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Directional Antenna Assisted Scheme to Reduce Localization Error in Wireless Sensor Networks

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ABSTRACT

The existing omni directional antenna assisted schemes for localization of sensors in wireless sensor networks (WSNs) are not very accurate due to various constraints, since issues like sensor distribution, topology control; high cost and localization error obstruct the effectiveness of these algorithms and schemes. This paper presents a modified High Resolution Robust Localization (HiRLoc) scheme assisted by a single beam directional antennas for improving the localization in WSNs. Simulation result show that the proposed modified scheme estimates the position of more number of sensor with less average localization error compared to some existing schemes.

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1. INTRODUCTION

The rising research interest in the area of WSNs during the past years has enabled many innovative and advanced applications [1]-[4]. These applications require precise location knowledge of sensors sometimes within meters, and at other occasions within a few centimeters [5]-[6]. The algorithms pertaining to localization of sensors are a fundamental focus of researchers and have lead to the development of various positioning schemes in order to support multiple applications on a single wireless sensor network [7]-[13]. These schemes involve some special sensors termed as locators, anchors or beacons, they obtain their locations either manually or through a positioning device and thereafter the locations of other sensors within the network are estimated by interacting with these special sensors and information either related to distance, range or angle is obtained [14]-[15]. The existing schemes provide services, privileges and trust towards the design of WSNs [16-17], but unfortunately fail to broadly highlight issues related to the localization error in WSNs [18]-[20]. This paper presents a modification to the existing HiRLoc scheme [19] assisted by single beam directional antenna for reducing the average localization error. The average localization error for centroid [18] and Secure Range Independent Localization (SeRLoc) [21]-[22] scheme is also evaluated. Simulation results show that the proposed scheme outperforms the above discussed schemes and offers more number of sensors to estimate their positions with less average localization error.

The remainder of the paper is organized as follows. In Section 2, we discuss the assumptions for our network and directional antenna model. Section 3 presents the modified algorithm. Simulation results of the proposed scheme and comparison of its performance with other existing schemes are presented in Section 4. Section 5 concludes the paper.

2. ASSUMPTIONS

This section describes the assumptions for the proposed scheme in terms of network model and the directional antenna model.

2.1 The Network Model

We assume that sensor nodes *N*, with a density ρ_s are randomly deployed at unknown locations within an area *A.* We also assume that directional antenna equipped special nodes *L*, with a density ρ_L, called as locators are also deployed and $\rho_S > \rho_L$. The deployment of the locators is modeled on fixed positions and the deployment of sensors is modeled randomly over an area *A*. The locators are static with known locations and have single directional communication range and no obstructions are present in the network. The network model is shown in Figure1.

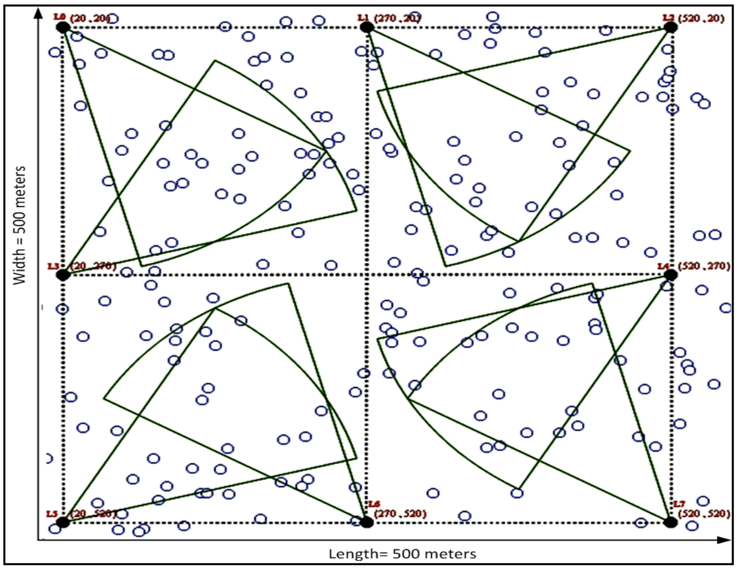

Figure 1.The Grid based network model with eight locator nodes

2.2 The Antenna model

Locators equipped with directional antennas are able to transmit simultaneously and have radiated power W_r with a directive gain $G_d > 1$. They can vary their transmission range from zero to a maximum value R_{max} further we assume that locators can change their antenna direction, either through changing their orientation or rotating their directional antennas. Sensor nodes inside the boundary of region of intersection (ROI) are only considered for position estimation and calculation of average localization error.

