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Extension to HiRLoc Algorithm for Localization Error Computation in Wireless Sensor Networks

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Abstract

Wireless sensor networks (WSNs) have gained importance in recent years as this support a large spectrum of applications such as automotive, health, military, environmental, home and office. Various algorithms have been proposed for making this technology more adaptive the existing algorithms address issues such as safety, security, power consumption, lifetime and localization. This paper presents an extension to HiRLoc algorithm and highlights its benefits. Extended HiRLoc significantly reduce the average localization error by suggesting a new method directional antenna based scheme.

Keywords: *HiRLoc, locator, localization error, sensor node WSNs*

1. Introduction

Wireless sensor networks (WSNs) consist of thousands of autonomous sensor nodes. These sensor nodes requires efficient positioning, localization because WSNs are application specific and are mainly used for advanced applications such as automotive, environmental, health, home and office, military etc. In most applications of WSNs, knowledge of the origin of the sensed information is critical for taking appropriate action based on the observations. Example, if a smoke detector reports the break out of a fire, this information, while useful, is not sufficient to initiate proper action. On the other hand, associating the report from the smoke detector in space enables the timely response to the reported event. Hence, the association of the observations reported by sensors in space increases the quality of the information aggregated via the sensor network. Furthermore, location is assumed to be known in many network operations such as routing protocols where a family of geographically-aided algorithms have been proposed [4] or security protocols where location information is used to prevent threats against network services [5, 6]. Various algorithms have been proposed and are under test for WSNs. These algorithms depend on various physical parameters and are essential or procedural part of WSNs. Existing algorithms for finite sized WSNs are Centroid, SeRLoc, HiRLoc-I, HiRLoc-II and HiRLoc. To significantly reduce the average localization error by suggesting a new method directional antenna based scheme. In order to modify these existing algorithms so that the simulation results obtained are better and more realistic [1]. In WSNs, enabling sensors to associate their reports with space is achieved via the location estimation process also known as localization. Lazos and Poovendran propose a high resolution localization algorithm called HiRLoc that improves the localization accuracy at the expense of more complicated hardware. Since sensors are hardware and power limited, SeRLoc and HiRLoc rely on two-tier network architecture. The network consists of a small number of nodes equipped with known coordinates and orientation we call locators and a large number of resource-constrained sensor devices with unknown location. Moreover, since distance measurements are susceptible to distance enlargement or reduction, we do not use any such measurements to compute the sensor location. Instead sensors rely on beacon broadcasts from the locator containing localization information to infer their location. We refer to methods that are not using distance measurements as range-independent localization schemes [8, 9 and 10]. Methods for securing range-dependent localization schemes are presented in [7], [11]. Since range independent schemes do not rely on any distance measurements to estimate location, they are not vulnerable to range-alteration attacks.

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2. Literature Review

Existing Algorithms for Finite Sized WSNS

The algorithms that are commonly used are listed and are explained in detail in sections ahead.

2.1. Centroid
2.2. SeRLoc
2.3. HiRLoc - I
2.4. HiRLoc – II
2.5. HiRLoc

2.1 Centroid algorithm

The Centroid algorithm proposed by Nirupama Bulusu, is a range-free, proximity-based, coarse-grained localization algorithm depends upon the connectivity of WSN and nodes density, in which the error of node orientation is high and the calculation for the minimum error is too lager and the time which it takes too long. It is simple but the location error is high due to the centroid formula [14]. The position of the unknown node is estimated to be the centroid of the anchor nodes from which it can receive beacon packets and connected adjacently. This algorithm is simple but it needs too many anchors. It achieves good localization performance. It remains independent of node density. It saves cost of localization algorithm. It reduces the complexity of algorithm. Estimation of localization produces large error. It remains difficult to realize accurate localization. Distance based centroid algorithm improves positioning accuracy. Improved Centroid algorithm demands no additional hardware [15]. Bulusu and Heidemann [8] have proposed that the algorithm implementation contains three core steps. First, all anchors send their positions to all sensor nodes within their transmission range. Each unknown node listens for a fixed time period t and collects all the beacon signals it receives from various reference points. Second, all unknown sensor nodes calculate their own positions by a centroid determination from all n positions of the anchors in range. The centroid localization algorithm uses anchor nodes (reference nodes), containing location information (xi, yi), to estimate node position. After receiving these beacons, a node estimates its location using the following centroid formula in equation 1.

$$(x_{est}, y_{est}) = \left(\frac{x_1+\dots+x_N}{N}, \frac{y_1+\dots+y_N}{N}\right) \quad (1)$$

In centroid algorithm the anchor node broadcasts one beacon containing its own ID and location to neighbour nodes, when the number of beacons of the node required localization has exceeded a certain threshold or a certain time, the centroid of all the anchors is the localization of the unknown node.

