Minimizing Localization Error in Wireless Sensor Networks

Harikrishnan.G
Assistant Professor,
Department of ECE,
Indira Gandhi Institute of Engineering and Technology, Kerala

***Abstract-* Sensor localization has become an essential requirement for realistic applications over Wireless Sensor Networks (WSNs). As such localization scheme designed for mobile sensor networks is necessary. Here the objective is to design a localization scheme to improve the localization accuracy by uing localization scheme Improved Monte-Carlo Localization (IMCL). In this method, all sensor nodes are mobile, normal node collects the locations of its one-hop and two-hop anchor nodes via message exchange, and constructs a new possible location set in each time slot where the normal node may locate. The normal nodes without location information can estimate their own locations by gathering the positions of location -aware nodes (anchor nodes) and the one - hop normal nodes whose locations are estimated from the anchor nodes. In each time slot each normal node executes these three phases once and gets its estimated location. Our simulation result shows that the localization error using this scheme is lower than the previous schemes such as MCL, MSL and bounded box schemes under various mobility models and moving speeds.**

***Keywords* - Localization error, mobile sensors, wireless sensor networks, anchor nodes, IMCL.**

I.INTRODUCTION

Wireless sensor networks (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions. Similar to many technological developments, wireless sensor networks have emerged from military needs and found its way into civil applications. Today, wireless sensor networks has become a key technology for different types of ”smart environments”, and an intense research effort is currently underway to enable the application of wireless sensor networks for a wide range of industrial problems. Wireless networks are of particular importance when a large number of sensor nodes have to be deployed, and/or in hazardous situations.

Localization is important when there is an uncertainty of the exact location of some fixed or mobile devices. It is typically useful for coverage, deployment, routing, location service, target tracking, and rescue. In any wireless sensor network, the location information of nodes plays a vital role in understanding the application context. 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. An effective localization algorithm can then use all the available information from the wireless sensor nodes to infer the position of the individual devices. Another application is the positioning of a mobile robot based on received signal strength from a set of radio beacons placed at known locations on the factory floor.

The design of efficient protocols for sensor networks has been a very active research area in recent years. A fundamental problem in designing sensor networks is localization – determining the locations of the sensors. This information is useful in many contexts – it may be used for clustering, routing and for mapping the field being sensed. In simple terms, localization is mechanism for discovering spatial relationship between objects. Determining the physical location of sensors after they have been deployed is known as the problem of localization. Sensors aware of their position can also improve routing efficiency by selective flooding or selective forwarding data only in the direction of the destination. Sensor nodes may not have an indi vidual identifiers or addresses. The location of the sensor may be part of other address of the sensors. Various algorithms that use the location as part of the address have been proposed.

Many localization schemes have been proposed in the past few years. Most of them are designed for static sensor networks. However, some applications assume that sensors are mobile and location aware. For example, in target tracking, the sensor nodes know their areas by tracking locations of moving objects. In addition, sensor nodes are mobile for enlarging the sensing region. Thus, a localization scheme designed for mobile sensor networks is necessary. The Monte Carlo Localization (MCL) scheme specifically designed for a mobile sensor network. In MCL, all sensor nodes are mobile. Each normal node collects the locations of its one-hop and two-hop anchor nodes via message exchange, and constructs a new possible location set in each time slot. The possible location set consists of various coordinates where the normal node may locate. The possible locations are also constrained by the communication range of anchor nodes and the moving region of location set in the previous time slot. However, the localization error with low anchor density in MCL does not work well. The Mobile and Static sensor network Localization (MSL) is one another range-free algorithm that uses the Monte Carlo method. MSL improves localization accuracy by using the location estimation of all neighbors (not just anchor nodes). The abo ve methods are time-consuming because they need to keep sampling and filtering until enough samples are obtained to construct a new possible location set in each time slot. The bounding box (BB) method used to reduce the scope of searching the candidate samples

The localization scheme proposed here is the distributed localization approach based on the Monte Carlo method to improve the localization error of previous works. The possible locations of a normal node are not only constrained from anchor nodes but also constrained from its one-hop normal nodes whose locations are estimated from the anchor nodes. Furthermore, each normal node predicts its moving direction to filter some impossible positions from the possible location set.

In this Improved MCL (IMCL) localization scheme, three constraints are proposed to confine the region of the valid samples near the actual position of the normal nodes. They are i) anchor constraint, ii) neighbor constraint, iii) moving direction constraint. The assumptions of IMCL scheme are the same as MCL: Time is discrete; A few sensor nodes are selected as anchor nodes which know their location. The mechanism has been evaluated using the network simulator ns-2. With our scheme, the localization accuracy outperformed previous range-free approaches.

