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Node Localization for Wireless Sensor Networks

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Abstract: **Awareness of location is one of the important and critical issue and challenge in wireless sensor network. Knowledge of Location among the participating nodes is one of the crucial requirements in designing of solutions for various issues related to Wireless sensor networks. Wireless sensor networks are being used in environmental applications to perform the number of task such as environment monitoring, disaster relief, target tracking, defences and many more. 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. So, one of the fundamental challenges in wireless sensor network is node localization. This paper provides an overview of different approach of node localization discovery in wireless sensor networks. The overview of the schemes proposed by different scholars for the improvement of localization in wireless sensor networks is also presented. Future research directions and challenges for improving node localization in wireless sensor networks are also discussed.**

Keywords—Localization technique, GPS, Anchor, Sensor node, Wireless Sensor Networks

I. INTRODUCTION

A sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument. Sensor in wireless network receives input information, store the information, compute and forward the data to other devices. For example, a thermocouple converts temperature to an output voltage which can be read by a voltmeter. A Wireless Sensor Network (WSN) [1][2] consists of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance and is now used in many industrial and civilian application areas, including industrial process monitoring and control, machine health monitoring, environment and habitat monitoring, healthcare applications, home automation and traffic control [3].

Since most applications depend on a successful localization [4], i.e. to compute their positions in some fixed coordinate system, it is of great importance to design efficient localization algorithms. Localization [5] means to determine location of nodes in a network. With the support of some infrastructure, a node can determine its location in the network by extracting information received from the infrastructure; also, by making a node to send signals periodically, the infrastructure can calculate the location of the nodes. For example, GPS [6] is a typical localization system. There are 24 satellites positioned at the altitude of 20200 km and distributed in 6 orbital planes. These satellites share the high accurate atomic clocks and they know exactly their coordinates. A GPS receiver can receive signals from at least 4 satellites if the receiver is not hidden from the line of sight. By matching the code pattern in the signal, a receiver can calculate the time shift and know the distance away from that satellite by multiply the time shift to the speed of light. After that, the GPS receiver can figure out its coordinate based on some localization algorithm.

II. PARAMETERS FOR LOCALIZATION

For the different ways of estimating location information, we have to name parameters to distinguish the similarities and differences between different approaches. In this section we present the most typical parameters to classify different techniques.

Accuracy: Accuracy is very important in the localization of wireless sensor network. Higher accuracy is typically required in military installations, such as sensor network deployed for intrusion detection. However, for commercial networks which may use localization to send advertisements from neighboring shops, the required accuracy may not be lower.

Cost: Cost is a very challenging issue in the localization of wireless sensor network. There are very few algorithms which give low cost but those algorithms don't give the high rate of accuracy.

Power: Power is necessary for computation purpose. Power play a major role in wireless sensor network as each sensor device has limited power. Power supplied by battery.

Static Nodes: All static sensor nodes are homogeneous in nature. This means that, all the nodes have identical sensing ability, computational ability, and the ability to communicate. We also assume that, the initial battery powers of the nodes are identical at deployment.

Mobile Nodes: It is assumed that a few number of GPS enabled mobile nodes are part of the sensor network. These nodes are homogeneous in nature. But, are assumed to have more battery power as compared to the static nodes and do not drain out completely during the localization process. The communication range of mobile sensor nodes are assumed not to change drastically during the entire localization algorithm runtime and also not to change significantly within the reception of four beacon messages by a particular static node.

III. LOCALIZATION TECHNIQUES IN WSNS

There are different kinds of localization approaches and accuracy requirements. Localization can be roughly divided into two categories: range-based and range-free. Range-based approach uses absolute distance estimate or angle estimate, meaning that a node in a network can measure the distances from itself to the beacons. [7, 8, 9, 10, 11, 12] are some examples of range-based localization techniques In contrast, range-free approach [13,14] means that it is impossible for a node to measure the direct distances from itself to beacons. Only through connectivity and proximity, a node can estimate its regions or areas where it stays. Range-based approach is precise while range-free method is often inaccurate.

Range-based localization can also divided into another two categories. One is distance estimation by one-hop; another is by multi-hop, meaning that a node in the network can not directly communicate with beacons. Localization in WSN is a multi-hop approach because a node may not communicate directly with beacons. Only through multi-hop routing, can a node send or receive messages to or from beacons.

Existing location discovery approaches [15] basically consists of two basic phases: (1) distance or angle estimation and (2) distance and angle combining. The most popular methods for estimating the distance between two nodes are described below: Received Signal Strength Indicator (RSSI), Time based methods (ToA, TDoA), Angle-of-Arrival (AoA, DoA), Triangulation and Maximum Likelihood (ML) estimation.

