Study on Selection of Useful Bacon node in Range Free Localization Algorithm in WSN

Supervised By

Dr. Anup Kumar Paul

Assistant Professor

Presented By

Farzana Yeasmin

ID: 2016-1-50-027

Department of Electronics & Communication Engineering

East West University, Dhaka

Declaration

I am Farzana Yeasmin, declare that this thesis paper based on study on selection of useful Bacon node in Range Free Localization Algorithm in WSN by myself under the supervision of Dr. Anup Kumar Paul, Assistant Professor, Department of Electronics & Communication Engineering, East West University, Dhaka. I am also declaring that this whole thesis or part of the thesis is not submitted anywhere for the award of any degree or diploma.

Supervisor

Dr. Anup Kumar Paul

Assistant Professor

Department of Electronics & Communication Engineering

East West University, Dhaka

Author

Farzana Yeasmin

ID: 2016-1-50-027

Acknowledgement

First of all, I would like to thanks ALLAH for enabling me to do the work successfully. Then I would like to thanks my supervisor Dr. Anup Kumar Paul. He gave me support and valuable advice to complete the research work. He gave me advice to improve the work.

I would also like to thanks all of faculty members, seniors, friends and my family members who have motivate me and constant support me.

Regards

Farzana Yeasmin

Abstract

Localization is an important part in wireless sensor network and briefly used it in WSN. Because, from it we get the required information to identify current location of sensor node. Now this become an interest field among the researcher. To determine the physical location of a node is known as localization in wireless sensor network. There are large number of small nodes in WSNs. The characteristic of these nodes is that, low energy, limited processing capability, low cost and most important part that they can identify their current location without GPS and manual configuration. They can exchange their information with their neighbor node in ad-hoc fashion. There is different different method to determine the location. For different location different method can give accurate result. Our main concern is to get accurate result. Localization can be challenges for some special scenario such as: fire detection in a big forest. In this paper I try to present a short survey on the localization technique that used in wireless sensor networks (WSNs).

Table of Contents

List of Figures:

List of Tables:

Chapter 1

Introduction

1.1 Motivation

The ‘Smart World’ cannot imagine without technology. The developed Smart World surround by various application of wireless sensor network. Thus, localization becomes the significant technology for Smart World facilities. Wireless sensor network is a self-arranged and framework less wireless network that monitor physical or environmental conditions, for example: temperature, sound, pressure, vibration, motion etc. and pass their data through the network to the main location where the data analyzed and observed [1]. The base station works as an interface between client and network. Wireless sensors network is very important for today world because it can be used in very rude and bad environment. Again, wireless sensors network is very flexible network and it can adjust itself with the changes [2]. There uses no wire so it saves cost. So, from this discussion we understand the importance of WSN and that encourage me to study on the topic.

1.2 Summary about the topic

Wireless Sensor Network (WSN) is made of a huge number of sensor nodes that spread over a certain region [3]. Every node can interact with other node to construct a network. Each and every node collects information from its nearby place and transmit the data to the sink node. Sink node is special type of node that used to collect data from regular sensors node [4]. Now a days WSNs are very popular in scientific community. Because they are small, cheap and low consumption energy solutions to a variety of real-world challenges. There are many areas where use WSN for research. Currently WSNs used in many sectors for example: environmental monitoring, target tracking, biomedical health monitoring, border security surveillance, disaster management etc. [5]. Localization scheme are divided into two categories, one is range free and another one is ranged based. For range-based method the sensors node needs additional devices like: directional antennas, timers, signal strength receivers etc. [6]. On the other hand, in range free method there does not need additional hardware rather it uses the content of messages. There are so many papers on wireless sensor networks localization technique. And different algorithm for different situation. For getting more accurate result use different algorithm.

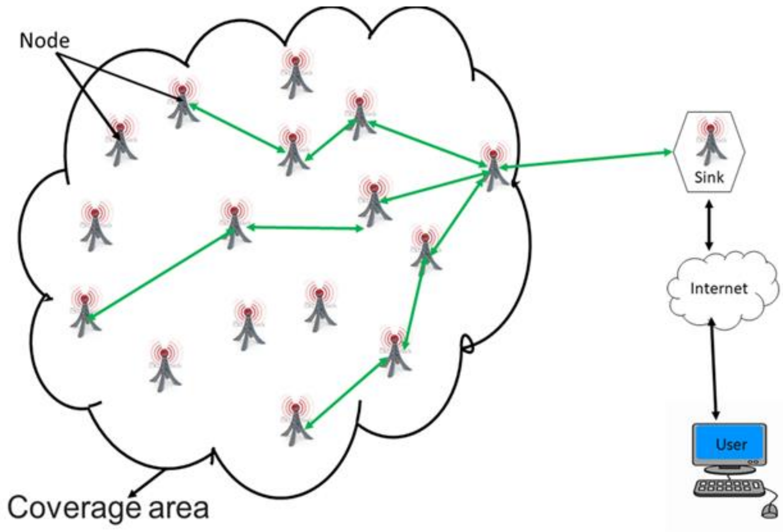

Figure 1.1: General architecture of WSNs

The rest of this paper is embodied as follow:

Chapter 2, in this chapter, discuss about the related work. How to select useful anchor node that is described in chapter 3. Chapter 4, contains the simulation result and discussion about the result. And chapter 5, consist of conclusion and future work.

Chapter 2

Related Work

2.1 Background

Sometimes we need to know the location of the forest fire, on the battlefield need to know the movement of enemy vehicles, the accurate position of the natural gas pipeline leak etc. [7]. Localization of wireless sensors network helps us to know all of this information. So, localization means, determine physical location of a given node in a wireless sensor network (WSN). For finding a node location we need to collect some information like atmospheric pressure, humidity and temperature. The term of localization before used in robotics. The robot localization helps to find the question answer that, where is the robot now [8]? In wireless sensor network system information is collected and transferred by using the sensors node. As per their own location information the nodes are may be classified into two types: one is beacon nodes and another one is unknown nodes.

i. Beacon node:

Beacon nodes are a special type of nodes. Because beacon nodes are knowing the own location information through GPS or manual pre-programming during deployment. Beacon node also known as anchor node. To get location accuracy we can use large number of beacon node. But need higher implementation cost for that because requires higher hardware's. For large scale situation it is not right decision. So, use fewer beacon node compare to unknown node.

The communication link of the sensor's node can be symmetric or asymmetric. For example: there are two points A and B. In symmetric system A can reach to B and B can reach to A. On the other hand, in asymmetric system A can reach to B but B cannot reach to A.

ii. Unknown nodes:

Unknown node does not know their own position at first just like beacon node. For knowing the location of unknown node need to use algorithm. The unknown nodes use for the estimate distance and angle from the beacon node. There are many algorithms for this process.

