A Review of Mobile-Assisted Localization Algorithms in Wireless Sensor Networks

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Abstract- The process of determining the positions of nodes called localization which it is important in many wireless sensor network (WSN) applications such as target tracking, battlefields and disaster rescue. In recent years, the idea of mobile assisted localization has received extensive attention in literature because it is an efficient approach that significantly reduces implementation cost by using one mobile anchor (beacon) or few mobile anchors instead of a large number of static anchor nodes. In this paper we present an overview of existing mobile assisted- localization algorithms. In addition, we provide taxonomy based on different features which can be used for classifying the mobile-assisted localization algorithms and by using the proposed taxonomy we compare between several existing mobile assisted-localization algorithms.
Keywords – Wireless Sensor Network, Mobile –assisted localization, Algorithms, Review, Anchor, Beacon.

I. INTRODUCTION

Recent advancements in micro-electro-mechanical systems (MEMS) and wireless communication technology have made it possible to develop wireless sensor networks (WSNs). Wireless sensor networks are collection of spatially distributed autonomous inexpensive sensors connected by wireless communication links in ad hoc manner. Usually WSNs are densely deployed in a region of interest to monitor environmental or physical conditions such as sound, pressure temperature and vibration. WSNs have been used in many applications including military, medical care, intelligent transportation, target tracking and routing. In these applications and in many others WSNs it is important for the nodes to know their own physical positions [1- 3].

The operation of finding the spatial locations or positions (coordinates) of nodes in a wireless sensor network has been called localization. A straightforward solution is to equip all nodes with Global Positioning Systems (GPS) [4] receiver that can provide node with its exact location. But this is not a cost-effective solution also it is high energy consuming because a WSN normally contains a massive number of nodes [5]. In recent years, a number of localization schemes have been proposed to reduce the dependence on GPS in WSNs [6-13]. In general, these localization algorithms are classified into range-based localization and range-free localization. Range-based localization algorithm apply range measurements (angle or distance) such as AOA [6], RSS [7] and TDOA [8] to calculate the locations of unknown nodes. Range-free localization algorithms apply network connections information (connectivity or hop count) to calculate the locations of unknown nodes, e.g. APIT [9] and DV-Hop [10].

Most of the localization algorithms share a common feature: that small portion of nodes called anchors or beacons or landmarks which they know their positions (e.g. via manual placement or GPS) send beacon messages contain their coordinates to help the rest nodes which called sensor nodes or unknown nodes need to discover their positions or locations [5,14]. In this paper, a node that has its own location information is called an anchor; otherwise, a node that need to estimate its location is called unknown node.

The accuracy of the localization increases with the number of anchors increases, but the problem with an increased number of anchor is that they are more expensive than the rest of the sensor nodes (unknown nodes), so to solve this problem the idea of mobile assisted localization has been actively pursued. The method of mobile assisted localization that single mobile or few mobiles equipped with GPS travel the entire deployment region based on some traverse route periodically broadcasting their current locations to help localize the entire network. Thus using mobile anchor (beacon) that knows its position is broadly equivalent to using many static anchors.

In this paper the mobile node which used in assisting localization is called mobile beacon to distinguish it from the static anchors of the WSN. Figure 1 shows the main components of mobile assisted localization algorithm as general.

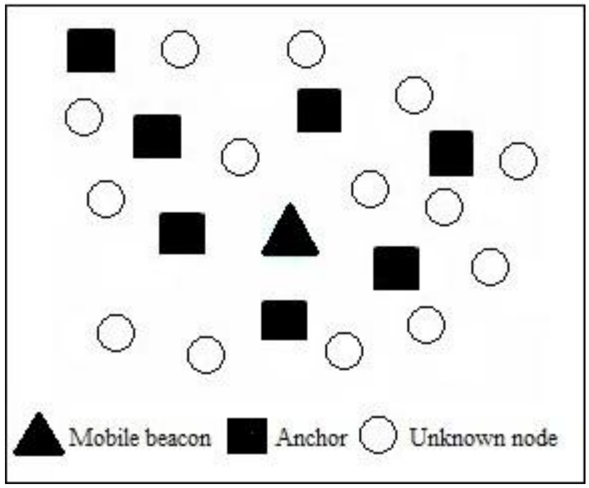

Figure1. Mobile - assisted localization

In Figure 1 the black squares are static anchors at known locations, the white circles represent the unknown nodes which are needed to determine its locations and the black triangle is mobile beacon which assist to localize the WSN.

