Energy Efficient Dynamic Node Localization Technique in Wireless Sensor Networks

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Abstract

Objective: This paper represents an energy efficient algorithm for localization of nodes in wireless sensor network by the help of a small number of anchor nodes (mobile). It calculates the node distance and node location.

Method/Statistical Analysis: A small group of mobile dynamic anchor node is being associated with a powerful GPS receiver, Radio frequency and ultrasonic device. Location information is broadcasted periodically by the mobile anchor node and by trilateration/multilateration technique, the static node location is calculated. To calculate the approximate position of a sensor node it takes three rounds.

Findings: The technique is evaluated with the matlab and result compared with chord selection approach. The simulation result shows that the proposed localization method performs better and efficient than the other localization algorithms.

Application/Improvement: The proposed algorithm adopts distance measurement as TDOA technique and static sensor node can localize when it comes into the reception range. The method is applicable location computation based routing, sensing nodes, node signal processing, and for node localization.

Keywords: Localization Algorithm, Mobile Anchor Nodes, Wireless Channel, Wireless Sensor Network

1. Introduction

Localization is used to determine the position of location of sensor nodes, dynamically. For sensor networks, localization means locating a sensor node in a network. Localization is the process of finding the sensor node's position and highly desirable exactness of the localization technique. The localization algorithms are divided into two types such as Range based and Range free technique.

In the range based mechanisms, distance or angle metrics can determine the location of a sensor node. These metrics include TOA (Time of Arrival), TDOA (Time Difference of Arrival), AOA (Angle of Arrival), Received signal strength Indicator. The hardware used by range based method for node localization are highly expensive but it gives accurate result and requires a lot of calculation. The network cost is more and the computations are inefficient. There are several range based techniques that have been used previously are as follows: Radio Interferometric measurement (RIM)¹, Multidimensional scaling (MDS)², 3D-Landscape³, DV-hop, Euclidean instance⁴, the location for the unknown sensor node⁵ etc. In the range free method, sensor node's position is found by the help of the nearby anchor nodes or the neighbouring nodes with the help of Hop and triangular basic. The different range free methods used previously like APIT⁶, chord selection method⁷,⁸ three dimensional approach⁹, SerLOC¹⁰, centrorid scheme¹¹ etc. Many techniques are discussed in¹²-¹⁷. The error in accuracy of these range free techniques of the individual node and the range free method is better than the range based techniques.

In², three dimensional wireless sensor networks and this approach gives an idea of flying anchor equipped with GPS and continuously broadcasts node position.
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information. The location of the node is computed by this message. As compared to existing range free localization scheme, this is a better method. A static sensor node is taken by us and when we run the algorithm, the flying anchor node perform its operation in the network. A self localization\(^2\) is achieved by GPS device in wireless sensor network.

A novel TDOA localization algorithm is proposed for wireless sensor network. Using a small no of mobile anchor nodes, the proposed dynamic range based localization scheme is implemented. The mobile anchor node moves in random direction along with it broadcast its current position information. Then using the trilateration/multilateration method, the mobile anchor node computes the position of the sensor node. The mobile anchor node changes it's position after the completion of the first round localization and the same node position value is calculated by the participation of another three node and the approximate value for the node position will be decided finally after the third iteration. Then this node participates for the localization process. The proposed localization algorithm is simulated in Matlab. The proposed localization scheme is better than the other localization algorithms using mobile anchor nodes as shown by the simulation results.

The paper is organized as follows. In Section 2 describes the proposed localization scheme. In Section 3 represents simulation and result. Section 4, represent conclusion part.

In wireless sensor network mobile anchor node localization is represented in a critical environment\(^{18,19}\) proposed the mobile anchor node localization algorithm. The anchor nodes moves in random direction and broadcasts its current location information. A static sensor node receives and records the position information and when it received position information from three mobile anchor node then the position of the sensor node is computed via trilateration/multilateration method by the mobile anchor node. After the first round localization is done, then mobile anchor node changes its position and another three node participate to calculate the same node position value and finally after third iteration the approximate value will be decided for the node position. Then this node participates in the localization process. In TDOA measurements the minimum number of sensor required is two. This localization\(^{20,22}\) based on moving sensor and find the distance between sensor node and anchor node.