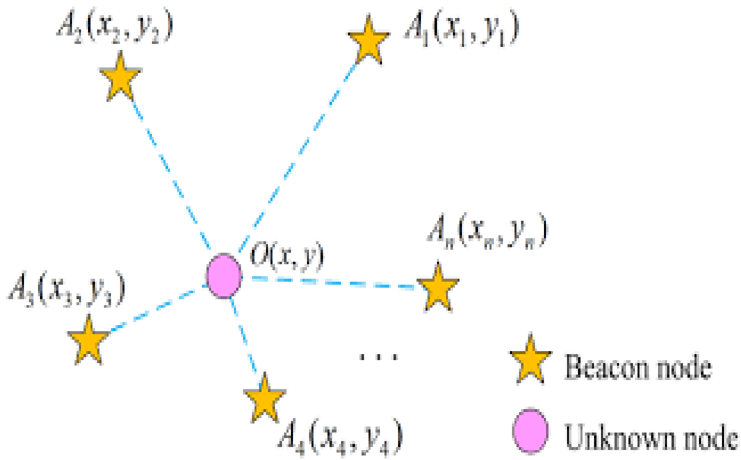

Figure 2.1: Beacon node and unknown node

2.2 Localization process

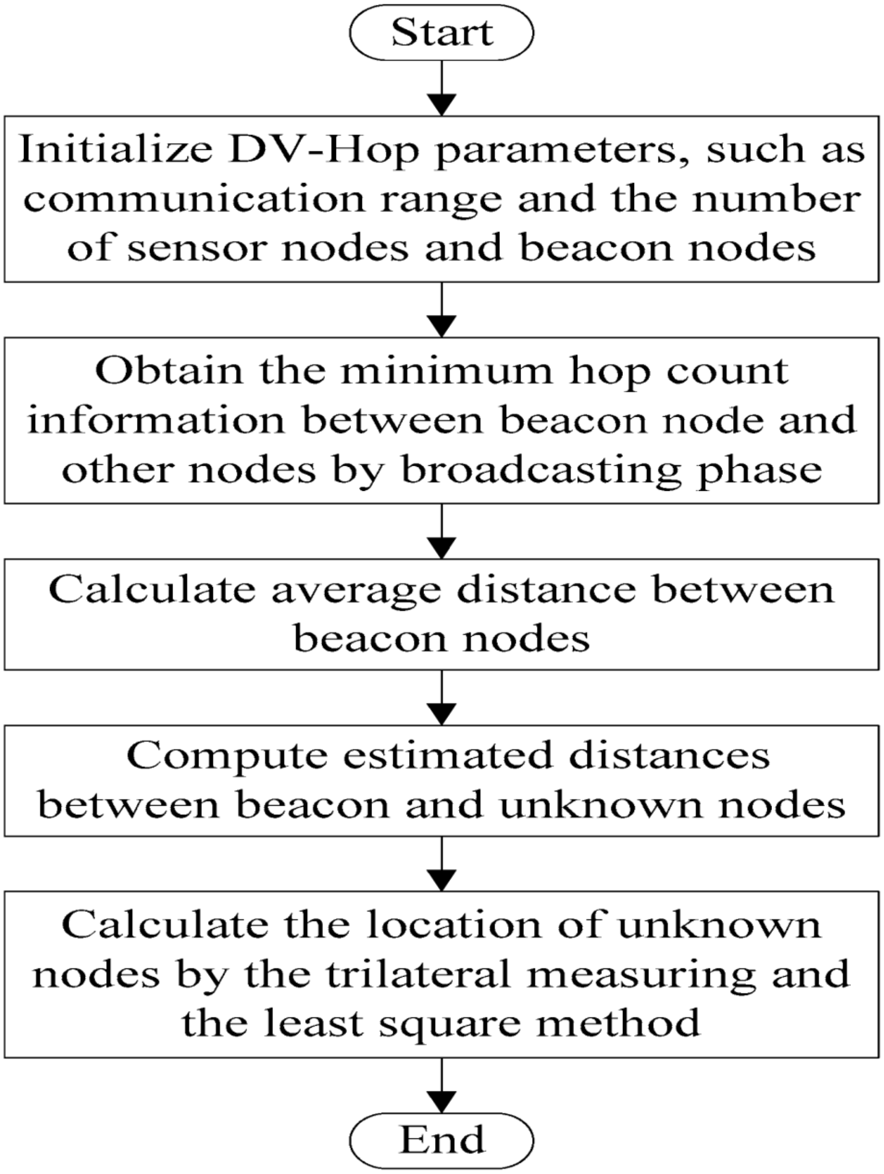

Figure 2.2: Flowchart of localization

For finding the location we need to use algorithm. There are many algorithms on this. Basically, we need to find out the unknown sensor node location. At this point we need the help of beacon node. Figure (3) show the flow chat of localization.

2.3 Measurement Technique for Localization

The calculation of localization algorithm for WSNs rely upon different measurement technique. There are so many reasons that influence the accuracy of the localization algorithms. Which algorithm is best, that also depend on various application? So, there is a challenge to select the best algorithm. For accurate result, right measurement technique is required. As we say accuracy depend on many things such as, network architecture, geometric shape of the measurement area, number of anchor node etc. [9]. Mainly there are three main phases share almost all the sensor network localization algorithm. The three main phase is:

1. Distance estimation
2. AOA (Angle of arrival)
3. RSS (Radio signal strength)

Point no (1) also divided into three parts. After that again divided. So, now I am going to discuss these briefly with a figure.