This paper gives a survey on mobile beacon- assisted localization in wireless sensor network. It provides taxonomy for classifying the existing mobile -assisted localization algorithms based on different features , also our taxonomy can be used to classify any new proposed mobile -assisted localization algorithms . In addition, this paper presents comparisons of these algorithms.

The rest of this paper is organized as follows: Section II reviews mobile-assisted localization algorithms in WSNs. Section III proposes taxonomy to classify the mobile-assisted localization algorithms and presents comparisons of these algorithms. Finally, concluding remarks are given in section IV.

II. A REVIEW OF MOBILE-ASSISTED LOCALIZATION ALGORITHMS

2.1 Ssu Algorithm

Ssu et al. [15] developed a range-free localization algorithm using mobile beacon points that move around in the sensing area and periodically broadcast beacon messages, including their current location information. After unknown nodes receive the beacon messages with appropriate filtration, the valid beacon points and chords will be determined. Therefore, the center of the circle the unknown node's location can be discovered. With [15] algorithm, no extra hardware or data communication is needed for the WSN nodes. Moreover, obstacles in the sensing fields can be tolerated.

2.2. MALS Algorithm

MALS algorithm was proposed in [16], MALS employs a single mobile beacon obtains geographical position using GPS or by some other means. Based on rigidity theory, the original large scale network is partitioned into several localization units, each of which can be uniquely localized given three non-collinear anchor positions. The shortest path traversing all localization units is chosen as the trajectory of the mobile beacon which follows the designed path step by step from one localization unit already localized to the next one yet to be localized. So MALS skipped the blank areas and avoided unnecessary movements.

2.3 BRM Algorithm

In [17] they proposed algorithm called Beam-width Related Motion BRM for locating static sensor nodes randomly deployed in a two dimensional coordinate system by using one mobile beacon node equipped with directional antenna and moves in a certain pattern (radiation pattern). The mobile beacon node transmits a message called Beacon Message (BM) at certain points along the moving path. The unknown nodes receive these BMs and apply the statistical median to compute their coordinates based on the information included in these BMs. In BRM algorithm a hybrid localization technique is used; hybrid between range-based technique and mobile beacon with Directional Antenna-Based technique.

2.4 Snake -Like Algorithm

In [18] they proposed a range-free algorithm for localization by using a mobile anchor in presence of obstacles. For simplicity in this paper, we will denote this algorithm as snake-like. In snake-like algorithm [18] the mobile anchor moves in a snake-like pattern, which consumes less energy compare to the other schemes such as random methods. When the mobile beacon faces obstacle it changes its direction and stores the information of circulating point for future movements to have correct direction. The mobile anchor transmits beacons periodically while they are travelling to set the coordinate for each unknown nodes in turn.

2.5 MBAL Algorithm

A range-based algorithm called Mobile Beacon-Assisted Localization (MBAL) was proposed in [19]. MBAL minimizes the length of the movement path of the mobile beacon with consideration of a low computational complexity. The mobile beacon in MBAL is assumed it can always know its own position and unknown nodes are able to calculate the position with three or more beacon messages from the mobile beacon or anchor nodes. MBAL adopted a new range check technique for position-ambiguity problem of bilateration which can messages from the mobile beacon or anchor nodes. MBAL adopted a new range check technique for position-ambiguity problem of bilateration which can improved performance to both unknown node and mobile beacon by reducing energy consumption. So MBAL with its specific movement strategy has more promising results over random movement method.

