. Hence the time difference of arrival technique makes use of the difference between the times at which the sent signal is received at the recipient nodes. Using this time difference it creates hyperbolae. The intersection point of these hyperbolae gives us the exact location of the source which had initially sent the signal.

This time difference of arrival scheme helps to overcome the disadvantage associated with the time difference of arrival technique which wanted stringent synchronization be done amongst the nodes. It was very difficult to obtain synchronization at this accuracy and this in turn led to mistakes and errors in the localized position estimated. Hence to combat this flaw time difference of arrival is used where slight tolerance to the synchronization is there since any errors are eventually cancelled out when the difference between the times is calculated.

Other than this, TDOA provides scalability and its easy implementation has made it one of the favourites amongst the researchers.

2.9 Angle of Arrival

Angle of arrival scheme generally makes use of some anchor nodes which know their location. The location of these nodes is usually estimated by using GPS, in the sense that these nodes are generally GPS-enabled, which allows us to get their location or positioning with respect to the global coordinates. It further consists of the non-anchor nodes which are the nodes whose locations are unknown to us. These nodes are made to send signals to the anchor nodes. The anchor generally have omni-directional antennas instilled in them . As a result they are able to judge the direction from which the signal is coming and hence infer the location of the unknown node.

[33] simulates the Angle of Arrival Scheme by following the same terms and notations in [34]. They use a network where each node has one main axis against which all angles are reported so as to estimate the direction from which a neighbour is sending data. They denote the angle formed by this main axis with north by the term Heading, represented in Figure 2.7.1 by a thick black arrow. The term bearing refers to an angle measurement with respect to another object. In Figure 2.9.1, for node A, bearing to B is denoted by b, bearing to C is denoted by c, and heading is denoted by h. A node can find out the angle between its own axis and the direction the signals come from by interacting with two neighbours, as shown in Figure 2.7.1. Node A has the possibility of inferring the angle α_{BAC} formed by the neighbours B and C as $c - b$. For the sake of consistency, all angles are assumed to be measured in trigonometric direction. The figure demonstrating the above situation is as follows:

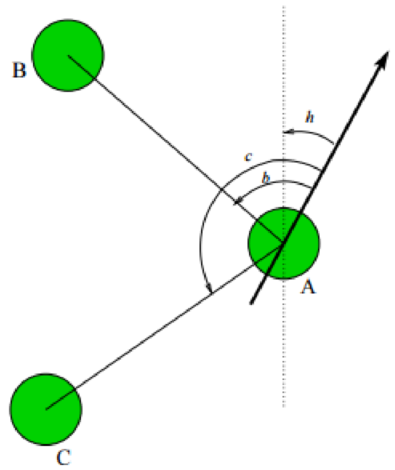

Figure 2.9.1 Node A with its heading and bearing to node B and node C[33]

[35] suggests that this is not really favourite among the wireless sensor users due to the requirement of large sized directional antennas associated with this technique. As a result there is the need of further investigation in context of the system configurations so that they can be incorporated in the light weight wireless devices. Further [36] explains how the ad hoc nature and the lack of a proper infrastructure in the wireless sensor networks leads to the rise in the positioning problem. This problem comprises of the calculation of the position of the non-anchor nodes which is complicated by the fact that sometimes all nodes are treated equal.

2.10 Graph neuron Algorithm

[37] comes with another technique of pattern matching which follows on the lines of decentralization. This algorithm namely the Graph Neuron Algorithm is based on the concept of distributed cooperative problem solving [37]. This is a very light weighted algorithm which does in-pattern recognition by developing a graph like structure which interconnects the sensor nodes. This graph is called the GN array.

This algorithm provides a very efficient way for depicting the spatio-temporal information in form of a pattern. It also enables parallelism through a virtual structure in the sensor network.To implement this algorithm, every pattern space is decomposed into a set of fundamental elements called the value-position pairs. A significant part of the computation taking place within the array is conducted through message passing. The GN algorithm may be categorised into the following stages:

(1) Mapping of the input pattern to the appropriate sensor node.

(2) Marking the end of the incoming pattern.

(3) Lookup operation for the pattern recall or memorisation.

