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Range Free Localization Techniques in Wireless Sensor Networks: A Review

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Abstract

Recent developments in micro electro mechanical systems (MEMS) technology and wireless communication have propelled the growing applications of wireless sensor networks (WSNs). Wireless sensor network is comprised of large number of small and cheap devices known as sensors. One of the important functions of sensor network is collection and forwarding of data. In most of the applications, it is of much interest to find out the location of the data. This type of information can be obtained by use of localization techniques. So node localization is very crucial to find out the position of node with the help of localization algorithms. Hence, node localization becomes one of the fundamental challenges in WSNs. We make the rigorous reviews on different schemes of localization in sensor networks. On the basis of range measurements, the localization schemes can be broadly classified in two categories such as: range based and range free schemes. The cost and hardware limitation on sensing node preclude the use of range based localization schemes. In most of the sensor network application coarse accuracy is sufficient so range free localization schemes are considered as a substitute to range based schemes. In this paper, the detailed study has been carried out to understand and select the best range free localization algorithm for WSNs. At the end some issues are discussed for future research in the area of localization techniques for WSNs.

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Keywords: wireless sensor networks; range free localization; localization algorithms; range; accuracy.

1. Introduction

Recent advances in MEMS-based sensor and wireless communication technology have enabled the growth of comparatively economical and low power sensors. The general goal is to make wireless sensor network that is capable to sense the surroundings, compute some task and communicate with each other to attain some objective like monitoring some phenomenon, target tracking, forest fire detection, and battlefield surveillance [1]. In the majority of the applications, location information of each node in the network is needed. However, in a large amount of cases, sensor nodes are deployed randomly right through some region. Thus, the first task is to find out the location of the nodes. To find out the physical location of sensor node in WSN operation is crucial problem because of its use in (i) identification of the origin of sensor reading, (ii) energy aware

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geographic routing, (iii) self organization and self configuration of networks. Apart from the above, in various applications the location itself is information of interest [2]. There is one easy way i.e. manual configuration but this is impractical in large scale deployment. Simple wireless sensor network is shown in figure 1.

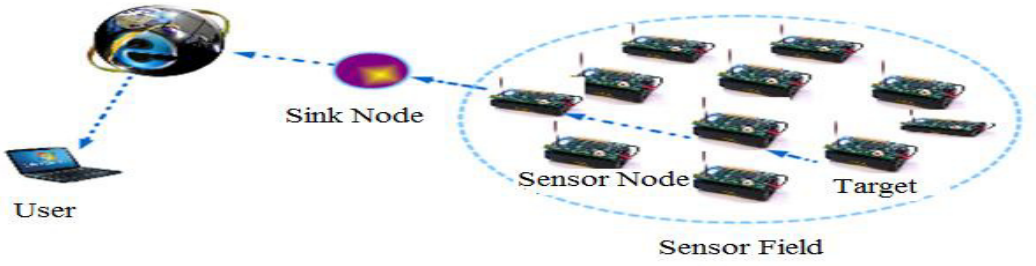

Figure 1. Wireless Sensor Network (Source: [29])

The other possible way for node localization is to add Global Positioning System (GPS) to sensor node [3]. However, adding a GPS receiver to each node is not viable solution because of its large power consumption, high cost, and imprecision [3], [4]. In the literature, numbers of localization system and algorithms for sensor network have been reported, which are broadly classified into range based and range free schemes on the basis of location estimation mechanism. The range based schemes are defined by protocols that use absolute distance estimates for the location computation. The range free schemes make no assumptions about the accessibility or legality of such information [5]. Due to hardware restrictions of sensors, solutions in range free schemes are being considered as cost effective substitute to the most expensive range based schemes. The taxonomy of the localization algorithms based on several distinct criteria such as: dependency of range measurements; computational model; anchor. In this paper various range free localization algorithms have been discussed. The rest of the paper is organized as follows. Section 2, describe the overview of localization process. Section 3, describe the classification of localization techniques. In Section 4, comparative study of localization schemes is discussed. Some issues need to be addressed are discussed in Section 5 and Section 6 conclude the paper.

2. Localization Process

The problem of sensor localization is to find out the location of all or subset of sensor nodes. Localization process localizes the sensor nodes based on input data. If there is any anchor available in the network, the common inputs are the location of anchors while other inputs are based on the measurement techniques. The overview of localization process [6] shown in figure 2.

