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A Comparative Approach for Localization Techniques in Wireless Sensor Networks

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Abstract: Localization of sensor nodes in wireless sensor nodes plays an important role in many applications. It is important to monitor the location of the data source and event occurrences to track the target and phenomena. This paper provides different kind of localization techniques and their properties. We have also done a comparative study to filter out the better algorithms. Each algorithm's advantages and drawbacks have been highlighted.

Keywords- *Localization, Sensor Nodes, One-hop localization, Hybrid Localization, Centralized Algorithms.*

1. Introduction

A Wireless Sensor Network is a collection of many tiny sensing and wireless communication device called sensor nodes. Each node consists of a processor, a battery and a transceiver for communication [4]. Nodes are connected to each other via transceiver. Wireless Sensor Network consists of one node, called base station which collects sensory information from other nodes in the network and transfers the information to the Computer. They perform specific tasks of sensing some physical phenomena. They are smart, cheaper and deployed in large numbers help in controlling and monitoring the surroundings [1].

There is a wide range of WSNs applications in large number of civil and military needs [2]. There are some civilian applications like environmental habitats, community areas, and smart homes. WSNs are used for surveillance of armed troops and for their tracking, detection of targets [2]. This has also been widely used in smart disaster & relief, search and rescue [5]. The performance of WSNs is quite dependent on how the sensor nodes are located within the network [3].

Fig. 1 A Wireless Sensor

There are different kinds of sensors which can monitor different ambient condition like lightening, pressure, vehicular movement, sound levels, humidity, and availability of certain object [7][8].

2. Localization

The Localization has been a fundamental problem in Wireless sensor networks as the nodes should have the knowledge of the positions of sensors.

Prior information of location enables nodes in a WSN to annotate data with location information. So, the knowledge of location can help to implement feasible message-routing protocols in WSN and Wireless ad-hoc networks [6]. Localization has been categorised into different techniques as shown in fig. 2:

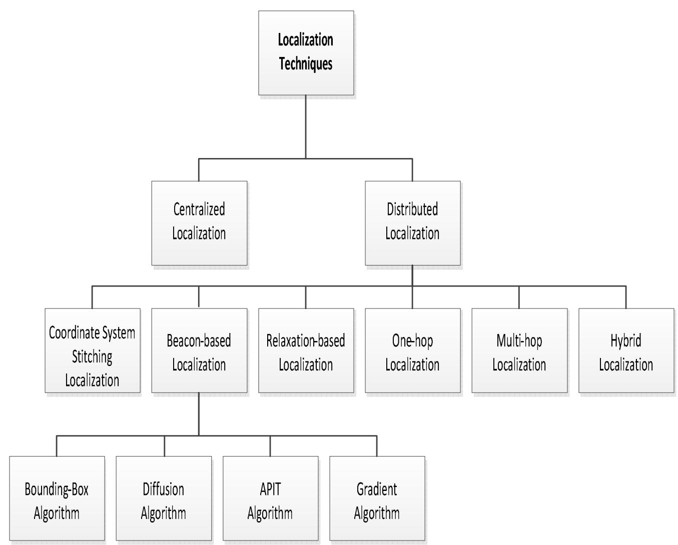

Fig. 2 Different Localization techniques proposed

2.1 CENTRALIZED LOCALIZATION TECHNIQUES

In centralized algorithms, there is a central processor which collects the information from each sensor node. This approach tries to obtain maximum accuracy [1]. Centralization requires the migration of the related node connectivity data and ranging to a centralised base station and then the migration of respective locations return to the related nodes [17]. Centralized algorithms are quite complex with respect to computation [1]. The advantage of centralized algorithms are that it reduces the problem of computation in each node, at the same time the there are certain limitations in the cost of communication of getting data back to the base station [18]. Transmission of data from the sensor nodes to a central base station is very expensive because of limited power supply for each node. Eventually, transmitting time series data within the sensor network results in latency and which also uses energy and bandwidth [19].