3. THE MODIFIED ALGORITHM

We consider a set of sensors *N* and $N \subseteq$ ROI, let *LHs* denote the messages heard by the sensor *N*; during the transmission. By collecting beacon messages from the set of locators $L_{0\text{-}7}$ the sensors can obtain their location (within an area rather than on a single point) inside the ROI of two locators. In the proposed modification, we assume that a sensor only receives beacon messages from locator and does not receive messages from its neighboring sensors. The sensors that lie in the ROI of two locators can receive beacon message only from their respective locators, where as the sensors that lie outside the ROI are unable to receive the message. The location estimation of sensors is based on beacon information transmitted from a set of locators outfitted with single beam directional antennas. The single beam directional antenna concentrates its energy only in a particular direction and reduces interference of surrounding environment to increase the localization accuracy of sensors that lie within the ROI [23]. The locator transmits in a particular direction with directed gain, $G_{d:}$

$$G_d(\theta,\psi) = \frac{4\pi\phi(\theta,\psi)}{\int \phi d\alpha} \tag{1}$$

G_d is a function of angles θ and ψ , with $\phi(\theta,\psi)$ specified as radiation intensity in a particular direction. The orientation of the directional antenna is denoted as *α.* If the main lobe of directional antenna is towards a specified direction its radiation pattern can be approximated considering the locator at the center. Hence G_d also depends on the radiated power W_r.

$$G_d(\theta,\psi) = \frac{4\pi\phi(\theta,\psi)}{W_r} \tag{2}$$

The radiated power is a function of solid angle $d\Omega$ and can be obtained as,

$$G_d(\theta,\psi) = \frac{4\pi\phi(\theta,\psi)}{\int \psi d\Omega} \tag{3}$$

According to (3), $d\Omega$ for a directional antenna is calculated by,

$$d\Omega = \frac{ds}{R^2} \tag{4}$$

The elemental surface area, *ds* is constant and *R* is considered as the transmission range of the locator. Since the ROI indicates the confined region where the sensors are tracked, therefore reducing the size of the ROI leads to a decrease in average localization error. We can precisely reduce the size of the ROI by reducing *R* of the locators having a fixed position on a grid. Hence the average localization error $\overline{LE}$, that depends on the real coordinate X and estimated coordinate X_i for the sensors that lie inside the boundary of the ROI as shown in (5).

$$\overline{LE} = \frac{1}{|N|}\sum_{i=1}^{N}\frac{\|X - X_i\|}{R} \tag{5}$$

Algorithm 1 presents the steps of the modified HiRLoc scheme.

Algorithm 1 Modified HiRLoc Scheme

1. Select locators $L_{0\text{-}7}$ with single beam directional antennas
2. Deploy locators over grid, such that $L_{0\text{-}7} \in LHs$
4. Deploy sensor nodes in network area, *A*
5. **define** locator node antenna orientation = *α*, locator range = *R* and directed gain = G_d
6. Estimate ROI for all locator nodes
7. Compute sector intersection for number transmission rounds **if any**
8. **if** position of nodes $N \subseteq$ ROI is estimated **then** calculate average localization error $\overline{LE}$ with respect to X and X_i, the coordinates **else, go to** step 5 **end if**
9. Position of sensor nodes is estimated

The position of locators in our proposed scheme is fixed over a grid, these locators can periodically broadcast beacon message including their current locations. It is obvious that the sensors compute their individual locations by listening to the beacon information sent by each locator. By means of all of the beacons that a sensor detects, the sensor computes an approximate location based on the coordinates of the respective locators that form an overlapping region. The final computed location for the sensors is therefore the ROI where they lie.

