TARGET LOCALIZATION IN WIRELESS SENSOR NETWORK

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BY

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UNDER SUPERVISION OF

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CERTIFICATE

This is to certified that the dissertation entitled **"TARGET LOCALIZATION IN WIRELESS SENSOR NETWORK"**, being submitted by **Mr. SHRAWAN KUMAR** to the **School of Computer & Systems Sciences, Jawaharlal Nehru University, New Delhi** in partial fulfillment of requirements for the award of the degree of **Master of Technology in Computer Science and Technology**, is a record of bonafide work carried out by him under the supervision of **Dr. D. K. Lobiyal**, Associate Professor.

This work has not been submitted in part or full to any university or institution for the award of any degree or diploma.

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DECLARATION

This is to certify that the dissertation entitled **"TARGET LOCALIZATION IN WIRELESS SENSOR NETWORK"**, being submitted to the **School of Computer & Systems Sciences, Jawaharlal Nehru University, New Delhi** in partial fulfillment of requirements for the award of the degree of **Master of Technology** in **Computer Science and Technology** is a record of bonafide work carried out by me.

The matter embodied in the dissertation has not been submitted for the award of any degree or diploma in any university or institute.

July 2009
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Shrawan Kumar
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Dedicated to

My parents

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Shrawan Kumar

ABSTRACT

Wireless sensor networks are special area of communication network in which target localization is one of the important research topics. To get accurate location of sensor nodes with limited resources is challenging task. GPS receivers are used with sensor nodes to know their location information. However, enabling all the sensor nodes with GPS receiver is cost ineffective. Therefore, only few nodes are enabled with GPS receivers and they are called anchor nodes. These anchor nodes further helps other nodes in updating their location information. DV-Hop and Euclidean algorithms using anchor nodes determine the location information of sensor nodes but both the algorithms have localization error. Error in localization is inversely proportional to anchor node. On increasing anchor node, cost of network increases. Further, to improve the location error, the concept of virtual anchor nodes is introduced in VANLA algorithm. Virtual anchor node based localization algorithm reduces localization error by creating virtual anchor nodes with the help of real anchor nodes. VANLA algorithm has been used in static networks.

In the current dissertation, we have applied virtual anchor node based localization algorithm for mobile networks in which sensor nodes are moving with random velocity in a random direction. In mobile network, this algorithm takes randomly anchor nodes at any time instant and upgrades some unknown nodes as virtual anchor node that help in localization remaining nodes. In mobile network error in localization is approximately same as in static network for VANLA algorithm on same statistics. Our work establishes the applicability of VANLA algorithm for mobile networks.

Further, we have also applied VANLA algorithm using dominating set to determine the anchor nodes in static network. Application of dominating set results in small number of anchor nodes but reduced localization error in comparison to static network without use of dominating set. Use of dominating set also gives the similar results even if the communicating range is reduced to half.

List of Figures

List of Abbreviations

AOA	Angle of arrival
AODV Ad-hoc	On-demand Distance Vector Algorithm
APIT	Approximate point in triangle
DV-Hop	Distance Vector Hop
GPS	Global Positioning System
MLE	Maximum Likelihood Estimation
RADAR	Radio Detection And Ranging
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
TDOA	Time Difference On Arrival
VANLA	Virtual Anchor Node based Localization Algorithm
WSN	Wireless Sensor Network

CONTENTS

CHAPTER – 1

Introduction

1.1 Wireless Sensor Networks

Wireless Sensor Network (WSN) [7] means a group of inexpensive sensors which are linked by wireless medium. In sensor networks small and lightweight wireless nodes are highly distributed. Each sensor node is typically outfitted by a radio transceiver or wireless communication device, microcontroller and energy source. These sensors consists three subsystems first one is sensor subsystem that sense the environment, second is processing subsystem which make computation on sense data and third one is communication subsystem which exchange message with its neighboring sensor node. WSN is use to monitor the environment by calculating the physical parameter such as temperature, pressure and humidity. It is usually arrange in particular region, and sense special physics information in the region.

In the sensor network every sensor node have limited sensing region, processing power and energy but a large number of sensor make robust and reliable network which cover wider region. When more number of node sense same data then due to cooperation and collaboration between nodes this network have fault-tolerant.

In WSN there are two important operations: data dissemination and data gathering. Data dissemination means propagation of data or queries throughout network. Data gathering means collection of sensed data from sensor nodes to a sink. WSN consist different type of sensor nodes such as seismic, thermal, visual and infrared all these are use to monitor different object in the network.

1.2 Application of Wireless Sensor Networks

The development of wireless sensor networks was originally provoked by military applications. Application of WSN in military is battlefield surveillance monitoring, guidance system of intelligence missiles and detection of attack by chemical, biological and nuclear weapon. However, wireless sensor networks are now used in many industrial and civilian application areas. It is also use in industrial process monitoring and control, machine health monitoring, environment and habitat monitoring, healthcare applications, home automation and traffic control [6].

WSN can be used in environmental application such forest fire and flood detection. It is also use in patient diagnosis and monitoring. To measure heart rate and blood pressure patient wear small sensor device that monitor physiological data. Now this data is send by network to the automated monitoring system which is designed to alert the concern doctor on detection of disease.

Smart sensor is used into home appliance such as refrigerators, oven, and vacuum cleaner which enable them to interact with each other and remote controlled.

WSN is used in traffic monitoring; by the help of sensor nodes number of vehicles passes through a particular place can be count.

By the use of WSN temperature and humidity levels can be controlled inside commercial greenhouses. When the temperature and humidity drops are below to definite levels then via e-mail or cell phone text message, or host systems, greenhouse manager must be notified can trigger misting systems, open vents, turn on fans, or control a wide variety of system responses [6]. Similarly there unlimited application of WSN in different area

1.3 Characteristic of WSN

Characteristic of WSN is as follow [6]:

- Limited power they can yield or store
- Mobility of nodes
- Communication failures
- Ability to survive harsh environmental conditions
- Ability to handle with node failures
- Dynamic network topology
- Heterogeneity of nodes
- Huge scale of operation

- Unattended operation

Sensor nodes can be likely small computers, on basis of interfaces and their components. They usually consist following component: processing unit which have limited computational power and limited memory; sensors used to sense the data; a communication device (usually radio transceivers), and an energy source usually in the form of a battery.

1.4 Challenges in Designing of Wireless Sensor Networks

In designing wireless sensor networks it faces many problems due to many reasons some of them is given as following [1]:

1 Sensor networks are infrastructure-less. So all routing and maintenance algorithm required to be distributed.

2 An important challenge in sensor networks is energy. Usually sensor node is battery driven, in many cases battery can not be recharged or replaced. Therefore in designing of protocol energy is considered as a main constraint.

3 In WSN sensor node are randomly deployed in the sensor field. So it is not fit in any regular topology therefore setup and maintenance of the network should be autonomous.

4 Primary requirement in designing of hardware is energy efficiency. Therefore when component of hardware is designed, it should be energy conserving.

5 Sensor network should be able to adapt to connectivity change due to failure of node.

6 Security is also an issue of WSN, in transmission of a sensitive or secret data.

1.5 Requirement of Localization in Sensor Networks

The applications of WSN are mostly related to determining and using the position of sensor nodes. To get correct location of nodes in the sensor field is called localization. For example, in battlefield, it is required to detect the position of enemies for correct attacking. So the localization of sensor nodes has become a hot topic in WSN.

When sense data is collected to the sink, location of sensor node is required. It means that, it is important for receiver to know that from where this information is coming. Location information of coming data can be obtained to receiver by knowing the location of sensor node. When a sensor node knows its location, send to sink coupling with data.

As we know that sensor nodes are battery driven and have large computation work, so finding location of node, a low power, inexpensive and reasonable method is required.

1.6 Motivation

In the Euclidean algorithm, existence of ranging error will influence the estimation of the distance between the neighbor nodes. This error can be accumulated hop by hop and at last it will be found that which node are farther from anchor nodes get poorer localization.

