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Performance Analysis of High-Resolution Robust Localization and Secure Range Independent Localization in Wireless Sensor Networks

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Abstract: In the field of computing, Wireless Sensor network has got interest of researchers due to its applications. WSN is a resource constrained network. Recent advances in wireless sensor network have led to many applications like health care, environment monitoring, target tracking and many others. In many applications node localization is one of the system parameter that is required to report event, the location of the event, routing and some network coverage information. In this paper two approaches of localization, High-resolution Robust Localization (HiRLoc) and Secure Range Independent Localization (SeRLoc) are discussed and then simulated. The results are compared to come up with the best approach keeping network parameters constant. The main focus of this paper is on Localization Error (distance between the actual position and estimated position of a sensor node). The algorithm having less localization error is considered to be the best.

Key words: Wireless Sensor Network · Localization · Localization Error · Beacons · HiRLoc · SeRLoc

INTRODUCTION

In the past few years Wireless Sensor Network has gained the attention of most of the researchers due to its adhoc and infrastructure less nature. Due to the increasing functionality and the decrease in the cost of the sensors, WSN are used in most of the applications [1]. These sensors are low-cost, low-power and multifunctional, which are wirelessly connected. The basic operation of a sensor network is to deploy sensors in a targeted area, an important aspect of such network is that the nodes are unattended to collect information or monitor and track certain specific phenomena [2]. This deployment could be a continuous process in order to replace nodes, which have been destroyed or have depleted batteries due to environmental effects.

These sensors can equip any object, creature or place with information processing capabilities. They could either establish links by one-to-one relationship or by just throwing these nodes into an area of interest where they have to be deployed, there after they have to function on their own. Once the sensors are deployed, the sensor nodes start communicating with each other in a self-organized manner [3]. The sensor nodes can be given a specific task either by external resource (by passing movable object) or can sense the external environment, for example temperature, pressure etc. The sensor sends the gathered information to neighbor nodes and thus the information reaches to base station for further processing. The sensor network is application specific network, deployed to monitor only the desired event. WSN has many applications, it can be deployed indoor and outdoor, for example; in industry, environmental monitoring, climate monitoring, military and security, medical use, habitat monitoring, fire detection and tracking, detection of chemical or biological agent threats, traffic management and much more [4]. The task is divided among different nodes in order to get the high level

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results. The coordination and distribution of task is mainly due to the limited functionality taking into account the individual characteristics of the nodes (e.g. attached sensors, location and energy level) [5].

Localization is one of the essential services provided by wireless sensor network. We are concerned not only in the types of events that have taken place, but also in where the events have taken place in most of the applications [6]. The position of the sensor node is important. When the network is initially deployed the position of the sensor nodes will not know to them. Nodes that know their positions are known as beacons and the nodes that are at unknown position are known as blind nodes. The beacons know their position either through GPS (Global Positioning System) or already deployed at fixed position. In most of the WSN, location information is an essential part such as geographical routing, target tracking and monitoring etc) [7].

The exact distance for the localization can be affected by reflection, diffraction and scattering on obstacles that can influence the propagation of signals [8]. In this paper, High resolution robust localization (HiRLoc) and Secure Range-Independent Localization algorithm (SeRLoc) are compared to come up with the best option on the basis of the results achieved. WSN Localization Simulator is used to simulate the sensors in a specific environment.

The work of this paper focuses on the localization error; it is the distance between the actual position and the estimated position of the sensor node. Localization error is important to in WSN to find out the accurate position of the sensor node. Two algorithms are simulated and the results are analyzed to come up with the best one. The experimental result shows the algorithm with less localization error. Rest of the paper is structured as follow: Literature review is discussed in section 2. The section 3 is about the simulation environment, section 4 is about the experimental results and section 5 concludes the work done.

Literature Review: Sensor nodes are densely deployed in the specific environment to gather data. The gathering of data is important, but the location of sensor nodes is important as well. The sensor nodes deployed in the network should know their position, which can be calculated with the help of localization algorithms. Locators (know their position either through GPS or can be deployed at fixed position) are the nodes that help in finding out the location of the sensor nodes.