2.6 DREAMS Algorithm

In [20] a dynamic mobility scheduling algorithm called DREAMS was presented, the beacon trajectory is defined as the track of Depth-First Traversal (DFT) of the network graph. The mobile beacon performs DFT dynamically, under the instruction of nearby sensors on the fly. It moves from sensor to sensor in an intelligent heuristic manner according to Received Signal Strength (RSS)-based distance measurements. To shorten the beacon trajectory, DFT may be performed on a Local Minimum Spanning Tree (LMST) sub graph, where edges are weighted by RSS, and in addition, unvisited, but localized, sensors may be excluded from DFT if the exclusion does not affect discovery of unlocalized sensors. Li et al.[20] extended DREAMS algorithm to multi beacon cases and they showed through extensive simulation that the full localization guarantee property preserves even with measurement noise .

2.7 LMCS Algorithm

In [21] Zhao et al. proposed range-free localization called Localization with a Mobile beacon based on Compressive Sensing (LMCS). LMCS use compressive sensing (CS) to get the related degree of the unknown nodes and all the beacon points. According to the related degree, LMCS decides the weight value of each beacon point for the mass coordinates and estimates the unknown node location by weighted centroid. LMCS suitable for practical application and the obstacles and degree of irregularity have little effect on LMCS.

2.8 RELMA Algorithm

Karim et al. [22] proposed algorithm called Range-free Energy efficient Localization technique using Mobile Anchor (RELMA). RELMA was designed for large scale for a large scale WSN consisting three overlay networks: sensor networks, Wi-Fi and Wi-Max. In RELMA the network is divided into zones or clusters based on the nodes hop count from Base Station (BS) and select a node as Cluster Head (CH) that work as a mobile beacon. For instance, nodes whose hop count is less than or equal to three reside in a specific zone. These zones have nodes that are uniformly distributed and all these nodes have the same sensing and communication ranges.

2.9 MACL Algorithm

Hu et al. [23] developed Mobile Anchor node Centroid Localization (MACL) algorithm. An idealized radio model for wireless communication is used because it was simple and easy to reason about mathematically. MACL is rang free algorithm uses a single mobile beacon node to move in the sensing field following a spiral path and broadcast beacon messages which contain its current location periodically. Unknown nodes receive the position information of the mobile beacon node and localize themselves to the centroid of these locations.

2.10 Virtual Ruler Algorithm

In [24] authors proposed a localization algorithm called Virtual Ruler. In virtual ruler [24] mobile beacon (vehicle) is fixed with multiple ultrasound beacons travels around the area to measure distances between unknown nodes pairwise. Virtual ruler is considered as dynamic path planning algorithm, the vehicle moves through the deployed monitoring area, and stops at places for distance measurements. Virtual ruler can not only obtain sufficient distances

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between pairwise unknown nodes, but can also filter incorrect values through a statistical approach. By assigning distance measurements with confidence values, virtual ruler algorithm can intelligently localize each unknown nodes based on high confidence distances, which greatly improves localization accuracy.

III. CLASSIFICATION AND COMPARISON

Mobile-assisted Localization algorithms for WSNs can be classified according to several criteria or features. Figure 2 shows our proposed taxonomy. The criteria of the taxonomy are as following:

1. Environment: based on the environment, we classify algorithms into ideal and obstacle. Ideal means without considering obstacle in WSN environment otherwise obstacle means with considering obstacle in WSN environment.
2. Number of mobiles: Based on the mobile node numbers we classify algorithms into single and multiple. Single means only one mobile is used to assist localization. Multiple means more than one mobile is used to assist localization.
3. Type: Based on the type, the algorithms can be classified into range-based and range-free. Range-based algorithm applies range (angle or distance) information to calculate unknown node location. Range-free algorithm applies network connections information instead of rang to calculate unknown node location.
4. Mobile movement: It means the path of mobile beacon according to this feature the algorithms can be classified into three categories : static path, dynamic path and random.