DV-hop algorithm, communication range of each node is not a standard circle ideally. It is a quite anomalistic polygon. This makes the distance of every hop much different (to real distance) with each other. So if we use the average distance of each hop to compute the distance from unknown nodes to anchor nodes in the network. This increases the error with increase of the hops.

In Virtual Anchor Node-Based Localization Algorithm (VANLA) to create virtual Anchor more communication is require between nodes that consume more energy so it reduce energy efficiency.

1.7 Proposed Work

Most of the localization algorithms are approximation algorithms. Finding exact localization algorithm is challenging task. Most of the Localization algorithms provide solution for static networks. In the current work, we investigate the Virtual anchor node based algorithm for mobile network. Further we will use a concept of dominating set to determine a small set of virtual anchor nodes that will help in finding the location of unknown nodes. Further, we will attempt to enhance the precision of localizing by reducing errors to improve the whole network localization. To carry out the work we set the following objective:

- Implement the existing algorithm for mobile network.
- Apply dominating set to find the small set of virtual nodes that can help in finding the location of unknown nodes.
- Improve the precision and reduce error in algorithm.
- Evaluate the performance of the algorithm.

1.8 Related Works

Several studies have already done in the field of localization in wireless sensor networks. There are many application of WSN but some important applications are as target detection, surveillance, and localization [14]. In such type networks energy management is crucial because there is severely energy constrained due to battery-driven sensor nodes. Many schemes and methods for localization in WSN for many purposes had developed to fulfill different goal. These methods vary in many parameters including accuracy, cost, size, configurability, security, and reliability [20] [12]. Microsoft's RADAR [13] is an example witch uses 802.11 networks.

Many localization system and algorithms that have been proposed in the past few years divided into two parts: rang based and rang free. Range-based location technique use some kind of rang to estimate the location .this measurement can be obtained by using one of the four basic techniques: TDOA [19], AOA [3], TOA [22], RSSI [13]. But all the above technique do not give accurate result due to multipath reflection, irregular signal propagation model and non-line-of-sight condition. So to get better accurate result some additional infrastructures (ultra-sound, laser radiation, acoustic etc) are used in this technique.

Nagpal et al. [21] improve the nodes location accuracy by proposing an approximate point in triangulation test (APIT) algorithm. APIT employs an area-based method to calculate nodes position by using three anchors. The effect of localization accuracy on application also has been studied in [21].

Amorphous algorithm [17] is similar to DV-Hop but it assumes to know the network density in advance and uses offline hop distance estimations. This algorithm proposed to generate a relatively accurate coordinate system on distributed processors via local information.

Centroid algorithm [2] is a simple range free localization algorithm. In this technique sensor node receives signals from beacon node in its sensor field and makes its coordinate as the centroid of these anchor nodes. This algorithm do not require additional device of localization. So we can say that node may be simple by hardware. Centroid, APIT, DV-Hop, Amorphous all are characterized by simple computing, low traffic and scalable ability. Environmental factor affect very less the range free localization scheme.

Savvides et al [18] proposed a collaborative multi-lateration localization algorithm. In this algorithm unknown nodes determines its location by using the information of beacon node which is several hops away. To prevent the effect of error propagation and accumulation localization problem was formulated as a global non-linear optimization problem.

Doherty et al. [10] proposed a centralized positioning scheme that collects the entire topology in a server. Now by applying optimization technique positioning error is minimized for each node.

As we have seen that many localization algorithm proposed. All these algorithm are anchor based in which position of anchor nodes is determine using GPS and then location of unknown nodes is calculated by using these anchor nodes. Anchor free algorithms do not require any anchor node. This technique is connectivity based.

Lei Fang, et al [11] proposed knowledge based positioning algorithm in which same group sensor can be in different location, and that locations usually follow probability distribution that can be known a priori. In this scheme in each group every sensor node finds its number of neighbors. Then sensor node evaluates its location based on the principle of the maximum likelihood estimation (MLE).

Pengxi Liu et al [15] proposed a novel virtual anchor node-based localization algorithm (VANLA) for wireless sensor networks. This algorithm is mainly based on DV-Hop algorithm. In this algorithm highly accurate location of some nodes are determinate by GPS system. These nodes is called anchor node. Now by the help of these anchors some other unknown nodes location is calculated, these nodes is called virtual anchor node. And at last by the help of real anchor nodes and virtual anchor nodes location of remaining nodes is determine.

Improvement of localization precision with lower cost, less energy consumption and less hardware support has become more and more important. (VANLA) calculate highly precise positions for some special unknowns, and then these nodes are upgraded as virtual anchors to assist in locating the rest unknowns along with primary real anchor nodes.

1.9 Thesis Organization

First chapter of dissertation contains introduction to wireless sensor network. It describes problem in WSN, requirement of localization in WSN, related work, motivation, and objectives. Second chapter define target localization with its challenges and discusses analysis of localization error occurring in different algorithms. In the third chapter we apply virtual anchor node-based localization algorithm for mobile networks, and dominating set to determine anchor nodes. In the implementation part of this chapter we give the details of main function (in MATLAB simulator) used to implement the algorithm. In fourth chapter values of parameters considered for simulation and the results obtained are discussed. Finally, the fifth chapter concludes the work done in the dissertation with contribution and future scope to extend the current work.

CHAPTER – 2

Target Localization

2.1 Localization

In wireless sensor network, it is necessary to know the position of sensor node. To know the position of sensor nodes by a scheme is called localization. Localization is divided into two categories - first is indoor localization and second is sensor network localization. In former case by the help of fixed infrastructure (such as within a building, where RF signal can not reaches) location of sensor node is estimated. Latter case it is for open region, but there is no fixed infrastructure.

2.2 Importance of Localization Systems

Generally sensor nodes are randomly deployed in sensor field (inaccessible terrains or disaster relief operation) [7]. Therefore a localization system is required to know the position information of nodes. The importance of localization information is due to several factors, some of them as follow.

- **Gathered Data Identification:** Main goal of WSN is to monitor the area of interest. When data is collected at the nodes then it is important to know that from which region this data belongs.
- **Gathered Data Correlation:** When data is forward through the network, intermediate node correlate and make fusion of the data gathered on same region [16].
- **Nodes Addressing:** In node addressing each node uniquely identified by physical location.
- **Network Management:** When nodes are localized in the region some query is required by node or to node as nodes coverage [23], all this done by network management.
- **Geographic Algorithms:** In geographic algorithms some algorithms are used to localize the node under optimal use of the network resources [24].

2.3 Requirements of Localization System

Due to limitations and applications of WSN some condition is applied that must be consider in localization system. Some of the condition is as:

- **Auto –organization:** It means independent of any infrastructure.
- **Scalability:** It means algorithms must be work with same property in both large or small and dense or spars network.
- **Robustness:** It consists of tolerance to communication problems and also to inaccurate distance and position information.
- **Efficiency:** On using the resource of WSN efficiency of result should not decrease.

2.4 Component of Localization System

Localization system is divided into three components [9]

- **Distance/Angle Estimation:** In this component distance or angle between two nodes **is** calculated that is used in other component of localization system.
- **Position Computation:** On getting the information of distance or angle between nodes, position of nodes is calculated.
- **Localization Algorithms:** It is main component of localization system. This component decided that how the available information will be manipulate to determine the position of nodes.