Semidefinite programming (SDP) localization algorithm was proposed by Doherty et al [16] in which geometric constraints between sensor nodes are shown in the form of linear matrix inequalities (LMI). In a network, when all the geometric constraints are represented in same manner, the LMIs are added to develop one semidefinite program, which is used to produce a bounding region for every node. This is also called as bounding box. The advantage of this algorithm is that It finds the intersection of the geometric constraints, but some drawback include the inability to access range data in better way and insufficient scaling [17].

In [20], an approach was given based on Simulated Annealing which helps in localizing the sensor nodes in a centralized way. It gets all the information about.

In MDS-MAP centralization algorithm which was developed by Shang et al [15], multidimensional scaling is used for this approach. MDS is an $O(n^3)$ algorithm which reform the relative positions of the sensor node's points using Law of Cosine and linear algebra [17]. This algorithm works on three steps which are as follows:-

Step 1: First of all, we collect data from the network and construct distance matrix by implementing the shortest path computed with the help of Dijkstra's algorithm.

Step 2: We can run classical MDS to compute estimated location for each node.

Step 3: Now transform the relative position map into absolute position map and which help in reducing the error between the correct position and absolute position of each node. MDS-MAP location estimates produce better with the ranges get better [17]. Some disadvantages lies with MDS-MAP is that it all the information about the network and centralized conditions.

the neighbour sensor nodes and accesses the computed locations. It has been described with two steps. In the first step, simulated annealing is used to achieve the location estimate of the sensor nodes with the help of distance constraints. In the second step, some errors are removed with the help of flip ambiguity.

This algorithm provides better accuracy compared to semi-definite programming localization technique.

2.2 Distributed Localization Techniques

This In Distributed localization technique, they do not require a large centralized computer and this technique gives better scalability [17]. In Decentralized or distributed localization techniques, each sensor node gives limited communication with the closer sensor nodes to get the location information [19]. All required computations take place in the sensor nodes themselves and the sensor nodes communicate between one another to get their exact position within the network [18].

A. COORDINATE SYSTEM STITCHING

It is a type of distributed localization technique which is based on Cluster based approach proposed by [21], is used in locating the sensor nodes within the network wherein the node can compute the distance to closer nodes. This algorithm has two stages. Stage 1 is called cluster localization where every node is treated as a centre of the cluster and it calculates the relative position of its neighbour nodes which could be localized in an ad-hoc manner. In the second stage, which is called cluster transformation, the each node's position is overlapped and shared on the local coordinate. It has some advantage in the form of node mobility and insertion of node dynamically [18].

B. BEACON-BASED DISTRIBUTED ALGORITHMS

In this algorithm, an unknown node positions can be estimated using beacon positions. All the required computation can be completed on the relevant sensor nodes themselves in these algorithms. The nodes can be localized into the beacons area [17]. Beacon-based algorithms can be categorized into four approaches: Bounding box, diffusion, APIT and gradient.

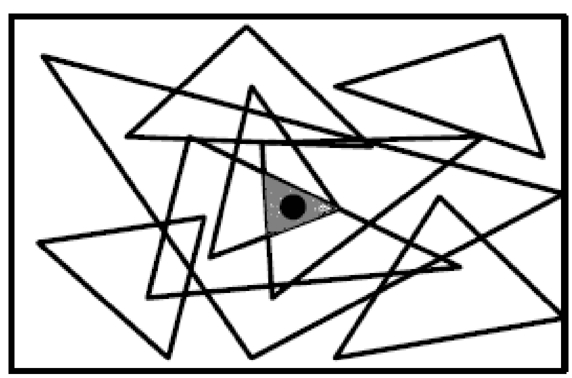

Fig. 3 APIT Technique

1. *Gradient algorithm:* In the Gradient algorithm [24], sensor nodes are randomly scattered in a two dimensional area where every sensor node communicate with the nearest node within some

distance which should not be more than dimension of the plane. The gradient based distance estimates from a beacon are often longer than or equal to the linear distances [17]. This algorithm is divided into two parts: Gradient algorithm and Multilateration algorithm. The advantage of this algorithm that it is scalable whenever needs to add extra sensor or removal of sensors. But, there should be sufficient number of nodes to get the better accuracy [18].