Execution of the Graph Neuron algorithm within a small-world network [38] solves the problem of searching for a matching pattern in a large pattern domain.

Even though Graph Neuron Algorithm promises us good accuracy and scaling properties yet there are pretty much chances of its accuracy being getting hindered due to the incorrect input patterns. In such a case there may be interference in the patterns which may ultimately lead to incorrect results.[39] Further the Graph Neuron algorithm pays considerations only to neighbourhood communications, hence there is no obvious way to attain a global decision.

2.11 Voting Graph Neuron Algorithm

To overcome the flaws of GN the Voting Graph Neuron Algorithm [40] or VGN approach is proposed. The VGN approach recognizes events by adopting a novel energy-efficient template-matching approach. In essence, the VGN approach uses graph neuron (GN) concepts. The VGN approach deals with how to intuit exhaustive global information from the local information of sensor nodes. Patterns are matched by means of votes, in contrast with the GN algorithm, which uses a simple binary decision. Additionally, techniques such as node collaboration along with distributed in-network processing as well as distributed storage, and life-cycle management are employed to enable rational, pragmatic and energy-efficient pattern-recognition using resource-constrained sensor nodes.

In the VGN algorithm, sensor nodes are members of a committee which co-operatively solves the pattern matching problem by individually solving sub-problems and integrating the solutions. The algorithm preserves the operational modularity and parallelism of the original GN algorithm, and establishes a loosely coupled committee of sensor nodes that cooperatively perform in-network pattern recognition. Doing so we have shifted our approach from using well-established decision making structures to a new form of decentralized decision making.

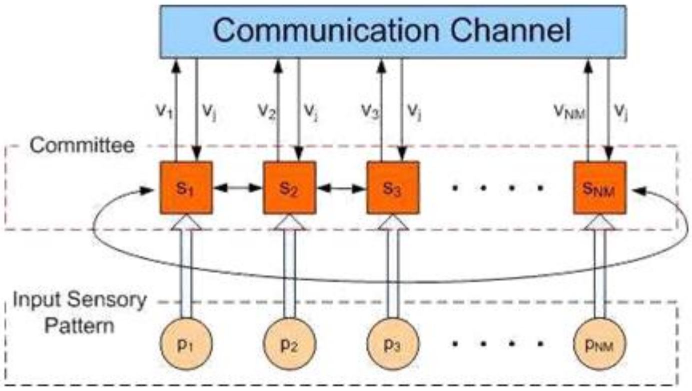

Figure 2.11.1 A schematics illustrating decentralized detection using N*M wireless sensor nodes.[40]

The algorithm for voting graph neuron algorithm is as follows:

```
Input: Sensory Pattern
Each Committee member execute simultaneously
Begin Initialise vi ={Lx1,..,Lxy}
  do
    if ( granted access to communication channel) then
        broadcast(vi)
    else listen to the communication channel
        if received vj then
            vi= recreate(vj)
  until ( broadcast vi , vi= vj , or((vi ∩ vj ≠ ϕ) and (|vj|=1)))
end
where vi is the committee member's own vote vector, vj any received vote
vector, and |vj| is the size of the received vote vector
```

2.12 GPS Based Algorithms

Another technique is given in [41] is GPS based localization. Most of GPS-based localizations inhere to absolute localization. These systems help the nodes to localise their position in the global coordinates by using comparatively lesser number of beacon nodes. Even though GPS based localization techniques help us to pan an area of few squared metres and determine the locations of the noes lying within this area, but still the cost associated with the GPS devices combined with the phenomenon of canopying that is unavailability of the GPS signals in confined areas intercepts their wide scale implementation in wireless sensor networks.

With a network of thousands of nodes, it is unlikely that the position of each node can be precisely predetermined. Although GPS based localization schemes can be used to determine node locations within a few meters, the cost of GPS devices and the nonavailability of GPS signals in confined environments prevent their use in large scale sensor networks.

2.13GPS free Algorithms

[42] provides us a WSN localization scheme which is a GPS-free method called the Matrix transform-based Self Positioning Algorithm (MSPA). It tries to find out the coordinates of the static nodes in 2D as well as 3D space by using the distance between the nodes. This method basically relies on the matrix transform technology and follows a completely distributed network structure. However since in SPA every node individually participates in the process of building and merging the clusters that is the local coordination systems this turns out to be a disadvantage since now the communication costs and the convergence time grow exponentially with the increase in the number of the nodes.