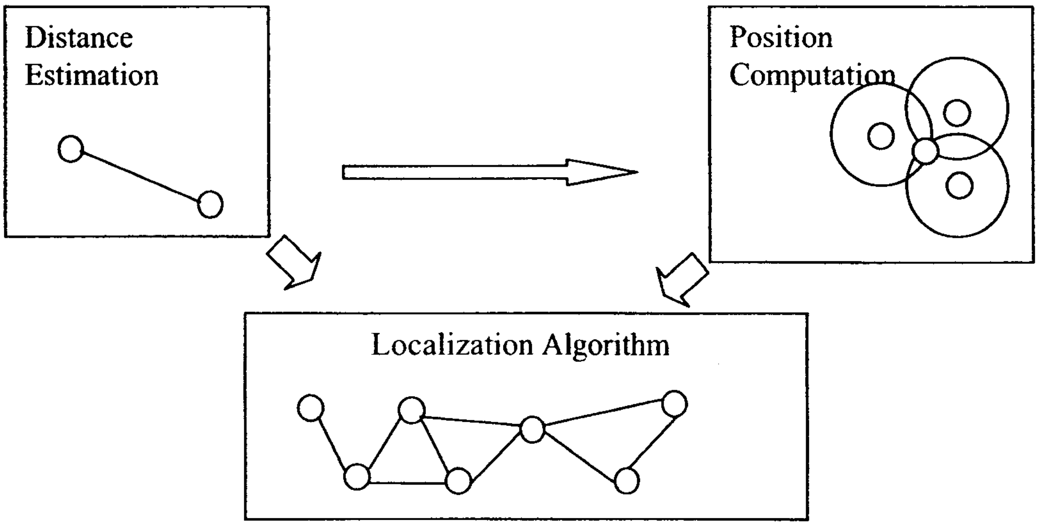

Figure 2.1 Localization System [9]

Above figure shows component division of localization system. As we will see that final performance of the localization system depends directly upon each component, so division of localization system is important. Here each component has its goal and solution method. These components can be seen as sub area of localization problem that need analyzed and studied separately.

2.5 Issues and Challenges in Target Localization

When a node receives some information from sensor field it is very important to know that from which region information is coming. To do this task target localization is required. But target localization in WSN have some challenges, some of them are given below.

2.5.1 Resource Constraints

Wireless sensor network are obviously comparatively resource starved. Sensor nodes are small in size. They are mostly battery powered and have quit weak processors but have more computational work. This shows that all communication, processing and sensing action are expensive, because they dynamically reduce the lifespan of the nodes. Another thing is that sensor networks are typically imagined on large networks having hundreds or thousands nodes in a typical deployment. This fact shows that there are two important consequences:

1. Nodes must be cheap to make,
2. Trivially easy to deploy in sensor field.

If nodes are not cheap then 40 cents of per nodes additional cost increases $400 for one thousand nodes network. And if deployment of nodes is not easy then thirty second of treatment time per node to prepare for localization, increases eight man-hours of works to deploy a 1000 node network. Therefore localization cost must be as little as possible with producing satisfactory result.

2.5.2 Node Density

Node density means number of nodes in sensor field. More number of nodes (anchor nodes) give more information about region, but due to more number of nodes communication between these nodes increases so lifespan of nodes reduced and more number of node also make network expansive. Many localization algorithms are aware to nodes density. For example count based schemes require high node density to get accurate hop count approximation for distance. Similarly when anchor nodes density is not enough high in particular region, algorithms that depends on anchor nodes fails. But some time high node density becomes expensive if not totally Infeasible. So number of nodes must be in suitable manner in the sensor field.

2.5.3 Non-convex Topologies

There are often troubles in positioning of nodes that are near the edge of sensor region. This problem generally occurs because only one side area of border node lies in the sensor region. In other word we can say that about border nodes there is less information and that information is of lower quality. This problem became worse when a sensor network has a non convex shape. Sensor nodes that are outside the main convex body of the network often prove un-localizable. If by chance locations found, the result tends feature inconsistent error.

2.5.4 Environment Obstacles and Terrain Irregularities

Environmental obstacles and terrain irregularities can also cause of disorder of localization. Huge rocks, mountains, and large tree are as obstacle in line of sight. They preventing TDOA ranging or interfere with radios, introducing error into RSSI ranges and creating incorrect hop count ranges. Deployment on grass vs. sand vs. pavement can affect radios and audio ranging system. Indoor, natural features like walls are also affect radio signal. All of these issues come in real deployment, so localization system should be able to cope.

2.5.5 System Organization

Centralized algorithms run on a central machine. Sensor node collects data from sensor field and sends it to base station for analysis. After position computation base station sends back into the network. This algorithm avoids the problem of nodes computational limitations by accepting the communication cost of moving data back to the base station. This exchange becomes less pleasant as the network increases. It requires that there should be an intelligent base station with sensor nodes which may not always possible. This scaling problem can be partially reduced by deploying multi base station.

2.6 Type of Localization Algorithm

When data is collected at the base station by the sensor nodes, it is important to know the location of sensor nodes. Localization algorithm in WSN provides location information of every sensor nodes. According to used parameter in localization, localization algorithm is divided into two parts:

1. Range-based,

2. Range-free.

Range-based technique works on point-to-point distance estimates or angle estimates to provide location information of sensor nodes.

Some example of range based algorithm are : Time Of Arrival (TOA), Time Difference On Arrival (TDOA), Angle Of Arrival (AOA) and Received Signal Strength Indicator (RSSI) [13], all these use the distance information.

In range-free technique physical distances related properties between anchor nodes (nodes that knows it location) and unknown nodes is not required. The Centroid, Approximate Point in Triangle Test (APIT), Knowledge-based Positioning, DV-hop, Amorphous, all are range-free algorithms.

2.7 Error Analysis in Range-based and Range-free Algorithm

Many localization algorithms had been proposed time to time but few algorithms give accurate position of sensor node. But whichever gives accurate position is more expansive and requires more hardware equipments. Both the above algorithm (Range based and Range free) do not give accurate location information of sensor node due to different parameter. By taking one algorithm of each type, error can be analyze.

2.7.1 Euclidean Algorithm (Range-based)

This algorithm use local geometry of the nodes which is surrounding the anchor nodes. In this algorithm when intermediate nodes receive any message from another anchor nodes it flooded this message in place of forwarding in the network.

By Euclidean algorithm [3] position of unknown nodes which are several hops away from the anchor nodes can be calculated. As shown in the following Figure, A is anchor node. In the neighborhood of anchor node A there are two unknown node N_1 and N_2 ; these two nodes are also in the neighborhood of each other. An unknown node M is in the neighborhood of N_1 and N_2 , but it is not in the neighborhood of anchor node A. all sides and diagonal N_1N_2 of quadrangle AN_1MN_2 are known. Then by the help of geometry length of diagonal AM can be evaluated. But node M may have two possible locations: one is M and other is M'. If a node P is in the neighborhood of node M and also in the neighborhood of anchor node A and either N_1 or N_2, then node N_1 or N_2 can be replace by node P. Now again length AM is calculated to find correct location of node M. By repeating this process correct distance of unknown node M to anchor node A is calculated.

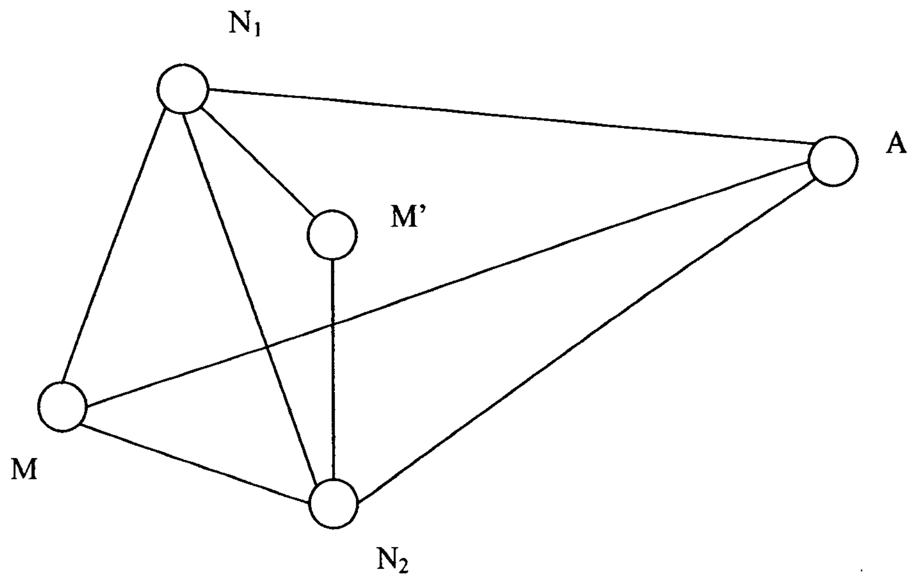

Figure 2.2 Euclidean propagation model [3]