2. *The Bounding Box algorithm:* This algorithm is a method [22] where nodes can be localized within the range of many beacons. It creates a bounding region for each node and then it starts filter their right positions. The collaborative multilateration helps nodes get their location estimate appropriately through identified beacon positions which are hops away [18]. When the node's position is closer to the centre of the beacon nodes, Bounding box algorithm gives accurate results.
3. *Diffusion algorithm:* In diffusion the most likely position of the node is at the centroid of its neighbouring known nodes. Bulusu et al [23] propose the localization of the unknown nodes by getting the average positions of all beacon nodes with which the node is having radio connectivity. The advantage of diffusion algorithm is in the networks where nodes need to do less computation [17].
4. *APIT algorithm:* The APIT algorithm uses a novel area-based approach where nodes can hear huge number of beacons. An unknown node forms a triangle by connecting three beacons. This test is repeated until it gets the required accuracy. At the same moment, APIT computes the centre of gravity of all the triangles to estimate the location of the unknown node. The advantage of APIT is that it is very simple in computation and easy to implement. But, it needs large number of beacons to get accurate result [18].

C. RELAXATION-BASED DISTRIBUTED LOCALIZATION ALGORITHM

It is used to roughly estimate the location within the network. The initial position of the sensor nodes is refined against their neighbouring node's estimate positions. Then, each node changes its position to get the approximate result [17]. In [25], the author has proposed an algorithm which is also called s spring Model where the edges between nodes are called springs and the resting lengths are the actual calculated distance. The nodes adjust their position towards the direction of forces. If the nodes are having zero spring forces applying on them, then the optimization stops. The advantage of Relaxation algorithms are they are fully distributed and can be operated without use of beacons. But, it could not perform well in case of more scalability [17].

D. ONE-HOP LOCALIZATION TECHNIQUES

One-hop localization is a technique where in the non-anchor node which is supposed to be the one-hop nearby from the certain numbers of anchors [9]. In one-hop localization techniques, every blind node should be within the range of its reference node [1]. One-hop localization can be achieved by different techniques which are as follows:- One-hop localization technique can also be achieved by Lighthouse approach in which a base station contains three optical beams which are mutually perpendicular and parallel to one another and which helps in locating optical receivers which comes under the range and line of sight of the optical beams [9]. Ni *et al.* presented strong points on the RSS profiling approach on localization technique which gives a better estimation of the location. In Ni et al.'s weighted version of the RSS-profiling based localization algorithm, the estimation of location for the non-anchor point is shown by:

$$\widehat{X_t} = \sum_{i=1}^{N} \frac{\frac{1}{||\gamma-\beta_i||^2}}{\sum_{i=1}^{N}\frac{1}{||\gamma-\beta_i||^2}} X_i \quad (1)$$

Where γ is the signal strength vector of the non-anchor node and X_i and β_i are the location vector and signal strength vector for the i^{th} point. $||\gamma - \beta_i||^2$ Denotes nodes [13]. Range-free or Connectivity-based localization algorithms are useful in the situations where needs to get approximate estimate of the location. Niculescu *et al.* [14] have designed the DV-hop approach where in the all anchor nodes cover with other sensor nodes within the network. The signals are propagated hop by hop. Hop-count can be stored in the signal message. It also contains the information about the no. of hops it is away from the respective anchor. There is another approach developed by Shang *et al.* [15] which uses multi-dimensional scaling where in the closest path is calculated with the help of distance matrix and then approximate value is calculated for the each node's relative coordinates. In the another multi-hop localization algorithm which was proposed by Doherty et al. [16] which says that Semidefinite programs are a general form of the linear programs and given as in this form:

$$\begin{aligned} &\text{Minimize} \quad c^T x \\ &\text{Subject to:} \quad F(x) = F_0 + x_1F_1 + \cdots + x_nF_n \\ &\qquad Ax < b \\ &\qquad F_i = F_i^T \end{aligned} \quad (2)$$

Where $x = [x_1; x_2; :::; x_n]^T$ and x_i are the coordinate vector of node i.