In this paper, we investigate a GPS-free node localization algorithm for WSNs. It is assumed that distance measurements are already made hop-by-hop between neighboring sensor nodes. There are a number of technologies and techniques for performing the distance measurement. The simplest way is to measure the received signal strength and then apply a path loss model, such as the log path loss model [43] or the Walfisch-Ikegami model [44] to calculate the distance. The distance can also be determined based on the time-of-arrival measurements and the measurements of round-trip time-of-flight of a radio signal [45,46]. When both a radio signal and an ultrasound signal are employed, an extremely accurate time-of-flight estimate and hence distance estimate can be obtained [47].

2.14 DV Hop Algorithm

Typically the scheme to use DV-Hop algorithm to do positioning is divided into three phases:

1) Minimum hops are beaconed by unknown node and compute nodes.

（1）Beacon nodes then broadcast their locations to the neighbours of information packets, along with the jump number field which is initialized to 0. Each beacon node having the minimum number of hops is recorded by the recipient node, whereas the beacon node from the same large number of hops a packet are ignored. After this the Hop count is incremented by one, and forwarded to the neighbours. This method allows all nodes in thenetwork to be able to record each beacon node under the minimum number of hops.

（2） Next the unknown node and beacon node's actual hop distance are computed. Other beacon nodes position information and the distance hops are recorded by each beacon node according to the first stage record, after this the average hop actual distance is calculated.

2) Calculate and obtain the unknown node average hop distance. Average hop distance is calculated after the beacon node has the coordinates of the other beacon nodes and the minimum number of hops in the network distance.

The beacon node will calculate the average distance per hop fields with a packet with a lifetime of broadcasting to the network, the unknown node record only received the first average distance of each jump, and forwarded to the neighbours. This strategy ensures that the most recent beacon node from the node receives the value of the average distance per hop. Unknown node receives the average hop distance, according to the recorded number of hops to each beacon node calculate the hop distance.

3) Using trilateration measurement or maximum likelihood estimation method to calculate its own position. Unknown node uses the second phase to each record jump distance beacon nodes using trilateration measurement or maximum likelihood estimation method to calculate their coordinates.

2.15 Conclusion

After having gone through widely diversified collection of the existing algorithms and after deeply analysing the advantages and disadvantages associated with these algorithms, we have finally reached to the conclusion as in which algorithm we want to implement. We have decided to implement Time difference of Arrival scheme to do the positioning of the species in the habitat monitoring system. The reason behind the same is that, the Time difference of arrival algorithm provides much more accurate results as compared to others. Further unlike GPS based schemes its hardware is not very costly and also its performance is not hindered by any canopying effect. As a result we get accurate results at minimal costs. Also its implementation is quite less complex as compared to other algorithms and the mathematical modelling is much easier since it is not complicated by any exterior factors as in the case of RSSI where the computations are highly intricated due to the presence of any external obstacles. Along with this there is also no stringent synchronization requirement call as in the case of Time of Arrival which otherwise gives faulty results. Hence we can conclude that Time difference of arrival algorithm ideally fits almost all our metric criteria.

In addition to this to make our system even more energy efficient and to increase the lifetime of the individual nodes and hence the entire network we can modify and refabricate the existing TDOA algorithm by merging it with the NIRAA that is Neighbour Informed Rate Adaptation Algorithm. This will enable us to exploit the various working modes of the nodes and all the nodes need to stay active all the time. This will lead to more efficient use of the energy involved.

The use of both these algorithms combined will help us to fetch the best benefits of both the algorithms. We will be able to get accurate results at much lesser price and also avail the advantage of energy conservation provided by the NIRAA algorithm. Not just this it will also enable us to combat the disadvantages associated with both the algorithms. Namely, we will be able to get results while maintaining energy efficiency and the results will also be not affected by any foreign obstacles.

