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Average Localization Accuracy in Mobile Wireless Sensor Networks

Preeti Singh*, Hardeep Singh Saini

Department of Electronics and Communication Engineering, Indo Global College of Engineering, Abhipur (Mohali) Punjab, India

Abstract

In this paper an augmented event triggered algorithm based on IR (infra red) and RSSI (received signal strength indicator) techniques has been proposed for a wireless sensor network. It is a distributed and low cost localization algorithm with extremely high precision and accuracy. The proposed localization algorithm has better performance as depicted by simulations. Also the results based on RF (radio frequency) localization with proposed technique on the basis of average localization error have been compared. With enhancement in average speed with respect to number of anchor nodes, average localization error is reduced for proposed techniques comparative to the RF techniques.

Keywords

Average Localization, Infrared, Radio Frequency, Sensor Nodes, Wireless Sensor Networks

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1. Introduction

WSN (wireless sensor network) consists of a massive conglomeration of sensor nodes that are highly constrained in terms of their computing power, communication capabilities and battery power. Each node senses the environment thereby performing simple computations and communicating with its other sensors or to the central unit. Basically, each sensor node will monitor and scrutinizes its local environment and thus entirely collaborate to provide information about the sensor field. The deployment of sensor networks is done by sprawling and scattering the nodes throughout some region of interest consequently leading to a random network topology. Sensor network can signal a machine malfunction for controlling the center in a factory or it can also warn about smoke on a remote forest hill indicating the likelihood of a forest fire. On the contrary wireless sensor nodes are designed for the detection of ground vibrations originating from the silent footsteps of a burglar and trigger an alarm. Since most applications has a dependence on successful localization, i.e. the computation of their positions in some fixed coordinate system, the design efficient localization algorithms is of great interest and prominence [1]. Localization for mobile wireless sensor networks has not paid as much attention as that for static sensor networks. Most of location algorithms for static WSNs are inefficient or ineffective for mobile sensor networks. The original ideology is to localize a mobile sensor node which incorporates a GPS (global positioning system) on every mobile sensor node. As per the consideration of the cost and power consumption, the GPS solution is unacceptable in several applications. Some exquisite sensor nodes, namely anchor nodes, have been suggested and they already know their absolute location via GPS or manual placement. Other sensor nodes anticipate their location based on the information available from these anchor nodes [3].

In many applications, a mobile sensor node does not need to reveal its position all the time and rather it is required to intimate its position on demand [4]. Thus instead of localization itself at a fixed frequency, which is a

* Corresponding author
E-mail address: prekshi.singh88@yahoo.com (P. Singh), hardeep_saini17@yahoo.co.in (H. S. Saini)

cumbersome process; an event triggered localization algorithm based on IR (infrared) and RSSI (received signal strength indicator) techniques has been proposed. The algorithm thus proposed exhibits the area localization with in a wireless sensor network and is advantageous regarding localizing the desired area. Furthermore the desired region to be localized is traversed by mobile sink. Henceforth, this technique facilitates the location estimation of the places of interest. The paper is manoeuvred as follows: the section 2 depicts an overview of existing localization algorithms. Also in section 3, our localization scheme is presented and discussed profoundly. The simulation and analysis are presented in section 4. Comparison is presented in section 5. At the last we draw our conclusion.

2. Related Work

Numerous existing localization schemes have been proposed for the solution of localization problems in WSNs. Localization algorithms of the older era for static sensor networks are unsuitable to MWSN (mobile wireless sensor network) as MWSN applications expect newly featured localization algorithms. An event-triggered localization algorithm relying on RF (radio frequency) fingerprint and RSSI technique was proposed by B. Zhang and F. Yu [5]. A detailed survey about localization techniques is provided by literature [6] and [7]. These methods are based on the presumption that each sensor node incorporates techniques for the computation of distance (or angle) with its neighbors (or neighbor anchor nodes). The highly renowned techniques are AoA (angle of arrival) [8], ToA/TDoA (time of arrival/time difference of arrival) [9, 10] and RSSI [11]. Considering the cost of network application, complexity, availability of transceivers on the market, localization based on RSSI has been executed with a much deliberate and careful consideration. As per the theory of propagation loss, the received power of the radiated signal from its neighbors is measured by a sensor node and from the received signal strength; its relative distance can be deduced.

K.F. Su et al. [12] proposed a localization algorithm incorporating a mobile anchor node. In such an algorithm, a mobile anchor node moves around in a sensor area and beacon messages encompassed with current location information are broadcasted periodically. A stationary sensor node receives and records the first and last locations of the mobile anchor node when it moves into the communication range of the stationary sensor node. As per the consideration of wireless communication channels, G. Yu et al. [13] have proposed a localization algorithm using a mobile anchor node. In their algorithm, maximum RSSI values and corresponding locations are recorded, which are referred to as beacon points, where the sensor node has an imperceptible error probability in receiving a packet from the mobile anchor node.