Ranging error is the main flaw of range-based algorithms. As seen that every time calculation of distance of unknown nodes to anchor nodes is based on range. If one time an error occurred in length due to ranging error, this error increases in repeated calculation. At present time, there are many ranging techniques for example TOA, TDOA, AOA, and RSSI. RSSI mainly uses the RF signal. By the help of RF signal strength it calculates distance between nodes. Due to different broadcasting attenuation (as reflection, multi-path broadcast and antenna gain etc.) for the same distance the accuracy of ranging is not obtain satisfactory [4]. Some time ranging error in RSSI reaches up to 50%. In Euclidean algorithm due to ranging error the distance between the neighbor nodes is not calculated correctly. This ranging error increased hop by hop and at last it founded that node which is farther from anchor nodes calculate more error in distance and get poorer localization. And some node not localized in network.

2.7.2 DV-hop Algorithm (Range-free):

In the first step of this algorithm each anchor node broadcast a beacon packet in the flooded mode in the network. This beacon packet contains the location of anchor node and a flag with initial value one. This flag is used to count the number of hop. When this beacon passes through intermediate nodes, the flag value increases by 1 at each hop. Each intermediate node maintains minimum hop count per anchor node. When an intermediate node receives a beacon packet with higher hop count it discards this packet, because beacon packet of higher hop count is stale information. And if it is of low hop count then this beacon packet is received by intermediate nodes and forwarded to next hop. By this mechanism all nodes in the network calculate minimum hop-count to every anchor nodes.

In the second step as an anchor nodes gets hop count to other anchors, it calculates average hop size of one hop. This average hop size is broadcast in whole network in flooding mode. When unknown nodes receive it, calculate approximate distances to the anchor nodes. It calculates three or more expected value from anchor nodes, and then location of nodes is estimated.

In DV-hop algorithm [3] it assumes that the network is of high density of nodes and shortest hops is like to a straight line. Its main drawback is in practical application, means it assume that communication range of each node is circular while it is not a standard circle ideally. As shown in following Figure it is a fairly anomalistic polygon. Due to this reason distance of every hop is much different with each other. Therefore if to compute the distance from unknown nodes to anchor nodes in the network, the average distance of each hop is use, then in case of less anchor node localization error will increase with increasing the number of hop.

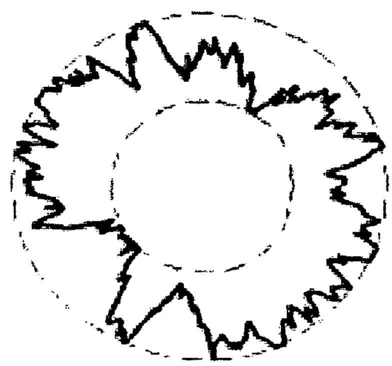

Figure 2.3 Irregular radio pattern of sensor [3]

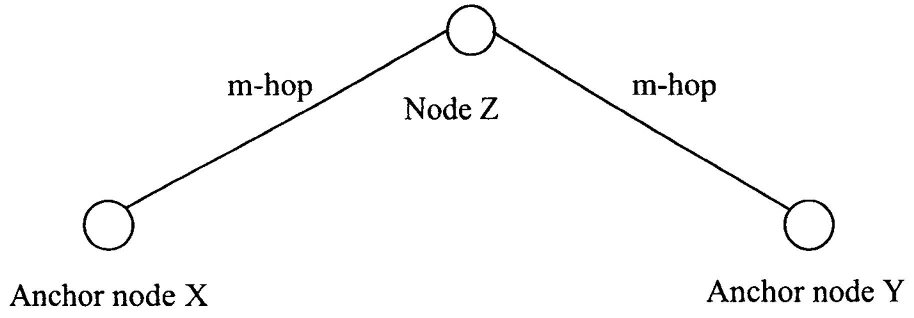

Figure 2.4 Example that show the error in DV-hop [3]

To make clarity, take an extreme case, in which it assumes that there is a shortest-hop path XY. An intermediate node Z is m-hops away from X and m-hops away from Y too. The communication radius of each node is r. If from X to Z the average hops distance is r and $\frac{r}{2}$ from Z to Y.

The actual distance between X and Y is

$$D_{XY} = mr + m\frac{r}{2} = \frac{3}{2}mr$$

And the real distance between X and Z is

$$D_{XZ} = mr$$

Although, based on DV-hop,

$$D_{XZ} = \frac{D_{XY}}{2} = \frac{3}{4}mr = \text{distance between X and Z.}$$

The error is $D_{XZ} - D_{XZ} = \frac{1}{4}mr$

In above example the error will increase on receiving the number of hops. Based on the above analysis conclusion is that the exactness of localization algorithm is associated to the density of anchor nodes. As the density of anchor nodes increases, the distance (hops) from unknown nodes to the anchor nodes reduced.

CHAPTER – 3
Algorithm Design and Implementation

3.1 Virtual Anchor Node-Based Localization Algorithm (VANLA)

As we know that accuracy of localization of sensor node in sensor networks depend upon the node density of network. This means more number of nodes with known position will give more accurate results. But with precise results there are some other constraint as cost, energy etc. So due to cost and energy issue only few nodes knows its location through GPS (Global Positioning System) called anchor nodes. GPS can not be applied in whole network because it consumes more energy and becomes expensive. Therefore, it can be applied only in a network with small number of nodes. As seen that if we want more precise localization then it requires more number of anchor nodes and physical resources. It is contradictory to each other that by reducing the hardware consumption, precision of localization increases.

In (VANLA) [15], first, accurate position of some particular unknown nodes is figured out by the help of Anchor nodes. Now these nodes work as virtual anchors. These virtual anchor nodes together with real anchor node find the location of remaining unknown nodes. In this technique density of anchor nodes increases so inexpensive and more precise position of location can be obtained without increasing hardware equipments.

3.1.1 Method to Select Virtual Anchor Node

To select virtual anchor nodes VANLA used with the same assumption as in DV-hop [3] for a dense network. In this technique some unknown nodes can be upgraded as virtual anchors from all the unknown nodes. Each unknown node decides whether it lies on shortest path between any anchor node pair or not. If it is true, it should record all information of that anchor node pair. This intermediate node on the shortest path between anchor pair works as a virtual anchor node.

At the beginning of this algorithm, each anchor nodes will broadcast message packets in flooding mode. This massage packet contains a sector H in packet header. This sector is use to hop count. Hop count means number of times the packet has been forwarded. Initially, sector H is taken 1 and each node of network calculate the smallest hops to each anchor node. So to calculate smallest hop count, nodes maintain a local variable h. This local variable is use to count the number of hop to anchor nodes. The value of this local variable is different for different anchor nodes. When anchor nodes flooded packet and this reaches to other nodes of the network, the following work take place. (As in following Figure):

```
If a node never receive the message packet flooded by anchor node (say, X)
Then put the value of H in local variable h;
else {
        Compare the variable h with H;
        If h<= H
        Then discard this message packet;
  else {
        h=H;
        Forward this packet in next hop;
      }
    }
```

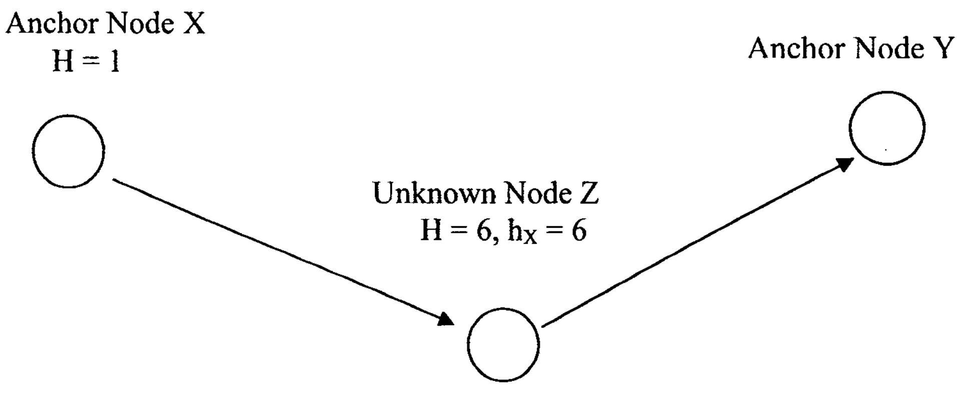

Figure 3.1 Example of shortest-hop path between anchors [15].