Chapter 3 System Development

3.1 Technologies Used

The technologies used for the implementation of this project are as follows:

Intitially for the purpose of the implementation of the existing algorithm that is the TDOA algorithm we used MATLAB software. The software was used to simulate a square field of 500*500 m^2 . In this field we deployed the sensors in an ad-hoc manner. The number of sensors to be deployed depended on the user. The system took in a sound wave as an input and finally gave out the output.

In the next phase of our project where we modified the existing Time difference of arrival algorithm by merging it with the NIRAA scheme that is the neighbour informed rate adaptable algorithm , then we implemented the modified algorithm in JAVA.

The reason behind the same being Matlab is good for rapid prototyping, whereas Java really isn't; on the other hand, it is likely be easier to interoperate with other programs / libraries if we write our code in Java. Further, Java is free, Matlab is not. This leads to significant cost factor when we are planning to deploy our code on a cluster or a large number of workstations. And as we already know, in case of wireless sensor networks, scalability is one of the most desired characteristics hence in such a case using Matlab over Java may prove inefficient in terms of the cost associated. Above all it is not desirable to deploy Matlab on a server for long live processes.

After implementing the code in Java the software that we have used is Eclipse. Although the code also very efficiently can be run on other Java supporting softwares such as NetBeans.

3.2 System Requirements Specifications

We know that gathering system requirement specifications is of utmost importance for a project to become a success. The system requirement specifications can be further categorized into: functional System requirements as well as non-functional system requirements. Both of these requirements are explained in detail as follows:

- Functional System Requirement:
  - The system should not miss out on any target

- The system should provide accurate result in the form of coordinates of the position of the target
- The system should have a user-friendly interface
- The interface should be sufficiently informative
- The system should undergo thorough testing before the actual implementation
- The system should run on all the softwares that support Java

- Non-Functional Requirements:
  - The system should be efficient and provide accurate positioning
  - The system should try and use minimum amount of memory
  - The system should be reliable under all circumstances
  - The system should be robust that is the failure of a single node should not lead to the entire network to shut down
  - The system should be energy efficient and hence must help in increasing the life-time of the nodes
  - The error rate of the system should be very less

3.3 Proposed Algorithm

We have proposed to merge time difference of arrival algorithm along with the neighbour informed rate adaptation algorithm. As explained above this will enable us to fetch the advantages of both the algorithms that is provide accurate results and that too in a very energy efficient way.

The proposed algorithm is given as follows

1. **Set**position of N microphones
2. Rate = Low
3. Receive high frequency acoustic waves
4. **if** LocalEventDetected( ) **then**
5. Rate = MAX
6. AlertNeighbours( )
7. **else if** NeighbourAlertReceived ( ) **then**
8. Rate = Medium
9. **else**
10. Rate = LOW
11. **end if**

12. **While** Rate = MAX

13. **For each** i and i + 1

14. Calculate difference between time of arrival

15. Constant = distance * speed of sound

16. Focus = node(i)

17. Construct hyperbolae

18. Source = point of intersection

The algorithm can be explained as follows: firstly we deploy N sensor nodes and set the transmission rate for these nodes as Low. Now whenever the target sends acoustic waves, then we recognize the nodes which lie in the range of the target, the rate of transmission of these nodes is set Max and the nodes which are next expected to come into range, their rate is set medium. All the other nodes still have their rate of transmission set as low. Now for all the algorithms which have high transmission rate we calculate the time difference in the arrival of the signal and generate hyperbolae. The intersection points of these hyperbolae gives us the position of the target.

This is explained in a more lucid manner in the following flowchart.