4. RESULTS AND DISCUSSION

In this section, we discuss the simulation results of our proposed scheme and compare the results with centroid, SeRLoc and HiRLoc schemes. The impact of single beam directional antenna on the locators deployed over a grid was evaluated for reducing the average localization error in the modified scheme. Table 1 highlights the simulation parameters. The simulations are performed on Wireless Sensor Network Localization Simulator v1.1 [24].

Table 1.Simulation Parameters

Parameter	Value
Network Area	500m ×500m
Locator radio range	250 m
Beacon radio range	40 m
Locator beam width	45°
Beacon nodes	50
Number of locators	8
Sensor nodes	200

Figure 2 shows the variation in the number of nodes versus the average localization error for the centroid scheme. It was observed that most of the nodes remained unlocalized, and the average localization error was high.

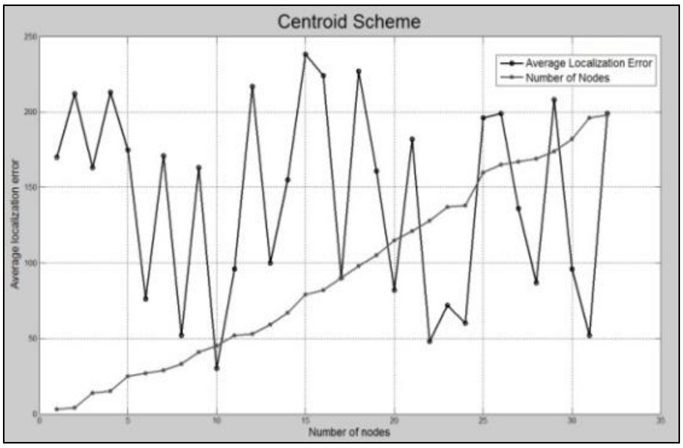

Figure 2.Number of nodes Vs Average localization error for Centroid scheme

The simulation results of the SeRLoc scheme show that the sensor nodes localize with higher accuracy compared to the centroid localization scheme. Figure 3 shows the performance of the SeRLoc scheme which is secure against varying sources of localization error.

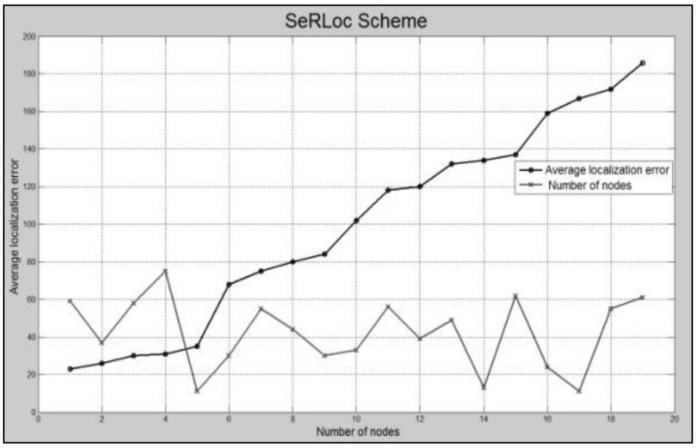

Figure 3.Number of nodes Vs Average localization error for SeRLoc scheme.

Figure 4 refers to the results of a robust and secure scheme, HiRLoc. The performance of this scheme offers more accurate results compared to centroid and SeRLoc schemes in terms of average localization error.