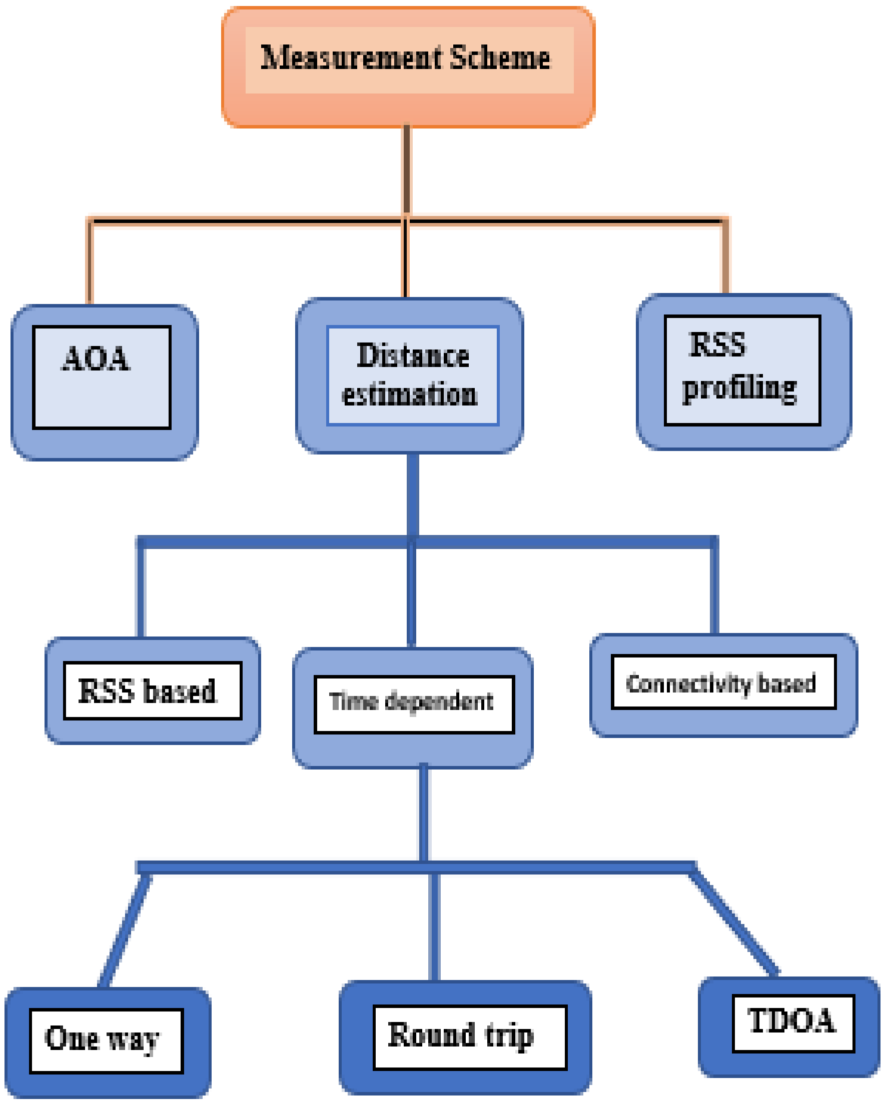

Figure 2.3: Measurement scheme of localization algorithm

2.3.1 Angle of Arrival (AOA)

Angle of arrival (AOA) is a measurement technique that helps to determine the direction of propagation of a radio frequency wave. AOA also known as the direction of arrival measurement or the bearing measurement [10]. There are two technique that helps to measurement AOA. First one is amplitude response that come from the receiver antenna's side. Second one is phase response that come from the receiver antenna's side. Minimum two beacon nodes are needed to measurement the AOA. These two techniques are help to measure the angle of the signal that come from the beacon node to the dump node. Multipath effect, presence of shadowing, measurement, direction of antenna etc. can be affect the accuracy of the result. Wireless Sensor Networks use small sensor nodes and that is not convenient to energy.

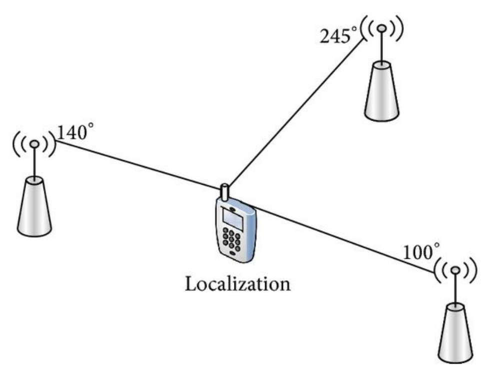

Figure 2.4: AOA method of positioning

2.3.2 Distance Estimation

Distance related measurement is a time-based measurement. Distance related measurement can be classified into: RSS measurements, TDOA measurements, one-way propagation time measurements, round trip propagation measurements [11].

2.3.2.1 Time measurement propagation:

The one-way propagation measurements and the round-trip measurement are also known as time-of arrival measurement. This helps to calculate the distance between nearby sensor node.

The one-way measurement technique helps to estimate the difference between the signal sending time from the transmitter and signal receiving time at the receiver. To accurate synchronization it demands local time for both transmitter and receiver. This requirement may be costly. For this reason, this method less attractive.

The round-trip measurement estimates the difference between the time when a signal is sent from the sensor node and the time when signal return from the second sensor node to the main sensor node. There is no synchronization problem because here uses same clock. The delay required for handling the signal on second sensor node and that cause error for this method. Here used Ultra-Wide Band (UWB) signal for accurate measurement [12]. Noise, signal bandwidth, non-line of sight, and multipath environment can be reason for synchronization problem for both one way and round-trip measurement system.

The Time difference of arrival measurement estimate the distinction the arrival times of a transmitting signal at two known location separate receiver respectively. They are perfectly synchronized. For this technique need three receivers to locate the transmitter location uniquely. Synchronization error and multipath can affect the accuracy. If the distance between receivers are increased then the accuracy can improve. Because it raises the inequality between the times of arrival [13].

2.3.2.2 RSS measurement

Another type of localization measurement technique is Received Signal Strength measurement. It is mainly used for WLANs but it also appears attractive for wireless sensor networks. Receive Signal Strength (RSS) measure the space between two sensors node from the received signal strength of the signal. Most of the sensor are able to measure the RSS. The algorithm of localization is typically based on AOA and propagation time management [14]. These two-measurement systems give batter accuracy then RSS measurement system. In RSS, accuracy is possible if the cost of the equipment is increased.

2.3.2.3 Connectivity based

So far, we discuss many measurement techniques but among these technique connectivity-based techniques is the simplest form of measurement. A sensor can connect with another sensor if the sensors are in the radio transmission radios of each other. This measurement techniques also called as binary measurement. If the sensor is connected then it is referring as binary 1 and if it is not connected that means it is outside the radio transmission range then it is referring as binary 0. The distance between one sensor to another sensor is represented as the hop count. There use many algorithms for finding accurate average hop distance.

2.3.3 RSS profiling measurement

Previously we discuss about the RSS that, it measures the distance between sensor nodes. The localization algorithm uses this distance to calculate the position of sensor node. To implement RSS measurement system, need to face two major challenges. The 1st challenge is to use RSS measurement scheme in wireless environment both for indoor and outdoor. And the 2nd challenge is model parameter selection. These measurement systems can estimate the sensors position by using the map of RSS measurement, to avoid the described problem. To get the form of map just spread the device at known position which refer the online way or use priori measurement which is the way of offline.

2.4 Range Free Localization scheme

In recent years range free localization snatch the attention of people. Because it is very simple and low-cost system. There is no special hardware used for distance measurement. The taxonomy of range free localization scheme is given below:

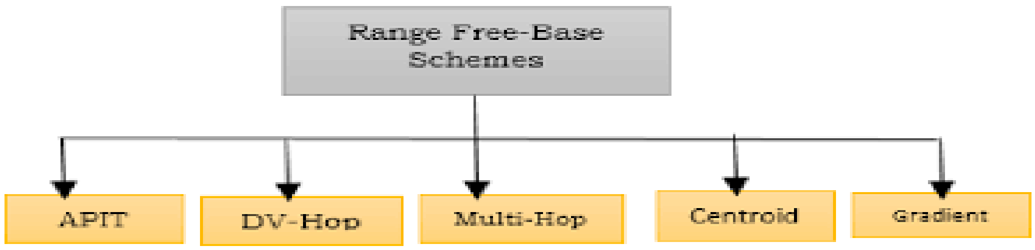

Figure 2.5: Taxonomy of range free localization scheme

In this paper mainly focused on this topic. To find out the position of sensor node in range free localization scheme DV-HOP and Centroid are the most popular algorithm. So here I am going to discuss only these two algorithms:

i. DV-HOP:

DV-HOP localization algorithm uses a formula thar is uniform to the general distance vector routing method. It plays an important role to give primary distance calculation from sensor node to anchor node. It spreads distance calculation among beacon nodes represented by number of hops all through a wireless sensor network. Then beacon node calculate the average distance of each hop. The location is estimated by using multiliterate process. The formula that is using for location estimation in range free localization system as follow:

$$\begin{cases} \sqrt{(x-x_1)^2+(y-y_1)^2} & = d_1 \\ \sqrt{(x-x_2)^2+(y-y_2)^2} & = d_2 \\ \vdots & \vdots \\ \sqrt{(x-x_i)^2+(y-y_i)^2} & = d_i \end{cases}$$

$$A = -2 \times \begin{pmatrix} x_1 - x_n & y_1 - y_n \\ x_2 - x_n & y_2 - y_n \\ \vdots & \vdots \\ x_{n-1} - x_n & y_{n-1} - y_n \end{pmatrix}$$

$$B = \begin{pmatrix} d_1^2 - d_n^2 - x_1^2 + x_n^2 - y_1^2 + y_n^2 \\ d_2^2 - d_n^2 - x_2^2 + x_n^2 - y_2^2 + y_n^2 \\ \vdots \\ d_{n-1}^2 - d_n^2 - x_{n-1}^2 + x_n^2 - y_{n-1}^2 + y_n^2 \end{pmatrix}$$

$$P = \begin{pmatrix} x \\ y \end{pmatrix}$$

where, $P = (A^T A)^{-1} A^T B$

Figure 2.6: Equation for calculating location in range free localization

Where,

(x, y) = unknown node

(x_i, y_i) = known location of i'th anchor node receiver

d_i = distance between anchor node and unknown node

ii. Centroid

Centroid is worked when sensor nodes have minimum three neighbor beacon node.

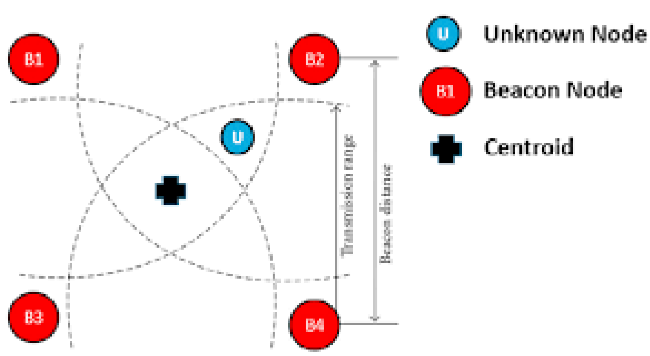

Figure 2.7: Centroid algorithm nodes representation

Let consider M is the sensor node that have three neighbor anchor node P_1, P_2 and P_3. Whose Coordinates are (X_1, Y_1), (X_2, Y_2) and (X_3, Y_3). The communication range among the nodes are equal. The position of M centroid can be calculated as:

$$(\boldsymbol{X_{centroid}}, \boldsymbol{Y_{centroid}}) = \left({(\boldsymbol{X_1} + \boldsymbol{X_2} + \boldsymbol{X_3})}/{\boldsymbol{3}} \right), ({\boldsymbol{Y_1} + \boldsymbol{Y_2} + \boldsymbol{Y_3})}/{\boldsymbol{3}})$$

Here, M centroid denoted as $(\boldsymbol{X_{centroid}}, \boldsymbol{Y_{centroid}})$.

After regular distribution of beacon nodes, it gives relatively better accuracy and it has low computation cost. It gives inaccurate result when distribution of bacon nodes is not even.

Chapter 3
Useful Anchor Selection Methodology

3.1 Proposed Method

In this section, I am going to describe how to determine useful beacon set for different sensor. Here uses the information that is containing each beacon node and average hop size.

3.1.1 Determining average hop size

1st step: At first, we need to find out minimum number of hop count for every node. All beacon nodes know its own position information. At the beginning transmission the position coordinates and hop count set to zero. A beacon message broadcast by every bacon node with its position coordinates and hop counts [15]. By using classical distance vector all nodes in the network can get distance. So, we get distance between bacon node and neighbor unknown node by using this equation:

$$d_{ab} = \sqrt{(x_a - x_b)^2 + (y_a - y_b)^2} \tag{3.1}$$

To update the table, we can use {Xi, Yi, h_{ij}} and just interchange update with neighbor node. The total transmission distance can be estimate as:

$$T_d = \sum \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (3.2)$$

2nd step: All nodes are interchange its information with its neighbor node after first estimation. So, from this interchange network know the total number of transmission hop in the network. Now consider that there are h_{ij} number of hops in the network. The formula of calculating average hop size for the network is given below [16]:

$$H = \frac{\Sigma_{j \neq i} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{\Sigma_{j \neq i} h_{ij}} \quad (3.3)$$

Where,

(x_i, y_i) (x_j, y_j) = coordinates of the anchor node i and j

h_{ij} = number of hops between anchors i and j

This will give us guarantee that most of the nodes receive the value which is near to the bacon node.

3rd stage: By using triangulation and least mean square estimator along with getting values from previous to stage an unknown node can calculate its distance.

3.1.2 Selection strategy of useful beacon node:

The route between two bacon nodes is not straight in reality. So, we need to adopt some strategy to find out the better bacon nodes among all the nodes. Here I am going to show an algorithm that is useful for finding bacon nodes. So here I am going to present an example to clear the process.

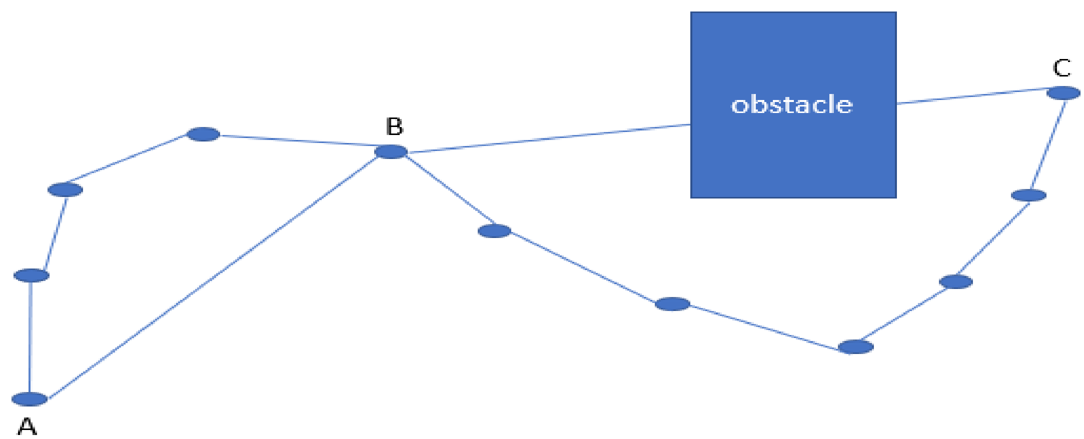

Figure 3.1: WSN anchor node localization with obstacle

From this figure we see that there are three bacon node A,B and C. Bacon nodes know their position. The euclidean distance from A to B and B to C are e1 and e2 respectively. Consider H is the average hop size of the network. From figure 8 we see that there is no onstacl between A and B. There is 4 hop from A to B. As we know that each bacon inchange their information with their neighobur node. So each bacon node get the information. The hop distance from A to B is $d1 = 4$. Now we can easily count the transmission distance from A to B. Let the transmission distance is $p1 = d1 \times H$. That is almost equal to e1. As the transmission path is almost straight from A to B so the difference between euclide distance and transmission distance is, $q1 = p1 - e1$.

Now we calculate for B to C. From figure 8 e see that, the hop distance is 6 for B to C. So the hop distance is $d2 = 6$ and the transmission distance $p2 = d2 \times H$. So now we can write $q2 = p2 - e2$.

