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A Pragmatic Survey On Localization Techniques In Wireless Sensor Networks

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ABSTRACT

Localization is a way to determine the location of sensor nodes. Localization has been regarded as one of the fundamental and supporting technology for many applications of wireless sensor networks. Localization of sensor nodes is an interesting research area and many works have been done so far. This paper presented an overview of localization techniques and surveyed the currently available algorithms for localization. In this survey, we proposed different classification methods, reviewed important localization algorithms, summarized their advantages and disadvantages for wireless sensor networks and finally, discussed some possible directions of future research.

Key Words Wireless Sensor Networks, Centralized Localization, Distributed Localization, Anchor based Localization, Range based Localization.

1. INTRODUCTION

Wireless sensor networks consisting of hundreds and thousands of nodes [1]. Each node is able to sense the environment, perform simple computations and communicate with its other sensors or to the central unit. Wireless sensor networks are tremendously being used in different environments to perform various monitoring tasks such as search, rescue, disaster relief, target tracking and a number of tasks in smart environments. In many such tasks, node localization is inherently one of the system parameters. Node localization is required to report the origin of events, assist group querying of sensors, routing and to answer questions on the network coverage. Since most applications depend on a successful localization, i.e. to compute their positions in some fixed coordinate system. So, node localization in sensor networks is an active field of research in wireless networking. Unfortunately, for a large number of sensor nodes, straightforward solution of adding GPS to all nodes in the network is not feasible because

- In the presence of dense forests, mountains or other obstacles that block the line-of-sight from GPS satellites, GPS cannot be implemented.
- The power consumption of GPS will reduce the battery life of the sensor nodes and also reduce the effective lifetime of the entire network.
- In a network with large number of nodes, the production cost factor of GPS is an important issue.
- Sensor nodes are required to be small. But the size of GPS and its antenna increases the sensor node form factor. For these reasons an alternate solution of GPS is required which is cost effective, rapidly deployable and can operate in diverse environments.

This paper is organized as follows. Section II presents the formulation of localization problem in wireless sensor networks. Literature survey has been discussed in section III. In section IV, Comparison of different Localization approaches in wireless sensor networks (WSN) has summarized. In section V, conclusion and different proposals to improve localization in WSN are discussed.

2. PROBLEM DEFINITION

Consider the case when we have deployed a sensor network consist of N sensors at locations $L = \{L_1, L_2,\ldots\ldots,L_N\}$. Let L_x^i refer to the x-coordinate of the location of sensor i and let L_y^i and L_z^i refer to the y and z coordinates, respectively. Constraining L_z^i to be 0 suffices the 2D version of this problem. Determining these locations constitutes the localization problem. Some sensor nodes are aware of their own positions, these nodes are known as anchors or beacons. All the other nodes localize themselves with the help of location references received from the anchors. So, mathematically the localization problem can be formulated as follows: given a multihop network, represented by a graph G = (V, E), and a set of beacon nodes B, their positions $\{x_b, y_b\}$ for all b ε B, we want to find the position $\{x_u, y_u\}$ for all unknown nodes u ε U.

3. LITERATURE SURVEY

Wireless sensor network (WSN) consists of large number of sensor nodes deployed in a physical environment. Each node is able to sense the environment, perform simple computations and communicate with its other sensors or to the central unit. Wireless sensor network (WSN) consists of

- Anchor nodes: Nodes in WSN contain who know their location earlier, known as Anchor or Beacon node.
- Base Station: This is a special anchor node that acts routing the WSN information from the network to a PC.

For localization in WSN, many 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.

1. Centralized vs. distributed.
2. Anchor based vs. Anchor less.
3. Range based vs. Range free.

3.1 CENTRALIZED LOCALIZATION

Centralized localization is basically migration of inter-node ranging and connectivity data to a sufficiently powerful central base station and then the migration of resulting locations back to respective nodes. The advantage of centralized algorithms are that it eliminates the problem of computation in each node, at the same time the limitations lie in the communication cost of moving data back to the base station. [4][5].

3.2 DISTRIBUTED LOCALIZATION

Distributed localizations all the relevant computations are done on the sensor nodes themselves and the nodes communicate with each other to get their positions in a network. Distributed localizations can be categorized as follows[26].