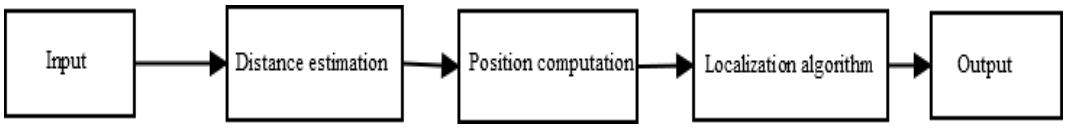

Figure 2. Overview of Localization Process

Localization process localizes the nodes on the basis of input data [7]. If any anchor available in the network, the common inputs are the locations of anchors. Other inputs are connectivity information for range free techniques and distance or angle between nodes for range based techniques. The flow sheet of a localization process is shown in figure 3.

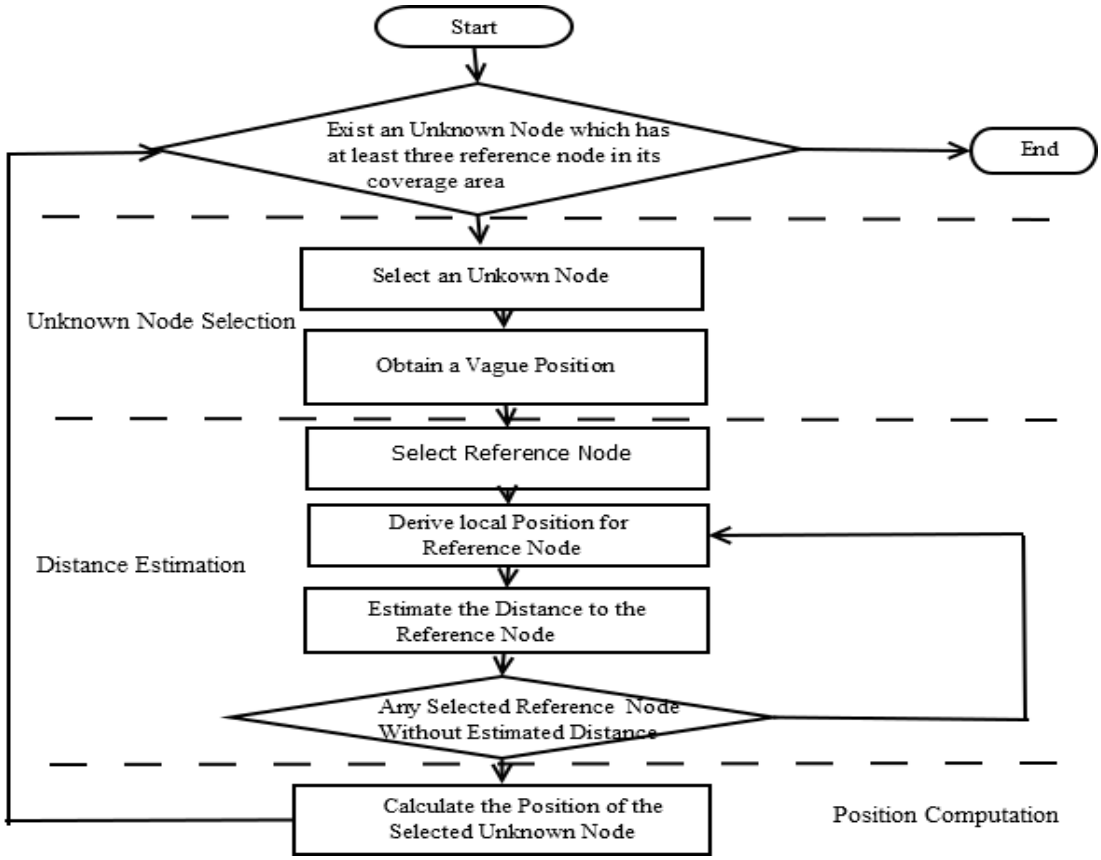

Figure 3. Flow sheet of localization process

3. Classification of Localization Techniques

There are different possibilities how to divide the computation between sensor nodes and how to choose the localization algorithms. On the basis of computation model [8], the localization techniques can be broadly categorized into centralized and decentralized or distributed techniques. The taxonomy of the localization techniques is shown in figure 4.