If the network consist of M number of bacon nodes then the difference between eeuclide distance and transmission distance consider as $q = q1, q2, q3, q4, \ldots\ldots\ldots, qn$. To solve the problem at first we need to sort the array into asscending order. Then we need to select the first half portion for calculation and remove the seconf half portion. Now we need to find out the median value. By using an algorithm we can easily find out the median value of q. Let consider, the **qm** is the median value of q. When $q < qm$ then the becon node is useful. If $q \geq qm$, the bacon node will be null.

Algorithm:

Require: k: bacon ID;

V_A: The bacon set {(x_i, y_i); h_{ij}}

Where,

Require: k: Bacon ID;

V_A: The bacon set {(x_i, y_j); h_{ij}}

Where,

$1 \leq I \leq | V_A |$ and $I \neq j$: received position of bacon I and corresponding hop count to bacon j

Ensure: Useful bacon position (x_p, y_p)

P € $Friendly_j$

While i € V_A and $i \neq j$

do

$$d_{ij} = \sqrt{(x_j - x_j)^2 + (y_j - y_i)^2}$$

$H = \frac{\Sigma\sqrt{d_{ij}}}{h_{ij}}$

End while

While i € V_A and i ≠ j

do

$r_{ij} = q_{ji} \times H$

$u_{ji} = r_{ji} - e_{ji}$

end while

u = sort(u)

u = [0: (u / 2)]

U = round (median (u))

While i € V_A and i ≠ j

do

if $u_{ji} < U$

$Friendly_j = V_{ji}$

end if

end while

Broadcast useful bacon nodes position (x_m, y_m)

Chapter 4

Result and Performance Evaluation

In this chapter I am going to discuss about result that get after research. Here I want to clear that this paper based on study on other published paper. Here I am going to present localization error in different approaches such as DV-HOP [17], RAL [18], FASS [19] and pattern-driven [20].

4.1 Topology

Now I am going to talk about topology. Topologies plays an important role for selecting best algorithm among all the algorithm. Topologies divided into two categories: one is even and another one is random. Between two categories random topology is more popular among the researchers [21]. According to the placement of sensor nodes topology can subdivided into two categories one is regular and another one is irregular.

4.1.1 Regular topology

Here sensor nodes are placed uniformly all over the area as grid or randomly. Regular topology gives very accurate calculation or give a bounded value. But for the real-world regular topology does not reflect because there are many factors that affect the deployment of sensor nodes.

4.1.2 Irregular topology

Irregular topology calculate distance all of node that are greatly deviates from the actual Euclidean distance. Nodes are deviates due to the obstacles or other object present in the networks. The shape of the irregular topology can vary depending on the shape of network area, obstacles size etc. The shapes are: C-shape, s-shape, L-shape, O-shape.

Table 1: Simulation parameter:

Network Parameter	Value of Parameter
Area	10×10m
Number of sensors	200
Number of bacon node	20
Radio Rang	2m

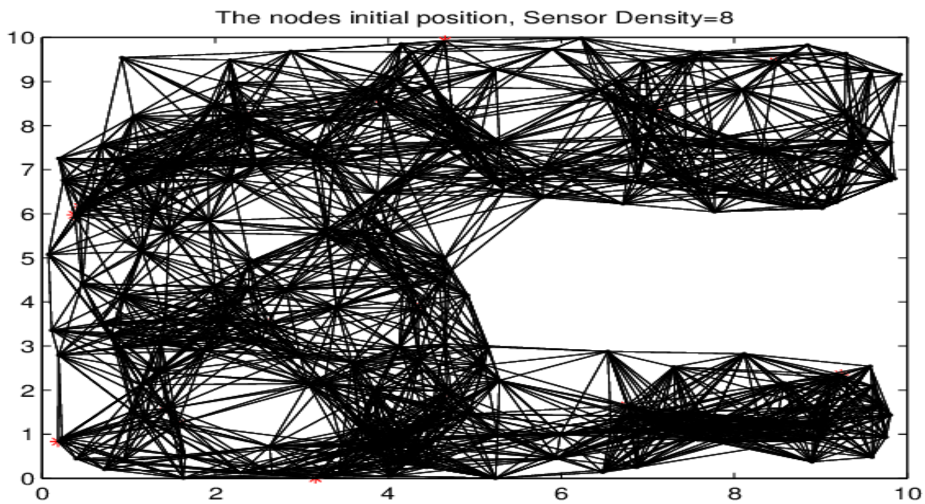

Figure 4.1: C - shape topology

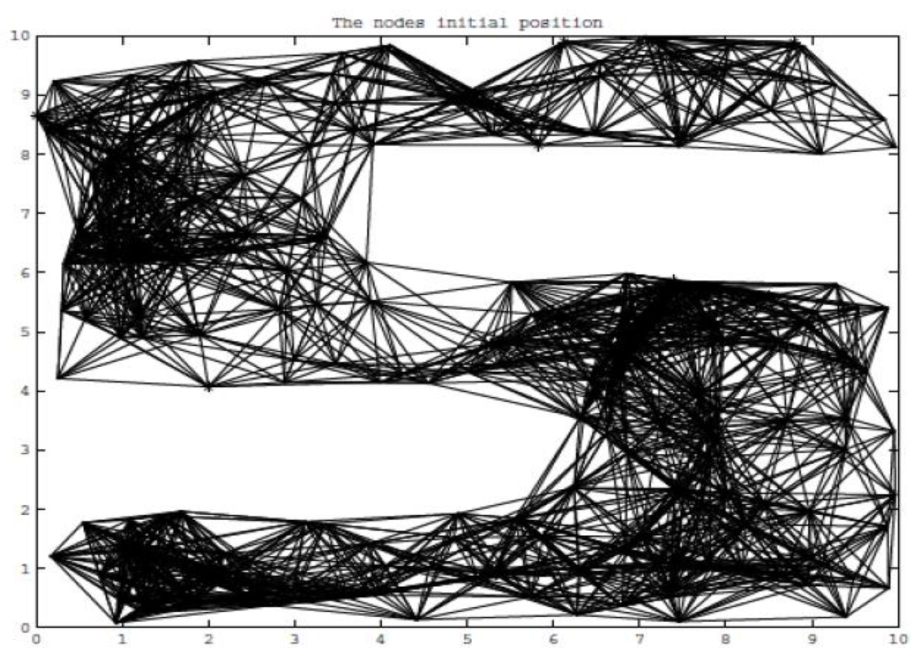

Figure 4.2: S - shape topology

Figure 10 and 11 represent the C-shape topology and S-shape topology respectively. From table (1) we see the area of the topology is 10 × 10m and the sensor density 8. Actually, these types of topologies are useful to compare and stress the various attributes of localization algorithm to prove themselves robust. The node of C-shape and S-shape can connect via a detoured path around the obstacle. Because the distance between Euclidean and calculated hop is large. Nodes are spread irregularly throughout the region. Using a robot spread the sensor nodes an ad hoc arrangement network.