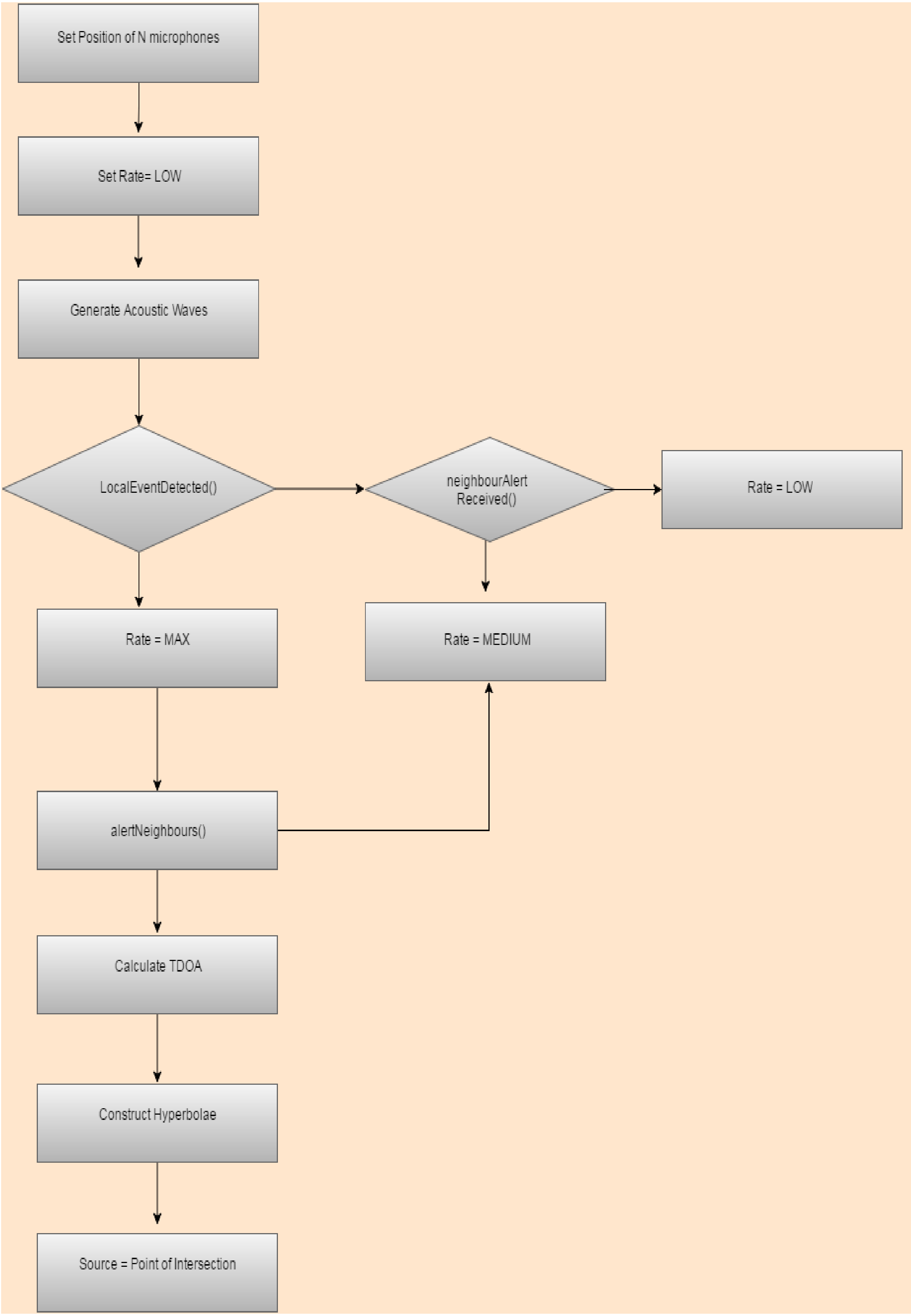

Figure 3.3.1 Flowchart for the proposed Algorithm

3.4 Conclusion

After simulating the TDOA algorithm individually on Matlab, we finally propose a new algorithm by merging it with NIRAA and then implementing it in Java. This approach will help us to get the benediction from both the algorithms and ultimately give us accurate positioning results in a very energy efficient method

Chapter 4 Performance Analysis

4.1 Scenario

Intitially for the purpose of the simulation of the existing algorithm that is the TDOA algorithm we used MATLAB software. The software was used to simulate a square field of $500*500\ m^2$. In this field we deployed the sensors in an ad-hoc manner. The number of sensors to be deployed depended on the user. The system took in a sound wave as an input and finally gave out the output.

In the next phase of our project where we modified the existing Time difference of arrival algorithm by merging it with the NIRAA scheme that is the neighbour informed rate adaptable algorithm , then we implemented the modified algorithm in JAVA. In this case again we took a field of $500*500\ m^2$ and deployed 30 sensor nodes in an ad hoc manner. These sensor nodes were then use to localize the target by using the proposed algorithm.

