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Technical Review of Range Free Localization Technique in Wireless Sensor Network

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ABSTRACT

Wireless sensor networks are becoming more popular as a result of recent advancements in wireless communication (WSNs). A wireless sensor network is made up of a large number of small and inexpensive sensors. Data collecting and forwarding is one of the most critical activities of a sensor network. The provenance of the data is of great interest in the majority of applications. Localization techniques can be used to gather this type of information. As a result, node localization is critical for determining the position of a node using localization techniques. As a result, node localisation is amongst the most difficult problems in WSNs. We conduct thorough analyses of various sensor network localization strategies. Localization techniques can be broadly categorized into two groups based on range measurements: range focused and range free schemes. Range-based localization techniques are not feasible due to the cost and technical limitations of the sensing node. Because coarse precision is sufficient in most sensor network applications, range free localization techniques are regarded a viable alternative to range-based schemes. This work presents a thorough investigation into and selection of the optimal range free localization algorithm for WSNs. Finally, several challenges for upcoming research in the domain of WSN localization approaches are discussed.

I. INTRODUCTION

Recent advancements in wireless communication technologies have paved the way for the development of low-cost, low-power sensors. The overall purpose is to create a wireless sensor network which can sense the environment, compute a task, and interact with one another to achieve a goal such as monitoring a phenomenon, tracking a target, detecting forest fires, and battlefield surveillance. The location of every access point is required in the vast majority of applications. Sensor nodes, on the other hand, are frequently put at random throughout a territory. As a result, the first step is to figure out where the nodes are. Because it is used in (i) identifying the source of sensor readings, (ii) energy conscious geographic routing, and (iii) self organizing and self configuring of networks, determining the physical position of sensor nodes in WSN performance is a critical problem. Apart from the foregoing, the locality itself is relevant information in a variety of applications. Manual configuration is the simplest option, but it is impracticable in large-scale deployments. Figure 1 depicts a simple wireless sensor network.

The addition of a Global Positioning System (GPS) toward a sensor node is another option for node localisation. However, because of its high power consumption, high cost, and imprecision, attaching a GPS receiver to every node is not a realistic solution.

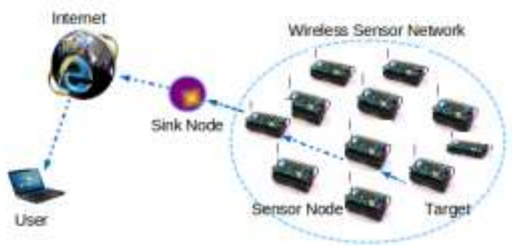

Figure 1. Wireless Sensor Network

On the basis of location estimation mechanism, a variety of localization systems and algorithms for sensor networks have been published in the literature, which are broadly grouped under range based as well as range free schemes. Techniques which use absolute distance estimations for location calculation create range-based systems. The range-free techniques remain agnostic about the information's accessibility or legality. Due to sensor hardware limitations, solutions in range-free schemes are seen as a cost-effective alternative to the most demanding range-based schemes. The taxonomy of localization algorithms is based on a number of different characteristics, including range measurement dependency, computational model, and anchor.

Various range-free localization methods are presented in this study. The rest of this paper is laid out as follows. The second section gives an overview of the localization process. The typology of localization techniques is described in Section 3. The comparative examination of localisation schemes is discussed in Section 4. Section 5 discusses certain difficulties that need to be addressed, and Section 6 concludes the study.

II. LOCALIZATION PROCESS

Sensor localization is the task of determining the position of all or a subset of sensor nodes. The sensor nodes are localized using input data during the localization process. The typical inputs include the placement of anchors if any are accessible in the network, whereas additional inputs are reliant on measurement methodologies. Figure 2 depicts an overview of the

localization process.

Figure 2. Overview of Localization Process

The nodes are localized using input data in the localization procedure. The typical inputs are indeed the positions of anchors if any are accessible in the network. For range-free strategies, connection information is also required, as is the length or angle among nodes for range-based techniques. Figure 3 depicts a flow chart for a localization procedure.