- **Number of Bacon nodes impact on localization:**

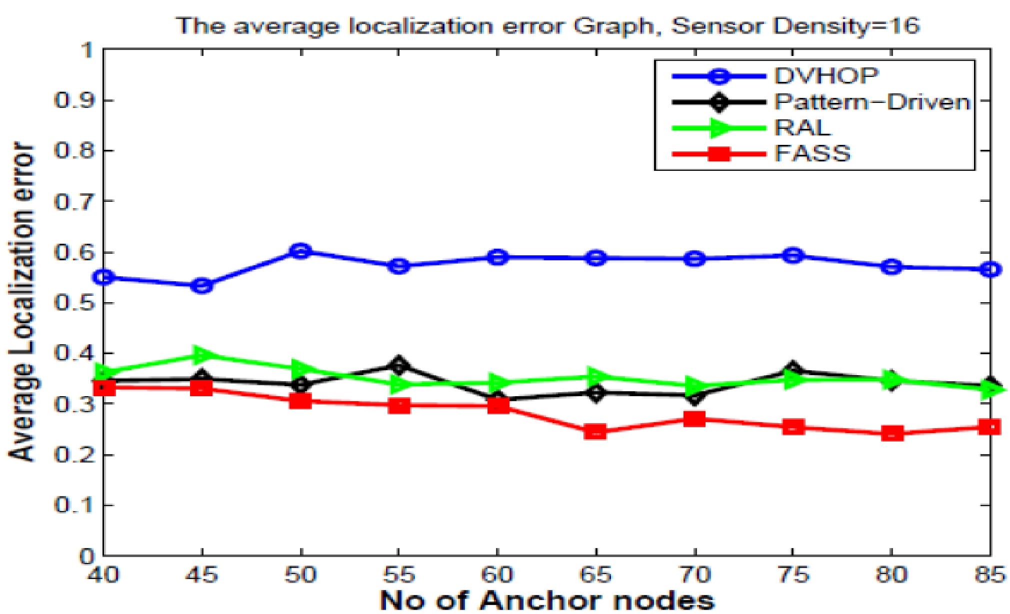

Figure 4.3: Localization error Vs no. of bacon nodes in C - shape network

For the first simulation we took various number of bacon node to look its result on localization. Then we comparing different algorithm at a rough region for the C – shape topology in figure (10). To calculate the position each bacon nodes are used in DV – HOP scheme. It shows high localization error. Even after increase the number of bacon nodes. Because the new added bacon nodes could not ensure the difference between the Euclidean distance and bended shortest transmission path distance is small. That's why the average error of localization fluctuated. But other approaches estimating position with the increasing number of bacon node i.e., FASS, RALL, and pattern driven.

The transmission path among bacon nodes and sensor nodes are terribly curved in S – shape topology. As every node are used to calculate the distance in DV-HOP scheme, so the localization error will be very high for this approach.

- **Density of sensor impact:**

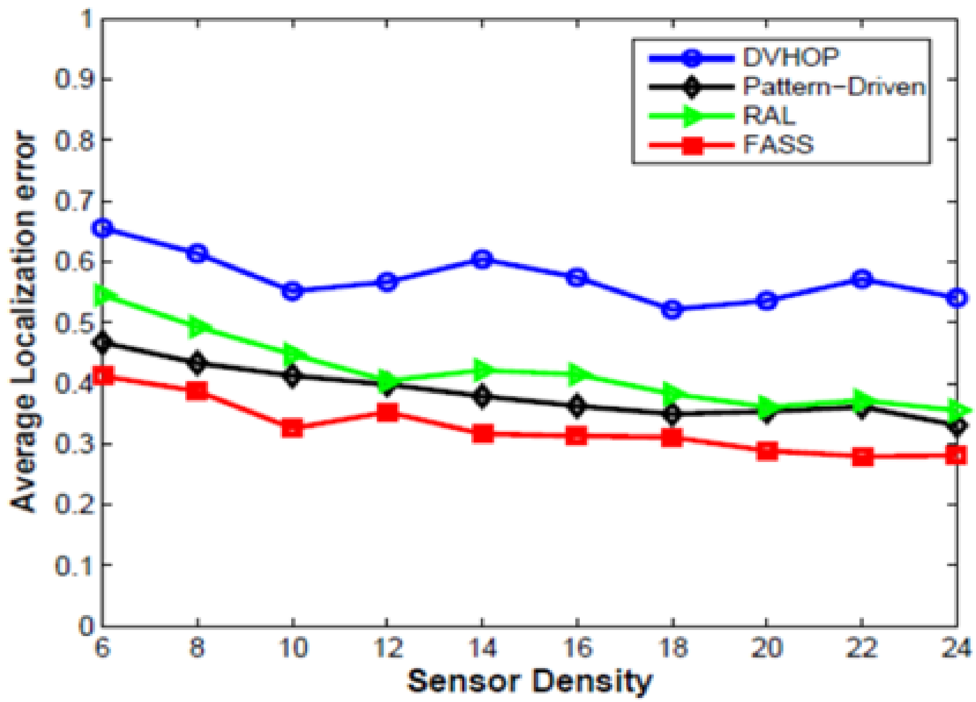

Figure 4.4: Localization error Vs sensor density in C - shape network

For the second simulation, we see what is the impact of density of sensor nodes on localization. From figure (13) and figure (14). Figure (13) for the C – shape anisotropic network and figure (14) for the S – shape anisotropic network. λ = N/(L×L) is defined as the sensor density of the network. Where, N = Total no. of network and L = length of one side of the network area. We can see that the sensor density starts from 6 and end at 24. From the figure (13) we also see that the performance of FASS is better than other approaches at the point 6. But with the increasing of sensor density the performance is decreasing of FASS as well as other approaches. Because with the increasing sensor node density the neighbor one hop nodes also increasing. So, the calculating error increasing in per hop average distance calculating. When the sensor density is low such as 6 or 8 at that time the hop number is large. So, there will be high possibility that the transmission path between to bacon nodes is curved. The transmission path will be almost straight when hop number is less between two bacon nodes. Then the distance calculation will be more correct than before.

