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Node Localization for Wireless Sensor Networks

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Abstract: Wireless Sensor Networks (WSNs) are useful for applications related to environment aspects and physical phenomena, traffic, military, hospitals and underwater acoustic signals. In many applications, sensor nodes need to be localized. Many sensor nodes know their locations by having additional hardware such as GPS known as anchor or beacon nodes. But it is not feasible to equip all the sensor nodes with additional hardware due to its cost. There can be a few number of anchor nodes which vary at some speed from their initial positions, so known as mobile WSN. Configuring each node with its position manually is very difficult and not feasible in networks with mobile nodes or dynamic topologies. Wireless Sensor Networks; therefore rely on localization algorithms for the sensor nodes to determine their own physical locations. A number of localization methods have been developed for mobile WSN. The focus of most of the existing work is on the accuracy in position estimation using different methods. In this paper, a new method for localization has been proposed and tried to reduce the location error. Location error is a difference in estimated value of location calculated by localization algorithm from the actual one. The method works in two phases: initialization phase and refinement phase. In the first phase, a sensor node gets a rough estimation of its position. In the second phase, each node iteratively broadcasts its initial position, and then repeats the estimation using the new information to estimate a refined position. The performance of this method is evaluated using simulations.

Keywords: WSN, Anchor node, Location error, Mobility, GPS.

I. INTRODUCTION

A wireless sensor network consists of few to several number of nodes interconnected to form a network. Each node consists of several components including microcontroller, Radio frequency transceivers, power supply and memory. The sensor nodes in WSN form a network that passes the data through it to main location where it is analyzed and used for different purposes. WSNs are widely used in medical and health, military defense, manufacturing, environmental monitoring, traffic management, air pollution monitoring, green house monitoring and other fields [1].

Many sensor network applications require location awareness, but it is often too expensive to include a GPS receiver in each sensor node. Hence, localization schemes for sensor networks typically use a small number of anchor or beacon nodes that know their location and protocols whereby other nodes estimate their locations from the messages they receive [2].

Localization algorithms are of two types: centralized and distributed based on their computational organization. Centralized algorithms are designed to run on a central machine with high computational power. Distributed algorithms are designed to run in the network using parallelism and inter-node communication. Distributed algorithms can be classified as range based and range-free [3]. Range free algorithms include neighborhood and Hop counting techniques. Range based algorithms include Received signal Strength Indicator (RSSI), Time Difference of Arrival (TDoA), Angle of Arrival (AoA) techniques [4]. When anchor or beacon nodes move at some speed i.e. change their positions in the sensor area such network is known as mobile WSN.

II. RELATED WORK

Xiaojun et al. proposed a refined hop count method for localization. Nodes exchange their neighbor information with their neighbors and compute distances to neighbors [5]. King-Yep and Vincent Tam proposed a simple heuristic based algorithm by choosing the nearest three anchors with respect to each individual sensor node using triangulation mechanism [6]. Sudhir et al. proposed a maximum power reception based node-sourse localization which initially requires location of three sensor nodes. The mobile anchor traverses and is positioned to an optimal location for further localization [7]. Yao et al. proposed a Refined RSSI-based localization algorithm in which the mobile beacon is an anchor point with accurately known position [8]. Q. Q. Shi et al. proposed a node localization refinement method having three phases. The refinement is added using steepest descent method also called gradient method [9]. Xia et al. proposed a localization scheme with mobile beacon for WSN having two steps. The steps consist of time difference of signal arrival times and trilateration [10]. Baoli et al. introduced a localization for mobile sensor network based on beacon information transmitted from an anchor node equipped with GPS and RF fingerprinting and RSSI technique [11]. Hongjun et al. proposed the localization scheme which use one mobile anchor equipped with GPS to localize sensor networks. Probability density function table is used to obtain the distance of the anchor node and sensor node [12]. Baoli et al. proposed a collaborative localization algorithm based on RSSI technique using group of three mobile anchor nodes which form an equilateral triangle [13]. Yuan et al. proposed a localization algorithm in which mobile anchor broadcasts its current position periodically and. Stationary sensor nodes compute its location using two positions of mobile anchor node and then un-located sensor nodes compute their locations with the help of stationary sensor nodes [14].