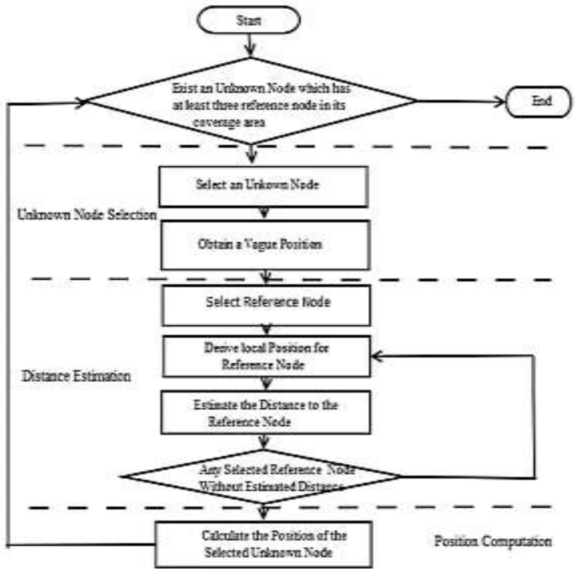

Figure 3. Flow sheet of localization process

III. CLASSIFICATION OF LOCALIZATION TECHNIQUES

There are a variety of options for dividing computing across sensor nodes and selecting localization algorithms. Localization technologies can be categorized into centralized, decentralized, and distributed strategies based on the computation model. The classification of the localisation techniques is shown in figure 4.

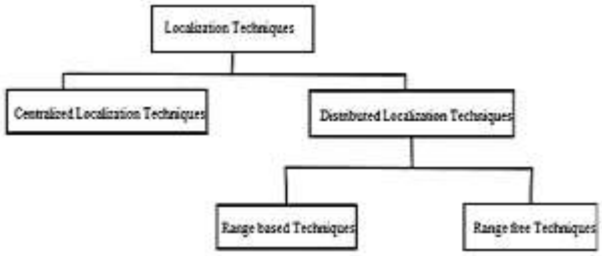

Figure 4. Taxonomy of localization techniques

3.1. Centralized Localization Techniques

All measurements are obtained at the central base station (BS), in which the computation takes place, in centralized localisation. Following that, the results are sent again to the nodes. Latency, increased energy usage, and bandwidth utilization are all consequences of transmitting data in the network. The advantages of this strategy are that it eliminates the computing problem in each node. The lack of capacity to retrieve data in a meaningful manner, but also inadequate scale, are both disadvantages of this system. Smaller networks will find it easier to use. It is even more efficient than other algorithms due to the existence of global information. Multiple Dimensional Scaling-Mobile Assisted Programming (MDSMAP), Semi Definite Programming (SDP), and Simulated Annealing based Localization are some of the most common centralized localization systems.

3.2. Distributed Localization Techniques

Sensor nodes using distributed localization do the appropriate computation and communicate with one another to determine their own network location. The distributed localization approaches can be divided as range based as well as range free localization strategies based on range measurements. Figure 4 depicts a broad classification of dispersed localization approaches.

3.2.1. Range Based Localization Techniques

For estimating locations, range-based algorithms required a distance (or angle) across nodes. Range-based strategies use distance estimate algorithms to calculate the accurate distance across transmitters and receivers' nodes.

As a result, these strategies include a variety of distance estimate methods for computing an inter node range, evaluating their proximity, and then calculating their position using some geometry principles.

3.2.2. Range Free Localization Techniques

Various range free localization approaches have been thoroughly studied in this section. Specialized technology for distance estimation is not used in range free techniques. As a result, their low cost and ease of distance measurement have piqued people's interest in recent years. Figure 5 depicts the taxonomy of range-free schemes.