Received Signal Strength Indicator (RSSI): The RSSI technique is based on the fact that the radio signal attenuates exponentially with the increase of distance. According to the receiving power, the distance can be evaluated by translating the power loss with theoretical model. RSSI has also been employed for range estimation in [16, 17, 18].

Time based methods(ToA, TDoA): ToA and TDoA techniques [19, 20, 21] evaluate the distance by translating the propagation time between two nodes with known signal propagation speed.

Angle-of-Arrival (AoA): AoA is also called DoA [22, 23] (Direction of Arrival) techniques measure the position by geometric relationships with the angle where signals are received. ToA, TDoA and AoA techniques can typically achieve better accuracy than RSSI techniques, because radio signal amplitude is affected by environmental factors [24].

Triangulation: Triangulation method is used when the direction of the node instead of the distance is estimated, as in AoA systems. The node positions are calculated in this case by using the trigonometry laws of sines and cosines.

Maximum Likelihood (ML) estimation: ML estimation estimates the position of a node by minimizing the differences between the measured distances and estimated distances.

IV. LOCALIZATION APPROACHES IN WSNS

In terms of computation, the WSN localization algorithms can be classified into centralized and distributed schemes. Further each category divided in to corresponding methods to solve localization problem. In the centralized scheme, sensor nodes send control messages to a central node whose location is known. The central node then computes the location of every sensor node and informs the nodes of their locations. In the distributed scheme, each sensor node determines its own location independently. These algorithms are given by researchers but there are some aspects which we will consider as a challenge in future.

(a). Distributed Localization:

If each node collects partial data and executes the algorithm then localization algorithm is distributed.

Beacon-based distributed algorithms: Categorized into three parts:

Diffusion: In diffusion the most likely position of the node is at the centroid [25] of its neighboring known nodes. APIT requires a high ratio of beacons to nodes and longer range beacons to get a good position estimate. For low beacon density this scheme will not give accurate results.

Bounding box: Bounding box forms a bounding region for each node and then tries to refine their positions. The collaborative multilateration enables sensor nodes to accurately estimate their locations by using known beacon locations that are several hops away and distance measurements to neighboring nodes. At the same time it increases the computational cost also.

Gradient: Error in hop count distance matrices in the presence of an obstacle.

Relaxation-based distributed algorithms: The limitation of this approach is that the algorithm is susceptible to local minima [26].

Coordinate system stitching based distributed algorithms: The advantage of this approach is that no global resources or communications are needed. The disadvantage is that convergence may take some time and that nodes with high mobility may be hard to cover.

Hybrid localization algorithms: The limitation of this scheme is that it does not perform well when there are only few anchors. SHARP gives poor performance for anisotropic network.

Interferometric ranging based localization: Localization using this scheme requires considerably larger set of measurement which limits their solution to smaller network.

(b). Centralized Localization:

If an algorithm collects localization related data from one station and execute it from the same station then it is called centralized. In centralized model the problem is that if computing server fails due to some problem then entire processing goes down. Scalability is another problem when we consider the centralized model for computation of our data. For security reasons this approach is also not best. The techniques which are based on centralized model are explained below.

MDS-MAP: The advantage of this scheme is that it does not need anchor or beacon nodes to start with. It builds a relative map of the nodes even without anchor nodes and next with three or more anchor nodes; the relative map is transformed into absolute coordinates. This method works well in situations with low ratios of anchor nodes. A drawback of MDS-MAP [27] is that it requires global information of the network and centralized computation.

Localize node based on Simulated Annealing: This algorithm does not propagate error in localization. The proposed flip ambiguity mitigation method is based on neighborhood information of nodes and it works well in a sensor network with medium to high node density. However when the node density is low, it is possible that a node is flipped and still maintains the correct neighborhood. In this situation, the proposed algorithm fails to identify the flipped node.

A RSSI-based centralized localization technique: The advantage of this scheme is that it is a practical, self-organizing scheme that allows addressing any outdoor environments [28]. The limitation of this scheme is that the scheme is power consuming because it requires extensive generation and need to forward much information to the central unit.

V. RELATED WORK

Localization in sensor networks can be defined as identification of sensor node's position For any wireless sensor network, the accuracy of its localization technique is highly desired. Localization is the issue of locating the geometrical position of the sensor node in the network. Localization problem is an estimation of position of wireless sensor nodes and to coordinate with one another. Localization is a challenge which deals with wireless sensor nodes and it has been studied from many years. There are different solutions and they are evaluated according to cost, size and power consumption. Localization is important when there is an uncertainty of the exact location of some fixed or mobile devices. One example has been in the supervision of humidity and temperature in forests and/or fields, where thousands of sensors are deployed by a plane, giving the operator little or no possibility to influence the precise location of each node [29] [30].

