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Analysis of Localization Methods using Wireless Sensor Networks

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Abstract: *Wireless Sensor Network is a type of wireless network which consists of a collection of tiny device called sensor node. Wireless Sensor Network is one of the rapidly developing areas. Applications of Wireless Sensor Network includes remote environmental monitoring, target tracking, etc. Various algorithms are proposed in 2D for location tracking which provides accuracy but in the real world, we require all the three planes for correct estimation and more accuracy in localization. The 2D works on flat terrain but we need to position WSN in harsh terrain also, so we need an algorithm in 3D that provide better accuracy and decrease the error of estimation and provide a real world view also. The goal of our survey is to present the localization techniques of node.*

Keywords: Localization Techniques, Wireless Sensor Network, centralized, range, anchor, distributed

I. INTRODUCTION

Wireless Sensor Networks (WSN) is collection of small, low cost, randomly placed heterogeneous sensor nodes connected by wireless media to form a sensor field. Nodes can sense or monitor the environment, gather the data through it and send to the user through base stations. Its applications include military as battlefield surveillance, habitat monitoring, environmental monitoring, health application, target tracking etc. A node before sending the data to its neighbours must know the location of its own. The need of location arises because the number of nodes is very large and it is not possible for the Base Station to find the nodes position, so the individual node is required to send the location information along with the information collected in order to provide the exact location to the user. This means the node must localize itself.

Collaboration among nodes is highly essential so that localization can be accomplished by the nodes themselves without any human intervention. In WSNs, normally such collaboration occurs among nodes located in a certain region. In most of the localization algorithms, the normal, beacon and anchor nodes collaborate with each other to calculate the location information of the nodes by considering several aspects like limited energy resource, number and density of nodes and existence of obstacles.

Location identification or Localization in Wireless Sensor Networks (WSN) refers to creation of a map of a WSN by determining the geographical coordinates of each and every node [1]. Localization can be done either manually or by using GPS. Manual Localization is done by calculations and human interaction whereas GPS Localization is done with the help of satellites. The Limitation of GPS is that it cannot be implemented in dense forests, mountains or other obstacles that block the line-of-sight from GPS satellites. Localization uses the reference node, just as neighbor node and anchor node (which known their position earlier with the help of GPS) for localization. Localization algorithm mostly works on 2-dimensional plane, i.e. x and y plane where the x and y coordinate are the same as the real position of the surface and altitude is fixed. 2D localization system is less complex and requires less energy and time. It provides good accuracy on flat terrains and is difficult to estimate in harsh terrains. It provides accurate distance when the number of nodes is more and anchor nodes are present. In 3D plane one extra plane called z plane is required which provide better results using height. It can be used in harsh and hilly terrains to provide good accuracy in it. During mapping of these estimated positions to the real world, an error can occur because it consists of all three planes. Using 3D localization system, this problem is eliminated completely.

II. LITERATURE SURVEY

Wireless sensor network (WSN) consists of large number of small devices deployed in a physical environment for its study. Each node has special capabilities, such as wireless communications with its neighbours, sensing, data storage and processing.

2.1 Localization Method

To determine the location of node in 2D, 3 Anchor nodes are required whereas in 3D, four anchor nodes are required. Consider the following types of nodes:

- Anchor nodes: Nodes in WSN contain who know theirlocation earlier known as Anchor or Beacon node.
- Base Station: This is a special anchor node that acts routingthe WSN information from the network to a PC. This PC provides the information acquired by the network to the rest of the AmI devices [2].

For localization in WSN, more than 50 localization algorithms exist till date. It is impractical to discuss all of these algorithms; therefore we will first broadly classify these algorithms into different categories. These algorithms can be classified on the basis of different aspects like.