It is represented in Figure 1 given. The anchor node position is marked by the location A and C and static sensor node is marked at point S inside the circle which receive message from anchor nodes first time. The other two anchor nodes B and D broadcast message which is received by static node Sat the last time. The two bisectors AB and CD is intersect each other at the centre of the circle, i.e. the location of the static sensor node.

![Figure 1. Beacon point selection in ssu's algorithm.](image)

Where the circle is defined as the reception range in and a localization method using a moving anchor node by considering the wireless communication channels\(^{23}\). In this algorithm, there is certain probability of received data packet containing noise in mobile anchor node.

The maximum RSSI location value is recorded as beacon point which is described in the given algorithm. There is smaller possibility of error probability when received packet from moving anchor node as shown in the Figure 2. When the maximum RSSI value points and , the line and is perpendicular to the line and respectively. The intersection point of line and holds the sensor location.

![Figure 2. Determination of sensor node location.](image)

3. Algorithm Design

The proposed algorithm adopts distance measurement as TDOA technique. In this proposed method static sensor node can localize when comes into the reception range.
The proposed algorithm is divided into two steps 1) Mobile anchor node Localization. 2) after the completion of step 1, still there is possibility of the presence of some uncovered sensor nodes. To localize the neighbours, the localized node considers as stationary anchor nodes which are done using the algorithms mentioned in section I. The proposed scheme is discussed in this section. To reduce the energy consumption, we also present a dynamic technique.

2.1 Assumption

2.1.1 Static Sensor Nodes
The sensor nodes having similar configuration and homogeneous in nature, the node battery power configuration is unique at deployment.

2.1.2 Mobile Anchor Nodes
It is a special node having more energy level. The mobile anchor nodes have similar configuration from system point of view. It moves randomly in any direction and transmits its location information to the static non anchor node and also during the localization they won't drain out completely.

2.1.3 Transmission Range of a Node
The sensor nodes have the same transmission range i.e. ‘r’ transmission procedure is Omni-directional signal broadcasting. A sphere of radius ‘r’ with sensor node at its centre represents the connectivity region of each node.

2.1.4 Quick Interaction
Mobile sensor nodes broadcast their location continuously. It will receive the broadcast message each time a static sensor node enters in its communication range.

2.1.5 Random Deployment of Sensor Nodes
There is random deployment of all the sensor nodes in different critical environment with critical condition.

2.2 Objective of the Work
To Design a method for localization of the wireless sensor nodes which are deployed in sensor field having low communication and low computation. The proposed algorithm follows in an adhoc fashion stationary sensor nodes and they are self-configured.

The anchor node moves randomly in sensor network and broadcast its current location value frequently. It is configured with GPS device and the anchor node moves randomly in any direction of the sensor network where all unlocalized node received location information from anchor node.

2.2.1 Distance Measurement
For measuring distance, some approach like time-of-flight transmission of signals uses GPS in unidirectional transmission of signals to estimate distance by using satellite, to determine altitude it takes help of an electromagnetic signal for reflect off the ground by a radio altimeter in an air craft\(^24\). Hence it computes the distance by ultrasonic signal and radio signal in one-way transmission time from the mobile anchor node. Once the RF signal is received by static node, ultrasonic receiver is immediately turned on for receive ultrasonic pulse after a short quantum time. To estimate the distance between the stationary node and mobile anchor node, the receiving time of RF and ultrasonic signal difference is calculated and used for computation of node location. This is shown in Figure 3, RF radio carries the information about location of mobile anchor node and also ultrasonic carries the location information of mobile anchor node.