Therefore, the network localization problem, namely, the problem of determining the positions of nodes in a network, has attraction of many engineering field and have been researched for many years. The device whose location is to be estimated is called localization node, and the network entity with known location is called localization base station. Wireless sensor network consists of a large set of inexpensive sensor nodes with wireless communication interface. These sensor nodes have limited processing and computing resources. Thus, algorithms designed for wireless sensor networks need to be both memory and energy efficient. In most of the algorithms for wireless sensor network, it is assumed that the sensor nodes are aware of their locations and also about the locations of their nearby neighbors. Hence, localization is a major research area in wireless sensor networks. Nodes can utilize a global positioning system, but this solution is typically very costly. Many researchers are focusing on designing different algorithm but paying less attention on range measurement inaccuracy Localization is usually carried out by measuring certain distance dependent parameters of wireless radio link between the localization node and different localization base stations. Many services are provided to users on the basis of location in wireless sensor networks. The role of location is very important in the wireless sensor networks. To access the data location is very important as the data itself. Location is also important for the upcoming areas such as ubiquitous computing, mobile services, networks planning and sensor networks [28]. There are considerable amount research activities to improve localization in wireless sensor networks. But there are also some interesting open problems that need further attention.

Interferomatric ranging based localization that takes error propagation into account*:* Interferometric ranging technique has been recently proposed as a possible way to localize sensor networks as it gives precise measurements than other common techniques. But simulation results from [31] indicate that error propagation can be a potentially significant problem in interferometric ranging. In order 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.

Attack the challenges of Information Asymmetry: WSNs are often used for military applications like landmine detection, battlefield surveillance, or target tracking. In such unique operational environments, an adversary can capture and compromise one or more sensors physically. The adversary can now tamper with the sensor node by injecting malicious code, forcing the node to malfunction, extracting the cryptographic information held by the node to bypass security hurdles like authentication and verification, so on and so forth. 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. To solve this problem, in [32] the authors propose a Distributed Reputation-based Beacon Trust System (DRBTS), which aimed to provide a method by which beacon nodes can monitor each other and provide information so that unknown nodes can choose who to trust, but 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 spaces [33] can be a good area of future work.

VI. CUREENT ASPECTS IN LOCALIZTION

Resource constraints: Nodes must be cheap to fabricate, and trivially easy to deploy. Nodes must be cheap, since fifty cents of additional cost per node translates to $500 for a one thousand node network. Deployment must be easy as well: thirty seconds of handling time per node to prepare for localization translates to over eight man-hours of work to deploy a 1000 node network. That means designers must actively work to minimize the power cost, hardware cost and deployment cost of their localization algorithms.

Node density: . Many localization algorithms are sensitive to node density. For instance, hop count based schemes generally require high node density so that the hop count approximation for distance is accurate. Similarly, algorithms that depend on beacon nodes fail when the beacon density is not high enough in a particular region. Thus, when designing or analysing an algorithm, it is important to notice the algorithm's implicit density assumptions, since high node density can sometimes be expensive if not totally infeasible.

Environmental obstacles and terrain irregularities: Environmental obstacles and terrain irregularities can also wreak havoc on localization. Large rocks can occlude line of sight, preventing TDoA ranging, or interfere with radios, introducing error into RSSI ranges and producing incorrect hop count ranges. Indoors, natural features like walls can impede measurements as well. All of these issues are likely to come up in real deployments, so localization systems should be able to cope.

Security: Security is the main issue in localization as the data is transferred from beacon node to anchor node then any of mobile beacons which is a virus or not secure acting as original mobile beacons transmit false messages due to this an error will occur which is harmful for our computation.

Non convex topologies: Border nodes are a problem because less information is available about them and that information is of lower quality. This problem is exacerbated when a sensor network has a non-convex shape: Sensors outside the main convex body of the network can often prove unlocalizable. Even when locations can be found, the results tend to feature disproportionate error.

VII. CONCLUSIONS

Some localization schemes have fewer merits and greater demerits and some of them have less demerits and greater merits. These merits and demerits were the main source for proposing the idea of a unique approach which is the enhanced composite approach. Localization problem is an open challenge in wireless sensor network. There are many aspects where we need improvements such as how to define threshold value in wireless sensor network. The performance of any localization algorithm depends on a number of factors, such as anchor density, node density, computation and communication costs, accuracy of the scheme and so on. All approaches have their own merits and drawbacks, making them suitable for different applications. Some algorithms require beacons (Diffusion, Bounding Box, Gradient, APIT) and some do not (MDS-MAP, Relaxation based localization scheme, Coordinate system stitching). Beaconless algorithms produce relative coordinate system which can optionally be registered to a global coordinate system. Sometimes sensor networks do not require a global coordinate system.

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