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Minimization of Localization Error in Wireless Sensor Networks

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Abstract

A wireless sensor network is made up of small sensors which are deployed in a specific geographical area. These sensors can communicate with each other and collects the required environmental data of the specific location. This concept is utilized in various fields and industries for their ease of work. But the most important aspect in this approach is estimation of location of nodes (localization), where the sensors are deployed. Without knowing the location, the data which is collected by a sensor is not more valuable. A lot of research is being carried out to determine the accurate position of the sensor node. The challenge lies in reducing the localization error required in wireless network applications. In this paper, basically, the Time of Arrival (ToA) technique, is used as the range based technique to reduce the localization error in wireless sensor network. The outcome of the proposed approach proves its effectiveness in terms of error tolerance and distance error performance.

Keywords:

INTRODUCTION

A Wireless sensor networks (WSN) is a wireless network consisting of self-configuring devices distributed in a specific geographical area. WSN helps in many applications (e.g. monitoring environmental conditions, target tracking etc.) by using deployment of small sensors. There is a lot of research going on continuously to develop new techniques, which can improve the operational parameters (e.g. battery consumption, cost and accuracy) of WSN. The applications of WSN spread rapidly into various fields including agriculture, military and medicine. These application demands a more accurate location definition expected by distributed sensor nodes, called localization. This problem can be solved easily by implementing GPS with sensor nodes, but practically it is not possible due to the high cost factor and high consumption of power [1]. Localization of the nodes with low cost is a challenging issue in WSN. Many algorithms have been proposed to find the accurate position of the nodes without GPS, but still these algorithms are not able to perform best across all networks. By receiving the information of the sensor nodes, WSN estimates the location of the node and that information of the node is associated with that specific location, where it is deployed [2]. In order to achieve the optimum performance in localization technique, there are various parameters which need to be kept in mind like mobility and security. There are a lot of localization techniques available and can be classified with their own pros and cons [3]. Generally, localization techniques can be classified into two major categories: range based and range free localization approaches. The range based techniques are totally based on range measurement of the nodes and any one of the techniques such as, Timing based - Time of Arrival (ToA), Time Distance of Arrival (TDoA); Directionality based- Angle of Arrival (AoA); Signal strength based- Received Signal Strength Indicator (RSSI); and Hop based- DV-HOP both single and multi-hop techniques are used.

In addition to the above, position estimation is done by any one of the mathematical techniques such as Lateration, Multilateration, Trilateraton etc. To overcome the limitations of range-based localization techniques, many range-free localization techniques have been proposed. This technique eliminates the need for extra and specialized hardware on each sensor node and hence is very cost effective. In this technique, the estimation of location of the sensor node is by determining the radio connectivity information among neighboring nodes or sensing capabilities that each node possesses. A further classification of range-free technique is anchor-based schemes–networks in which sensor nodes have knowledge of their localization. To mention a few methods, for eg. Centroid, APIT, SeRLoc, Multidimensional Scaling, Gradient, Ad-hoc Positioning System etc. [4]. Anchor-free schemes – networks in which sensor nodes require no special nodes for localization. Example - Spotlight, Lighthouse and Walking-GPS methods. Most of the localization techniques which are described in literature survey depend on infrastructure. However, some of them uses a fraction of anchor i.e. location aware nodes. Sometimes, both types of schemes are not sufficient to meet the need of WSN application requirement and hence the necessity for hybrid solutions. In this paper, analysis of a range based localization technique which minimizes localization error is discussed. This technique implementation is based on combination of estimation of distance and direction from neighboring node. Estimation of distance depends on the time difference of arrival whereas direction corresponds to angle of arrival. Based on the obtained information, the coordinate system is constructed and the reflection ambiguity is eliminated. Further a transformation matrix at each node is constructed to reduce computation complexity. Rest of the paper is organized as follows briefly, literature survey of related work where methods adopted by various authors in both range free and range based methods are discussed. In the next section, the proposed approach is discussed. Based on the proposed approach, the outcomes are evaluated and analyzed which is presented. The last section concludes with discussion of analyzed results.