3.2.1 BEACON-BASED DISTRIBUTED ALGORITHMS

Beacon-based distributed algorithms start with some group of beacons and nodes in the network to obtain a distance measurement to a few beacons, and then use these measurements to determine their own location.

3.2.2 RELAXATION-BASED DISTRIBUTED ALGORITHMS

In relaxation-based distributed algorithms use a coarse algorithm to roughly localize nodes in the network. This coarse algorithm is followed by a refinement step, which typically involves each node adjusting its position to approximate the optimal solution. Some of the proposals [11] in this category are discussed in greater details.

3.2.3 COORDINATE SYSTEM STITCHING BASED DISTRIBUTED ALGORITHMS

In Coordinate system stitching the network is divided into small overlapping sub regions, each of which creates an optimal local map. Next the scheme merges the local maps into a single global map [28].

3.2.4 HYBRID LOCALIZATION ALGORITHMS

Hybrid localization schemes use two different localization techniques such as:
Multidimensional scaling (MDS) and proximity based map (PDM) or MDS and Ad-hoc Positioning System (APS) to reduce communication and computation cost. Such kinds of approaches are discussed in [29].

3.2.5 INTERFEROMETRIC RANGING BASED LOCALIZATION

Radio interferometric positioning exploits interfering radio waves emitted from two locations at slightly different frequencies to obtain the necessary ranging information for localization. Such types of localization techniques are proposed in [30].

3.2.6 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 suppress error propagation [31] has proposed a scheme called error propagation aware (EWA) algorithm.

3.3 ANCHOR BASED LOCALIZATION

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.

3.4 ANCHOR LESS LOCALIZATION

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 [7] 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.

3.5 RANGE-BASED LOCALIZATION

This technique estimate the distance between all the nodes using sensors such as ultrasound [8]. 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) [9], Time of Arrival (TOA) [10], Angle of Arrival (AOA) [11], Time Difference of Arrival (TDOA), Lateration and Angulation methods are used [12].

3.5.1 RECEIVED SIGNAL STRENGTH INDICATION (RSSI)

RSSI measures the signal power coming in a received node and calculates distance using received signal [25]. 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.

3.5.2 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 advantage is it is more accurate than RSSI [13] and is not affected by channel fading but issue is to achieve synchronization between nodes. Therefore this method is not popular.

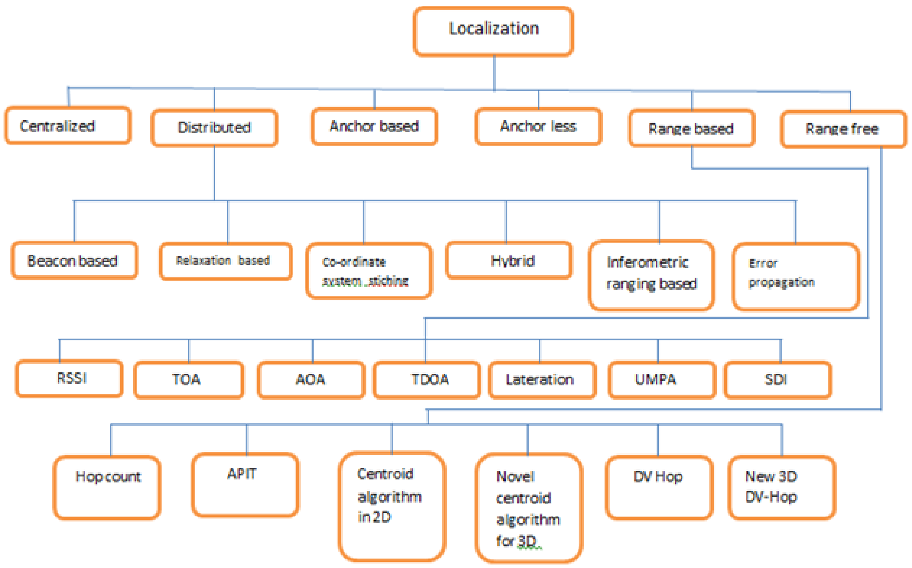

Figure 1. Classification of different Localization technique

3.5.3 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 [14], the accuracy up to 10 of AOA estimation can be achieved.