III. RESULTS

A. Minimum Mean Square Error (MMSE) Estimation

It is an estimation method which minimizes the mean square error (MSE) of the fitted values of a dependent variable. The formula is:

$$x = (H^T H)^{-1} H^T z.$$

Where

$$H = \begin{bmatrix} 2(x_N - x_1) & 2(y_N - y_1) \\ 2(x_N - x_2) & 2(y_N - y_2) \\ \vdots & \vdots \\ 2(x_N - x_{N-1}) & 2(y_N - y_1) \end{bmatrix}$$

$$z = \begin{bmatrix} D_1^2 - D_N^2 - x_1^2 - y_1^2 + x_N^2 + y_N^2 \\ D_2^2 - D_N^2 - x_2^2 - y_2^2 + x_N^2 + y_N^2 \\ \vdots \\ D_{N-1}^2 - D_N^2 - x_{N-1}^2 - y_{N-1}^2 + x_N^2 + y_N^2 \end{bmatrix}$$

And $x = \begin{bmatrix} x_0 \\ y_0 \end{bmatrix}$

B. Network Scenario

We use NS-2 to simulate. In simulation, the deployment area is 200m×200m. The number of anchor nodes is 50 and increasing up to 200. The speed of mobility is 1m/s, 3m/s and 5m/s. The routing protocol is AODV. The data channel is wireless and we are taking 10 unknown nodes whose location is to be searched.

C. Implementation

The first method named as Single Estimation is implemented with the parameters as number of anchor nodes some of which are mobile, the speed at which the anchors are moving in the sensor area and location error. The method is implemented firstly having 50 number of anchor nodes and the starting speed of mobility is considered 1m/s then speed is increased to 3m/s and 5m/s. The steps and results are as below:

1. Initialization
   Broadcast "location request" messages
   Receive "location response" messages from neighboring references (*Ri*).
2. Initial position estimation
   a) Measure distance to the references.
   b) Apply MMSE to determine position.
3. Position update

Table 1: Single Estimation Method

Anchor_nodes	**Loc_error (with speed 1m/s)**	**Loc_error (with speed 3m/s)**	**Loc_error (with speed 5m/s)**
50	0.14331	0.23965	0.23379
80	0.02683	0.07004	0.10442
100	0.02701	0.059	0.10543
150	0.02744	0.06348	0.10945
200	0.02584	0.05849	0.11078

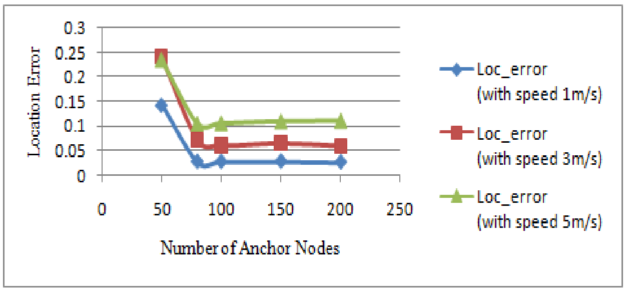

Fig 1: Single Estimation Method

The second method named as Nearest is implemented. In this method the information is gathered only from nearest three mobile anchor nodes. The steps and results are as below:

1. Initialization

    Broadcast "location request" messages

    Receive "location response" messages from neighbouring references (*Ri*)

    If (*C(Ri)*<3) then exit.

2. Initial position estimation

    Select nearest three references (*Si)* from *Ri*

    Measure distance to the references in *Si*

    Apply MMSE to determine position.

3. Position update

Table 2: Nearest Method

Anchor_nodes	**Loc_error (with speed 1m/s)**	**Loc_error (with speed 3m/s)**	**Loc_error (with speed 5m/s)**
50	0.3131	0.23543	0.62521
80	0.04998	0.19742	0.24203
100	0.04217	0.06504	0.10757
150	0.13457	0.19023	0.20906
200	0.11711	0.17481	0.32967

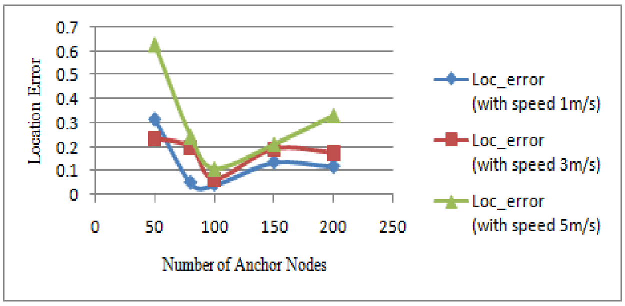

Fig 2: Nearest Method

Then the Refine Estimation method is proposed and implemented. In this method, the localization error is updated if new value of error is smaller and repeating this procedure until minimum error value is found. Hence, position is updated.

