Pre Defined Trajectory Algorithm for Mobile Anchor Based Localization in Wireless Sensor Networks

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Abstract
Accurate and low-cost sensor localization is a critical requirement for the deployment of wireless sensor networks in a wide variety of applications. Many applications require the sensor nodes to know their locations with a high degree of precision. Various 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 project presents a path planning scheme, which ensures that the trajectory of the mobile anchor node minimizes the localization error and guarantees that all of the sensor nodes can determine their locations. The obstacle-resistant trajectory is also proposed to handle the obstacles in the sensing field. Later this path planning algorithm is adjusted so that it suits most of the effective localization algorithms. The performance of the proposed scheme is to be evaluated through a series of simulations with the ns-2 network simulator.

Keywords:
Localization; Wireless Sensor Networks (WSNs); GPS; mobile anchors; beacons;

I. Introduction

In the recent years, the advent of Micro-Electronics and Wireless Communications proliferated to the development of multi-functional sensor nodes in a Wireless Sensor Network (WSN). A sensor node has the ability to sense, process and communicate over a shorter distance. Basically a wireless sensor network (WSN) consists of a number of sensor nodes that are densely deployed over the region of interest. The position information of a node is essential practically because sensing the data without knowing the location information of a node becomes meaningless. In a wireless sensor network, the location information of a node is significant as it has gained significant momentum especially for the applications such as tracking the position of an object, pollution monitoring, surveillance etc.

The Node Localization problem is viewed as finding the positional information i.e. spatial coordinates of all the nodes over a region of interest in a network. Localization becomes very critical when there is an uncertainty about the position of the nodes. Location information of a node lays the foundation [1] for all other applications such as routing, topology control, reporting the origin of events, coverage, node life-time control and target tracking. Node localization was initially done by adding Global Positioning System(GPS) to the nodes but it is quite unfortunate that adding GPS to all the nodes in a WSN environment leads to the following demerits:- (i) Cost factor increases. (ii) GPS cannot work in indoor environments or during the obstacles such as Line of Sight(LOS) obstructing the GPS satellites.(iii) GPS consumes more power thereby decreasing the battery power of individual nodes and hence reducing the life time of nodes in a sensor network.

In order to overcome these demerits, Node localization was done by configuring few nodes as reference nodes either manually or using GPS in order to determine the location of the remaining unlocalized nodes in the network. Basically there are three set of nodes namely anchor nodes, unlocalized nodes and localized nodes. The first set of sensor nodes whose positions are known i.e. reference nodes are termed as anchor (or) beacon (or) location aware nodes [2]. The second set of sensor nodes whose positions are unknown are termed as unlocalized nodes. The third set of nodes contains nodes which were in the second set but subsequently had their positions estimated are termed as localized nodes. Localization algorithms are usually classified into range based and range free. Range based algorithms are based on distance or angle estimation techniques of unknown nodes to anchor nodes in the network. Then the anchor nodes will use this distance or angle estimate in order to find the position of unlocalized sensor nodes. The commonly adopted range based localization approaches [3] are Received Signal Strength (RSS), Time of Arrival (ToA), Time Difference of Arrival (TDoA) and Angle of Arrival (AoA).Range based schemes has higher location precision and for achieving fine accuracy, range based schemes allow the use of hardware, which is expensive. Range free approaches are based on the content of received messages [4] as they support coarse accuracy. Range free approaches use proximity or connectivity information for finding the position of unknown nodes in the network. The commonly adopted range free

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localization approaches are Centroid, Amorphous, Distance Vector (DV) - Hop and Approximate Point-in-Triangulation Test (APIT). Range free schemes do not involve the use of expensive hardware and has lower location precision, less accurate and less complexity.

In this paper, we proposes an optimal path planning method for the mobile anchors used in the localization scheme presented by Ssu et al. Here a single mobile anchor is used to enable the sensor nodes to construct two chords of a communication circle of which they form the center point, and the intersection of the perpendicular bisectors of these two chords is then calculated in order to pinpoint the sensor position. However, the mobile anchor moves randomly through the sensing field (i.e., in accordance with the Random Waypoint model), and thus it is possible that some of the sensor nodes cannot be localized. Therefore, the path planning scheme proposed in this study is specifically designed to both minimize the localization error of the individual sensor nodes and to maximize the number of sensor nodes which can determine their locations. Section V provides the concluding remarks and discusses future directions.

2. Related Work

In the localization scheme presented by Sichitiu and Ramadurai[5], the sensor nodes determine their locations based on the beacon messages transmitted by a single mobile anchor. However, in this case, the sensor nodes estimate their positions by applying the RSSI technique to the beacon messages.

Galstyan et al.[6] proposed a distributed localization scheme based on a single mobile anchor, in which radio connectivity constraints were imposed in order to minimize the uncertainty in the localization results.