3.5.4 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:

a) Both at Radio frequency. b) One at radio and other at Ultrasonic frequency. c) 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 [15]. 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= Δt* s where Δ is the difference in time of reception of two signals and s= (C1*C2)/(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 [22] 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.

3.5.5 LATERATION

Three or more non-collinear anchor nodes are present 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.

3.5.6 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.

3.5.7 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.

3.6 RANGE-FREE LOCALIZATION

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 [12], Centroid (CL) [16] and DV-Hop [17].

3.6.1 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 neighbor nodes are more than 15.Hop count is discussed in detail [17].

3.6.2 APPROXIMATE POINT IN TRIANGLE (APIT)

An algorithm is proposed in [18], [19] in which an unknown node determines whether it is inside a triangle formed by three anchors in the neighborhood 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 [20] 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.

3.6.3 CENTROID ALGORITHM IN 2D

In Centroid based Algorithm in 2D [21], 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.

3.6.4 NOVEL CENTROID ALGORITHM FOR 3D

This algorithm uses the earlier 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 in 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.

3.6.5 DV HOP

In DV-HOP algorithm, the unknown node calculates 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.

3.6.6 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.

4. COMPARISON OF DIFFERENT LOCALIZATION TECHNIQUES

Technique	Cost	Accuracy	Energy efficient	Hardware size
GPS	High	High	Less	Large
GPS free	Low	Medium	Medium	Small
Centralized based	Depends	High	Less	Depends
Decentralized based	Depends	Low	High	Depends
RSSI	Low	Medium	High	Small
TOA(using ultrasonic pulse)	High	Medium	Less	Large
TDOA	Low	High	High	Less complex, may be large
AOA	High	Low	Medium	Large
DV hop	Low	Medium	High	Small
APIT	Medium	Medium	High	Medium

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.

5. CONCLUSION AND FUTURE WORK

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. 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 favored 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. This paper shows that there are many localization techniques. However, there still exist a number of issues and open problems that need to be addressed in future research.

Using GPS

Localization of sensor nodes using GPS is not suitable, because it is less energy efficient and expensive; it needs large size of hardware and has a line of sight problem. If GPS is installed on every node, then it increases the node size and deployment cost. Furthermore, GPS is not energy efficient as it consumes a lot of energy and not suitable for a network like WSN.

Interferomatric ranging based localization that takes error propagation into account

To localize large networks using interferometric ranging from a small set of anchors, future localization algorithms need to find a way to effectively limit the error propagation.

Robust algorithm for mobile sensor networks

Recently there has been a great deal of research on using mobility in sensor networks to assist in the initial deployment of nodes. Mobile sensors are useful in this environment because they can move to locations that meet sensing coverage requirements. New localization algorithms will need to be developed to accommodate these moving nodes. So, devising a robust localization algorithm for next generation mobile sensor networks is an open problem in future.

Challenges of Information Asymmetry

In a beacon-based localization model, since sensor nodes are not capable of determining their own location, they have no way of determining which beacon nodes are being truthful in providing accurate location information. There could be malicious beacon nodes that give false location information to sensor nodes compelling them to compute incorrect location. This situation, in which one entity has more information than the other, is referred to as information asymmetry, future research work is needed in this field.

Finding the minimum number of Beacon locations

Beacon based approaches requires of a set of beacon nodes, with known locations. So, an optimal as well as robust scheme will be to have a minimum number of beacons in a region. Further work is needed to find the minimum number of locations where beacons must be placed so the whole network can be localized with a certain level of accuracy.

Finding localization algorithms in three dimensional space

WSNs are physical impossible to be deployed into the area of absolute plane in the context of real-world applications. For all kinds of applications in WSNs accurate location information is crucial. So, a good localization schemes for accurate localization of sensors in three dimensional space can be a good area of future work.

Accuracy

Accuracy is highly important factor in all localization techniques. Localization accuracy is compromised when position of node is wrongly estimated. When a node localizes itself with wrong information of coordinates and propagates wrong information through- out the network, overall accuracy of the localization process is decreased.

Node density

Node density is an important factor in designing localization algorithm. For example, in beacon node based algorithms, beacon node density should be high for accurate localization, whereas if node density is low, then accuracy is decreased and localization algo- rhythms cannot perform well.

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