A localization algorithm proficient in consumption of energy for wireless sensor networks incorporating a mobile anchor node was presented by B. Zhang et al. [14]. It relies on the distance measurement with additional hardware. The mobile node is embedded with accessories such as a GPS receiver, RF and an ultrasonic transmitter. Every immobile sensor node is equipped with a RF and ultrasonic receiver. The location information of the mobile node is updated periodically, and the current position of the mobile node is considered as an immobile sensor node by a virtual anchor point. The distance to the virtual anchor point using TDoA method is considered while calculating the location of a sensor node.

Directional antennas are advantageous for wireless sensor networks as they offer an augmented spatial reuse ratio and depreciation in energy consumption [15]. Once investigation of the impact of directional antenna on wireless sensor networks is done, the sensor location can be anticipated implying geometric features on a 2-D plane. The mobile anchor node has a movement around the sensor area and subsequently broadcast beacons. Immobile sensor nodes imply the information to determine their locations.

LF (location fingerprinting) technique was elaborated by N. Swangmuang et al. [16], specifying the location information with characteristics of received signal strength and these characteristics are used to infer sensor node location. All locations throughout the area of interest are generally expressed as a conglomeration of rectangular grid points. Fingerprinting based positioning has the division in two phases: training phase and online phase. In the training phase, a fingerprint database is built whereas in the online phase, a sensor node manipulates the fingerprint vector of RSSIs from different anchor nodes. Afterwards the fingerprint vector is compared with fingerprints stored in the fingerprint database in order to determine the location of sensor node. Building a fingerprint database is rather difficult in the training phase and the database needs to be re-established with the subsequent changes in the application scenario.

Although many protocols and algorithms have been proposed for WSNs in recent years, they may be not suitable to MWSNs. Considering application scenarios of MWSNs (for example, environmental monitoring) and power restriction of sensor node (impossible to recharge or replace battery), mobile sensor nodes do not need to localize themselves all the time. They only need to localize themselves when they are asked to report collected data. Based on the IR fingerprinting and RSSI technique, we propose an enhanced event-triggered localization algorithm.

3. Algorithm Design

In this paper, we consider a novel, robust and IR signal strength based distributed algorithm for localizing wireless sensor nodes. Very few nodes have a beforehand knowledge of their position referred to as beacons. On the contrary the nodes, which estimate their position using beacons, are called unknowns. The central objective here is to give the position estimation. A localization algorithm for mobile sensor network has been introduced in this section. It relies on beacon information transmitted from an anchor node equipped with GPS (or other method to deduce its position information) incorporating the IR fingerprinting and RSSI techniques.

3.1. Network Model

The network model for the proposed localization scheme is shown in Fig. 1. It has been assumed that two-tier network architecture with static anchor nodes manually deployed in a certain region 'A' and a mobile sensor node moves in 'A'. Anchor nodes being pre-deployed in the region 'A', identify their location and remain stationary. A triangular style is preferred for the deployment of anchor nodes, as shown in Fig. 1, ratifying that the mobile sensor node can be encompassed by at least three anchor nodes at any time. The mobile sensor node has movement in arbitrary directions and thereby conglomerating event information.

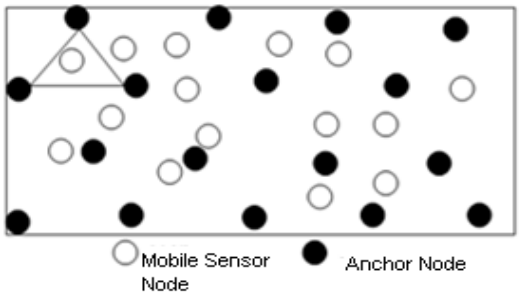

Fig. 1. Network model for the proposed localization scheme.

3.2. Creation of Random Sensor Network

Initialization of the parameters is done in the beginning: field dimensions, number of nodes in the field and initial energy. No cluster heads are there in the beginning but there are only nodes and the normal nodes are selected randomly. Then we set the parameters N, M: where N is the number of anchor nodes and M is the number of mobile nodes. An 100×100 area to be wandered by the mobile is considered. Thereafter we set the anchor at 4 vertices of the region and building as a random location for the mobile node.