Sun and Guo[7] proposed various probabilistic localization schemes based on a single mobile beacon, and showed that non-parametric probabilistic estimation techniques yield more robust and accurate localization results than parametric estimation methods.

Koutsonikolas[8] et al. proposed three path planning schemes for the mobile anchor node in the localization scheme presented by Sichitiu and Ramadurai, namely SCAN, DOUBLE SCAN and HILBERT. In SCAN, the mobile anchor node travels along a single dimension (e.g. the x-axis or y-axis direction), and the distance between two neighboring segments of the node trajectory defines the resolution of the trajectory. SCAN is simple and provides uniform coverage to the entire network. However, the collinearity of the beacons degrades the accuracy of the localization results. In DOUBLE SCAN, the collinearity problem is resolved by driving the anchor in both the x- and the y-directions. However, whilst this strategy improves the localization performance of the sensor nodes, the path length is doubled compared to that of SCAN, and thus the energy overhead increases accordingly. In HILBERT, the mobile anchor node is driven along a curved trajectory such that the sensor nodes can construct non-collinear beacon points and the total path length is reduced.

Huang and Zaruba[9] presented two further path planning schemes designated as CIRCLES and S-CURVES, respectively, for avoiding the collinearity problem inherent in the localization method. In CIRCLES, the mobile anchor follows a sequence of concentric circular trajectories centered at the center point of the deployment area, while in S-CURVES, the anchor follows an S-shaped curve rather than a simple straight line as in the SCAN method.

Han et al. introduced a path planning scheme for a mobile anchor node based on the trilateration localization scheme[10]. The anchor node moves according to an equilateral triangle trajectory and broadcasts its current position information in the sensing area. After receiving three position information, each sensor node can estimate itself location based on trilateration calculation. The distance between the sensor node and the anchor node can be measured based on Received Signal Strength (RSS).

Kim et al. presented an adaptive path planning for the mobile anchor node[11]. The anchor node moving according to a regular triangle with the length of its radio range first broadcasts three beacon messages. The sensor nodes that do not know their own positions then request the anchor node to deliver more beacon messages. The anchor node thus decides its trajectory on the basis of the received request messages.

M.Patil et.al [12] has proposed a distributed localization scheme based on Received signal strength Indicator (RSSI) by the three masters. The distance from three masters is determined and the unknown nodes can compute its location by using circular triangulation concept. Based on the simulation results, with regard to the localization error and power consumption, they have proposed and verified that the three master approach performs relatively much better than two master and one master approaches.

Frankie K.W.Chan, H.C.So et.al [13] has proposed a novel subspace approach of deterministic type for positioning the nodes in a WSN with the use of the node-to-node distance estimates, deduced from Received Signal Strength (RSS) or Time of Arrival (ToA) measurements. They have developed three versions of subspace algorithm for positioning the nodes in a WSN. They are full-set subspace algorithm, minimum-set subspace algorithm and distributed subspace algorithm.

Ji zeng Wang et.al [14] has proposed an improved Approximate Point-in-Triangulation Test (APIT) algorithm for location estimation in WSN. The improved APIT algorithm that is proposed in this work performs best when compared to the original APIT algorithm, based on the metrics such as high Node Packet Loss Rate and Node Density etc.

3. Algorithm Description

In this section, we describe the Path Planning Based Localization (PPL) [1] with regard to single mobile anchor in WSN environment. This algorithm is typically a range based distributed algorithm.

Wireless Sensor Network Modeling

WSNnetwork is a self-configuring infrastructure less network of mobile nodes connected by wireless links. Each node in this network is free to move independently in any direction, and will therefore change its links to other devices frequently. Each must forward traffic unrelated to its own use, and therefore be a router. The primary challenge in building a WSNnetwork is equipping each node to continuously maintain the information required to properly route traffic. Such networks may operate by themselves or may be connected to the larger Internet. WSNNW is a kind of wireless ad-hoc networks that usually has a routable networking environment on top of a Link Layer ad hoc network. With this module a new simulation object is created in tcl and the initialization procedure with the following operations:

- Packet format initialization
- Scheduler Creation
- Agent Creation
- Link Creation

The packet format initialization sets up field offsets within packets used by the entire simulation. The scheduler runs the simulation in an event-driven manner and may be replaced by alternative schedulers which provide somewhat different semantics. The agent is generally useful as a sink for dropped packets or as a destination for packets that are not counted or recorded as a sink for dropped packets or as a destination for packets that are not counted or recorded

Localization Implementation

The localization scheme was inspired by the perpendicularbisector of a chord conjecture. The conjecture describes that theperpendicular bisector of any chord passes through the center ofthe circle. As shown in Fig., the chord of a circle (AB) is a segmentwhose endpoints are on the circle. With two chords of thesame circle, the intersection point of two perpendicular bisectorsof the chords will be the center of the circle. The localizationproblem can be transformed based on the conjecture. The center of the circle is the location of the sensor node; the radius of the circle is the largest distance where the sensor node can communicate with the mobile anchors. The endpoint of the chord is the position where the mobile anchor point passes through the circle.