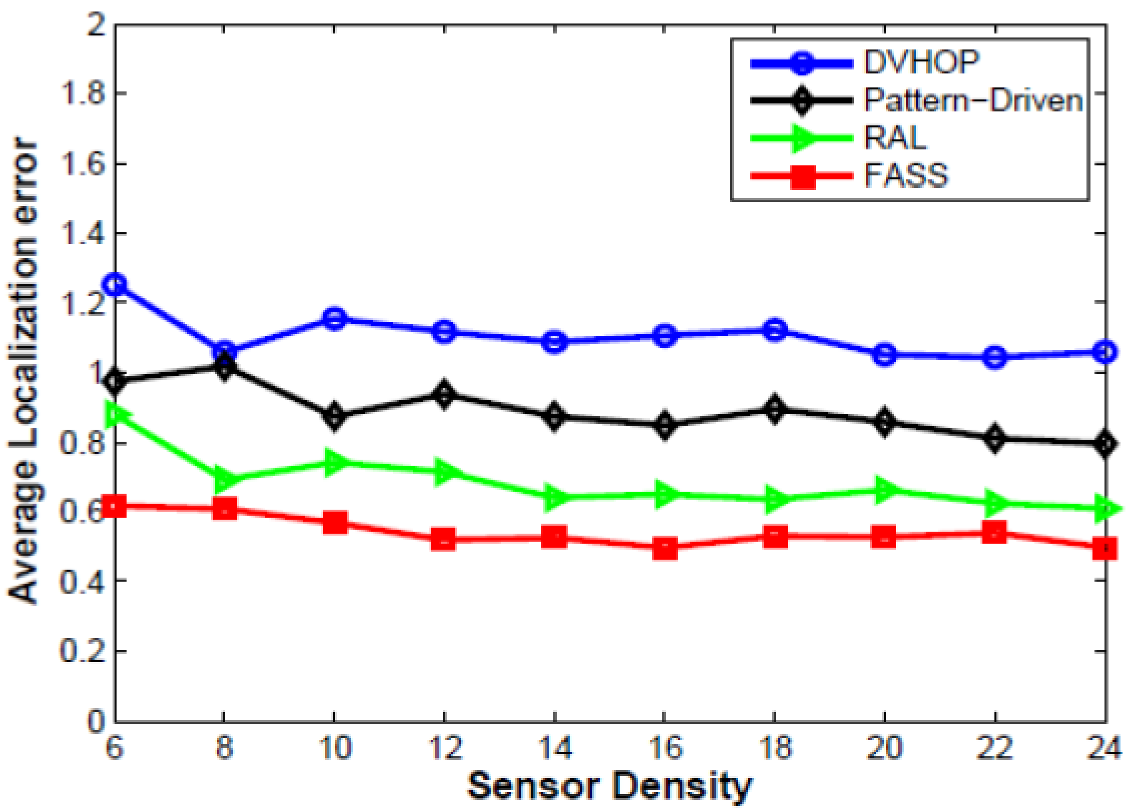

Figure 4.5: Localization error Vs. sensor density for S - shape network

In the range 6-15 the localization remains in a problem in S – shape network. S – shaped network localization deserved more investigation. Lower sensor density represents less possibility of traffic jam, radio interference and low spread cost. From figure (14) we see that the localization error of FASS is 0.6r when sensor density is very low at point 6. Localization error reduce from 0.6r from 0.5r when sensor density increases up to 24.

➢ Varying useful Bacon nodes impact on localization:

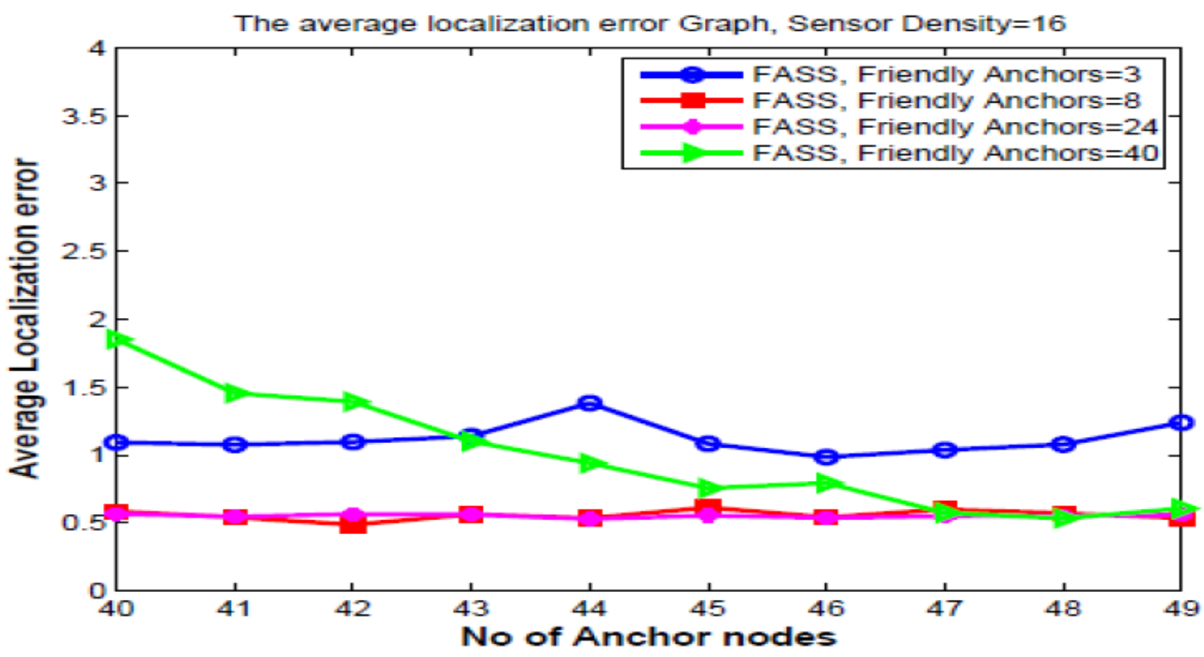

Figure 4.6: Localization error with varying no. of useful bacon nodes

From figure (15) we can see that here compares the performance of FASS by varying number of useful bacon nodes. From the figure we see that there use 3, 8, 24 and 40 useful bacon nodes. We have 40 – 49 bacon nodes to evaluate the performance of FASS. We can use any bacon node from the range. When the total no. of bacon node 40 than the performance of FASS is worse but with the increasing number of bacon node the performance is improve. When the useful bacon node is 3 than the performance in not so good with the comparison of 8 and 24 useful bacon node. The performance of 8 and 24 are almost same. To meet the bad geometry 8 useful bacon nodes are enough. So, from this we can easily said that, it is very important to select enough useful bacon node for localization network.

4.2 Scalability

A localization system scalable that means, when it gets larger scope then it performs equally well. A localization system needs to scaling on two dimensions: geographical scaling and sensor density scaling. When you increase the network area size then it is known as geographical scaling. On the other hand, when you increase the sensor node in a unit area then it is known as sensor density scaling. It's a challenging work to increase sensor density. Because due to wireless signal collision you can loss information. 2D system gives better result than 3D. That's why most of the algorithms of localization are designed for 2D.

4.3 Computational complexity

In terms of software and hardware localization algorithm have complexity. Software complexity represent computational complexity. A software is good or bad that depend on how fast it computes the algorithm. When a computation done in a distributed way then that is a very critical factor. Because sensor battery life short, spent energy for computation. Moreover, analytically represent various localization algorithm computation is really a difficult work for the researches.

4.4 Accuracy Vs Cost effectiveness

Positioning accuracy for different position depend on measurement technique that used for location calculation. For example, accuracy depend on number of bacon node in the network area, for rang free localization. So, if you increase number of bacon node then you get more accurate result. But It increase cost along with increase bacon node.

Chapter 5

Conclusion

5.1 Concluding Remark

Accuracy is the main concern for the localization evaluation. A set of good selection bacon node can play an important role in accuracy increasing. Most of the application of wireless sensor networks need high accuracy. In this paper I try to focused on that matter. The algorithm which is proposed here, it is easy to implement and less costly.

Location information almost used everywhere. Such as: location-based application, data tagging, target tracking etc. So, we can easily understand the importance of Wireless Sensor Networks. And the main task in WSNs is Localization. For estimate localization required anchor node. Bacon node utilize information to compute sensor node position. We already know that anchor node knows own position. So, from here we easily understand the importance of bacon node. But selecting a set of good bacon is not so easy. In this thesis paper has proposed one novel method to identify the useful anchor node. Hope that, the algorithm that proposed here will be worked successfully after implementation and make the range free localization more efficient in wireless sensor networks.