Different schemes have been developed in the last few decades for localization in WSN, mainly motivated by military use but used for civil purposes later on [9]. In reference [10] it is pointed out that the noise has some influence on the localization process and the importance of some system parameters that can affect the accuracy and efficiency of the localization process. The localization methods can be divided into two methods: 1) range dependent and 2) range-independent.

The range methods use information regarding the distance to nearby nodes. These methods estimate the distance between two sensor nodes and then compute the position of each individual sensor node, the most common approach for computing the position is triangulation. The distance can be derived from the signal attenuation or can be measured by time-of-flight for a packet between two sensor nodes. The simplest range method is to have information about the distance of three sensor nodes and then use triangulation [7]. RSS (Receive Signal Strength) and ToF (Time of Flight) are used to estimate the distance between two sensor nodes.

The second technique used is the range free or range-independent. These methods do not calculate the distance to the nearby nodes, but they use hearing and connectivity information to discover the nodes and locators and then calculate their position [7]. Different range-independent localization algorithms are proposed like Centroid, DV-hop and APIT [11]. Range and range-free techniques can be used depending on the environment.

In this paper two algorithms (HiRLoc and SeRLoc) are compared on the basis of their accuracy. High-resolution Robust Localization and Secure Range-Independent Localization Schemes are simulated and then the results are drawn in the separate files. The aim of this paper is to compare both schemes and come up with the best scheme among the two on the basis of their accuracy, while fixing the position and keeping the network parameters constant.

High-Resolution Robust Localization (HiRLoc): It permits sensors to find out their location with high precision even if there are some security threats. HiRLoc attains passive sensor localization based on beacon information transmitted from the locators. Locator's communication range is variable and each locator sends beacon information more than once

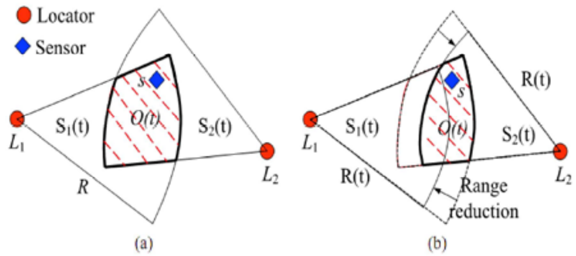

Fig. 1: (a) The sensor is located within the intersection of sectors S1 and S2, known as ROI; (b) Shows the reduction of range and transmits updated beacons, which leads to the reduction of ROI [12].

(multiple rounds). This approach is more accurate and robust as in each round the locator may change its direction or its range or may be both [12].

This algorithm works as; the sensor first decides the locators in which they are interested and determines the initial calculation for its location. The sensors then collect the beacon information in the multiple rounds. The locators may change its direction and range in the multiple rounds. Region of Interest (ROI) is calculated from the information send by all locators. ROI is the intersecting area of the locators towards that sensor [12].

Secure Range-independent Localization Algorithm (SeRLoc): SeRLoc is the range independent algorithm to find the location of the sensor nodes. In Secure Range-Independent localization algorithm sensor nodes find out their position based on the beacon information which is transmitted by the locators. SeRLoc is a distributed algorithm which is based on two-tier network architecture; it allows sensor nodes to inactively find out their position without cooperating with other sensor nodes in the network. Each locator transmits different beacons at each antenna sectors, which is received by the sensor nodes within their range R. Each beacon contains the respective beacon coordinates and the sector boundary lines. Each Sensor calculates its position as the Center of Gravity (CoG) of the overlapping area of the different sectors [11].

The Simulation Enviornment: The Simulator used in this experiment is Wireless Sensor Network Localization Simulator v1.1 [13]. This simulator supports a large scale network and can support 400 nodes x 400 nodes (means 1,6000 connections).

Table1: Parameter Setting Before Simulation

S. No	Parameters	Values
01	Locator Radio Range	250m
02	Beacon Radio Range	40m
03	Locator Beam Width	45º
04	Number of Random Locators	8
05	Number of Static Sensor Nodes	100
06	Locators' Antenna Type	Directional/Omni
07	Localization Algorithms	HiRLoc/ SeRLoc

The Table 1 shows the parameters that are used in the network, like the number of nodes that are used during the network simulation, the number of Locators etc. The total number of sensor nodes deployed is 'M'; the number of detected nodes is represented by 'N'. The number of locators 'L' that will send beacon information to the N sensor nodes to find their location. D_E is the Euclidean Distance, 'x' and 'y' are the actual coordinates of the sensor node and 's' and 't' are the estimated coordinates of the detected sensor. D_E is calculated as the distance between the actual position and the estimated position and putting them in equation 1 we will get Distance of the detected node.