2.2. Secure Range Independent Localization (SeRLoc) Algorithm

SeRLoc is a decentralized, range- independent and no message exchange required between any pair of nodes. The anchor points in a system using SeRLoc possess additional capabilities in the form of several directional antennas. These anchors know their location as well as the orientation of each of their antennas. The transmission power of sensor nodes is less than transmission power of anchor nodes [2]. It is two-tier network architecture. Location estimation of SeRLoc is range-less. Implementation in SeRLoc is decentralized. SeRLoc is robust against security threats. Each anchor node contains information about the coordinates of the anchor and the angles of the antenna boundary lines with respect to a common global axis. Each anchor is encrypted using a globally shared symmetric key. It can detect Sybil and Wormhole attacks. A node only can determine the sector if anchor range co-ordinates of anchor and sector boundary information in the form of angles is available. The final location of the system node is then determined as centre of gravity (CoG) of the over-lapping region of different sectors. CoG is least square error solution given that a node can lie with equal probability in any point in overlapping region. It supports node mobility. The number of locators in the network is assumed to be quite small [17]. Accuracy is less due to the limited number of locators used. The network consists of sensors and locators and the sensors position is unknown and position of locators are known by using Global positioning system (GPS) receiver. Sensor antenna is omnidirectional and locator antenna is directional, before network deployment the communication range of sensors and locators are well known. Sensors receive localization information from near locators and sensors define an intersection region in which it lies. Its location is estimated to be the Centroid of intersection region. It has low communication cost and requires few reference points. It provides a basic and simple approach for localization using directional antennas [16]. To improve the localization accuracy, either more locators have to be deployed or more directional antennas have to be used.

2.3. HiRLoc - I Algorithm

It involves collecting the beacons over several transmission rounds. It computes the intersection of corresponding antenna sectors. It makes use of a smaller number of sectors. Only the beacon corresponding to the smallest range that the node can receive is included.

2.4. HIRLOC - II Algorithm

It involves estimating the Region of intersection (ROI) after each transmission round. It provides the node with an estimate of its location at any time instead of having to wait for several transmission rounds. The ROI in this algorithm is obtained as the intersection of the ROI of HiRLoc-I with the sectors corresponding to the beacons received in the successor round.

2.5. High Resolution Range-Independent Localization Algorithm (HiRLoc)

The HiRLoc algorithm was introduced after combining the HiRLoc-I and HiRLoc-II algorithm. It allows sensors to determine their location with higher accuracy compared to SeRLoc at the expense of more complex hardware at the locator side. It allows sensors to passively determine localization with high resolution without increasing number of reference points, complexity of hardware. It is a range independent localization algorithm. It allows sensors to passively determine localization with high resolution without increasing number of reference points, complexity of hardware [3]. Sensors determine location based on intersection of areas covered by beacons transmission by multiple reference points. It is similar to SeRLoc. The anchors are assumed to be capable of varying their transmission range from zero to maximum value R using power control. The anchors are assumed to have the capability to change their orientation over time. On changing the orientation the anchors retransmit beacons in order to improve the accuracy of the location estimate. System node can hear beacons from multiple anchors as multiple beacons from same anchor. Location of system node is the ROI of all the sectors [13]. The ROI can be calculated after every round of beacon transmission. To increase localization accuracy then reduces the size of ROI. It can be reduced by two ways- by reducing the size of sector areas, increasing the number of intersecting sectors. It reduces ROI by the anchors vary antenna direction, vary communication range. Communication range is varied by decreasing transmission power. Beacons contain information about range being used. The algorithm of HiRLoc works as follows. First, sensor s determines the locators of interest LHs as the locators heard by s and it determines an initial estimate for its location. Then, it collects beacon information from locators in rounds. In these rounds, a locator may vary its direction, communication range or both. After that ROI is calculated from the range estimates sent by all locators.