When an anchor node (say, Y) receive message packet sent by anchor node X. It (anchor Y) gets the number of hop to the other end anchor (say, X). This anchor node (Y) broadcast packets in the whole network to inform the number of hops between them (X and Y). This hop value is stored in a sector named "Shortest-hop" (Shortest-hop XY=10) of the packet sent by anchor node (Y). It can be seen In following Figure. When this packet received by any intermediate node (say, Z) it take following judgment:

If the sum or absolute difference between the number of hops from itself (node Z) to the two end anchors (X & Y) equals to shortest-hop between X and Y.

ie. $(h_X + h_Y)$ = shortest-hop XY or

$Max(h_X, h_Y) - Min(h_X, h_Y)$ = shortest-hop XY.

Then the intermediate node (Z) will be on the shortest-hop path of the two anchors (X and Y). And if this intermediate node (Z) lies on shortest hop path, it will record the related position information about them (X and Y).

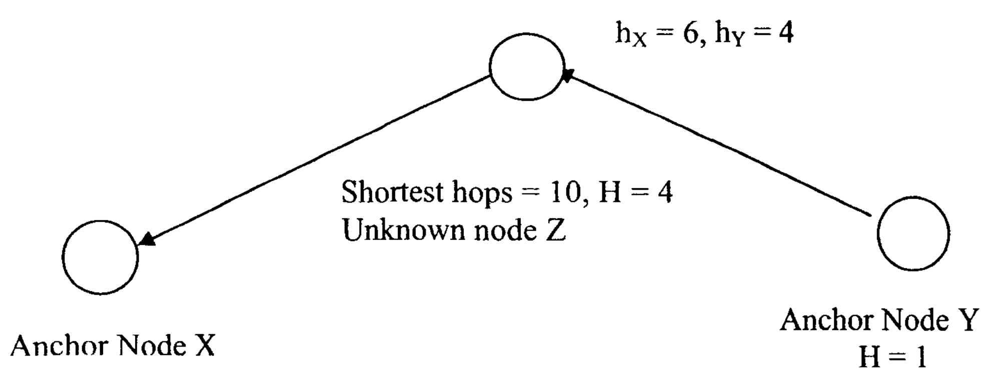

Figure 3.2 Example, A node check that it lies or not on the shortest-hop path between two anchors [15]

In the above algorithm each anchor node broadcast message packet in flooding mode and this packet is received by each nodes of the network. Now anchor node who receives this packet, broadcast the number of hop to the sender node. In this whole work communication increases between the nodes that makes network heavy and reduce the life-span of the network. Therefore to decrease the communication overhead, some anchor nodes of the network broadcast packet in flooding mode, and until the remaining node receives flooding packets from other some anchor nodes they will wait.

3.1.2 The Upgrade the Unknown Node as Virtual Anchor Node

If there is a shortest hop path between anchors node pair P (X_P, Y_P) and Q(X_Q, Y_Q). A certain unknown node T lies on this shortest-hop path of anchor pair and T also lies on the shortest-hop path of anchor node pair R(X_R, Y_R) and S(X_S, Y_S). Then the coordinates of the point T, that is intersection point of beeline PQ and RS can be determinate, that represent unknown node coordinate. This unknown node becomes virtual anchor node.

Now, position of this virtual anchor node T is computed by following way:

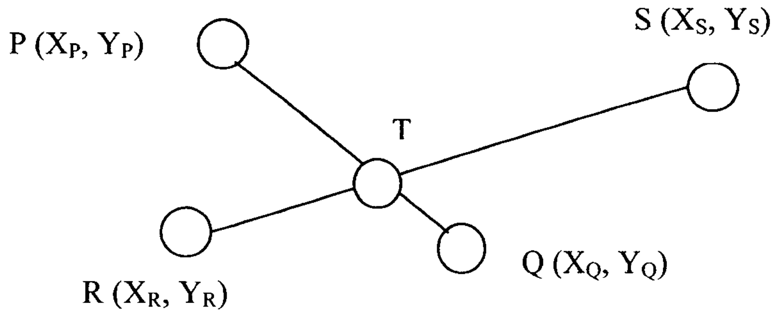

Figure 3.3 Example of intersection point of shortest path of anchor pairs as a virtual anchor

$$\begin{bmatrix} X_T \\ Y_T \end{bmatrix} = K \begin{bmatrix} -1 & 1 \\ -K_2 & K_1 \end{bmatrix} \times \begin{bmatrix} B_1 \\ B_2 \end{bmatrix} \qquad (1)$$

$$K_1 = \frac{Y_Q - Y_P}{X_Q - X_P}, \qquad K_2 = \frac{Y_S - Y_R}{X_S - X_R};$$

$$B_1 = \frac{X_Q Y_P - X_P Y_Q}{X_Q - X_P}, \qquad B_2 = \frac{X_S Y_R - X_R Y_S}{X_S - X_R}$$

$$K = \frac{-1}{\begin{vmatrix} K_1 & 1 \\ -K_2 & 1 \end{vmatrix}}$$

If an unknown node lies on m shortest hop path of anchor pairs then node will have $n={}^{m}C_2$ coordinate. Coordinates for the node be(X_1,Y_1), (X_2,Y_2)..... (X_n,Y_n). Location of node T is calculated by taking average of these n coordinates. This location of T will be precise.

$$(X, Y) = \left(\frac{X_1 + X_2 + ...X_n}{n}, \frac{Y_1 + Y_2 ....Y_n}{n} \right) \qquad (2)$$

As the coordinate of this node T is determine, it is upgraded as a virtual anchor node automatically. Then this node will broadcast packets with its position and help to localizing of remaining node.

3.2 Analysis of the Algorithm

In this algorithm, it is assume that WSN is dense. For dense WSN shortest hops paths are asymptotic to a beeline. In dense WSN if a node lies on shortest-hop paths between two different anchor pairs then it lies on the cross point of the two shortest-hop paths.