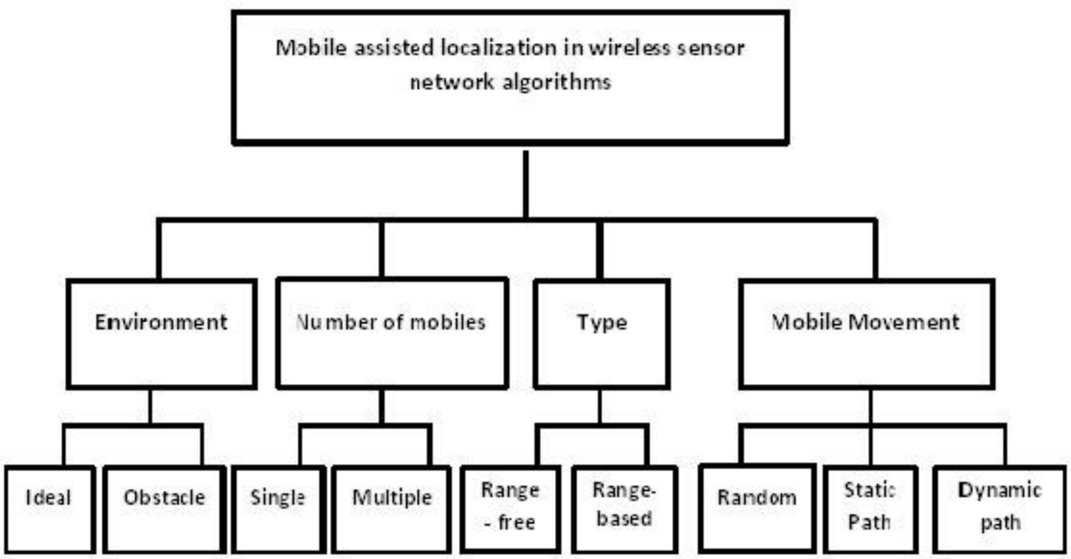

Figure 2. Taxonomy of mobile-assisted localization algorithms

Table 1 presents compassion between ten of existing mobile-assisted localization algorithms using the criteria of our proposed taxonomy i n Figure 2

Table -1 Compassion between mobile-assisted localization algorithms

Algorithm	Environment	Number of Mobiles	Type	Mobile Movement
Ssu [15]	Ideal	Single	Range- free	Random
MALS [16]	Ideal	Single	Range-based	Dynamic path
BRM [17]	Ideal	Single	Range-based	Static path
Snake-like [18]	Obstacle	Single	Range- free	Dynamic path
MBAL [19]	Ideal	Single	Range- based	Dynamic path
DREAMS [20]	Ideal	Single	Range- based	Dynamic path
LMCS [21]	Ideal	Single	Range-free	Random
RELMA [22]	Ideal	Multiple	Range- free	Random
MACL [23]	Ideal	Single	Range- free	Static path
Virtual ruler[24]	Obstacle	Multiple	Range- based	Dynamic path

As shown in Table1 most mobile-assisted localization algorithms designed for ideal environment only Snake-like [18] and virtual ruler [24] algorithms are designed for obstacle environment. Also most algorithms use single mobile to assist localization, only RELMA [22] and Virtual ruler [24] use more than one mobile to assist localization.

IV. CONCLUSION

The technique of mobile-assisted localization is more economic than other kind techniques of localization for wireless sensor networks. This paper discussed mobile-assisted localization technique and several current mobile-assisted localization algorithms are reviewed and compared. This paper provided taxonomy of the different criteria that used to classify current mobile-assisted localization algorithms in addition it can be used for classification the new proposed mobile-assisted localization algorithms. From our studying of the current mobile-assisted localization algorithms we found that majority of these algorithms do not consider obstacle environment so environment with obstacle should be taken into account from researchers in their new proposed mobile-assisted localization algorithms .

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