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Reduction of Localization Error in WSN by Efficient Path Planning Scheme

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Abstract: Wireless Sensor Networks (WSN) are commonly composed of a great number of randomly deployed nodes that communicate among themselves and gather information about the environment. Localization has been a major challenge in such networks because without discovering the location of the sensor that is informing sensed data, the informed data will not be useful. Localization algorithm is a vital and challenging topic in Wireless Sensor Networks (WSNs), especially for the applications requiring the accurate position of the sensed information. Many localization algorithms have been suggested and can be categorized into two families: range-based and range-free algorithms. Many applications require the sensor nodes to know their locations with a high degree of precision. Several localization methods based on mobile anchor nodes have been proposed for assisting the sensor nodes to determine their locations. However, none of these methods attempt to optimize the trajectory of the mobile anchor node. Accordingly, this work presents a path planning scheme, which optimizes the trajectory of the mobile anchor node minimizes the localization error and guarantees that all of the sensor nodes can determine their locations. To overcome the problem of node failure and link breakage, we will use redeployment of sensor nodes and used the mobile anchors to localize the nodes. The movement of mobile anchor nodes is like that it moves in the grids in a zigzag pattern such that it can efficiently cover the entire sensor field. Wireless Sensor Network (WSN) is a set of sensor nodes connected to each other via wireless links, some node are anchor node and some are unknown which are simulated on the MATLAB. In order to verify performance of our proposed algorithm against other algorithms viz. DV-Hop, simulations are conducted on MATLAB. DV-Hop is one of the range-free localization algorithms utilizing hop-distance estimation. The simulations of algorithms are randomly run many times for each result and the average values were used as final results. Simulation results show the performance of the proposed algorithm is superior to that of the DV-Hop algorithm.

Keywords: Anchor node, Improved DV-HOP algorithm, Localization, MATLAB, Wireless sensor networks.

I. INTRODUCTION

A sensor network is made of many sensor nodes, which are densely deployed either inside the phenomenon or in its vicinity. The location of sensor nodes need not be engineered or pre-determined. This allows random deployment in unapproachable terrains or disaster or rescue operations. On the other hand, this also means that sensor network protocols and algorithms must have self-organizing capabilities. Another unique feature of sensor network is the cooperative working of sensor nodes. Sensor nodes are fitted with an on-board processor. Instead of sending the raw data to the nodes use for the fusion, sensor nodes utilize their processing abilities to locally carry out simple computations and transmit only the required and partially processed data. Modern advances in Micro-Electro-Mechanical Systems (MEMS) technology, wireless communications, and digital electronics have enabled the evolution of low-cost, low power, multifunctional sensor nodes that are compact in size and communicate un ethered in short distances. These tiny sensor nodes, which are composed of sensing, data processing, and communicating components, influence the idea of sensor networks based on collective effort of a large number of nodes. Sensor networks show an outstanding improvement over traditional sensors, which are employed in the following two ways:

a) Sensors can be placed far from the actual phenomenon, i.e., something known by sense perception. In this method, large sensors that use some sophisticated techniques to distinguish the targets from environmental noise are required.

b) Multiple sensors that perform only sensing can be utilized. The positions of the sensors and communications topology are specially engineered. They transmit time series of the sensed phenomenon to the central nodes where calculations are performed and data are fused.

Localization means to find location of nodes in a network. With the support of some infrastructure, a node can discover its location in the network by extracting information received from the infrastructure; also, by making a node to transmit signals at intervals, the infrastructure can calculate the location of the nodes [4]. Localization is the method of finding the position of nodes as data and information are unusable if the nodes does not know their geographical positions. GPS

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(global positioning system) is the simplex method for localization of nodes, but it becomes very costly if many nodes exists in a given network. Many algorithms have been suggested to solve the issue of localization; although, a large number of existing algorithms are application specific as well as most of the solutions are not satisfactory for wide range of WSNs. Ultrawide band techniques are convenient for inward environment while acoustic transmission-based system requires extra hardware. Both are exact techniques but costly in terms of energy consumption and processing. Unlocalized nodes approximate their positions from anchor nodes beacon messages, which needs much power. Many algorithms have been proposed to reduce this communication cost. If one node evaluates its wrong location, then this error propagates to overall network and further nodes; consequently, wrong information of anchor nodes location is propagated. To compute the position of nodes is mainly depend on distance between anchor node with known location and unlocalized node with unknown location. Sensor nodes are employed in industrial, environmental, military, and civil applications [7]. Localization schemes are categorized as:

1. **Anchor Based and Anchor Free:** In anchor-based mechanis ms, the locations of few nodes are known. Unlocalized nodes are localized by these known nodes locations. Accuracy is highly depending on the number of anchor nodes. Anchor-free algorithms evaluate relative positions of nodes instead of computing absolute node positions.
2. **Centralized & Distributed:** In centralized schemes, all the information is passed to one central point or node which is generally called "sink node or base station". Sink node finds position of nodes and transmits information to respected nodes. Computation cost of centralized based algorithm is reduced, and it takes less energy as compared with computation at individual node. In distributed schemes, sensors compute and estimate their positions individually and directly communicate with anchor nodes. There is no grouping in distributed schemes, and every node estimates its own position
3. **GPS Based and GPS Free:** GPS-based schemes are very e xpensive because GPS receiver has to be put on every node. Localization precision is very high as well. GPS-free algorithms do not utilize GPS, and they compute the distance between the nodes relative to local network and are less e xpensive as compared with GPS-based schemes. Some nodes need to be localized through GPS which are called anchor or beacon nodes that begin the localization process.
4. **Coarse Grained and Fine Grained:** Fine-grained localization techniques result when localization methods use features of received signal strength, while coarse-grained localization techniques result without using received signal strength.
5. **Stationary and Mobile Sensor Nodes:** Localization algorithms are also designed according to field of sensor nodes in which they are deployed. Some nodes are static in nature and are fixed at one place, and most of the applications use static nodes. That is why many localization algorithms are designed for static nodes. Few applications employs mobile sensor nodes, for which few mechanisms are designed
6. **Range based and Range free methods:** Range-based schemes are distance- estimation- and angle-estimation-based techniques. Important schemes which are used in range-based localization are received signal strength indication (RSSI), angle of arrival (AOA), time difference of arrival (TDOA), and time of arrival (TOA) Range-free methods are distance vector (DV) hop, hop terrain, centroid system, APIT, and gradient algorithm. Range-free methods use radio connectivity to communicate between nodes to infer their location. In range-free schemes, distance measurement, angle of arrival, and special hardware are not used [7].

DV-HOP ALGORITHM: The main idea of DV-HOP algorithm is to evaluate the distance between unknown nodes and anchor nodes through the network average hops or the product of hops, and then get the node location through likelihood estimation. The algorithm consists of three steps:

(1) Information Broadcast & Correction Value Calculation: In WSN, every node will broadcast its location information in the form of data group. The initial hop is set to 0, when the unidentified nodes are recorded to the minimum hop of each anchor node, compare with the existing hop. If it is greater than the actual hop, just discard, 1 is added to the hop value, continue forward the rest unknown node, & each unknown node will get the least hop of anchor nodes.

(2) Correction Value Broadcast: Every anchor node will broadcast its correction value in the form of broadcast, and the non-located unknown nodes get the correction value of each anchor nodes.

(3) Localization of unknown nodes: By computing the correction value of anchor nodes and the hop from itself to anchor nodes, unknown nodes calculate the distance to anchor nodes. Eventually, the coordinates for unknown nodes will be calculated through the coordinate data of anchor nodes and the distance information to anchor nodes [12].

In DV-Hop algorithm, the beacon node transmits a beacon to the network and the beacon contains the location information of this beacon node and a hop parameter whose first value is 1. The beacon is delivered in the network by flooding way andthe hop-count increases 1 in every time during the beacon is delivered. The receiver node saves the beacon with the minimum-hop count between all the beacons about a certain beacon node which the receiver node has received and rejects the beacons with relative large hop-counts. In DV-Hop algorithm, locations of unknown nodes are computed through a few anchor nodes (i.e. GPS nodes which know its locations). DV-Hop algorithm consists of three steps as follows:
Step 1: Every anchor node transmits its information of location or coordinate & values of hop counts, which ensures all anchor nodes can acquire coordinates of anchor nodes & minimum hop-count of every anchor node through the Internet.

Step 2: Compute the average distance-sum of single-hop node and broadcast it. Unknown node will receive hop-count distance of nearest anchor node.
Step 3: Again, calculate the linear form of distance formula and adopt least square method to estimate the locations of unknown nodes.

