A Study for Finding Location of Nodes in Wireless Sensor Networks

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***Abstract*— The popularity of Wireless Sensor Network (WSN) has increased tremendously in recent times. WSN has the potential to connect the physical world with the virtual world by forming a network of sensor nodes. Sensor nodes transmit the data to the other nodes present in their range. Localization in radio networks has been an intense area of research for quite some years, for military, civil and sensor networks. To discover the location of neighbour nodes is an important task. Using location information is very beneficial in terms of energy consumption. Location of the nodes can be obtained directly through GPS (Global Positioning System) or by applying mathematical calculations. This paper performs detailed study for the different localization algorithms through which a position of sensor nodes or sink can be calculated.**

Keywords- GPS, Localization, WSN.

I. INTRODUCTION

Wireless Sensor Network (WSN) is made up of small sized sensor nodes which communicate with each other in wireless manner. The sensor node consists of radio, processor, sensors and a battery. They perform variety of functions such as sensing, processing and communication. The nodes in the network are may be static (fixed) or mobile. A sensor node can communicate with any other nodes which are present within its range. There are number of intermediate nodes participate in communication between the source node and the sink node.

Wireless sensor networks are being used tremendously in different scenarios to perform various monitoring tasks such as search, rescue, disaster relief and target tracking. Location of nodes plays an important role in some applications. Location information is used as a building block in routing protocols or data dissemination protocols. There are two cases: First, while monitoring the temperature of a building, it is possible that the exact position of each node in sensor network is known to us. Second, while monitoring the temperature in the remote forest, the location of most sensors may be unknown because sensor nodes may be deployed randomly in ad-hoc manner with the help of airplane. In the second case, an effective localization algorithm can be applied to compute the positions of the sensor nodes.

There are two types of applications. Some needs global coordinate system and others need local coordinate system [1]. However, finding an exact location of sensor nodes is a significant design challenge in WSNs. Manual configuration is impossible and using GPS (Global Positioning System) is also not a feasible solution. It is an expensive method and also not suitable for the applications where satellite signals are not available such as indoors and underground areas. Therefore, other approaches need to be developed and deployed. Researchers perform some significant amount of work to propose different techniques or algorithms to find the location of node in large sensor network without using GPS. The aim of these algorithms is to make a simple, low cost and small size sensor nodes randomly deployed in a given target area and automatically calculate their positions with respect to some reference point..

II. LOCALIZATION PARAMETERS

The Localization is defined as estimating the locations of sensors with initially unknown location information. Location can be estimated by the different techniques. The selection of the best technique is done by comparing various parameters of different schemes. [2] Some important parameters to compare are mentioned as follows:

Accuracy: Some applications like military needs accurate location information. Hence, accuracy is important parameter. Some location estimation techniques do not guarantee the accurate resultant information.

Cost: Cost is very challenging issue in localization schemes of sensor network. Some schemes are very expensive to use but gives accurate result such as GPS based localization. So it depends upon the requirement of application to select appropriate localization scheme.

Power: Power is a limited resource in wireless sensor networks. Power is used in computation process. Therefore, a technique which uses less computation to find the location is better.

Node Density: Some localization algorithms depend upon the node density. Localization scheme based on hop-count requires a network with high node density.

Type of Nodes: Nodes can be static or mobile. Static nodes have identical battery power at the time of deployment. Mobile nodes are assumed to have more battery power in comparison to static nodes.

III. CLASSIFICATION OF LOCALIZATION TECHNIQUES

In WSNs sensor nodes are deployed in an ad-hoc manner. Therefore, there is no information about the location of nodes. Sensor nodes estimate their position in the network by using the scheme known as localization. Use of Global Positioning System (GPS) is the basic solution to find location. But the use of GPS is expensive and works only in outdoor environment. Hence, is not successful in every wireless sensor network. Therefore, nodes need some other means for calculating their positions in the network. There are varieties of location discovery algorithms which are proposed and implemented. Location discovery algorithms are classified according to different ways as:

- Anchor based and Anchor less
- Range based and Range free
- Centralized and Distributed

A. Anchor Based and Anchor Free Localization

Sensors with known location information are called anchors. Anchors locations can be obtained by using Global Positioning System (GPS) or installing anchors at points with known coordinates. Sensors with unknown location information are called non-anchor nodes. Their coordinates will be estimated by the sensor network localization algorithm.