E. MULTI-HOP LOCALIZATION TECHNIQUES

In a multi-hop localization, each node gets the information their anchor nodes via neighbouring stage, some sensor nodes are taken as secondary sensors which are positioned by MDS. The normal sensors which are neither primary nor secondary are positioned by applying PDM. Every primary sensor transmits a packet having unique ID to their neighbours, and then it gets forwarded to the next neighbour until the last value. It also sends proximity which contains hop-count of the packet. In the same way, all the anchors distribute their proximities with another anchor and they can calculate the location using the classical MDS [18].

There is another approach for Hybrid localization which was proposed by A. A. Ahmed et al. [27], which compose two localization techniques: multidimensional scaling (MDS) and Ad-hoc Positioning System (APS). It works in three steps: In the first step, collections of reference sensor nodes are selected in a random manner within the network. In the second step, multidimensional scaling is applied on the set of nodes and then it calculates the shortest-path and then multidimensional scaling is used for mapping. In third step, Ad-hoc Positioning System (APS) is applied where the reference nodes are considered as anchors and the remaining nodes are localized using shortest-path to localize from their anchor nodes. Finally, multilateration process is applied for location estimate [18].

F. HYBRID LOCALIZATION

Hybrid localization can be described with the composition of two or more localization techniques. One approach proposed by King-Yip Cheng et al. in [26], which is combination of two localization methods: multidimensional scaling (MDS) and proximity based map (PDM). Some sensors are placed as primary anchors. There are two stages: in the first the Euclidean distance between the two vectors γ and β_i, and N is the total no. of sample points. Ni et al.'s approach succeeds to get median localization error of 1*m* and a highest localization error of 2*m* [10]. In AOA based localization techniques, optical beams which comes out from the receivers intersect at the particular location which gives the estimation of the location of the transmitter, in the presence of noise. In the absence of noise, some lines do not intersect at one point so a triangulation technique is applied to achieve the estimation of the transmitter location [11]. Stanfield has done a tremendous work in estimate location which provides biased location estimates for the many bearing measurements [12]. ML technique is unbiased at many measurements but contains more errors in terms of root mean square compared to Stanfield approach [11].

Table 1: Centralized Techniques vs Distributed Techniques

Comparison Parameters	Centralized Localization Techniques	Distributed Localization Techniques
Accuracy	It has approx. 75-80% accuracy.	It gives approx. 75-90% accuracy
Dependency on Specific hardware	No need of specific hardware	Requires specific hardware
Power Usage	It consumes more power	Consumes less power. So, energy efficient.
Deployability and Maintainability	Difficult to deploy and maintain	Easy to deploy and maintain
Communication Cost	High communication cost	It is cost saving.
Robustness	Weak	Robust

3. Conclusion

A lot of significant research work has been done in this area, even though still future works needs to be done. Any technique which is efficient to produce better results should have less communication cost, energy-saving, accuracy, robustness and scalability. The technique should have scalability with energy-saving. In terms of energy saving, distributed techniques are more efficient. In Distributed algorithms, Relaxation algorithms are good because they can be operated without use of beacons but, lags behind in terms of scalability. Gradient algorithm is scalable but needs more nodes for better accuracy. If we hybrid these algorithms and produce a new concept, which could be effective to resolve the no. of beacons and getting better accuracy. We have found many localization techniques which have some advantage but unable to resolve all issues. So, it could be combined few of them and try to overcome major needs of the localizations drawbacks and underperformance.

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