LITERATURE SURVEY

As discussed earlier, localization techniques can be classified into two categories-: range based and range-free systems. This classification is done based on the type of techniques used for distance estimation and position computation. Range based system utilizes timing, direction, signal strength for distance estimation. The position of node is computed using a multi-triangulation, which comes in category [5-9]. This estimation is fairly accurate, but it's not very accurate in the case of initial position estimation [10]. Range free system utilizes hop based techniques which concludes proximity of a node to some fixed point and by using centroid calculation, it estimates the position of the node. This type of system comes under category [11-15].In this technique the estimation of initial position may be more inaccurate compared to range based systems. The proposed system uses range-based localization approach. Some hybrid localization techniques are also used to optimize the result of node localization. On the basis of graph theory, the relation between nodes is utilized. Social network analysis is the part of this hybrid technique, which computes the distance in terms of metrics.

PROPOSED MODEL

In this section, an efficient modelling is presented to estimate the location of nodes using ToA measurements between nodes in a wireless sensor network. Assume that a network consists of n blindfolded and reference nodes t. The node factors can be represented as $\omega = C, \ldots . C_{t+n}$, where $C_x = [m_z + l_z]^D$ is the absolute relative error to the blindfolded nodes in a two dimensional sensor structure whose axis coordinated can be represented as $\alpha = [\alpha_m, \alpha_l]$.

$$\alpha_i = [m_1, \ldots, m_n], \quad \varphi_j = [l_1, \ldots, l_n] \quad (1)$$

The reference coordinates can be considered as $[m_{n+1}, \ldots, m, l_{n+1}, \ldots, l_{n+t}]$.

In ToA $M_{z,y} = D$ is the evaluated between nodes z and y in seconds. Here, we use only node subset $N(p)$ that evaluate pair-wise computation between nodes p, $\left((D_{z,y})\right)_{z,y}$ and $\left((R_{z,y})\right)_{z,y}$ and it is competitively independent because of upper triangular matrices utilization. Assume that $D_{z,y}$ is Gaussian dispersed with variance σ_D^2 and mean ${d_{x,z}}/{s}$, which is represented as follows,

$$D_{z,y} \sim H\left(e_{z,y}/s, \sigma_D^2\right), \ \ l_{z,y} = e\left(c_z, c_y\right) = \left\| c_z - c_y \right\|^{1/2} \quad (2)$$

Where s shows speed of propagation and σ_D^2 is not a function of $e_{z,y}$. The arbitrary matrices $R_{z,y}(dBm) = 10 \log_{10} R_{z,y}$ is in the form of Gaussian whose logarithmic normal can be represented as,

$$\bar{R}_{,y}(dBm) \sim R_o(dBM) - 10\, h_t \log_{10}\left(\frac{e_{z,y}}{e_o}\right) \quad (3)$$

Where σ_{dB}^2 shows shadowing variance whereas $D_{z,y}(dBm)$ shows average power, and $R_o(dBm)$ represents power received in $db\ milliwatts$ at reference distance e_o. R_o can be evaluated using path loss formula of free space and h_t represents the surrounding path loss exponent. Here we evaluate estimation strategy of the Adaptive information by assuming $h_t$is known and then the density of $R_{z,y}$is,

$$\tilde{e}_{z,y} = e_o \left(\frac{R_o}{R_{z,y}}\right)^{1/h_t}. \quad (4)$$

Where $\tilde{e}_{z,y}$ represents $AIES$ range $e_{z,y}$ then the specific computed power can be represented as $R_{x,y}$. Either $T_{m,l}$ or $R_{m,l}$ are assumed as stochastic process which does not vary according to time. If systems with the same relative node coordinates are simulated in numerous different areas, the unbiased coordinate variance predictor will be lower limited by the proposed AIES technique.