3. EXTENDED HiRLoc

Extended HiRLoc improves the existing HiRLoc algorithm. It requires a fixed placement of sensors on a desired co-ordinate in order to ensure this directional antenna based schemes need to be tested and evaluated. The performance of existing HiRLoc algorithm will be evaluated. In order to further reduce the average localization error a grid based structure is introduced [1]. Sensor nodes are deployed on a grid structure. The antenna is placed on the beacon nodes and then it is known as locator. There are two antennas in the simulator inbuilt directional and Omni directional, directional antenna is preferred because it will cover limited number of sensor nodes which were deployed. Average localization error will be calculated and the work is to reduce the average localization error for better localization. Grid structure is used random deployment is not done. The nodes which are on the boundary and inside the region are deployed and considered [12].

Extended HiRLoc Algorithm is shown in following steps.

STEP 1: Initial estimate of the ROI.

In step 1, the sensor determines the set of locators LHs that will be used for its localization. Based on the coordinates of the locators Li ε LHs;

The maximum communication range of the locators, denoted as

R_{max}; The sensor calculates the first estimate of the ROI as follows:

Let X_{min}; Y_{min}; X_{max}; Y_{max} denote the minimum and maximum locator coordinates form the set LHs defined as:

$$X_{min} = \min_{L_i \in LH_s} X_i,\quad X_{max} = \max_{L_i \in LH_s} X_i,$$

$$Y_{min} = \min_{L_i \in LH_s} Y_i,\quad Y_{max} = \max_{L_i \in LH_s} Y_i,$$

STEP 2: Beacon collection (Heard)

Lhs- Locator heards
Grid structure is used in this step.
There are 3 options in this step.

Option A: Antenna orientation variation
The locators rotate their antennas by a pre-specified angle

$$\alpha = \frac{2\pi}{QM}; \qquad (2)$$

Where α is the angle.
M is the number of antenna sectors at each locator.
(Q - 1) is the total number of antenna rotations.

Option B: Communication range variation
If N is the total number of distinct communication ranges,

$$\text{Range of locators} = \frac{R\max}{N};\ \text{at each round} \qquad (3)$$

Here N-1 rotations are there.

Option C: Combination of options A, B
Locators can variate both their communication range and their antenna orientation.
Here (Q-1) (N -1) both are there.

STEP 3: Determination of the ROI

Li ε LHs

ROI = {gi *: i* = arg max GST (i)} (4)

STEP 4: Computing the sector intersection at each transmission round

In our second approach, the sensor computes the ROI by intersecting all collected information at each transmission round.

$$ROI(m) = \bigcap_{j=0}^{m} \left(\bigcap_{j=1}^{|LHs(j)|} Si(j) \right) \qquad (5)$$

STEP 5: Computes ROI m

$$RO\text{Im} = \bigcap_{i=1}^{|LHs(m)|} Si(m) \quad (6)$$

STEP 6: Current estimate the position of sensor nodes that lie in the ROI.

$$ROI(m) = RO\text{Im} \bigcap \overline{RO\text{I}}(m-1) = \bigcap_{j=1}^{m} (\bigcap_{i=1}^{|LHs(j)|} S_i(j)) \quad (7)$$

4. Simulation Result

The Simulation Result is explained below in the form of a table. In table 1 Comparison of all range free algorithms is given. In table 2 Simulation parameters and their values are given.

Table 1. Comparison of all range free algorithm

Algorithm	MODIFIED HiRLoc	HiRLoc	SeRLoc	CENTROID
Localization objective	Self	Self	Self	Self
Encryption key	Used	Used	Used	Used
Use of anchors	Yes	Yes	Yes	Yes
Execution time	78 ms	15 ms	78 ms	0 ms
Average localization error	2	3	44	85
Observation	Less complex	Extra hardware complex	Extra hardware	Reduced cost
Number of sensor nodes with estimate position	38	10	48	103

Table 2. Simulation Parameters

PARAMETER	VALUE
Types of sensors	Static
Localization parameter	Estimate position
Locator radio range	250 m
Beacon radio range	40 m
Locator beam width	45◦
Number of beacon nodes	50
Number of random locators	8
Number of static sensor nodes	200
Number of mobile sensors	20
Number of locators	2
Locator antenna type	Directed
Locators deployment strategy	Grid with 8 locators
Gaussian parameters using Gaussian	No
Key used	Encrypted