The steps of the proposed method are as follows:

1. Initialization

    Broadcast "location request" messages

    Receive "location response" messages from neighboring references (*Ri*).

2. Initial position estimation

    a) Measure distance to the references.

    b) Apply MMSE to determine an initial position.

3. Refined position estimation

    Each node iteratively broadcasts its initial position, and then repeats the estimation using the new information to estimate a refined position.

    a) Calculate node position and localization error for all nodes

    b) Update localization error (if new value is smaller)

    c) Repeat until min error value is found

4. Position update

The results are as below:

Table 3: Refine Estimation Method

Anchor_nodes	**Loc_error (with speed 1m/s)**	**Loc_error (with speed 3m/s)**	**Loc_error (with speed 5m/s)**
50	0.14613	0.11943	0.1176
80	0.07604	0.07179	0.07759
100	0.11083	0.09358	0.09191
150	0.04675	0.04886	0.04621
200	0.04001	0.04425	0.04

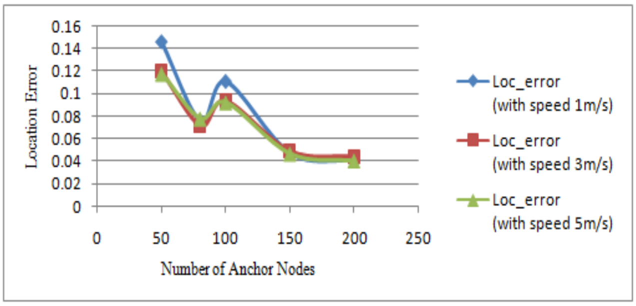

Fig 3: Refine Estimation Method

Then Refine Estimation method is compared with the first two methods and results are as below:

Table 4: Comparison of Single Estimation, Nearest and Refine Estimation Methods

Anchor nodes	Method-1 Loc_error (with speed 5m/s)	Method-2 Loc_error (with speed 5m/s)	Method-3 Loc_error (with speed 5m/s)
50	0.23379	0.62521	0.1176
80	0.10442	0.24203	0.07759
100	0.10543	0.10757	0.09191
150	0.10945	0.20906	0.04621
200	0.11078	0.32967	0.04

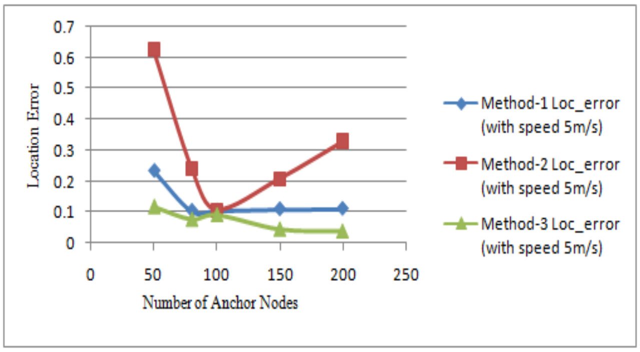

Fig 4: Comparison of Single Estimation, Nearest and Refine Estimation Methods

IV. CONCLUSION AND FUTURE SCOPE

Localization is a major problem in wireless sensor networks as applications related to sensors intend to use these locations for important purposes. Many of the researchers have done work in this field. They proposed a lot of methods for this problem. We have chosen mobile WSN with having a few of anchor nodes as mobile and the two methods proposed by other researchers, working on WSN are applied on our area. These two methods are performing well enough but as compared to our proposed technique, they produce more error. Our proposed technique named as Refine Estimation performs well according to its parameters such as location error, number of nodes and mobility speed of anchor nodes. It reduces the error to percent where existing methods reduce the error up to percent. In future, the number of mobile anchor nodes can be increased. The mobility speed of anchor nodes can also be increased and location error can also be improved.

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