- Centralized vs. distributed
- Anchor based vs. Anchor less
- Range based vs. Range free

2.2 Centralized Localization

In Centralized Localization, one central base station is present for computation. Disadvantage is overhead and cost increases. MDS-MAP is a centralized algorithm for computing the coordinates of unknown nodes after approximating the distances between the nodes using shortest path algorithm, whereas in [3], a centralized minimum least square approximation (LS) method is used for localization after distance approximation using RSSI measurements

2.3 Distributed Localization

In Distributed Localization, computation is done by own self and node communicate with each other to get their position in the network. The distributed algorithm in [4] was able to decrease the error but at the cost of using mobile nodes and acoustic energy for distance approximation. In [5], to determine the location of nodes in WSN, the authors have used Kalman filter based distributed localization algorithm.

2.4 Anchor Based

The anchor based algorithms provide a starting point for an algorithm by using position of anchor nodes and the result in global coordinates of the nodes. In anchor based localization algorithms, the average localization error is inversely proportional to the density of anchor nodes. More the anchor nodes more are the accurate reference points. Cost of the system increases by increasing such nodes with extra resources. The distance measurement techniques till date have not been accurate so far. In most of the applications, global coordinates are preferred over local coordinates therefore, anchor based localization has been in focus recently.

2.5 Anchor Less

The anchorless schemes measure the distance between nodes for creating a local map of the nodes. The local map created is not a unique one and can be stitched to any coordinate system with the help of translation, rotation or flipping. The MDS-MAP scheme like in [6] can create a local map of the nodes in WSN without anchors but at least three anchors would be required to create a global map without flip ambiguity problem.

2.6 Range-based

This technique estimate the distance between all the nodes using sensors such as ultrasound [7]. Using techniques such as triangulation, the absolute position of the non-anchor nodes can be estimated. These techniques provide higher accuracy but require additional hardware and therefore the size and cost increases. The most common ones are Received Signal Strength Indication (RSSI) [8], Time of Arrival (TOA)[9], Angle of Arrival (AOA) [10], Time Difference of

Arrival (TDOA), Lateration and Angulation method are used [11].

Received Signal Strength Indication (RSSI)

RSSI measures the signal power coming in a received node and calculates distance using received signal. Advantage is it is easy to estimate and the main drawback is power decreases when the node is at long distance. Power strength is fading in distance. Accuracy is affected by obstacles. Good accuracy is in less distance.

Time of Arrival (TOA)

It sends a single packet from the one node to the other node containing the time of its transmission, assuming perfect clock synchronization between the nodes. The receiving node knows when the packet arrived and that is synchronized with the sender node, the distance travelled can be calculated using the following formula:

$$d=c* \Delta t$$

where d is the distance between the nodes, c is velocity of light and , Δt the time difference. The advantage is it is more accurate than RSSI [12] and is not affected by channel fading but issue is to achieve synchronization between nodes. Therefore this method is not popular.

Angle of Arrival (AOA)

Nodes use Omni-directional Antenna. Angle is estimated with the help of known reference axis and the signal is send to another node Different AOA measurement methods exist. In first method, array of RF antennas or microphones at receiver node helps in determining AOA. By analyzing the phase or time difference between the arrival of signals at different antennas or microphones, it is possible to discover the angle of arrival of the signal. In second method, it is also possible to gather AOA data from optical communication methods. Using digital signal processing as in Multiple Signal Identification and Classification (MUSIC) algorithm [13], the accuracy up to 10 of AOA estimation can be achieved.

Time Difference of Arrival (TDOA)

In TDOA, measurement of distance depends upon the time difference between two waves reaching same or different destinations with following combinations:

- Both at Radio frequency
- One at radio and other at Ultrasonic frequency
- Both at Ultrasonic frequency.