The rest of this paper is structured as follows. In Section II, deals with the literature survey and Section III, with the proposed improved monte carlo localization scheme and Section IV, we discussed about the performance evaluation of the localization scheme. And finally, we draw conclusions in Section V.

II.RELATED WORK

In the literature, there exist many solutions to locating moving objects based on different localization issues for wireless sensor networks (WSN). Sensor networks are expected to revolutionize information gathering, processing and dissemination in many diverse environments. Existing localization algorithms can be categorized as either range-based or range-free schemes. Range - based schemes are not suitable for WSN because of their irregularity of radio propagation and their cost of additional devices. In contrast, range-free schemes do not need to use received signal strength to estimate distances. They only need simple and cheap hardware and are more suitable for WSN. However, existing range-free schemes are too costly and not accurate enough or are not scalable. To improve previous works, a fully distributed range-free localization scheme for WSN [12] is presented, based on the assumption that only a few sensor nodes, called anchors, know their locations, and the remaining (normal) nodes need to estimate their own locations by gathering nearby neighboring information. The improved grid-scan algorithm is used here to find the estimated locations of the normal nodes and a vector-based refinement scheme to improve the accuracy of the estimated locations.

A fundamental problem in designing sensor networks localization, or determining the locations of nodes. The algorithm used here [2] is Polygon based algorithm and it enables other nodes to estimate their locations by exchanging information between nodes and seeds. The basic idea behind this algorithm is to maintain the uncertainty associated with the location estimate of a node using convex polygons. Unlike past works, in this algorithm, a node uses the location information of all its neighbors, not just the seed nodes and works for both static and mobile sensor networks. Using simulation experiments, we demonstrate that, this algorithm significantly outperforms comparable existing algorithms like Distance Vector hop (DV-hop) and Monte – Carlo Localization (MCL). The algorithm uses convex polygons to represent regions of potential locations, and this allows quick exchange and processing of location information among nodes.

III.IMPROVED MONTE CARLO LOCALIZATION

The location of a normal node is estimated from the average locations of valid samples, the location estimated by the normal node will be close to its actual position if the valid samples are near to the actual position of the normal node. In the Improved MCL (IMCL) localization scheme, three constraints are proposed to confine the region of the valid samples near the actual position of the normal nodes. IMCL consists of three phases:

I. Sample selection phase,
II. Neighbor constraint exchange phase,
III. Refinement phase.

A. Sample Selection Phase

In this phase, each normal node gathers the locations of neighboring anchor nodes and selects samples to represent its possible located positions. The samples are selected from the circle with radius V_{max} centered on each sample in the last time slot. The selected samples must be placed in the sampling region whose sampling points satisfy the near anchor and farther anchor constraints.

At the beginning of IMCL, each anchor nodes broadcast their physical location to their one-hop neighbors. This information packet will be forwarded to two-hop neighbors of the anchor nodes. After collecting packets from near anchors and farther anchors, the normal nodes will decide the number of samples based on the size of sampling region. However, the area of the sampling region is irregular and difficult to calculate for the resource - limited sensors. Thus, a rectangle surrounding the sampling region called (ER) Estimated Region is used to replace the exact sampling region on deciding the number of samples.

B. Neighbor Constraint Exchange Phase

In the MCL scheme, each normal node only uses the constraints arising from anchor nodes, and it does not work well in low anchor density. If a normal node does not receive any anchor's information, it will estimate its position by utilizing the samples selected in the last time slot, and the localization error will become large until the new location information from the anchors is received. In order to improve localization accuracy, each normal node in IMCL can rely on the constraints arising from the anchor nodes and neighboring normal nodes. An additional constraint is that each normal node must locate in the communication range of its neighboring normal nodes. Note that the location of a normal node is estimated from its neighbor locations and there exists error between the estimated and actual positions. If we directly use the estimated locations to be the positioning constraints of normal nodes, it may increase the localization error of the normal nodes.