$$D_{E}=\sqrt{(x-s)^2+(y-t)^2} \quad (1)$$

The emphasis of this research is on the Localization Error (Loc Error), which is the difference between the actual and the estimated positions. In the simulation first we have calculated the Localization Error for individual detected sensor node and then through equation 2 we can calculate the Average Localization Error, where N shows the number of detected nodes.

$$LOC_{Error}=\frac{1}{N}\sum_{i=1}^{N} D_E \quad (2)$$

Simulation Results: The implementation is done using HiRLoc and SeRLoc; first we have implemented HiRLoc using Directional and Omni directional antennas and then SeRLoc using both antennas. The result in directional antenna is changed from that in Omni directional. The results are shown using Figures (2, 3, 4, 5) for HiRLoc first and then SeRLoc.

In the following graphs the X-Axis shows the nodes that are detected by the Locators in its range, as it is mentioned in Table 2 that the total number of nodes deployed are 100. Y-Axis is for the distance between two positions (Estimated and the Actual positions). The distance between Estimated and the Actual position is basically the Localization Error, which should be

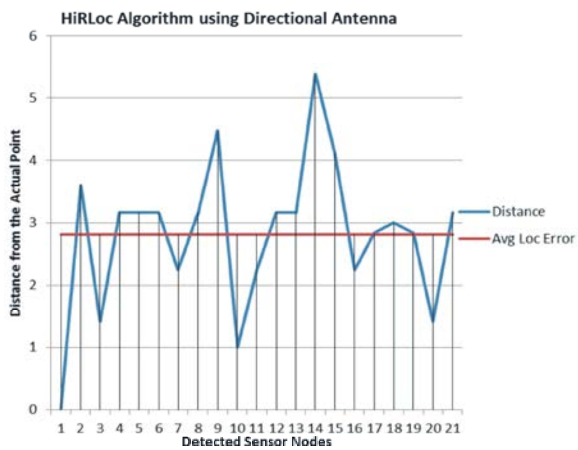

Fig. 2: HiRLoc algorithm is used using directional antenna

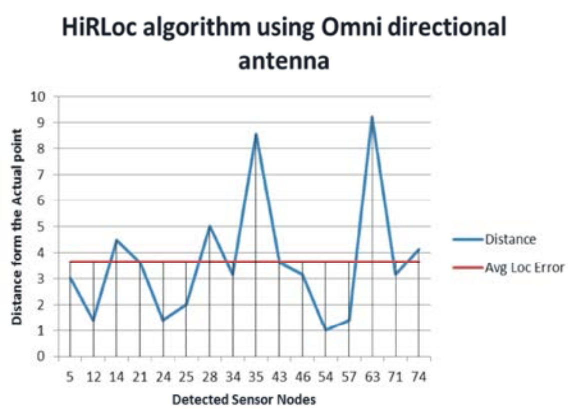

Fig. 3: HiRLoc algorithm is used using omni-directional antenna

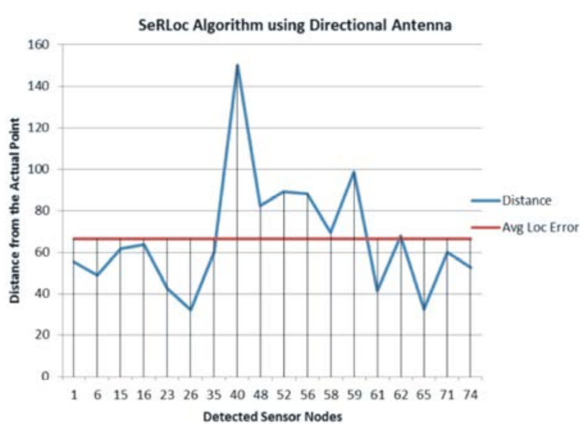

Fig. 4: The SeRLoc algorithm is used using directional antenna

minimized as much as possible. The Y-axis is important in this case, because it shows the error against each detected node.