Anchor Based Localization

In an anchor based algorithms, some anchor nodes are placed in the network. These nodes know their position either by using GPS or by manual configuration and helps the other non-anchor nodes to find their position in the network. [3] Anchor nodes broadcast their location information in network and non-anchor nodes use this information to estimate their absolute location. Although the overall cost of anchor based localization is less in comparison to GPS based localization scheme but the cost of each anchor node is still expensive because the accuracy of the calculated location is directly depends upon the number of anchor nodes present in that region. So, more anchor nodes results in the more accurate position information. Also broadcasting the location information of anchor node in the whole network may lead to a network-wide flooding.

Anchor Free Localization

In an anchor free localization schemes, a relative position of the node is calculated in place of absolute position. Reference points are used to find the location of the nodes. In anchor based localization, beacons are used as reference points but in anchor free localization there are no reference points. [4] Hence, deployment points are treated as reference points. Deployment points are those whose coordinates are known. Sensors are arranged into groups and while deploying, a same group of sensors are deployed at the predefined deployment point. After this, nodes need to establish a spatial relationship with these reference points to calculate their own positions. Spatial relationship with reference points (deployment point) is calculated by knowing the number of neighbors from each deployment group.

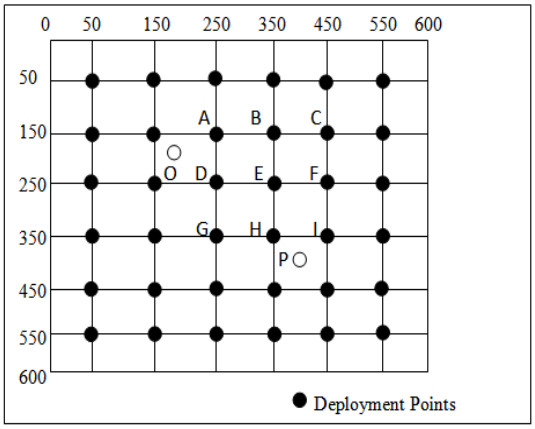

Fig 1. An Example of Group Based Deployment

In Figure 1 deployment points are arranged in a grid like structure and group of nodes are deployed at each deployment points [3]. Sensors will observe neighbors from different groups. A node present at location ‘O’ will have more neighbors from A and D than from I and H. Similarly a node at location ‘P’ will have more neighbors

from I and H than from A and D. Table 1 shows the comparison between anchor based localization and anchor free localization schemes [5].

Table1: Comparison between Anchor Based and Anchor Free Localization

Parameters	Anchor Based	Anchor Free
Accuracy	High	Medium
Hardware Cost	Very High	Very Low
Coordinates	Global	Relative

B. Range Based and Range Free Localization

Algorithms can be classified as either range based or range-free methods of localization.

Range Based Localization

Range methods are used to obtain the information of distance to neighboring nodes. Their basic purpose is to estimate the distance between node pairs and then compute the position of individual nodes in the network. Range-based approaches use Time of Arrival (ToA), Received Signal Strength Indicator (RSSI), Time Difference of Arrival (TDoA) and Angle of Arrival (AoA) to determine the distance and direction of the sensor nodes from the reference points, which is called Beacon Nodes. There are different methods but the simplest one is to need knowledge about the distances of three anchor nodes having known positions and then use triangulation to compute the position. However, there are also more advanced methods which need less assumption. Different ways to estimate inter-node distances are:

a) Angle-of-Arrival (AoA)

AoA used to estimate the angle at which signals are received and then calculate node positions by using simple geometric concepts. It uses antenna array to measure direction of neighbors. Once three landmarks are known position is being calculated. The results obtained using AoA are more accurate than RSSI based techniques. The main drawback is that it is less suitable for terrestrial systems because there is a possibility of error occurred during directions estimation caused by multipath reflections. In this, the cost of hardware is very high.

b) Received Signal Strength Indicator (RSSI)