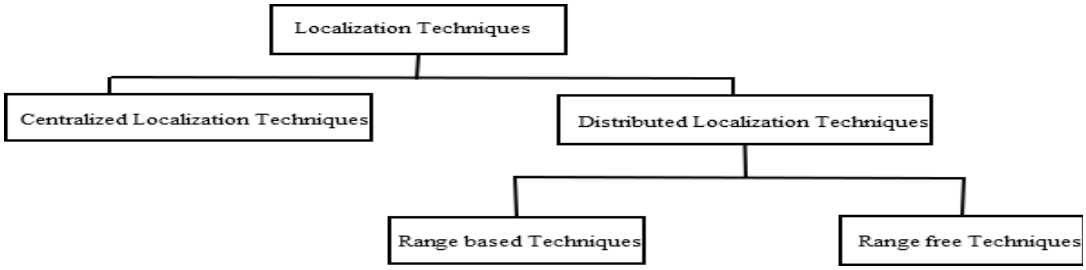

Figure 4. Taxonomy of localization techniques

3.1. Centralized Localization Techniques

In the centralized localization [9], [10], [11], all the measurements are collected at central base station (BS), where the computation takes place. After that the results are forwarded back to the nodes. The data transmission in the network causes latency, more consumption of energy and bandwidth [12]. The benefits of this technique are that they eliminate the problem of computation in every node. The drawback of this scheme is lack of ability to access data in proper way as well as inadequate scaling. It is more accessible for small scale networks. Because of existence of global information, it is more accurate than other algorithm. The popular centralized localizations algorithms are: Multi Dimensional Scaling-Mobile Assisted Programming (MDS-MAP), Semi Definite Programming (SDP), Simulated Annealing based Localization (LBSA).

3.2. Distributed Localization Techniques

In distributed localization [13],[14],[15],[16], sensor nodes perform the required computation themselves and communicate with each other to get their own location in network. On the basis of range measurements, the distributed localization can be categorized into range based and range free localization techniques. The broad classification of distributed localization techniques is shown in figure 4.

3.2.1. Range Based Localization Techniques

The range based techniques required distance (or angle) between nodes for estimating the positions. Range based techniques compute the precise distance between transmitting and receiving nodes on the the basis of distance estimation methods [17],[18],[19]. Thus these techniques contains diverse distance estimation methods to compute the inter node distance or range to measure their locality and then to calculate the position with help of some principles of geometry.

3.2.2. Range Free Localization Techniques

In this section, the range free localization techniques [20],[21],[22] have been discussed deeply. In range free schemes, special hardware for distance estimation are not used. So its low cost and simplicity in estimation of distance have attracted the attention of people in recent years. The taxonomy of range free schemes is shown in figure 5.

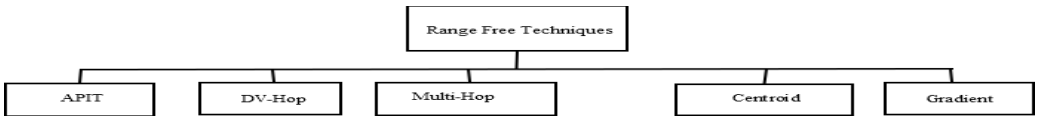

Figure 5. Taxonomy of range free localization techniques

3.2.2.1. Approximate Point in Triangle (APIT)

APIT is an area based range free scheme which assumes that some of nodes those are aware of their positions outfitted with high powered transmitters. APIT [20] is located in area to carry out position estimation by separating the area into triangular zones between anchors. Each node's presence inside or outside the triangle regions allows declining the viable location until and unless every possible sets have reached to an acceptable accuracy. The flowchart representation of APIT algorithm is shown in figure 6.