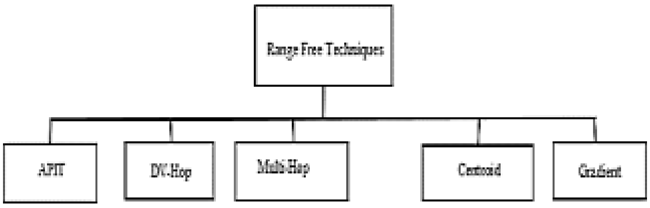

Figure 5. Taxonomy of range free localization techniques

3.2.2.1. Approximate Point in Triangle (APIT)

APIT is a range-free area-based method that implies some nodes are knowledgeable of their placements and are equipped with high-powered transmitters. By dividing the space onto triangular zones between anchors, APIT is able to do position estimate. The presence of each node within the triangular regions enables for the viable location to be reduced until all feasible sets have reached an acceptable level of precision. Figure 6 shows a flowchart representation of the APIT algorithm.

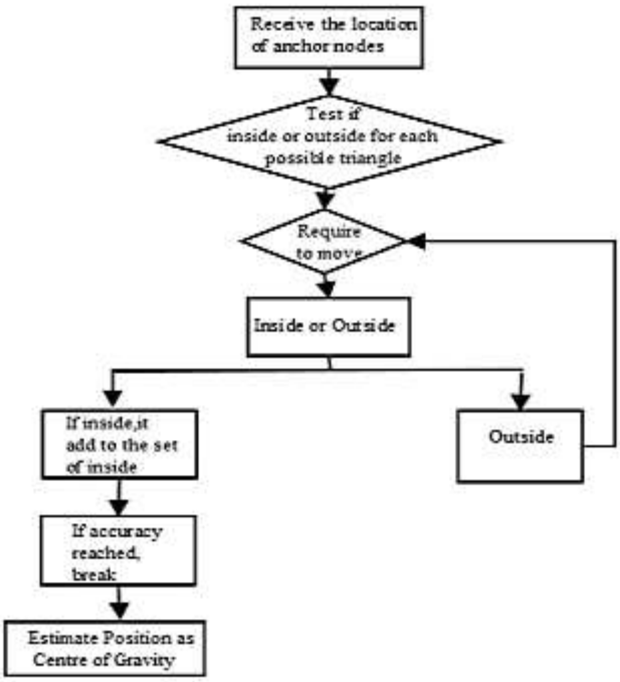

Figure 6. Flow sheet of APIT Algorithm

3.2.2.2. DV-Hop

DV-Hop localization has been using a methodology that is similar to that of distance vector routing. One anchor node sends out a message providing the positions of the anchors together with the hop count. Every receiving node saves the smallest value it gets. Each other message with larger values is then ignored. Messages were sent out, with the hop count numbers being incremented at each middle hop. All network nodes, as well as other anchors, are given the shortest hop distance under this technique. The following calculation can be used to calculate the entire single hop count in anchor I

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

Here, Anchor j is at (xi, yj), and hj is the hop distance between j and i. Anchors disseminate the predicted hop size towards the closest nodes. The triangulation technique is used to estimate the location of unknown nodes. A minimum of three anchor locations have been used in the above algorithm for two-dimensional network deployment.

3.2.2.3. Multi-Hop

A connectivity graph can be computed using multi hop algorithms. The multi-dimensional scaling (MDS) algorithm makes use of connectivity information to determine whether or not the nodes are within communication range. The following are the three steps in this system:

- The distance between each feasible pair of nodes is estimated in the first phase
- MDS is used to derive the locations to match the estimated distance in the second step.
- Finally, in the third stage, optimization is carried out by taking into consideration known locations.

Several types of MDS algorithms are employed in large-scale sensor networks, including metric, non-metric, classical, and weighted. Multihop nodes can collaborate to find better position estimations using the multihop based multilateration technique.