It requires no additional hardware as all sensor nodes are equipped with radios. By knowing the original transmitted power and comparing it with the received signal power, distance can be calculated. The performance is not so good. The main drawback is Non Line-of- Sight (NLOS) condition. In NLOS, the line of sight between two nodes is obstructed by different means. The propagation of a signal is affected generally due to reflection, diffraction and scattering. However, these effects are environment dependent.

c) Time-of-Arrival (ToA) and Time-Difference-of-Arrival (TDoA)

The distance is calculated directly through the propagation time i.e. recording the time of arrival or time difference of arrival. Propagation time measurements include:

- One way propagation time measurement which measures the difference between sending and receiving time.
- Roundtrip propagation time measurements which measures the difference between the sending time and receiving time of returned signal at the original sensor.
- Time-Difference-of-arrival (TDoA) measurements to estimate the location of the transmitter.

Range Free Methods

A range-free localization method depends on the connectivity of the reference points. [6] This method uses the neighborhood information such as node connectivity and hop count to find the node locations. The connectivity parameters are denoted in the content of received messages. Solutions of this type are well known as beacon less solution. No matter it is a beacon based solution or beacon less solution, Multilateration (ML) techniques is used as a basic procedure in the location discovery process. [7] Range free methods never calculate the distance to the neighbor nodes. To estimate the nodes location, connectivity information is used. They don't require any special hardware hence is cost effective method. It works well in dense environment because nodes are connected in more efficient way and more accurate location is computed.

a) DVHop

In one hop localization, the non anchor node which is to be localized is the one hop neighbor of a sufficient number of anchors. But it is not necessary that the non anchor nodes are the one-hop neighbors of anchors. In this case, range free localization is used which do not depend upon measurement techniques. [8] DVHop is similar to classical distance vector routing. In this an anchor broadcasts a beacon to be flooded in the network. Initially the

hop count parameter is set to one and incremented at every hop. A node receiving a beacon maintains the minimum counter value of all beacons per anchor. Node ignores the beacons having higher hop count value. By this method, a shortest distance to every anchor is calculated. Anchor 'i' converts the hop count value into distance by getting the hop count and location information for all the anchors in the network using following formula:

$$HopSize_i = \sum\sqrt{(x_i-x_j)^2+(y_i-y_j)^2} / \sum h_j$$

Where (x_j,y_j) is the location of anchor j, h_j is the hop distance between from anchor j and anchor i. After calculating the HopSize information is propagated to all nearby nodes. Using triangulation scheme node calculates its location. The more precise location can be calculated by hearing more anchors.

b) Centroid Localization

Each anchor node periodically broadcasts its position in the network. Each sensor node listens to all the beacon signals it receives from anchor node and computes the centroid location as shown in Figure 2. It is simple and easy to implement. The most important requirement is good anchor placement.

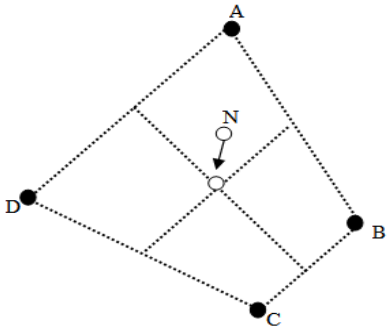

Fig 2. Node N localizes to the centroid of the ABCD quadrilateral.

c) APIT (Approximate Point In Triangulation)

APIT is an area based range free localization scheme for large scale sensor networks. The basic idea of APIT is to divide the environment into triangles using anchor nodes as shown in Figure 3. An individual node's presence or absence in each of those triangles will allow reducing the possible location area. This is repeated until it gets the desired accuracy. Once the area is known APIT computes the centre of gravity to estimate the location of the unknown node. The theoretical method used to narrow down the possible area in which a target node resides is called the Point-In-Triangulation Test (PIT). According to PIT "If no neighbor of M is further from/closer to all three anchors A, B and C simultaneously, M assumes that it is inside triangle ABC. Otherwise, it is outside".