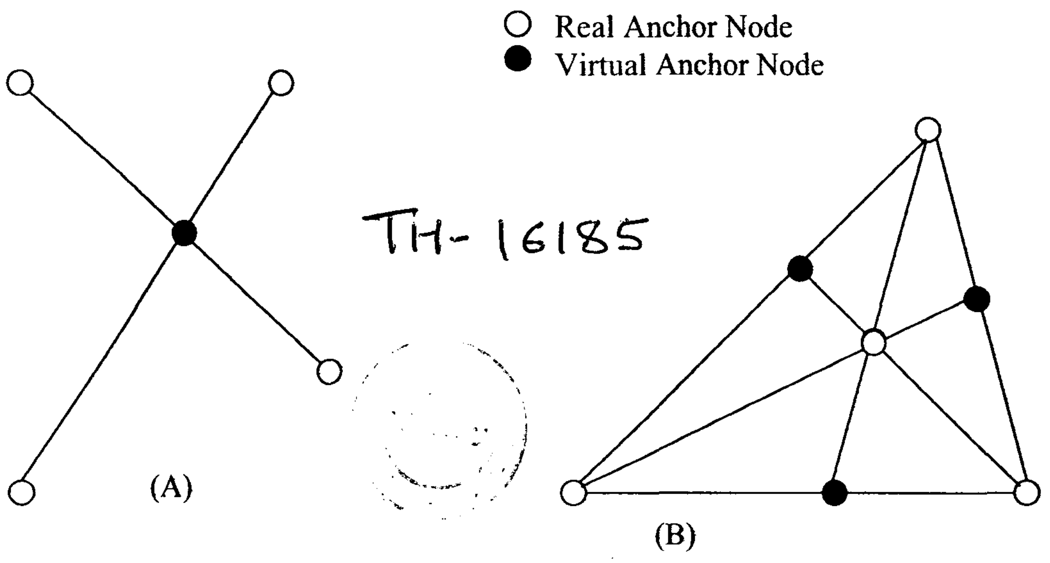

Figure 3.4 Relation between anchor and virtual sensor nodes [15]

In this algorithm each intermediate node which lies on shortest-hop paths of anchor pairs record the information of anchor nodes and compute the coordinate for each anchor pair. Now by the help of centroid [6] algorithm average value of all coordinate pair is calculated. This average value will be the final position of node, and this node is updated as anchor node. And this updated anchor node localizes the other unknown node together with real anchor node. For different position of anchor nodes different number of virtual anchor is obtained.

When 'n' anchor node form a convex quadrangle then ${}^{n}C_4$ node is updated as virtual anchor node this is shown in above figure (A). In triangle case $4\,{}^{n}C_4$ node is updated as virtual anchor node, shown in above figure (B). By the above figure it is clear that updation of virtual anchor nodes do not depend upon anchor node, small number of node can update sufficient number of virtual anchor node.

As seen that small number of nodes upgraded as anchor nodes. These updated anchors make network dense. If network is dense then location of nodes can be calculated easily with more precise result. In this algorithm a node is upgrade right in the middle of the path between anchor nodes. When the number of anchor nodes is very less in the beginning, newly upgraded nodes is more uniformly distribute in the network.

3.3 Virtual Anchor Node-based Localization Algorithm for Mobile Networks

After applying VANLA algorithm over static sensor network, sensor nodes are allowed to move around freely. Now problem is that how location of mobile node is update when they are moving place to place. Beside this nodes should update its neighbor's list. Other things are, that what will be new position of anchor nodes and which node is upgraded as virtual anchor node. To over come to this problem we define following method.

Let us suppose that nodes of sensor networks are moving with random velocity 0 to v. Now suppose that at initial time t_0 location of a node is (X, Y), after time t it reaches at point P (X_1,Y_1) with random speed v_1 which lies in the interval (0, v). This node will travel distance $d = (t - t_0) \times v_1$.

New location of node be within or on the circle of radius'd', anywhere in between 0 to 2π . Therefore new location of node after this time slot is (X_1, Y_1).

Where $X_1 = X + \delta X$, $Y_1 = Y + \delta Y$,

Where $\delta X = d \times \cos \theta$, $\delta Y = d \times \sin \theta$

Where $0 \leq \theta \geq 2\pi$

After getting new location of nodes we again estimate virtual anchor nodes by VANLA method. These virtual nodes assist in localization of the remaining unknown nodes. In this whole process anchor nodes remain same, only its position and list of its neighbor nodes changed.

3.4 Dominating Set

Let G = (V, E) is a graph with V set of vertices and E set of edges. A subset D of V is called dominating set if every vertex not in D is joined to at least one member of D by some edge. Dominating number γ (G) is the number of vertices in a smallest dominating set for G.

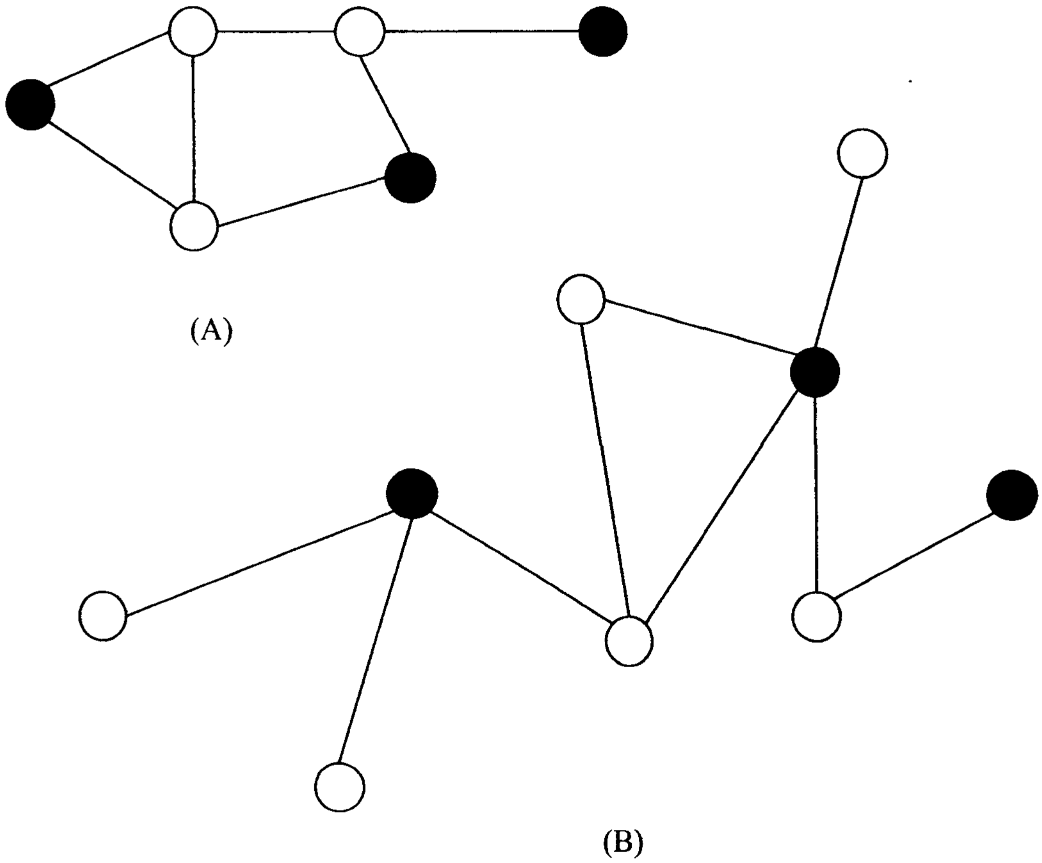

Figure 3.5 Dominating sets

There are two example of dominating sets. Black circle shows dominating set element. (A) & (B) show that dominating set with three, vertices each.

3.5 VANLA Algorithm for Dominating Set

In VANLA algorithm anchor nodes is taken randomly in a proportion. In VANLA algorithm for dominating set, the element of dominating set work as anchor node. Once dominating set is calculated, the position of Virtual anchor nodes and remaining other nodes is estimated by the same way as in VANLA.

3.5.1 Selection of Dominating Set

To select dominating set from a set of nodes we use greedy algorithm. Procedure of selection of dominating set is given as:

Let G = (V, E) is a graph.

Where V is set of vertices & E is set of edges.

Dominating set D of vertices $\leftarrow \phi$

Connected set C of vertices $\leftarrow \phi$

d $\leftarrow$ [degree (V), V]

Q $\leftarrow$ Heap Sort (d, degree (V) as key)

While ($C \neq V$)

    v $\leftarrow$ Extract max (Q)

    If ($v \notin C$)

        $D \leftarrow D \cup \{v\}$

        For each edge $(u, v) \in E$

            $C \leftarrow C \cup \{u\}$

        End For

    End if

End while

3.6 Used Function in Coding of Algorithms

To implement the VANLA algorithm for mobile network and dominating set, we use MATLAB simulator. Some function used in algorithm is distance function, shortest path function and predict position function (main function of the algorithm).