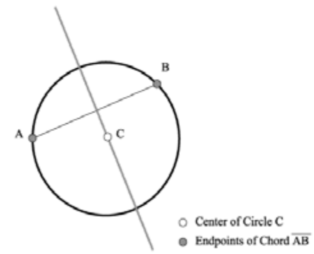

Fig 1.Perpendicular bisector of a chord conjecture.

Beacon Point Selection: In the mechanism, at least threeendpoints on the circle should be collected for establishing two chords. Each mobile anchor point periodically broadcasts beacon messages when it moves in the sensor network. The beacon message contains the anchor node's id, location, and timestamp.

Every sensor node maintains a set of beacon pointsand a visitor list. The beacon point is considered as an approximate endpoint on the sensor node's communication circle. The visitor list stores both the mobile anchors whose messageshave been received by the sensor node and their associatedlifetime. The th beacon point in the sensor is represented as (id , location , timestamp) and the th entry in the visitor list can be recorded as (id , lifetime). When a sensor node receives a beacon message from a mobile anchor point, the node willcheck whether the anchor point is in its visitor list. If not, a beacon point will be added and the anchor point with a predefined lifetime will be inserted in the visitor list. Otherwise, the beacon message will be ignored and the lifetime of the mobile anchor point will be extended. When the lifetime of the anchor point is expired, the corresponding entry in visitor list will be removed and the last beacon message of the anchor point will be recorded as a beacon point.

Location Calculation:

After three beacon points areobtained, two different chords can be generated. As shown in Fig. the set of selected beacon points is$\{B_I, B_J, B_K\}$and their locations are(x_i ,y_i), (x_j ,y_j), (x_k ,y_k), and . Two chords randomly chosen B_iB_j, B_iB_k, and , are formed basedon the beacon points. Consider that lines L_{ij} and $L_{jk}$are the corresponding perpendicular bisectors of the chords B_iB_j, $B_iB_k$and , respectively. Therefore, by simple algebraic calculation, the equations of two lines L_{ij} and L_{jk} can be presented as follows:

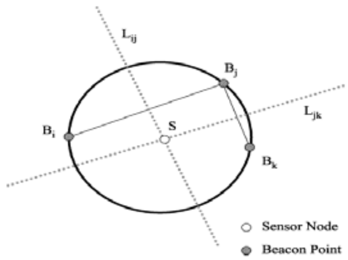

Fig 2.Anchor Path Planning Scheme

$$\begin{cases} L_{ij} : a_{ij}x + b_{ij}y = c_{ij} \\ L_{jk} : a_{jk}x + b_{jk}y = c_{jk} \end{cases}$$

If three beacon points are obtained on the communicationcircle of a sensor node, it follows that the mobile anchornode must pass through the circle on at least two occasions.

In the path planning scheme proposed in this study, thedistance between two successive vertical segments of theanchor trajectory (i.e. the resolution of the anchor trajectory)is specified as $R{-}X$, where R is the communication radius ofthe mobile anchor node and X is set in the range $0 < X \leq R/3$This is because if X is bigger than $R/3$,$R - X$ will be smallerthan $2R\ /3$. Hence, the distance between four successive verticalsegments is less than the diameter of the communication circle(i.e. $2R$). As a result, the mobile anchor node will pass throughthe circle more than three times. In other words, increasing thevalue of X may incur redundant beacon points.

Conversely, decreasing the value of X may cause the chord length tofall below the minimum threshold value. Thus, in practice, acareful choice of X is required. To determine the positions of the sensor nodes close to the boundary of the sensing field, the dimensions of the field are virtually extended by a distance of R on each side, as shown in Fig. By extending the sensing field, and choosing an appropriate value of X, the proposed path planning scheme ensures that the mobile anchor node passes through the circle of each sensor node either two or three times. As shown in Fig., the total path length D is given as

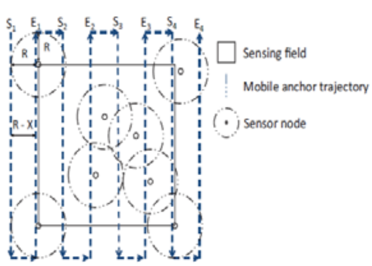

Fig 3 .Proposed mobile anchor trajectory.

$$D = (L+2R)\times\left(\left\lceil\frac{L+2R}{R-X}\right\rceil+1\right)+(R-X)\times\left\lceil\frac{L+2R}{R-X}\right\rceil$$

4. Performance Evaluation

We simulated the energy efficient localization technique on Network Simulator (version 2) widely known as NS2 [11], a scalable discrete-event driven simulation tool.