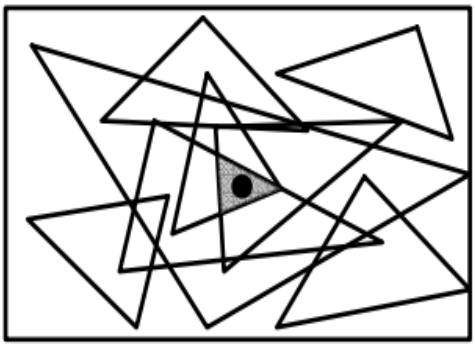

Fig 3. Area Based APIT Overview

Table 2 gives an overview of performance comparison between different range free localization schemes, and for applying these schemes in designing WSN systems it can be used as a guide. Node density is defined as an average number of nodes per node radio area. Average number of Anchors heard by a node and used during estimation is known as anchor heard.

Table 2: Comparison between Range Free Localization Schemes

Parametes	**DVHop**	**Centroid**	**APIT**
Accuracy	Good	Fair	Good
Node Density	>8	>0	>6
Anchor Heard	>8	>10	>10
GPS Error	Good	Good	Good
Overhead	Largest	Smallest	Small

C. Centralized and Distributed Localization

Localization algorithms are classified as centralized and distributed on the basis of the distribution of the calculation process.

Centralized Localization

In the centralized localization scheme, a single processor is used to collect all the data and then global map is computed. There is a central node whose position is known. Sensor nodes send control messages to a central node which computes the location of every sensor node and informs the nodes about their locations. But this requires high computational power and is less scalable. Certain networks are already equipped with centralized information architecture such as: Road traffic monitoring and control, environmental monitoring and health monitoring. In such a network, it is convenient to use a centralized localization scheme. This gives more accurate position information than distributed. Some centralized localization algorithms are as:

a) MDS-MAP

This method is based on multidimensional scaling (MDS). There is no need of anchor nodes to start with. It builds a relative map of the nodes even without anchor nodes and next with three or more anchor nodes. The relative map is transformed into the absolute coordinates when the positions of a sufficient number of anchor nodes are known. This method works well where the ratio of anchor nodes is less. A main drawback of this scheme is the requirement of global information of the network and centralized computation.

b) Localize node based on Simulated Annealing

This method use the simulated annealing to localize the nodes in a network. This algorithm does not propagate error in localization. It works in two steps. In the first step an estimated location is obtained using distance constraints with the help of simulated annealing. In the second step error is eliminated caused by flip ambiguity. Flip ambiguity occurs when a node's neighbors are placed in positions such that they are approximately on the same line, this node can be reflected across the line of best fit produced by its neighbors with essentially no change in the cost function.

c) A RSSI-based centralized localization technique

In this technique nodes are localized through RF attenuation in electromagnetic waves. It works in three steps such as RF mapping of the network, creation of ranging model and then localization model to provide the position to the node. This is a practical scheme and use for any outdoor environments. But a main drawback of using this technique is that it is a power consuming scheme because it forwards information to the central unit.

Distributed Localization

In the distributed localization scheme, each sensor node determines its own location independently. This concept relies on the self-localization of each node using the distance that node measures and the local information it collects from its neighbors. It does not require global knowledge. [9] Different algorithms fall under the distributed scheme which is given by the researchers. It also has some drawbacks such as large number of anchor nodes are needed to compute the location and the resulting location are not so accurate. It also has some characteristics such as less traffic, good scalability, less storage requirements and each node has equal burden of location calculation.

a) Beacon-based distributed algorithms

Beacon-based distributed algorithms use few beacons in the network to compute the location of the nodes. Beacon nodes know their position and other nodes use location information of beacon nodes to calculate their own position. This algorithm is further categorized into three parts as Diffusion, APIT, Bounding Box and Gradient.

b) Relaxation-based distributed algorithms

Relaxation-based distributed algorithms roughly estimate the position of node within the network. [10] This is followed by a refinement step, in which the initial position of nodes is refined by neighbor nodes estimated

position. These are fully distributed algorithms and use without anchor nodes. The limitation of this approach is that its performance degrades in case of more scalability.

c) Coordinate system stitching based distributed algorithms

This scheme is based in cluster approach. In this, the network is divided into small sub regions which may overlap. It works in two steps. In first step cluster localization is performed in which every node calculates the relative position of its neighbor nodes. in second step cluster transformation is performed in which position of nodes merges to form the local coordinate.