Once the difference in the arrival of the waves at destination is known, the distance is calculated. For example, in a) one source sends same RF signal to two different nodes. These two nodes calculate the difference of time arrival of the signal and calculate the distance between themselves and source node. Further details regarding a) is in [14]. In b), two destination nodes are not required and one source sends RF and ultra sonic signal at same time. The node at distance d will receive these two signals with some time difference since the speed of RF signal is higher than ultrasound signal. This difference of time in the reception of two signals is calculated by the node at distance d and using this information, the distance can be calculated as:

$$d= \Delta t*s$$

where is the difference in time of reception of two signals and

$$s=(c1*c 2)/(c1- c2)$$

c1 and c2 are the speeds of RF and ultra sound signal. In c), the method is similar to a) but instead of RF signal; the signals used are ultrasound signals. In Cricket ultrasound ranging system as in [21] maximum accuracy is in few cm over ranges of up to ten meters in indoor environments, provided the transmitter and receiver are in line-of-sight.

Table I: Comparison of TDOA Methods

Method	Additional Hardware Required	Synchronization between Nodes	Effect of Speed of sound
RF- RF	No	Required	No
RF-Ultrasonic	Yes	Not Required	Yes
Ultrasonic –Ultrasonic	Yes	Required	No

Lateration

Three or more non-collinear anchor nodes arepresent in 2D and four or more non-collinear anchor nodes are present in 3D. Position is calculated through this non-collinear anchor node and location is estimated using calculated value.

Unitary Matrix Pencil Algorithm for Range-Based 3D Localization

This method combines unitary matrix pencil(UMP) algorithm, three-dimensional Taylor algorithm and multilateral localization. To measure the propagation distance and to estimate the time of arrival (TOA) between nodes, UMP algorithm is extended. Centro-Hermitian property of a matrix is used and unitary transformation is applied to convert complex matrix into real matrix with eigenvectors. This reduces processing time for real time implementation. Multilateral localization is used here for node position computation. Taylor algorithm is extended to 3D to solve nonlinear equations. UMP algorithm is extended to the application of UWB WSN to improve resolution time and to reduce the computational load. To measure the distance between two nodes, UMP based TOA estimation algorithm is proposed. The estimation results will be used in 3D position computation.

Space Distance Intersection (SDI)

It is a 3D positioning algorithm in which each sensor node measures a set of distances with the help of mobile beacon. Mobile beacons know their location by GPS and each beacon contains the mobile beacons current location. This algorithm proposed a range based method, so mobile beacon uses UWB signal. It provides an excellent time resolution and is good for multi-path performance. For high precision, it uses TOA techniques. Finally, sensor node derives it 3D position form node-beacon distance measurements by using algorithm, for that SDI is proposed.

Range-free

This technique obtains the position of non-anchor nodes according to implicit information provided by anchor nodes, usually based on messages exchanged, commonly called beacons. This information is usually made up of different aspects, such as number of hops between devices or radio coverage membership. The most common ones are Hop Count, APIT [11], Centroid (CL) [15] and DV-Hop [16].

Hop Count

This method is used to estimate the distance between two nodes. A signal takes the number of hopes from sender node to receiver node and multiplies with the maximum communication range of a node. This method gives an accuracy of approximately 50 % of maximum range of a node and does not require complex calculations. Errors can be reduced up to 20 % of the maximum range when neighbour nodes are more than 15. Hop count is discussed in detail in [17].

Approximate point in Triangle (APIT)

An algorithm is proposed in [17], [18] in which an unknown node determines whether it is inside a triangle formed by three anchors in the neighbourhood or not. This is determined by reading RSSI values coming from anchor nodes. Node position is estimated to be centre of the triangle if it is inside the triangle of three anchors, Sometimes errors occurs deciding whether an unknown node is inside the triangle or not, especially when it is near the edge of a triangle formed by anchors. The modified version of APIT in [19] overcomes this error by calculating individual areas of the triangles formed in both in-case and out-case and then comparing it with total area. APIT is more accurate than simple centroid method but has slightly larger communication overhead than Centroid. More the number of anchor nodes, more the triangles formed around unknown node and hence more the accuracy.