In DV-Hop algorithm, it is supposed that the routes of minimum hop-count among nodes are similar. If the average distance of every hop-count is used to compute the distance between anchor node and unknown node, there are some error between the estimated distance and the real one [10] DV-Hop (Distance Vector) is the hop-count based localization. It does not need to measure the distance between the beacon node and unknown node. It utilizes the average hop distance to calculate the actual distance [11] DV hop estimates range among nodes using hop count. At least three anchor nodes broadcast coordinates with hop count across the network. The information propagates over the network from neighbor to neighbor node. When neighbor node receives such information, hop count is increased by one. In this way, unlocalized node can find number of hops away from anchor node. All anchor nodes estimate shortest path from other nodes, and unlocalized nodes also calculate shortest path from all anchor nodes. Average hop distance formula is co mputed as follows: distance between two nodes/number of hops. Unknown nodes use triangulation method to calculate their positions from three or more anchor nodes using hop count to measure shortest distance [7].

II. RESULT AND ANALYS IS

ALGORITHM: 1 WHEN ANCHOR NODE IS FIXED

In this algorithm, we propose that there are four anchor nodes which are placed at four fixed positions, there is 1 mobile node. We consider a 100by100 area that the mobile node can wander. The node is placed at the random location and we have to find estimated location of mobile node.

Table 1: Estimated error of fixed anchor node

No. of iterations	Estimated error (100m)	200m	300m
1	2.3174	6.4331	13.7523
2	6.0033	4.2772	6.9523
3	3.8502	5.4759	16.6606
4	4.9846	2.7757	17.0085
5	8.6481	1.7111	5.5455
6	0.13006	3.1521	10.2258
7	3.9576	7.1057	17.8417
8	5.9103	9.1609	10.9807
9	1.8684	7.1383	8.5984
10	4.8614	1.072	3.0472

In Table 1, we changed the network size from 100m to 300m, and perform a no. of iterations to find out the minimum estimated error.

ALGORITHM 2: WHEN ANCHOR NODE IS MOVING

It provides the facility to researchers to check functioning of algorithm in different scenarios. This algorithm explains that there are four anchor nodes which are moving so that they can cover the entire sensor field. There is 1 mobile node that we have to find its estimated location. In this algorithm, the anchor nodes are moving at various positions or various coordinates and then the localization error of the mobile node is to be estimated. There are four different scenarios in which anchor nodes are moving at various coordinates and the network size is remain fixed for all the four scenarios i.e. 100 m.

Table 2: Estimated error for different locations of anchor nodes

No. of Iterations	Error in location 1	Error in Location 2	Error in Location 3	Error in Location 4
1	4.6123	3.4097	4.6463	2.2685
2	8.5663	2.1712	0.20117	3.4952
3	1.7243	1.0358	3.4297	0.90037
4	1.0157	3.6831	2.8558	1.4392
5	2.9123	1.2412	1.431	0.52204

This table explains that in a network size of 100m, a no. of iterations is to be performed and anchor nodes which are moving to cover the entire sensor field can be designed into four different scenarios. In each scenario, four anchor nodes are placed at various positions and error is calculated for the mobile node. Errors are evaluated for each different location.

Table 3: Algorithm Error

No. of anchor nodes	Basic DV-Hop	Existing DV-Hop	Proposed DV- Hop
10	0.33	0.25	0.070125
15	0.32	0.11	0.022742

III. CONCLUSION & FUTURE WORK

The problem of node localization in WSN remains an important open research problem. In this dissertation, a scheme is suggested which is based on optimization of the trajectory of the mobile anchor node. By using this scheme, the localization error is reduced. To overcome the problem of node failure and link breakage, it's preferred redeployment of sensor nodes and used the mobile anchors to localize the nodes. The technique which is used to get the optimized results can be obtained by implementing the improved DV-HOP algorithm. The existing DV-HOP algorithm implies that the anchor nodes are fixed while our proposed DV-HOP algorithm explains that the anchor nodes are in moving position.The aim of dissertation is to plan an efficient path planning scheme to reduce localization error in wireless sensor networks. By proposing first DV-Hop algorithm, it is concluded that after performing simulations on MATLAB, localization error is reduced upto a greater extent. Also, in second DV-Hop algorithm, the anchor node moves at various positions in the network of four different scenarios, then the localization error reduces to 0.20117m. On comparing the existing DV-HOP algorithm and proposed DV-hop algorithm, it is clear that the localization error reduced from 0.11 to 0.022m for considering 15 anchor nodes. The simulation results indicate that the improved DV-Hop algorithm outperform the DV-Hop algorithm in all simulation cases.

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