d) Hybrid localization algorithms

Hybrid localization schemes can be a combination of two or more techniques. One approach is to combine the two different localization methods such as: MDS and Ad-hoc Positioning System (APS) or multidimensional scaling (MDS) and proximity based map (PDM) to reduce the computation and communication cost. This scheme does not perform well in case of few anchor nodes.

e) Error propagation aware localization

When sensors communicate with each other, error propagation can be caused due to the undesirable wireless environment, such as channel fading and noise corruption. To reduce the error rate, error propagation aware (EPA) localization scheme is proposed which combines the path loss and distance measurement error model.

Table 3: Comparison between Centralized and Distributed Localization

Parameters	Centralized Localization	Distributed Localization
Accuracy	75-80% accurate	75-90% accurate
Hardware Requirement	No need of special hardware	Requires special hardware
Power Consumption	Consumes more power	Consumes less power
Deployment and Maintainability	Difficult to deploy and maintain	Easy to deploy and maintain
Communication Cost	High	Less
Robustness	Weak	Robust

The comparison between centralized localization and distributed localization on the basis of different metrics is shown in Table 3.

IV. RANGE COMBINING METHODS

The localization process has two steps: distance estimation and position calculation. This paper discussed the different methods for distance estimation such as Angle of Arrival (AoA), Time of Arrival (ToA), Time Difference of Arrival (TDoA) and Received Signal Strength Indicator (RSSI). [11] [12] Once the localization algorithm estimates the distance, node location can be calculated by using: Trilateration, Triangulation and Multilateration.

Trilateration: This is the basic method to locate a node by calculating the intersection of three circles. If the intersection point of three circles is not same then it may contain error. Figure 4 shows the trilateration technique.

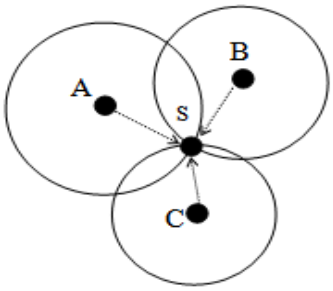

Fig 4. Trilateration technique

Triangulation: This method is used when the angle of the node is known instead of distance information. This happens in when Angle of Arrival is used. Trigonometric laws (sines and cosines) are used for calculating node position. Figure 5 shows the triangulation technique.

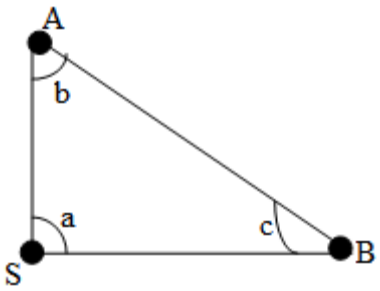

Fig 5. Triangulation Technique

Multilateration: This method is used for position estimation of a node that has three or more reference neighbors by minimizing the differences between estimated and actual position. Figure 6 shows the multilaterative technique. Multilateration techniques are further classified as: Atomic multilateration, Iterative multilateration and Collaborative multilateration.

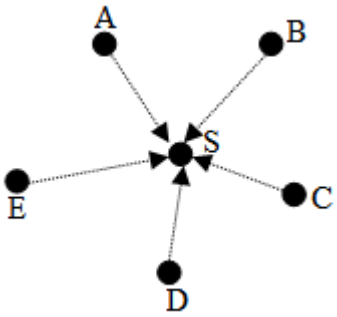

Fig 6. Multilateration Technique

CONCLUSION

In this paper, Sensor nodes are deployed in a network without any planned infrastructure. In order to reduce the energy consumption of nodes it is necessary to know the location information of the destination node. Localization is an important issue in wireless sensor networks. This paper concludes the variety of localization methods to find the nodes location. The paper serves as an overview in the field of localization methods in WSNs for the newcomers. GPS based localization is expensive so is replaced by the anchor based localization schemes but to reduce the cost of anchor nodes, a new scheme is introduced known as anchor free localization. All the mentioned localization schemes have their own benefits and drawbacks, making them suitable for different scenarios.

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