RESULT AND DISCUSSIONS

The Simulation platform utilized is INTEL (R) core (TM) i5-4460 processor with 64-bit windows 10 Operating System with 16 GB RAM , 3.20 GHz CPU and 2GB dedicated Nvidia CUDA graphic card. The tool utilized is MATLAB 2016b. A 10m*10m network area with 4 reference devices, 10m grid size, the total number of sensor devices is same as the grid size square and blind fold systems are same as the total number devices minus reference devices is used. The tolerance factor, localization iteration & distance factor parameters are varied and simulated. Evaluation of localization error is done and compared with standard localization technique and is represented in graphs. The localization error can be evaluated in terms of RMSE as:

$$RMSE = \sqrt{\frac{\sum_{j=1}^{m}(Loc_{real}^{j} - Loc_{est}^{j})^2}{m}} \quad (5)$$

In Figure.1 it is demonstrated that the proposed AIES-ToA technique achieves better results than any other conventional state-of-art-technique while evaluating localization error. Total number of iteration considered is 50 and the proposed AIES-ToA STD reduces the average localization error by 12.64% compared to conventional standards techniques.

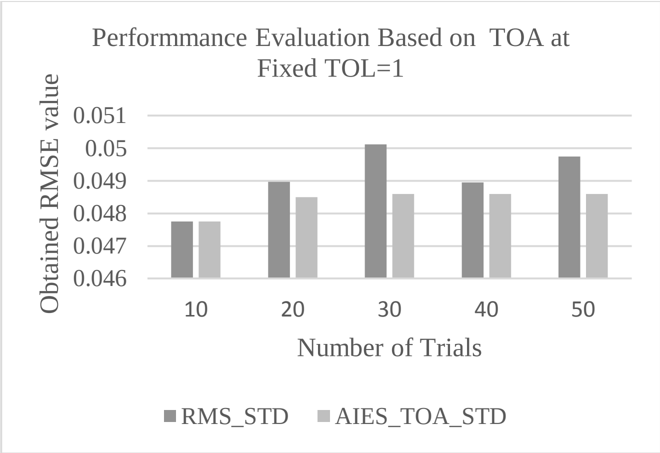

Figure 1. Localization Error performance with Fixed Tolerance

In Figure 2 it is demonstrated that the proposed AIES-ToA technique achieves better results than conventional methods while considering error tolerance performance. Total number of iteration is varied from 0.1 to 1 and the proposed AIES-ToA reduces the average localization error by 4.04% compared to conventional techniques.

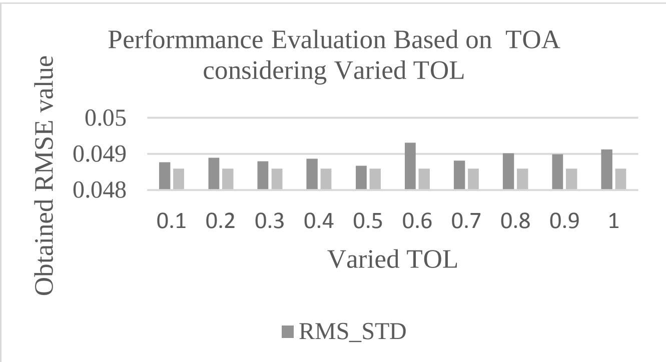

Figure 2. Localization Error performance with Varied Tolerance

Figure 3 depicts that the proposed AIES-ToA technique achieves better results for distance error parameter. The total number of iteration is varied from 10 to 100 and the proposed AIES-ToA reduces the average localization error by 86.62%.

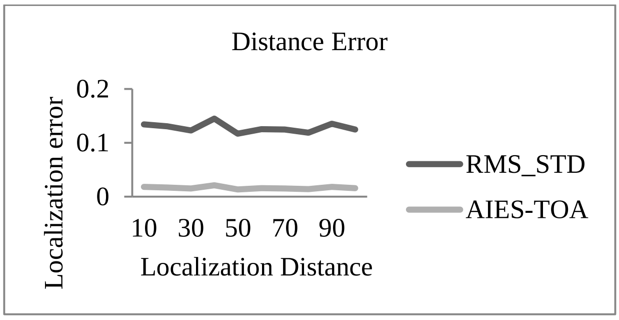

Figure 3. Distance Error Performance

CONCLUSION

Accurate estimation of location of nodes in wireless sensor network is a key factor for providing satisfactory services to the end user. In order to optimize the location estimation of nodes, a time of arrival based technique is proposed here, which reduces the localization error. Simulation results shows that the proposed approach reduces the localization error by approximately 12% and has an error tolerance of 10.62%. The overall result of the proposed approach expresses the effectiveness of the algorithm over the existing algorithms of localization.

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