5.2 Future Plan

In future we try to make the algorithm more efficient so that we get more better accuracy with low cost. And we also implement this algorithm in range free localization technique. And also apply different different situation and compare with another algorithm.

Reference

1. M.A. Matin and M.M. Islam, Submitted: May 9th 2012Reviewed: May 10th 2012Published: September 6th 2012
2. M.A. Matin and M.M. Islam, Submitted: May 9th 2012Reviewed: May 10th 2012Published: September 6th 2012
3. K. Johny Elma, Dr. S. Meenakshi, Energy Efficient Clustering for Lifetime Maximization and Routing in WSN
4. K. Johny Elma, Dr. S. Meenakshi, Energy Efficient Clustering for Lifetime Maximization and Routing in WSN
5. S.M.Udhayasankar, V.Vijaya Chamundeeswari and Jeevaa Katiravan, Department of CSE,Velammal Engineering College, Chennai, ANALYSIS AND ELIMINATION OF ATTACKERS IN WSN USING SECURE MULTIPATH ROUTING PROTOCOL
6. Chi-Yu Chang, Yan-Nong Li, Range-Free Localization Scheme in Wireless Sensor Networks Based on Bilateration, First Published January 16, 2013
7. Wei Zhou, Weiren Shi, Peng Gao, Hongde Zhang and Xiaogang Wang, Localization usinga Mobile Beacon in Wireless Sensor Networks, Information Technology Journal

   Year: 2013 | Volume: 12 | Issue: 2 | Page No.: 323-330, DOI: 10.3923/itj.2013.323.330

8. Shoudong Huang Gamini Dissanayake, Robot Localization: An Introduction, First published:15 August 2016
9. Anup Kumar Paul, Takuro Sato, Journal of Sensor and Actuator Networks, Received: 11 September 2017; Accepted: 24 October 2017; Published: 27 October 2017

10. Anup Kumar Paul, Takuro Sato, Journal of Sensor and Actuator Networks, Received: 11 September 2017; Accepted: 24 October 2017; Published: 27 October 2017
11. Guoqiang Mao, Barıs¸ Fidan and Brian D.O. Anderson, Wireless Sensor Network Localization Techniques
12. Guoqiang Mao, Barıs¸ Fidan and Brian D.O. Anderson, Wireless Sensor Network Localization Techniques
13. Anup Kumar Paul, Takuro Sato, Journal of Sensor and Actuator Networks, received: 11 September 2017; Accepted: 24 October 2017; Published: 27 October 2017
14. Guoqiang Mao, Barıs¸ Fidan and Brian D.O. Anderson, Wireless Sensor Network Localization Techniques
15. Elhadi Shakshukia, Abdulrahman Abu Elkhailb, Ibrahim Nemerb, Mumin Adamb, Tarek Sheltamib, Comparative Study on Range Free Localization Algorithms, The 10th International Conference on Ambient Systems, Networks and Technologies (ANT) April 29 - May 2, 2019, Leuven, Belgium
16. Anup Kumar Paul, Takuro Sato, Journal of Sensor and Actuator Networks, received: 11 September 2017; Accepted: 24 October 2017; Published: 27 October 2017
17. Yan Chen ; Xiaohui Li ; Yuemin Ding ; Jinpeng Xu ; An improved DV-hop localization algorithm for wireless sensor networks; Published in: 2018 13th IEEE Conference on Industrial Electronics and Applications (ICIEA).
18. Chao Wang ; Kai Liu ; Nan Xiao; A Range Free Localization Algorithm Based on Restricted-Area for Wireless Sensor Networks; Published in: 2008 The Third International Multi-Conference on Computing in the Global Information Technology (iccgi 2008).

19. Anup Kumar Paul, Yanwei Li and Takuro Sato; A Distributed Range Free Sensor Localization with Friendly Anchor Selection Strategy in Anisotropic Wireless Sensor Network; Vol.4, No.3, pp.96-106, 2012
20. Qingjun Xiao ; Bin Xiao ; Jiannong Cao ; Jianping Wang; Multihop Range-Free Localization in Anisotropic Wireless Sensor Networks: A Pattern-Driven Scheme; Published in: IEEE Transactions on Mobile Computing (Volume: 9 , Issue: 11 , Nov. 2010)
21. Anup Kumar Paul, Takuro Sato, Journal of Sensor and Actuator Networks, Received: 11 September 2017; Accepted: 24 October 2017; Published: 27 October 2017

Figure

1.1 Asside Christia Djedouboum Ado Adamou Abba AriAbdelhak GuerouiAlidou Mohamadou Zibouda Aliouat, Big Data Collection in Large-Scale Wireless Sensor Networks, Received: 24 September 2018; Accepted: 27 October 2018; Published: 18 December 2018

2.1 Xue, D. Research on range-free location algorithm for wireless sensor network based on particle swarm optimization. J Wireless Com Network 2019, 221 (2019).

2.2 Penghong Wang, A Multi-Objective DV-Hop Localization Algorithm Based on NSGA-II in Internet of Things, Published: 01 July 2019 in Journal of Parallel and Distributed Computing,

2.4 Zahid Farid, Rosdiadee Nordin, Mahamod Ismail; Recent Advances in Wireless Indoor Localization Techniques and System; September 2013 Journal of Computer Networks and Communications 2013

2.5 Santar Pal Singha , S. C. Sharmaba, Range Free Localization Techniques in Wireless Sensor Networks: A Review, Electronics and Computer Discipline, DPT, Indian Institute of Technology Roorkee, Roorkee-247667, India

2.6 Anup Kumar Paul, Takuro Sato, Journal of Sensor and Actuator Networks, Received: 11 September 2017; Accepted: 24 October 2017; Published: 27 October 2017

2.7 Elhadi Shakshukia, Abdulrahman Abu Elkhailb, Ibrahim Nemerb, Mumin Adamb, Tarek Sheltamib, Comparative Study on Range Free Localization Algorithms, The 10th International

Conference on Ambient Systems, Networks and Technologies (ANT) April 29 - May 2, 2019, Leuven, Belgium

4.1 Anup Kumar Paul, Takuro Sato, Journal of Sensor and Actuator Networks, Received: 11 September 2017; Accepted: 24 October 2017; Published: 27 October 2017

4.2 Anup Kumar Paul, Takuro Sato, Journal of Sensor and Actuator Networks, Received: 11 September 2017; Accepted: 24 October 2017; Published: 27 October 2017

4.3 Anup Kumar Paul, Takuro Sato, Journal of Sensor and Actuator Networks, Received: 11 September 2017; Accepted: 24 October 2017; Published: 27 October 2017

4.4 Anup Kumar Paul, Takuro Sato, Journal of Sensor and Actuator Networks, Received: 11 September 2017; Accepted: 24 October 2017; Published: 27 October 2017

4.5 Anup Kumar Paul, Takuro Sato, Journal of Sensor and Actuator Networks, Received: 11 September 2017; Accepted: 24 October 2017; Published: 27 October 2017

4.6 Anup Kumar Paul, Takuro Sato, Journal of Sensor and Actuator Networks, Received: 11 September 2017; Accepted: 24 October 2017; Published: 27 October 2017