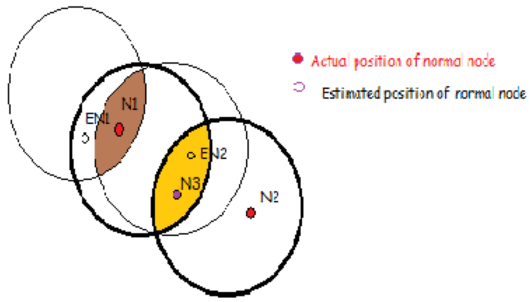

Fig. 1 Neighbor Constraint Exchange Phase

Assume that the normal node N_3 has two neighboring normal nodes N_1 and N_2 whose estimated locations are EN_1 and EN_2, respectively. The possible located region of N_3 will be located in the overlapping region of the two circles centered on N_1 and N_2, as shown. If we use EN_1 and EN_2 as the actual positions of N_1 and N_2, N_3 will be considered in the overlapping region of two circles centered on EN_1 and EN_2. However, the overlapping region centered on N_1 and N_2 is different with the overlapping region centered on EN_1 and EN_2. In order to reduce the localization error accumulated from the neighboring normal nodes, each normal node will broadcast its possible located region instead of its estimated position to neighbors. Here the possible located region of a normal node is enclosed by the distribution region of samples selected in the sample selection phase of current time slot.

Since the distribution region of samples is irregular, each normal node will estimate its possible located region as follows: First of all, each normal node calculates its central point $C_t(x_c; y_c)$ of samples selected in the sample selection phase. The variables x_c and y_c are calculated by averaging the x-coordinate and y-coordinate of samples, respectively. Then, each normal node constructs a two-dimensional coordinates and uses $(x_c; y_c)$ as the origin. The coordinates are partitioned into eight directions and each direction differs by 45 degree. The selected samples can be divided into eight groups according to their direction angles beginning with positive x-axis. It is obvious that partitioning the samples of a normal node into more sectors is more close to the shape of the possible located region of the normal node. According to our simulations, the localization error decreases as the number of sectors increases.

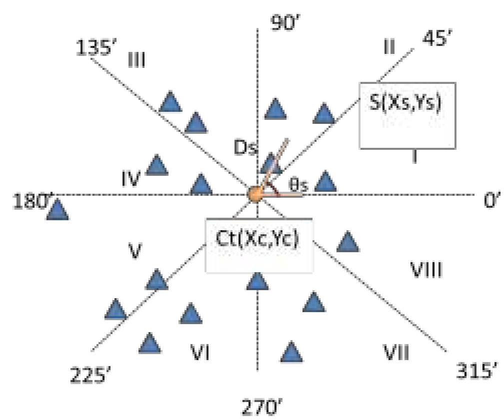

Fig. 2 The possible location region with neighbor constraint.

However, the improvement of localization error is stable when the number of sectors is larger than eight. This is because that the difference of the possible located region of a normal node estimated by using eight sectors and more than eight sectors is very small. Therefore, we adopt eight sectors to estimate the possible located region of a normal node.

C. Refinement Phase

In the refinement phase, each normal node refines samples selected in the sample selection phase. All impossible samples are filtered by constraints, including the neighbor constraint received from the neighboring normal nodes and moving direction constraint achieved by predicting the moving direction of normal nodes. In order to keep the number of valid samples, if one sample does not satisfy the new constraints, the normal node generates a new valid one to replace it. After receiving neighbor constraint, each normal node checks if each sample satisfies the neighbor constraint.

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IV.PERFORMANCE EVALUATION

A. Simulation Parameter:

The Improved Monte Carlo Localization Algorithm is evaluated through NS2 simulation. We use a bounded region of 500 x 500 sqm, in which nodes are placed using a uniform distribution. The power levels of the nodes are assigned such that the transmission range and the sensing range of the nodes are all 250 meters. The distributed coordination function (DCF) of IEEE 802.11are used for wireless LANs as the MAC layer protocol. The simulated traffic is Constant Bit Rate (CBR). The following table (Table I) summarizes the simulation parameters used

TABLE 1 Simulation Setup

No. of Nodes	350
Area Size	500x500
Mac	802.15.4
Simulation Time	50 sec
Packet size	100
Transmit Power	0.360 w
Receiving power	0.395 w
Idle power	0.335 w

B. Performance Metrics

The NS-2 simulation results of the IMCL are simulated and analyzed by the terms of localization error for a time slot and this has been compared with various other parameters such as i) Number of samples ii) anchor node density etc.

Localization error: Localization error is known as the improper location information of the normal nodes estimated by the anchor nodes in a wide area network.

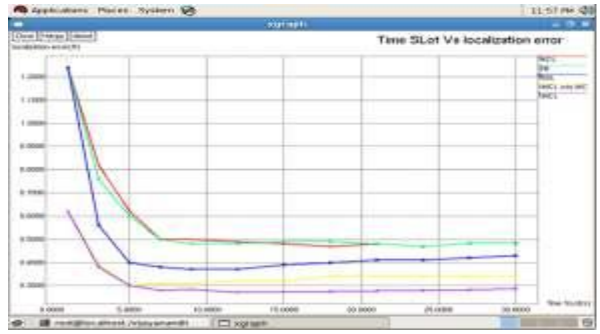

Fig 3 Time slot vs. Localization error

The above figure shows the performance comparison of IMCL over previous methods. It is shown that the localization error is larger in previous methods and reduced in IMCL method. The average simulation time is 20 time slots. The localization error of IMCL without moving constraint is a little higher than IMCL with moving constraint. The performance graph is shown here in the x-graph model of NS-2.