Centroid Algorithm in 2D

In Centroid based Algorithm in2D [20], all anchors first sends their positions to all sensor nodes within their transmission range. Each unknown node listens for a fixed time period t and collects all the beacon signals it receives from various reference points. Secondly, all unknown sensor nodes positions are calculated by a centroid determination from all n positions of the anchors in range. The centroid localization algorithm is simple but the location error is high due to the centroid formula.

Novel Centroid Algorithm for 3D

This algorithm uses theearlier developed and implemented Centroid algorithm. It requires no additional hardware support and can be implemented in a distributed way. Within their transmission range, all anchors send their positions information to all unknown nodes. To form a series of tetrahedrons, each unknown node after collecting all the beacon signals from various reference points randomly selects four anchor nodes range. It uses the proposed Centroid theorem of coordinate-tetrahedron in the volume-coordinate system which acts as a key component of estimation to calculate the barycentre (nodes present at the centre of two or more bodies and have non-rotating coordinates) of each tetrahedron. Finally, averaging the coordinates of these barycentre, the position of unknown node is estimated.

DV Hop

In DV-HOP algorithm, the unknown nodecalculates the minimum hops between the node and the anchors and the length of every hop is estimated which is then used to obtain the distance between unknown nodes and anchors by multiplying the minimum hops. Finally, the position of the unknown node can be obtained.

New 3-dimensional DV-Hop Localization Algorithm

It expanded the traditional range-free DV-Hop algorithm in to 3D-space. In this Algorithm, the minimum hop counts between the unknown nodes and the beacon nodes are computed and then average per-hop distance of the beacon nodes and measurement error is calculated. This value is broadcasted to the whole network. The unknown node saved all the average per-hop distance of the beacon nodes which it can receive and forwarded to the other neighbour of the nodes, then using this average per-hop distances estimation and previously saved hops information, the distance between the beacon nodes is calculated. If DV-Hop algorithm is extended to the 3-D space then the unknown node will only save the first received average per-hop distance of the beacon node, so that only the information of the most recent beacon node to be used.

In general, the range-based ones offer good accuracy, but additional hardware is often needed. Therefore, the weight, the cost and the power consumption of node devices increases and make these sorts of techniques unsuitable. Moreover, in 2D Algorithms, altitude is fixed, not with actual altitude whereas 3D localization works with real measurement and the algorithm proposed in 3D provide good positing error and unique features as compared to earlier methods.

Table 2: Measurement Techniques Comparison

Type of Measurement		Accuracy		Overhead	
		Line of Sight	Non Line of Sight	Hardware	Computational
Angle	AOA	High	Very Low	High	Low
Distance	Hop Count	Low	Very Low	Low	Low
	RSSI	Low	Very Low	Low	Low
	TDOA	Very High	High	High	Low
	TOA	High	High	Low	Low

III. CONCLUSION

Localization in wireless sensor networks is an important issue. Great efforts have been made by many researchers and a variant of algorithm also have been proposed. (Analysis on localization schemes focusing on the 3-D space is of particular interest to real applications of WSNs especially when the difference between localizations in 2-D place and 3-D space is significant. In 3D, computation and communication increases drastically compared to 2D localization.) In this paper, we proposed a new classification for localization techniques. In this classification, localization algorithms were classified based on different key features like Anchor Based, Anchor Less, Range Based, Range Free etc. Range Based RSSI provides less accurate estimate of distance still it has been favoured by researchers because of its low cost compared to any other measurement technique, especially for 3D localization. This classification is usable to understand the operation of varies localization methods and it is also usable for who wants to implement a new localization algorithm.

In additional, some evaluation factors were introduced to validate new proposed methods or to compare different existence techniques in order to find the best one for a specific application. More creative algorithms are expected to be designed out to solve these problems. Absolutely, all these efforts will greatly accelerate the development of WSNs technique to be applied into large scale application systems.

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