\[
\text{Distance Finding between mobile anchor node and unlocalized node.}
\]

\[
\text{Length}\left(d\right) = \left(R_c - U \right) \times \left(t_2 - t_1\right)
\]

2.2.2 Virtual Anchor Point Selection
The proposed work defines a localization scheme and selection virtual point. The mobile anchor node travels in a random direction and from a point it broadcasts messages in a certain time internal. The static non-anchor node received a signal, if a signal to noise ratio (SNR) of
the signal received is greater than the threshold point P is defined as a virtual anchor point. The stationary sensor node stores three virtual anchor points message distance, location of virtual anchor point with respect to static sensor node.

Figure 4. Sensor location calculation.

2.2.3 Trilateration

Trilateration refers to the process of computing position estimates using distance or angle estimates. The distance between anchor and unknown sensor node is estimated by RSSI. It is known that the sensor node is situated in the circumference of a circle centred at the anchor with a radius equal to the anchor node distance. 2D space define to obtain a unique location, there is a requirement of distance from three anchor node.

In this technique there are two cases.

a. The three anchor node's circle intersects each other at a given point that holds unknown node as shown in Figure 4, 5.

b. The three anchor node's circle does not intersects each other at a given point that holds non anchor node as shown in Figure 6

Figure 5. Trilateration by using TDOA technique A,B,C are anchor node and N is the sensor node.

2.2.4 Location Calculation

When a static node receive message from three virtual anchor point then localization process start as shown in

Figure 4. The anchor point P, Q and R, are represented by \((p_1,q_1), (p_2,q_2), \) and \((p_3,q_3),\) respectively its location coordinate and \(d_1, d_2\) and \(d_3\) are distance from PQ and R. Then computation process is represented in the given equations

\[
\begin{align*}
(x - p_1)^2 + (y - q_1)^2 &= d_1^2 \\
(x - p_2)^2 + (y - q_2)^2 &= d_2^2 \\
(x - p_3)^2 + (y - q_3)^2 &= d_3^2
\end{align*}
\]

(1)

\[
\begin{align*}
(x - p_1)^2 + (y - q_1)^2 &= d_1^2 \\
(x - p_2)^2 + (y - q_2)^2 &= d_2^2 \\
(x - p_3)^2 + (y - q_3)^2 &= d_3^2
\end{align*}
\]

(2)

\[
\begin{align*}
(x - p_2)^2 + (y - q_2)^2 &= d_2^2 \\
(x - p_3)^2 + (y - q_3)^2 &= d_3^2
\end{align*}
\]

(3)

The equation (2) and (3) is solved by using Newton’s iterative method to find the location of unknown sensor node. By considering equation (1), it is rewritten as in different form

\[
\begin{align*}
f(x, y) &= (x - p_1)^2 + (y - q_1)^2 - d_1^2 = 0 \\
f(x, y) &= (x - p_2)^2 + (y - q_2)^2 - d_2^2 = 0
\end{align*}
\]

(4)

Therefore we states the Jacobi matrix is

\[
F(x, y) = \begin{bmatrix}
2(p_1 - x) - 2(q_1 - y) \\
2(p_2 - x) - 2(q_2 - y)
\end{bmatrix}
\]

(5)

Its reverse can be written as

\[
f(x, y)^{-1} = B \times \begin{bmatrix}
-2(q_2 - y) & -2(q_1 - y) \\
-2(p_2 - y) & -2(p_1 - y)
\end{bmatrix}
\]

(6)

Where
Based on Newton iteration method, we have

\[(x, y)^{(k+1)} = (x, y)^{(k)} + A \times \left[ \frac{2(q_2 - y^{(k)}) - 2(q_1 - y^{(k)})}{2(p_2 - x^{(k)}) - 2(p_1 - x^{(k)})} \right] \]

Where

\[A = B^{(k)} \times \left[ \frac{-1}{(q_1 - y^{(k)}) \times (p_1 - x^{(k)}) - (p_1 - x^{(k)} \times (q_2 - y^{(k)}))} \right] \]

3. Simulation and Result

The proposed method is simulated and gives the average location error, node energy efficient and cost effectiveness.