Number Of Samples: Samples means that the possible location set where the normal node actually present in a network. Since the nodes are mobile, there are more number of samples at a particular time slot. The number of samples obtained for a time slot should be minimum for good localization.

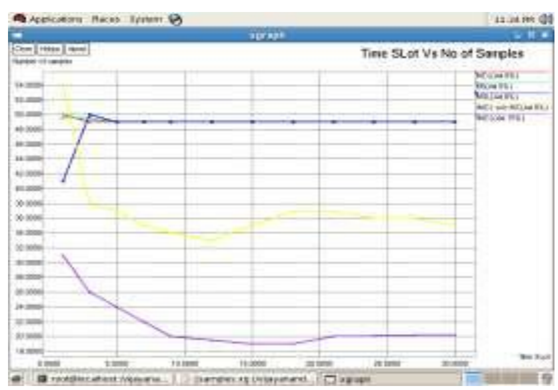

Fig. 4 Number of Samples.

The figure above shows that the number of samples used by all the methods. Usually in the first time slot the number of samples used will be high because, in the first time slot the location information of normal node is not known. So at the first time slot the number of samples used at the previous slot is used. The number of samples used by the IMCL method is less compared to the previous methods.

Anchor Node Density: The anchor node density (Ad) is defined as m / (n + m), where n and m are the number of normal nodes and number of anchor nodes, respectively. Here n =322, m=28. The anchor density is calculated as 8% and that is implemented in our scheme.

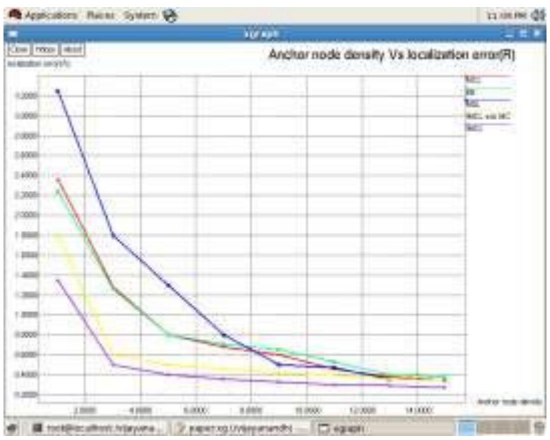

Fig 5 Anchor node density vs localization error

The figure shows the impact of the anchor node density over the localization error. As increasing the anchor node density, each normal node gets more anchor constraints to reduce the possible located region, and thus, the accuracy of estimated location arises. The figure shows that the localization error will go down as the anchor node density increases.

V.CONCLUSION

Many applications in WSNs must combine with locations of sensor nodes. In order to get location information, many localization schemes are proposed to automatically estimate sensors' positions. In the mobile sensor networks, the localization scheme becomes difficult to implement because of node mobility. Thus, a simple localization scheme should be developed with low estimated error for mobile sensor networks. Here a distributed localization scheme called IMCL to improve the localization accuracy of the previous schemes. Two more sampling constraints are added, the neighbor constraint and moving direction constraint, to improve the localization error of the previous work. The normal nodes need to exchange their possible located regions with each other for the neighbor constraint. To reduce the communication cost, a simple sectoring scheme is used to represent the possible located region of each normal node. To reduce the computation cost and memory occupation, the number of samples is adaptive to the estimated sampling region. Thus, the proposed scheme is suitable to be implemented on the resource-limited sensor nodes. With the simulation results, our scheme has lower localization error than the previous work in most scenarios.

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Author Profile

Harikrishnan G, received his MTech degree in Remote Sensing And Wireless Sensor Networks from Amrita Vishwa Vidyapeetham , Ettimadai ,Coimbatore. He received his B.E in Electronics and Communication Engineering from Tamilnadu College of Engineering, Anna University Chennai. His research areas includes Digital Image Processing , Software Defined Radio , Wireless sensor Networks, CUDA, Deep space and Hyperspectral Image processing. Currently he is working as Assistant Professor in Electronics and communication engineering, Indira Gandhi Institute of Engineering And Technology ,MG University Kerala.