4.2 Preliminary Analysis

There are always few uncertainties associated in TDOA measurements. These inaccuracies give rise to random errors in the emitter location. Reference [48)] forms the position MSE by adding the error squared of the two TDOA curves, with the assumption that the curves are statistically independent. But a TDOA estimator, because the same signal is present in all measurements, always generates correlated TDOA measurements, rendering assumptions invalid and underestimating the true MSE.

4.3 For the Existing algorithm

The input to our project shall be sound files which may be any .wav files. The randomly generates a location inside a microphone array and simulates the signals received by these microphones adjusting for spherical attenuation and time delay of arrival. This algorithm attempts to locate the source of the signal using the TDOA Localization technique. The sound file shall then be decoded and appropriate output shall be shown

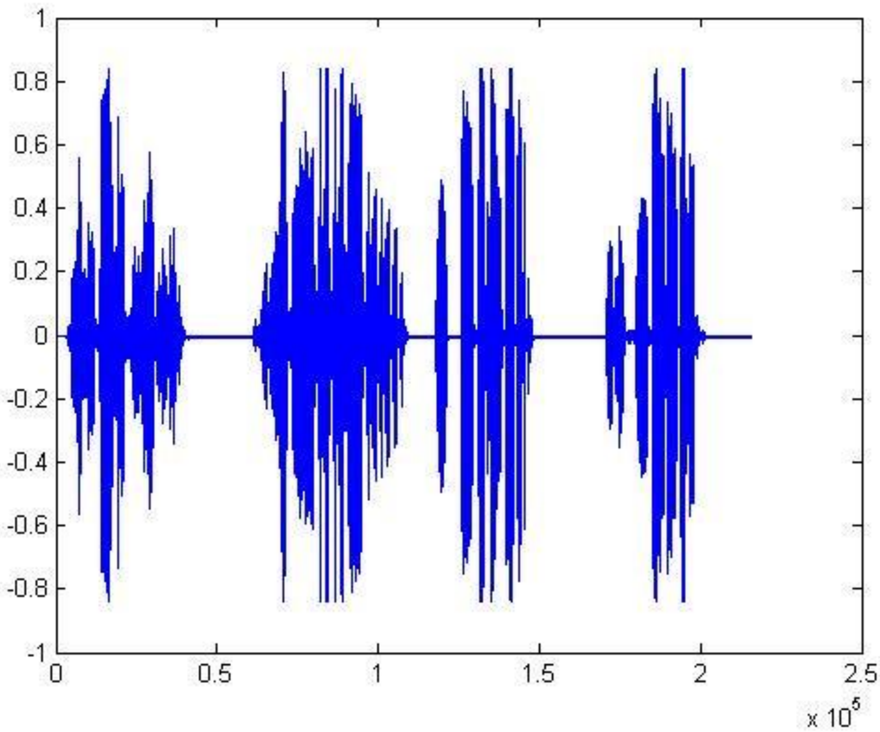

Figure 4.2.1: sine wave of cat noise given as an input .wav file

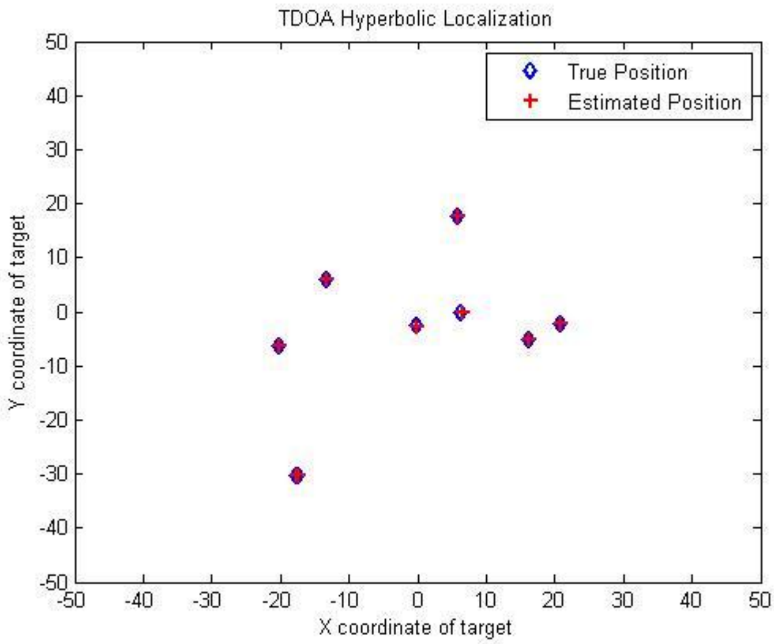

Figure4.2.2: Final output

4.3 After Modification

In figure 4.2.2:

- Around 30 nodes denoted by blue circles are deployed in an ad hoc manner in the the field.
- The dark black square represents the target whose location we need to find.

- The red square represents the signal sent by the target which shall be used to find the time difference of arrival and hence develop a correlation.

On the other hand figure 4.2.3 tells about the nodes which received the signal packet from the target node along with the time taken to reach each of them. These are the nodes which will be ultimately participating in the development of a correlation and hence in finding the position of the target. The rest of the nodes meanwhile remain in the idle mode.

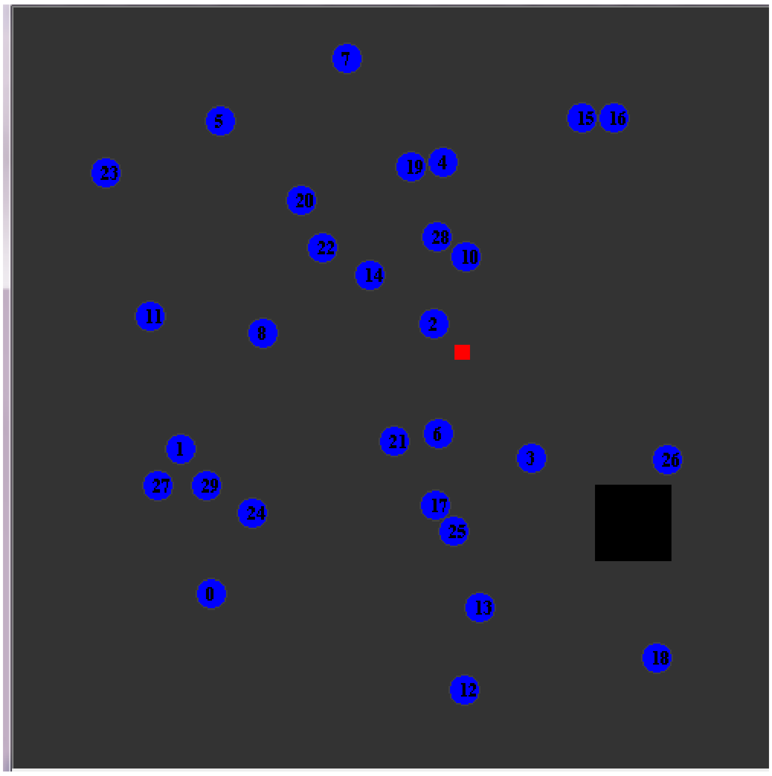

Figure 4.2.3 Simulation of the field

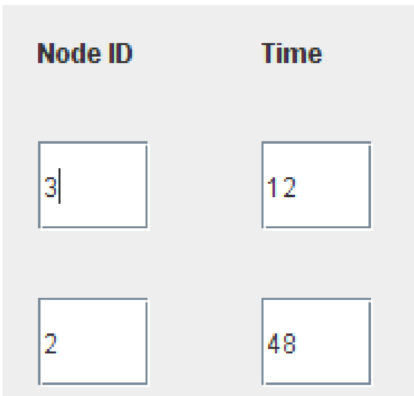

Figure 4.2.4The recipient nodes and the time taken to receive signal

4.4 Comparison of the two approaches

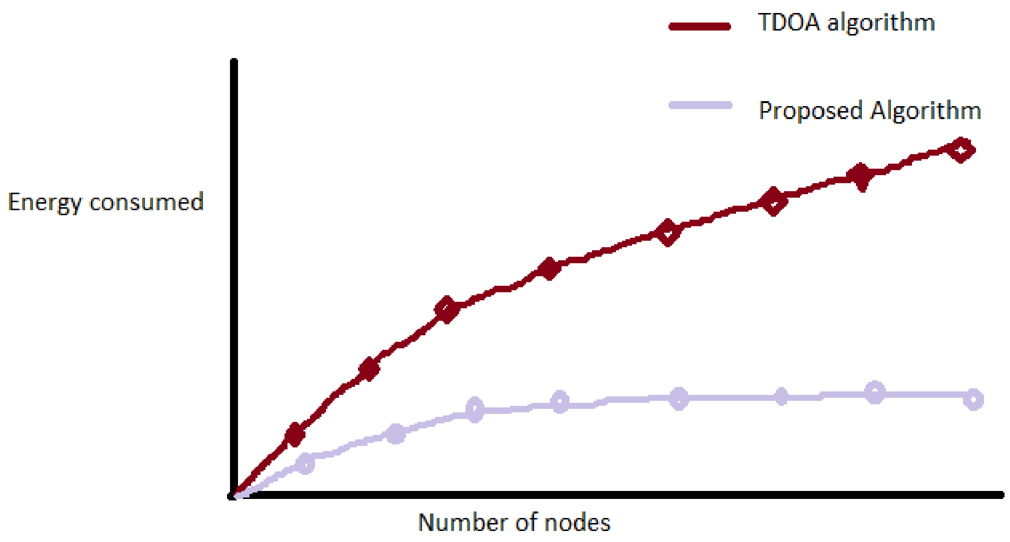

Figure 4.4.1 Comparison of energy consumed by TDOA and proposed algorithm

The above graph clearly demonstrates the fact that merging of the NIRAA with TDOA improvises the energy efficiency. The reason behind the same is that, adaptation of NIRAA algorithm allows us to exploit the various working modes of the sensor nodes. As a result we are able to make the sensors send at a febrile pace only when they have legitimate information to send while rest of the time their data transmission rate is set low. Since quite a large amount of energy is wasted in communication, this technique helps us to cut down on the communication costs.

Chapter 5 Conclusion and Future Work

5.1 Conclusion

The primary focus of the work in this project was to do localization of a species in a habitat. We have implemented the technique of Time Difference of Arrival to facilitate the localization process. The experiment was simulated first using Matlab by providing real time voice inputs in order to provide well balanced evaluation on the performance of the algorithm. The use of real time sounds as input has further enabled us to check the appropriateness of our implementation of our algorithm in the real time.

Next we implemented it using Java after applying some modifications that is combining the TDOA algorithm with the NIRAA algorithm. This was done so as to exploit the various modes of the sensor nodes hence increase the energy efficiency of the node and further increase the life time the of the node and the network.