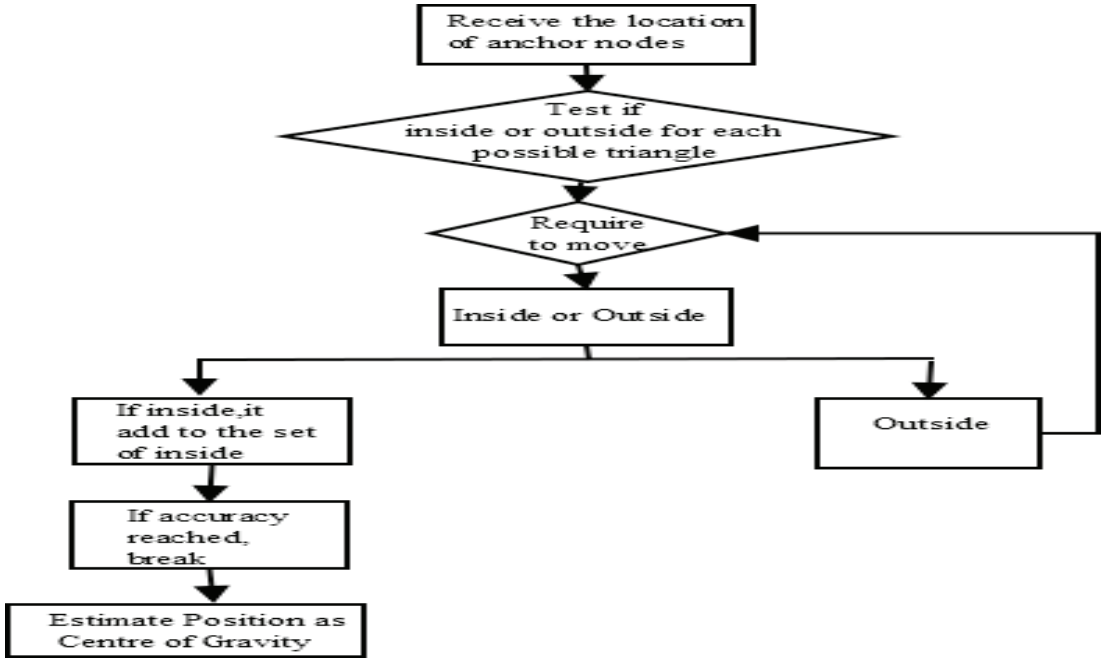

Figure 6. Flow sheet of APIT Algorithm

3.2.2.2. DV-Hop

DV-Hop localization [20] uses a mechanism similar to the classical distance vector routing method. One anchor node broadcasts a message which contains the anchors' positions with hop count. Each receiving node keeps the minimum value, which it receives. After that it ignores the other message with higher values [26]. Messages broadcasted out with hop count values incremented at every middle hop. In this scheme, all nodes in the network and other anchors obtain the shortest distance in hops. The overall single hop distance in anchor i can be computed with the following equation:

$$Hop\ Size_i = \frac{\sum \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{\sum h_j}$$

Where anchor j is at location (x_i, y_j) and h_j is the distance in hops from j to i. anchors propagate the estimated hop size to the closest nodes. The triangulation is used location estimation of unknown nodes. In this algorithm for 2 Dimensional deployment of network, minimum 3 anchor's locations are used.

3.2.2.3. Multi-Hop

Multi Hop techniques are able to compute a connectivity graph. The multi dimensional scaling (MDS) uses connectivity information considering the nodes are within the communication range. This scheme has three steps [23] as follows:

- In the first step, the distance estimation between each viable pair of nodes is done.
- In the second step, MDS is used for deriving the locations to fit the estimated distance.
- Finally, in the last step, optimization is done by putting the known locations into account.

In large scale sensor networks, there are several kind of MDS methods are used such as metric, non metric, classical, weighted. The multi hop based multilateration process allows multi hop nodes to collaborate in finding better position estimates.

3.2.2.4. Centroid

Centroid scheme uses proximity based grained localization algorithm. In centroid localization algorithm [24], node's location is computed on the basis of several reference node positions. The centroid localization algorithm uses the location (x_i , y_i) of anchor nodes (reference node). After receiving the information, unknown node estimate their position by using following formula:

$$(X_{est} , Y_{est}) = \left(\frac{X_1 + \cdots + X_N}{N} , \frac{Y_1 + \cdots + Y_N}{N} \right)$$

Where (X_{est} , Y_{est}) indicate the estimation of position of sensor node and N is the number of anchor nodes. The task of centroid algorithm is to take a number of nodes around the unknown nodes as shown in figure 7.

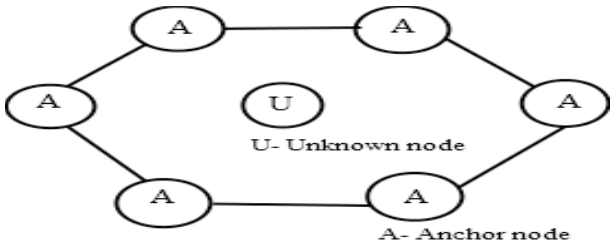

Figure 7. Centroid Algorithm

3.2.2.5. Gradient

In gradient algorithm, unknown nodes obtain their locations through multilateration. It also uses hop count which is initially set to zero and incremented as it propagates to other nearby nodes. Gradient algorithm follows certain steps such as the following:

- In the first step, anchor nodes broadcasts a message containing its coordinated and hop count value.