Building high performance WSN network systems requires an understanding of the behavior of sensor network and what makes them fast or slow. In addition to the performance analysis, we have also evaluated the proposed technique in measuring, evaluating, and understanding system performance. The final but most important step in our experiment is to analyze the output from the simulation. After the simulation we obtain the trace file which contains the packet dump from the simulation. The format of this trace file for WSN networks is as follows:

- N: Node Property
- I: IP Level Packet Information
- H: Next Hop Information
- M: MAC Level Packet Information
- P: Packet Specific Information

Depending on the packet type, the trace may log additional information. Then the packets record is analyzed to compute the following metrics –

- Number of data packets sent
- Number of data packets received by the destination host
- Total number of routing packets
- Packet delivery fraction – ratio of received packets over sent packets in percentage.
- Download Time – average time for a data packet delivered from host to destination.

A. Simulation Model

The distributed coordination function (DCF) of IEEE 802.11 is used as the MAC layer in our experiments. It uses RTS and CTS packet. The values of the parameters used for simulation are as shown in Table1

Table 1: Simulation Parameters

Parameters	**Value**
Topology Size	700 m X 700 m
No. of sensor nodes	50
No. of anchor nodes	1
MAC layer	IEEE 802.11
Simulation Time	50 sec
Traffic Source	Constant bit rate(CBR)
Node Placement	Random waypoint
Packet Size	512 bytes

Transmit Power	360 mW
Receive Power	395 mW
Idle Power	1 Mw
Initial Energy	5.1 Joules
Transmission Range	500m
Routing Protocol	Adhoc on-Demand Distance Vector (AODV)
Speed	10 m/sec

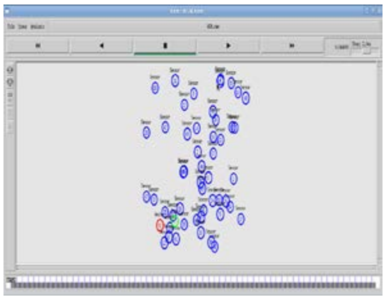

Fig 4. NAM window simulation showing the deployment of sensor nodes in WSN environment

5. RESULTS

The Path Planning algorithm is applied for the WSN environment as mentioned in the simulation parameter table and the result is obtained as follows.

Estimation Error:

The difference between the actual location and calculated location of all the nodes is known as estimation error. The average is taken and plotted.

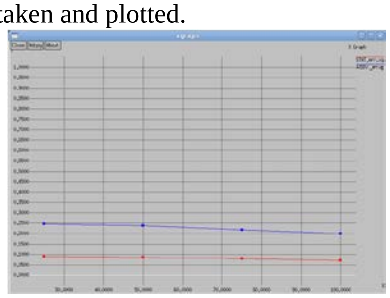

Fig 2.Nodes vs Localization error(J)

NLE=SQRT((X_Act-X_Loca)^2+(Y_Act- Y_Loca)^2)/Area

Table 2 Nodes vs Localization Error

No. of Nodes (X axis)	Localization Error (Y axis)	AODV
25	0.089769	0.245856
50	0.085427	0.239467
75	0.079865	0.219376
100	0.071729	0.200635

Nodes vs No. of Nodes Localized:

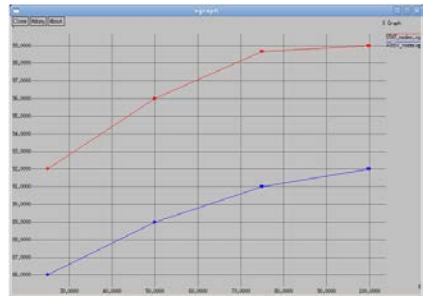

Fig 5. Nodes vs % of nodes localized

Table 3: Nodes vs % of Nodes localized

No of Nodes (X Axis)	% of Nodes localized (Y Axis)	AODV
25	86.00	86.00
50	96.00	89.00
75	98.67	91.00
100	99.00	92.00

6. CONCLUSION

In WSNs the localization has become an inevitable challenge [11] with regard to sensor nodes and is an emerging research as it is an unsolvable problem. The main goal of this work is finding the position of nodes at an unknown location using Location Aware or Anchor nodes. The analysis and simulation studies validate the effectiveness of our solution in incorporating sensor capacities of RSSI for the randomly deployed distribution of sensor nodes. This work can be further enhanced by providing generalized path planning algorithm that can be used almost with all efficient localization algorithms. The paper can also be modified such that it gives reduced energy consumption. Thus by providing a path planning algorithm we ensure that energy consumption between the nodes is reduced, with lower network overhead and improved accuracy and efficiency.

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