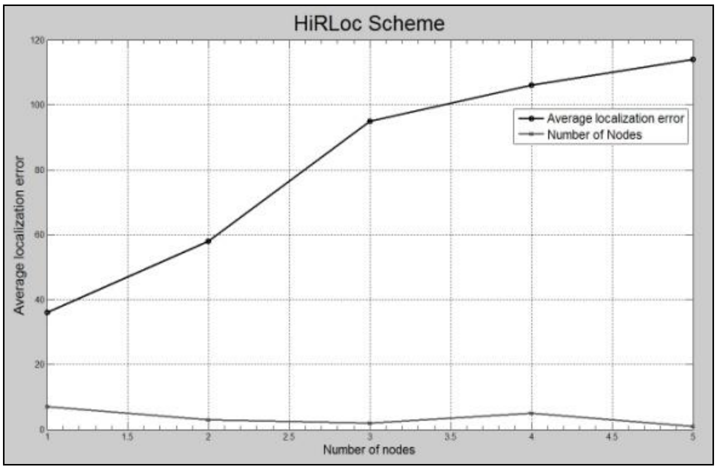

Figure 4.Number of nodes Vs Average localization error for HiRLoc scheme.

The position estimation accuracy for the modified HiRLoc scheme is shown in Figure 5.

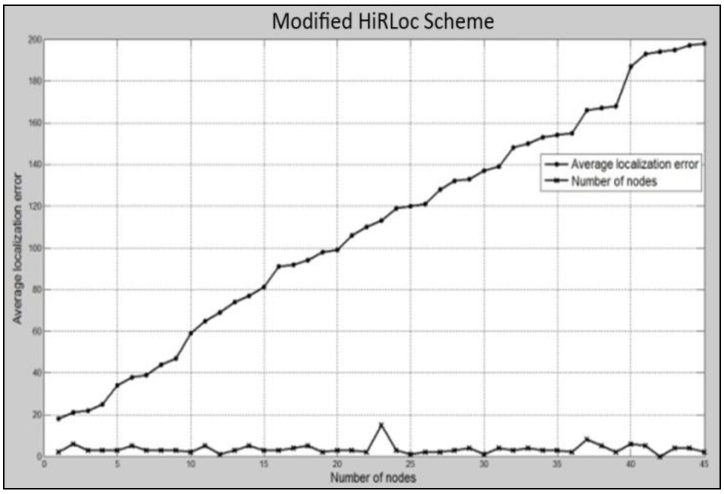

Figure 5.Number of nodes Vs Average localization error for modified HiRLoc scheme.

The increase in accuracy offers reduction in average localization error due to the locators outfitted with single beam directional antennas deployed over the grid experience a decrease in transmission range *R*, and estimate closer if ROI is reduced. The localization of sensors is more accurate because the distance difference between the estimated position and the real position of a sensor node is less. The proposed scheme has relevance if locators are distributed over a fixed position on a grid, and the ROI for each locator is obtained through the pattern of the single beam directional antenna outfitted on it to arrive at a precise calculation for estimating the position of sensor nodes. The locators are authorized and know their true positions on the grid it is easy for them to estimate the position of other stationary sensor nodes that lie within their ROI. Table 2 provides comparison of the proposed modified scheme with other existing schemes discussed in this paper for the same order of computational complexity.The average localization error calculated for the proposed modified scheme is less; the modified scheme also allows more number of sensor nodes to estimate their positions. The only drawback that is observed in our proposed scheme is with respect to the execution time, which is on the higher side as compared to other schemes.

Table 2.Comparison among discussed localization schemes

Observations	Modified HiRLoc scheme	HiRLoc scheme	SeRLoc scheme	Centroid scheme
Execution time(ms)	125	31	93	27
Average localization error(m)	3.51	3.6	42.21	142.18
Number of nodes with estimated positions	45	5	19	32

5. CONCLUSIONS

In this paper, we modified the HiRLoc scheme to locate the sensor nodes with consistently less average localization error. The modified scheme utilized the effectiveness of a single beam directional antenna and increased the localization accuracy with less number of locators placed at known locations on a grid. The simulation results show that the modified scheme offers better results for location estimation. The steps of the proposed algorithm are very simple and comparable to other global range free localization schemes. Our simulation studies confirmed that reducing the transmission parameters for the locators placed at a fixed reference points leads to better location estimation of more number of sensors with less average localization error. The suggested scheme can be implemented for information access in multiple applications support [25] for WSNs as a future extension to this work.

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