In distance function, every node calculates its distance to each nodes of the network and these distances are put into a matrix. Shortest path function calculate shortest hop path between anchor pairs.

Predict position function, in this function by the help of anchor node we calculate position of virtual anchor node.

When we apply VANLA algorithm in dominating set we write a code for Dominating set function for selection of dominating set.

Code of above main function is given in appendix.

CHAPTER – 4

Simulation and Result

4.1 MATLAB Simulator

MATLAB is an interactive numerical computing environment. Matrix manipulation, plotting of function and data implementation of algorithm, creation of user interfaces, interfacing with program in other language can be done by different tools of MATLAB. Its basic data element is an array that does not require dimensioning. It allows in solving many technical computing problems, mainly those with matrix and vector formulations, in a part of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN [5].

4.2 Simulation Environment

In this section, we evaluate the localization error in mobile network and dominating set for VANLA algorithm in comparison to static networks. To simulate the algorithm we use MATLAB simulator.

4.2.1 Simulation Parameter and its Effects

Main parameters used in simulation for static, mobile environment and dominating set are - dimensions (sensor field), node density, percentage of anchor nodes, and range of nodes. All these parameter are dependent on one another.

Node density is important parameter because in sparse network sensor node faces problem of communication. If the number of anchor nodes is not sufficient, more number of nodes remains un-localized. But on increasing the number of anchor nodes, the cost of network increases. This is a restriction on the simulation. Communication range is most important parameter, as with high communication range and less number of anchor nodes, we can obtain approximate localization. High communication range reduces lifespan of battery. This is other constraint used in simulation.

Localization error is taken as the ratio of Euclidean distance between real and calculated coordinate to the range of nodes. In changing the range or percentage of anchor nodes, we get change in localization error. Percentage of anchor node and range of nodes are used as input for the system simulation.

4.2.2 Input Parameter

In simulation we take area of 1000*1000 sq meters and 100 nodes. Transmission range of nodes is a function of network area.

In static and mobile networks communication range of nodes is square-root of the ratio of area to π .

But in dominating set approximate half range is required for better result of localization.

In mobile network nodes move here and there therefore we take its speed from 0 to 10 m/s randomly.

In static and mobile network we take ratio of anchor node from 2% to 20% but in dominating set case anchor nodes are not given by us as input. Taking all inputs as given above we simulate the algorithm in MATLAB simulator.

4.3 Simulation Result

On simulating all the three cases static, mobile, and dominating with above given input we obtain the results which are given below.

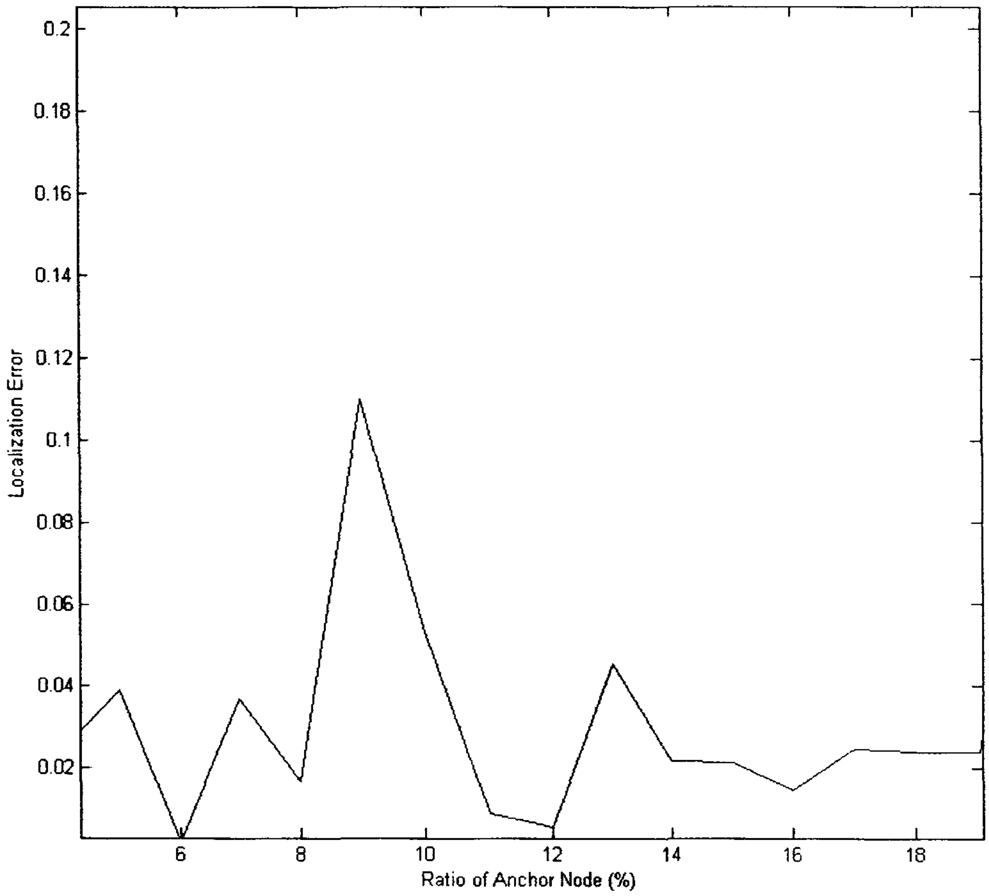

Figure 4.1 Localization Error in static network

Figure 4.1shows the results of simulation of VANLA algorithm for static networks. Here we can see that as percentage of anchor node increases localization error decreases.

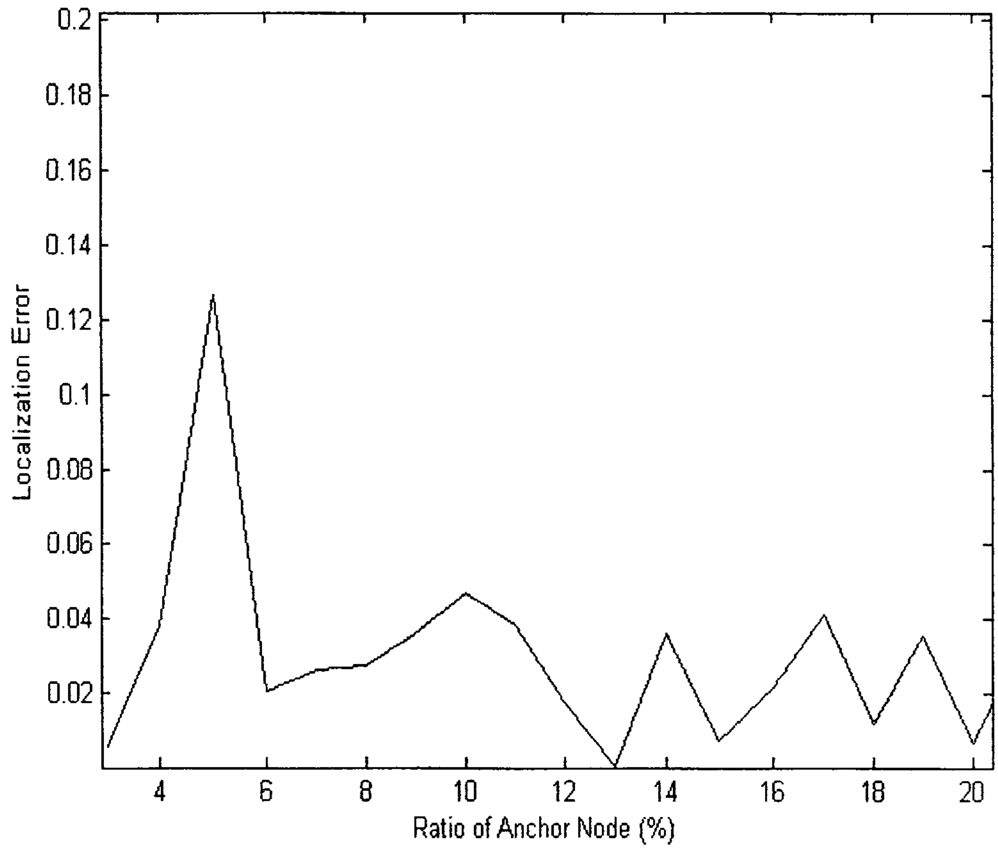

Figure 4.2 Localization Error in mobile network

Figure 4.2 shows simulation result of VANLA algorithm for mobile network. In our experiment we take the speed of moving nodes from 0 to 10 m/s and after 40 second localization error is shown by above figure. The localization error in mobile network is approximating same as in static network. This clearly indicates that VANLA algorithm is also applicable for mobile networks.