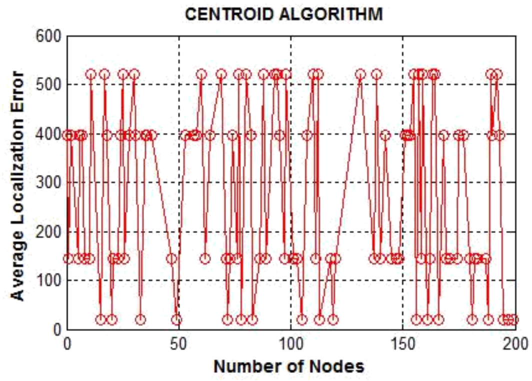

Figure 1. Centroid scheme

Figure 1 shows the Centroid Scheme, it shows the variation in the number of nodes versus the average localization error for the centroid scheme. As the nodes remain un localized the higher is the average localization error.

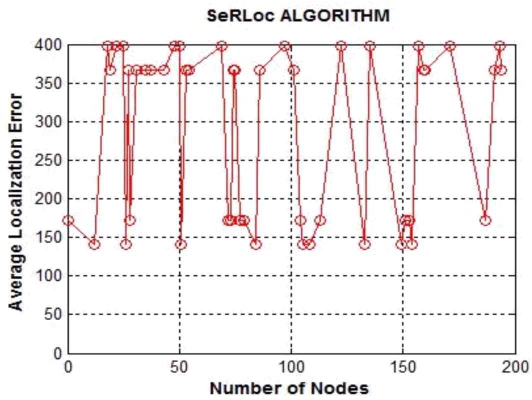

Figure 2. SeRLoc scheme

Figure 2 shows the performance of the SeRLoc scheme which is secure against localization error. During the simulation of the SeRLoc scheme, it was observed that the accuracy of sensor nodes localize is high compared to the centroid localization scheme

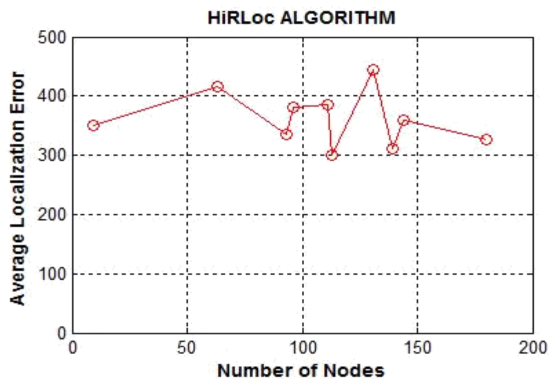

Figure 3. HiRLoc scheme

Figure 3 refers to the results of a robust and secure scheme, HiRLoc. The performance of this scheme provides more accurate results compared to centroid and SeRLoc schemes.

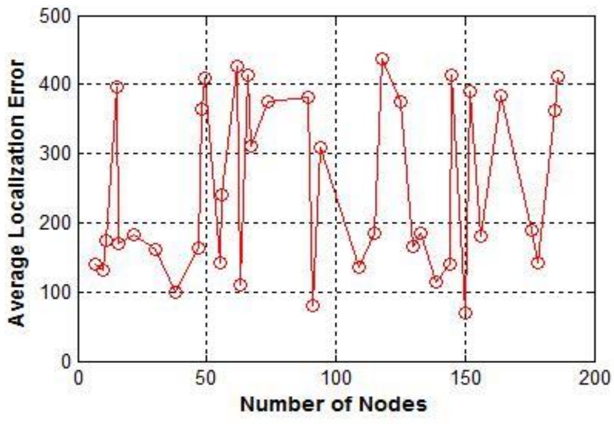

Figure 4. Extended HiRLoc scheme

Average localization error is reduced when the accuracy is increased. This process is done by directional antennas are deployed on a grid. The transmission range R is reduced and due to this ROI is reduced. The distance is very less between the real position and estimated position of sensor nodes and due to this accuracy of localization of sensors is increased. The extended scheme is better because on a grid structure locators are distributed on a fixed position and directional antenna obtains the ROI for each locator. The exact position of sensor nodes on grid is known by locators and the position of other fixed nodes lie within their ROI is easier to estimate.

4. Conclusion

In this paper, the HiRLoc scheme is extended to reduce the average localization error of the sensor nodes which are localized. The extended scheme use the directional antenna based scheme. On a grid locators which are placed at location which is known are less. The estimation of location provides good results in the simulation results of extended HiRLoc scheme. The extended HiRLoc algorithm is simple and comparable to other range free localization schemes.

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