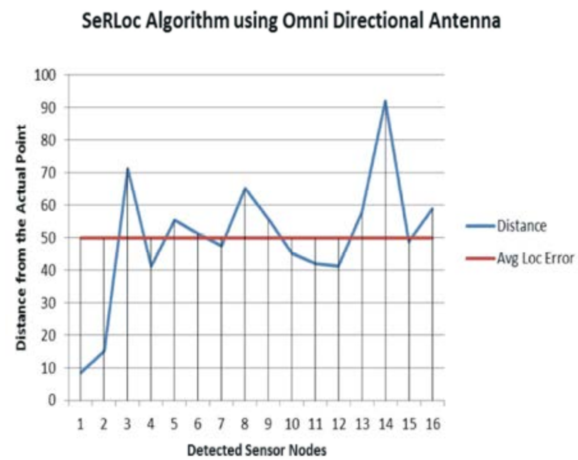

Fig. 5: SeRLoc algorithm is used using omni-directional antenna

Table 2: Localization Error and Number of Detected Nodes after Implementation of Algorithms

Protocols	Localization Error	Number of Detected nodes
HiRLoc (Directional)	2.8	25
HiRLoc (Omni)	3.6	22
SeRLoc (Directional)	66.5	24
SeRLoc (Omni)	49.7	19

HiRLoc Algorithm using Directional Antenna:

- Total Sensor nodes deployed = 100
- Locators = 8
- Number of Sensor nodes Detected = 25
- Average Localization Error = 2.8

HiRLoc Algorithm using Omni-Directional Antenna:

- Total Sensor nodes deployed = 100
- Locators = 8
- Number of Sensor nodes Detected = 22
- Average Localization Error = 3.6

SeRLoc Algorithm using Directional Antenna:

- Total Sensor nodes deployed = 100
- Locators = 8
- Number of Sensor nodes Detected = 24
- Average Localization Error = 66.5

SeRLoc Algorithm Using Omni-Directional Antenna:

- Total Sensor nodes deployed = 100
- Locators = 8
- Number of Sensor nodes Detected = 19
- Average Localization Error = 49.7

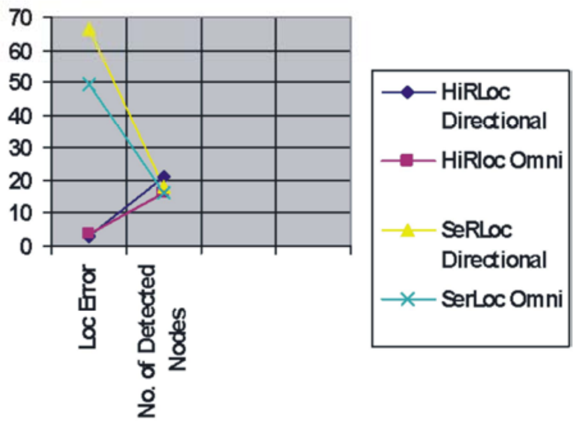

Fig. 6: Shows the localization error and number of detected nodes for HiRLoc and SeRLoc

The experimental results show that among the two algorithms, High Resolution Robust Localization is the more accurate one. As two methods are used inorder to find the accuracy of the algorithm, HiRLoc directional method is the most accurate having less localization error as shown in Figure 6. Localization error depends upon the distance between the Actual position and the Estimated position, it increases with increase in the distance between the Actual and Estimated postion. In order to increase the accuracy interms of localization, we have to decrease the localization error by decreasing the distance between the actual and estimated positions.

CONCLUSION

In wireless sensor network the sensor node is power limited and is an important issue. Preserving the power prolongs the battery life of the node and will ultimately increase the lifetime of the network as well. WSN has many applications like emergency rescue operations, patient monitoring, disaster relief and much more. In many WSN applications location information is important which needs to be addressed properly. Different algorithms are adopted to improve the accuracy of finding the location of the sensor nodes. Here, two algorithms (High-resolution Robust Localization and Secure Range-independent Localization algorithm) are implemented in 2D environment and their results are compared by keeping the network parameters constant. The results show that HiRLoc by having directional antenna is much more accurate than the SeRLoc (both in directional and Omni-directional). In future to extend this work, the said effort will be implemented in some other simulation tools like NS-2 or NS-3. In future, this work should be extended to 3D environment in order to get more accurate results and can be a good area of research.

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