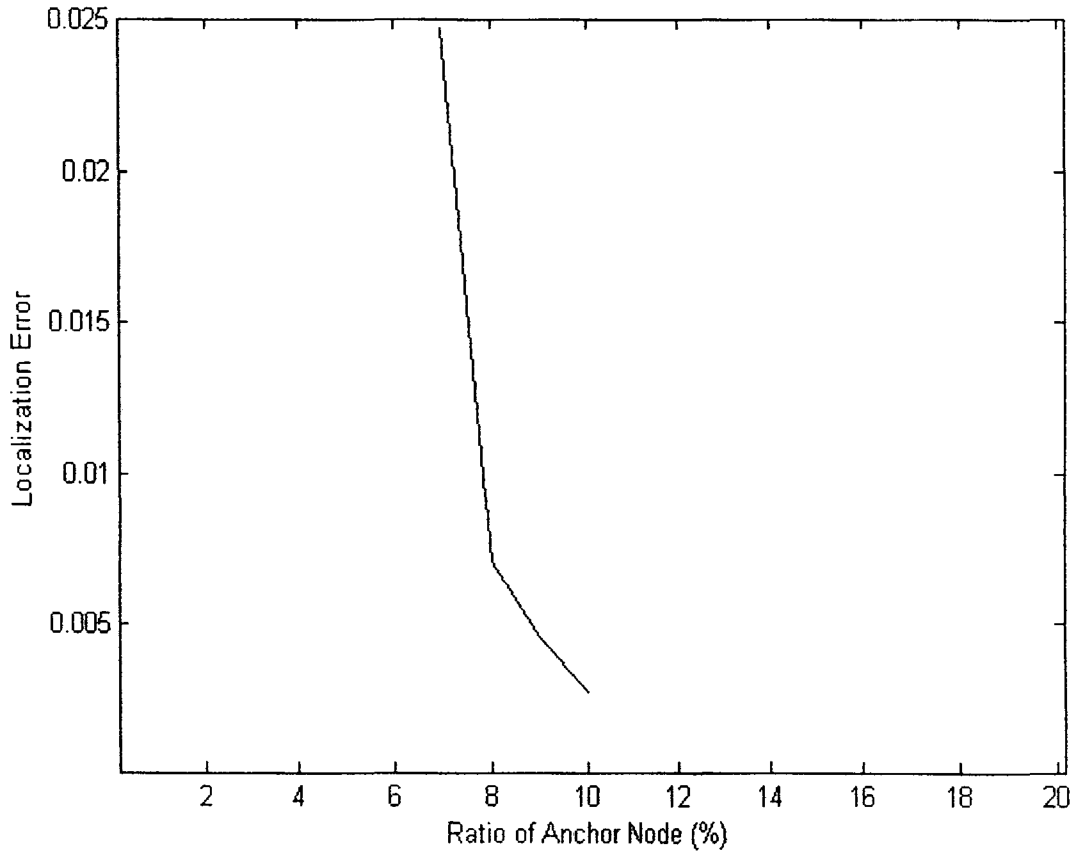

Figure 4.3 Localization Error in dominating set

Figure 4.3 shows simulation result of VANLA algorithm for dominating set. In this case number of anchor node is not given by us as input. From a given set of sensor node dominating set is created based on range. If we compare this result to static network, we got a great difference. In this case as number of anchor nodes increase from 6% to 10% localization error decreases rapidly.

CHAPTER – 5
Conclusion and Future Work

5.1 Conclusion

In the dissertation work we have implemented virtual anchor node based localization algorithm for both static and mobile networks. Further we have used dominating set to determine the anchor nodes. We have calculated localization error for static and mobile networks. We have also computed localization error for static network using dominating set. We found that localization error in case of static and mobile networks is approximately same. However, localization error static network with dominating set in localization error reduces drastically and therefore, the results are quite encouraging.

5.2 Contribution

All research work must end with contribution of some knowledge to the area. The current work is also a modest attempt towards the same. The contribution of the work presented in this dissertation is given below:

- Implementation of VANLA algorithm for mobile sensor network
- Testing of VANLA for mobile networks
- Implementation of dominating set based algorithm for determine anchor nodes
- Testing of VANLA with dominating set for static network.

5.3 Future Work

All research work naturally finishes in an incompletion state. Therefore, it always leaves scope for future extension. In the current work, we proposed to continue in the following directions in future:

- Use of dominating set with mobile network
- To compute the results for dominating set with varying transmission range in both static and mobile environment.

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APPENDIX

Code for Predict position function of virtual anchor node.

```
predictedPos = zeros(num_points,2);
  for n = 1:num_points
    if(nodeType(n)==2)
      predictedPos(n,:) = A(n,:);
      continue;
    end
    k=0;
    for i = 2:size(anchor,1)
      for j = 1:i-1
        if(or(shortestPath(i,anchor(j)) ==
shortestPath(i,n)+shortestPath(j,n),shortestPath(i,anchor(j))==abs(shortestPath(i,n)-
shortestPath(j,n))))
          nodeType(n)=1;
          k=k+1;
          anchorspair(k,1)=anchor(i);
          anchorspair(k,2)=anchor(j);
        end
      end
    end
    count = 0;
    X = zeros(k*(k-1)/2,1);
    Y = X;
    for ab = 2:k
      xa = A(anchorspair(ab,1),1) ;
      ya = A(anchorspair(ab,1),2);

      xb = A(anchorspair(ab,2),1);
```

```
  yb = A(anchorspair(ab,2),2);

  for cd = 1:ab-1
     count=count+1;

     xc = A(anchorspair(cd,1),1);
     yc = A(anchorspair(cd,1),2);

     xd = A(anchorspair(cd,2),1);
     yd = A(anchorspair(cd,2),2);
     b1 = (xb*ya-xa*yb)/(xb-xa);
     b2 = (xd*yc-xc*yd)/(xd-xc);

     k1 = (yb-ya)/(xb-xa);
     k2 = (yd-yc)/(xd-xc);

     k= -1/det([-k1 1;-k2 1]);

     x = k*[-1 1;-k2 k1]*[b1;b2];
     X(count) = x(1);
     Y(count) = x(2);
  end
end
predictedPos(n,:)= mean([X Y]);
```

Code for Dominating set function for selection of dominating set.

```
function [anchor] = generateDominating(A,range)
num_points = size(A,1);
D = zeros(num_points,num_points);
for i = 1:num_points
   for j = 1:i
      D(j,i) = norm(A(i,:)-A(j,:));
      if (D(j,i) >= range)
         D(j,i) = Inf;
      end
      D(i,j) = D(j,i);
   end
end
[adjlist]=isDirectLink(D);
 dominatingSet = zeros(num_points,1);
connectedSet = zeros(num_points,1);
sdegree = sum(adjlist,2);
[b,ix] = sort(degree,'descend');
for i = 1:num_points
   if(connectedSet(ix(i))==0)
      dominatingSet(ix(i))=1;
      connectedSet = bitor(connectedSet,adjlist(:,ix(i)));
   end
end
k =0;
for i = 1:num_points
   if(dominatingSet(i)==1)
      k = k+1;
      anchor(k) = i;
   end
end
anchor = anchor';
```