3.2.2.4. Centroid

The centroid approach employs a fine-grained localization algorithm based on proximity. The location of a node is determined using numerous reference node coordinates in the centroid localization technique [24]. The anchor node location (xi, yi) is used by the centroid localization algorithm (reference node). After receiving the data, the unknown node calculates their position using the 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}) indicates the estimated position of the sensor node and N represents the total of anchor nodes. As indicated in Figure 7, the purpose of the centroid algorithm should be to select a number of sensor nodes all around unknown nodes.

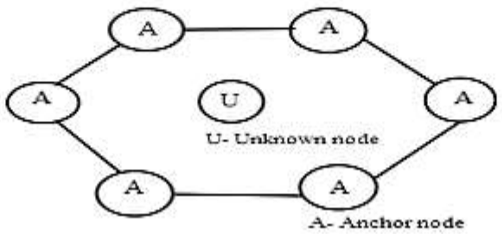

Figure 7. Centroid Algorithm

3.2.2.5. Gradient

Multilateration is used in the gradient approach to locate unknown nodes. It also utilizes a hop count, which starts at zero and grows as it proliferates to other nodes nearby. The gradient algorithm follows a set of steps, such as these:

- Anchor nodes broadcast a message comprising their synchronised and hop count value in the first step.
- The unknown node computes the distance path between itself and the anchor node where it receives beacon messages in the second stage. The following equation can be used to calculate the approximate distance:

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

- In the third stage, the following equation is used to find the smallest error in which a node calculates

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

its coordinate:

Where dji is gradient propagation based estimated distance.

IV. COMPARISON

The accuracy, communication, and computing costs, coverage data, numerical model, node density, as well as scalability all affect the performance of the localization algorithm. The presence of an anchor, a computational model, the availability in GPS, as well as range measurements can all be used to classify localization systems. Each localization technique has its own set of benefits and drawbacks, making it ideal for a variety of applications. We conducted a complete review and comparison of several localization approaches in this paper. The comparison was then summarized in tabular form.

Table 1 summarizes the differences among centralized and distributed localization. Table 2 shows an overview of the comparisons between range-based and range-free systems. Following that, we concentrated on a variety of range-free localization strategies. Table 3 summarizes the comparison of the different range-free localization strategies.

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

V. ISSUES IN LOCALIZATION TECHNIQUES

Sensor network localisation is indeed an active study subject with many challenges, thus there is still plenty of room for the research community to grow. The following are amongst the issues that must be addressed:

• ***Robust algorithms on mobile sensor networks***: Because of their mobility and coverage, mobile sensors are quite helpful in some contexts. As a result, new algorithms must be adapted to accommodate such mobile nodes.

• ***Accuracy:*** If the node position is incorrectly estimated, the accuracy of the localization is affected. When it comes to sensor localization, designers must take into account that precision is crucial.

• ***Algorithms for three-dimensional spaces***: Precise position information is critical for many WSN applications. The more proposed algorithms that seem to be applicable to 2D space, the better. WSNs must be positioned in three dimensions in some applications.

• ***Scalability:*** Enlarging the monitoring area between nodes is often desired in large-scale deployments. To test the scalability of localisation algorithms, thorough observations are required.

VI. CONCLUSION

Localization of wireless sensor networks has gotten a lot of attention from the research community. With the expansion of sensor network applications, this risk is projected to rise much more. This research reviewed different range-free localization strategies and their accompanying sensor network localization algorithms.

The taxonomy for localization algorithms is covered in this study. In this paper, we compare various localisation strategies and give the results in a tabular format. The categorization of distributed localization techniques based on range measurements was presented in this study.

This comparative analysis of all researched schemes led us to the conclusion that every algorithm has its own set of characteristics and that none is completely superior. The range-based approaches are, on the whole, either expensive or vulnerable to network dynamics. Range-free approaches, on the other hand, are inaccurate and easily influenced by node density. Despite tremendous research progress in this field, there are still some unanswered issues. Finally, we concentrated on the concerns that must be addressed. This paper will be of great assistance to researchers who are working on developing, modifying, and optimizing localization methods for wireless sensor networks.

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