- In the second step, unknown node determines the shortest path between itself and anchor node from which it receives beacon message [25], [27]. The estimated distance can be calculated by following equation:

$$d_{ji} = h_{j,Ai}\, d_{hop}$$

- In the third step, minimum error in which node calculates its coordinate is computed by following equation:

$$E_j = \sum_{i=1}^{n} d_{ji} - d^{ji}$$

Where d^{ji} is gradient propagation based estimated distance.

4. Comparison

The performance of localization algorithm depend on various factors such as accuracy, communication and computation cost, coverage information, computational model, node density, and scalability. The localization schemes can be classified on the basis of certain measures such as: presence of anchor, computational model, presence of GPS, and range measurements [28], [30]. All localization techniques have their own merits and limitations, making them suitable for different applications. In this paper, we have performed comprehensive review on various localization techniques and compare them. After that we summarized then comparison in tabular form. The comparison between centralized and distributed localization is summarized in table 1. However, the summary of comparison between range based and range free schemes is shown in table 2. After that we focused on various range free localization techniques. The comparison of various range free localization schemes is summarized in table 3.

Table 1. Summary of comparison between centralized and distributed localization techniques

	Centralized Techniques	Distributed Techniques
Cost	More	Less
Power Consumption	More	Less
Accuracy	70-75%	75-90%
Dependency on additional hardware	No	Yes
Deployability	Hard	Easy

Table 2. Summary of comparison between range based and range free localization techniques

	Range based Techniques	Range free Techniques
Cost	More	Less
Power Consumption	More	Less
Accuracy	85-90%	70-75%
Dependency on additional hardware	Yes	No
Deployability	Hard	Easy

Table 3. Performance summary of popular range free localization techniques

Technique	Node density	Cost	Accuracy	Overhead	Scalability
APIT	>16	Low	Good	Small	Yes
DV-Hop	>8	Medium	Good	Largest	No
Multi-Hop	>12	High	Good	Large	No
Centroid	>0	Low	Fair	Smallest	Yes
Gradient	>6	Low	Average	Large	Yes

5. Issues in Localization Techniques

Sensor network localization is an active research area and has numerous issues so still has a lot of scope for research community. Some of the issues need to be addressed are:

- *Cost effective algorithms:* During the design of localization algorithm, designer must keep in mind the cost incurred in hardware and deployment. GPS is not suitable because of its cost and size of hardware.

- *Robust algorithms for mobile sensor networks:* Mobile sensors are much useful in some environments because of mobility and coverage facility. Hence, development of new algorithms is needed to accommodate these mobile nodes.

- *Algorithms for 3 Dimensional spaces:* For many WSN applications, accurate location information is crucial. The more of the proposed algorithms are applicable to 2D space. some of the application needs 3 D positioning of WSNs.

- *Accuracy:* If there is incorrect estimation of node position, then localization accuracy is compromised. Designer must keep in mind that accuracy is very much important factor in sensor localization.

- *Scalability:* In large scale deployment, it is generally desirable to enlarge the monitoring area amid nodes. So careful observations are required to check the scalability of localization techniques.

6. Conclusion

Wireless sensor network localization has gain lot of attention of research community. This concern is expected to grow further with the proliferation in sensor network applications. This paper had provided a review of various range free localization techniques and their corresponding localization algorithms for sensor network. In this paper, the taxonomy of localization techniques has been discussed. In this work, we compare the different localization techniques and represent that comparison in tabular form. This paper reported the classification of distributed localization algorithms on the basis of range measurements. Among all studied schemes, this comparative analysis done by us to conclude that each algorithm has its own features and none is absolutely best. On the whole, the range based techniques are either expensive or susceptible to network dynamics. However, the range free techniques are imprecise and easily affected by node density. Regardless of significant research development in this area, some unsolved problems are still there. At the end, we focused on the certain issues need to be addressed. This paper is very useful for the research group those are interested in development, modification and optimization of localization algorithms for wireless sensor networks.

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