3.3. Euclidean Distance

This computation is very fast and easy to understand.

$$d = \sqrt{(x - x_i)^2 - (y - y_i)^2} \quad (1)$$

Where'd' is the real distance; x, y is the anchor node and x_i, y_i is the mobile node;

4. Simulation

In this section, we discuss the simulation of our proposed localization algorithm. MATLAB software is adopted in the simulation.

4.1. Simulation Environment

In our simulations, the sensor area is $100 \times 100\ m^2$. The anchor nodes are manually deployed in the area, which is equipped with a GPS (or other approaches to obtain their positions. The mobile sensor node moves in the sensor area in any directions.

4.2. Performance

The performance of our localization algorithm is evaluated with the average localization error which is defined as the average difference between the estimated location (X_{ei}, Y_{ei}) and actual locations (X_i, Y_i) of all sensor nodes.

$$\Delta E_{av} = \frac{\sum_{i=1}^{N} \sqrt{(X_{ei} - X_i)^2 + (Y_{ei} - Y_i)^2}}{N} \quad (2)$$

4.3. Simulation Result

The average localization accuracy is important for all localization algorithms. In proposed localization scheme, the localization accuracy is affected by two different factors: density of the anchor nodes and speed of mobile sensor node. If the density of anchor nodes is high, a mobile sensor node can receive location information from more anchor nodes. It will select the best RSSI to calculate its location.

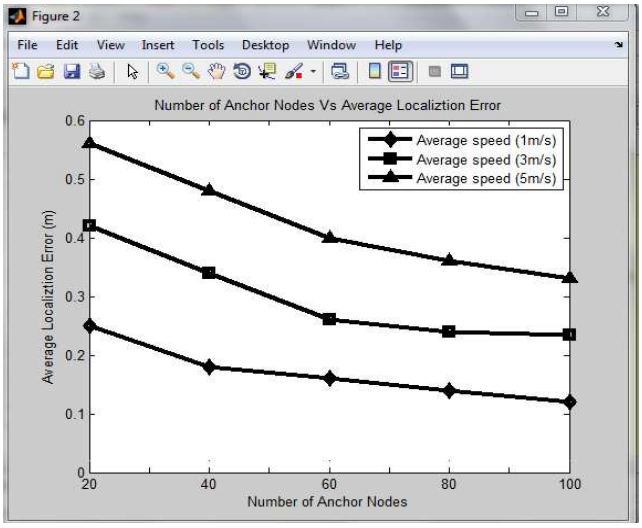

Fig. 2. Localization based on RF.

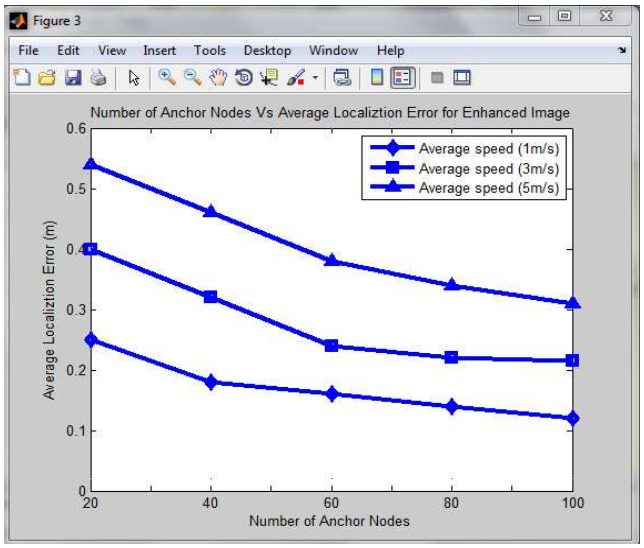

Fig. 3. Localization based on IR.

If the mobile sensor node moves fast, larger localization errors can occur due to delay. As shown in Fig. 2 and Fig. 3, the proposed localization scheme achieves better localization accuracy for high anchor node density and low moving speed.

5. Comparison

As per the comparison of our results as shown in Fig. 3 with results based on localization based RF [5] the proposed technique has less average localization error. As shown in Fig. 2 and Fig. 3, if average speed in respect of number of anchor nodes is 1m/s, 3m/s and 5m/s of IR technique then average localization error is imperceptible as compared to the average localization error of RF technique [5].

6. Conclusion

Many wireless sensor network applications has requirement of the locations of sensor nodes accurately. A distributed and range-independent localization algorithm for MWSN has been proposed in this paper and it is entirely based on the IR fingerprinting and RSSI techniques. Furthermore the localization precision and energy efficiency for location estimation have also been discussed. An augmented event triggered localization algorithm relies on IR and RSSI techniques, is a distributed and low cost localization algorithm with extremely high accuracy. Consequently the results depict that the proposed localization algorithm has better performance than localization based on RF.

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