The experimental results have shown that combined with an accurate estimation of synchronization the algorithm is effectively able to give the locations as per the sensors in an area of 500 x500 m^2. However note that conventional TDOA-based localization algorithms assume a perfect synchronization between the base stations and the mobile source. Yet, perfect synchronization is difficult to obtain in practical applications. Accordingly, an additional process using a correlation based on wideband signals should be provided for synchronization between base stations. Moreover, this additional synchronization process should be implemented periodically to prevent losing the synchronization due to the clock drift of the base stations.

Without the synchronization process, the TOA between the mobile source and a base station should be obtained before the calculation of the TDOA. In particular, there are two general techniques for estimating the TOA. One is two-way ranging (TWR) and the other is SDS-TWR. These two techniques do not require a synchronization process, making them suitable for comparison with the proposed algorithm.

Overall, the results have shown that the implemented localization algorithm is a useful step to keep a check on a particular habitat. But still the results may largely vary due to the computational complexities involved.

5.2 Future Work

Our idea is to use the revised geometric localization method based on TDOA for the wireless sensor network with sparse anchors. For improving the localization accuracy, in the original TDOA localization method, we may use the threshold to judge whether the determined sensor is upgraded an anchor node and the iterative refinement idea. For the typical simulation model of wireless sensor network localization problem, this revised strategy will be effective, compared with the original TDOA localization method. Along with this we can also try to increase the energy efficiency further by making the nodes go into sleep mode rather than idling and attaching a small hardware with them which periodically wakes up to see if it has any incoming data and wakes the node only when required.

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