3.1 Simulation Environment

The proposed method is simulated by matlab simulator with constant area and constant density. In our simulation proposed method is compare with chord selection approach. In simulation we use small number of moving anchor node, for distance measure TDOA approach is adopted.

3.2 Metrics

The proposed localization algorithm is evaluating the performance of sensor network by using three important metrics.

- **Average node localization error**: The average node localization is calculated by difference between node estimation location and node’s actual location of sensor nodes\[5\]

\[\Delta \hat{X}_{avg} = \frac{\sum_{i=1}^{N} \sqrt{(X_{ei} - X_i)^2 + (Y_{ei} - Y_i)^2}}{N} \]

where \(N\) = total number of static sensor nodes.

- **Average node energy consumption**: The node energy consumption is calculated as follows

\[P_{avg} = \frac{\sum_{i=1}^{N} E_i}{N} \]

Where \(E_i\) stands for static sensor node’s energy consumption.

- **Average throughput**: It is defined as

\[R_{avg} = \frac{\sum_{i=1}^{N} R_i}{N} \]

Where \(R_i\) stands for static sensor node’s throughput.

3.3 Results

Using these three metrics we observed the following results.

3.3.1 Localization Performance

By considering different iteration of data both static and moving anchor nodes observed that 3% of the total time
is being taken for the localization the first 75% nodes. Then next 10% nodes take 15% time of total time taken. Remaining time taken for node locating at the place in critical dense regions and shows the result. The shows the localization accuracy with respected to mobile anchor nodes. Localization accuracy is represented in Figure 7&8 based on energy efficient dynamic localization technique.

3.3.2 Node Localization Error

Localization error depends on beacon message connectivity range. Localization error is minimized if beacon message is in within the receiving node connectivity range. The location computed may have an error if mobile sensor nodes first and last receiving beacon message communication ranges changes.

\[
\text{Location error} = \sqrt{(x_{\text{est}} - x_{\text{sens}})^2 + (y_{\text{est}} - y_{\text{sens}})^2} \quad (14)
\]

\[
\text{Average location error} = \frac{\sum (x_{\text{est}} - x_{\text{sens}})^2 + (y_{\text{est}} - y_{\text{sens}})^2}{N} \quad (15)
\]

\[
\text{Average location error} = \frac{\sum \text{location error}}{N} \quad (16)
\]

3.3.3 Number of Mobile Nodes and Beacon Overhead

The research article provides chord selection technique is more preferable than centroid method. But in Figure 8, Figure 9 and Figure 10 shows that the proposed technique better outperform than chord selection method. If number of moving anchor node is increase then it gives better localization time and overhead of beacon is drastically reduce.

\[
\text{Beacon overhead} = \frac{\text{no of beacon message}}{\text{total number of mobile sensor node}}
\]

3.3.4 Energy Comparison of EEDNLT vs. Chord Selection Approach

EEDNLT seem have proved their efficiency number-wise, but they still have to consume less energy than the Chord selection approach in order to survive for the same of longer period of time. We computed the average energy consumption of these nodes in various scenarios and compared them. The EEDNLT approach proves their efficiency in terms of energy consumption in every scenario, making them suitable of deployment is shown in Figure 11.
4. Conclusion

In this paper represents a dynamic efficient localization algorithm that we have described above with the help of small number of mobile anchor node. Those nodes are equipped with a GPS device. It is used for the purpose of finding the distance between mobile anchor node and static sensor node using RF and ultrasonic techniques. The anchor node transmits its location information on moving over sensor area. Static sensor node location is computed locally. The technique is evaluate with the matlab and result compared with chord selection approach. The results show that our localization scheme outperforms better in energy efficiency and accuracy.

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