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Research on the Improved DV-HOP Localization Algorithm in WSN

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Abstract

To solve the inaccurate node localization in WSN, this paper first analyzes the problems in current DV-HOP algorithm, takes the received signal RSS as a reference standard through the weighted centroid algorithm, effectively reduces the localization errors, and adopts the improved two-dimensional hyperbola algorithm in the distance estimation to make the estimated distance more accurate. The simulation results show that the presented algorithm has been significantly improved compared to the algorithms in literature, and enhanced the localization accuracy to a certain extent.

Keywords: *Weight, RSS, Two-dimensional hyperbola, DV-HOP Algorithm, WSN*

1. Introduction

In wireless sensor network (WSN), the node location information is the key to application. How to achieve accurately node localization is a main concern for wireless sensor network, which plays a very important role in WSN. In WSN, node localization includes anchor node localization and unknown node localization. Among this, anchor node refers to a small number of nodes with GPS localization device, which cannot be widely used due to high energy consumption of GPS installation. Meanwhile, the localization of unknown node location has to localize through anchor nodes [1-3].

According to the distance between measurement nodes in the localization process, WSN node localization consists of range-based and range-free localization algorithms [4]. Range-based algorithm primarily measures the range between adjacent nodes, calculates the range of surrounding unknown nodes through the actual range between nodes, and this algorithm has high requirements over hardware, which is not suitable for consumption power and low cost application fields. Currently, RSSI, TOA, TDOA, AOA algorithms are frequently used measuring technologies [5-6]. Range-free algorithm does not need to measure actual distance between nodes, but instead, it obtains the node location through distance estimation, which can reduce the damage to hardware. However, the localization error between nodes will be increased, and centroid algorithm and DV-HOP algorithm are frequently used [7]. Among this, DV-HOP algorithm mainly obtains the information of all anchor nodes through distance vector path protocol. However, with the increases in hop distance between anchor nodes and unknown nodes, the measures distance will also be accumulated gradually, and have certain influences on the localization accuracy of nodes. Literature [8] presented when conducting the unknown node localization, and beacon nodes successively use two communication radiuses to broadcast their location information, so as to obtain the more accurate hop number between unknown nodes and beacon nodes, calculate the more accurate distance between them, and get the more accurate coordinate for unknown nodes. Simulation results show that the improved algorithm has reduced 13%~15% of localization error and reduced the localization error difference incurred from different network topology structure compared to the traditional DV-Hop algorithm.

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signal RSS as a reference standard through the weighted centroid algorithm, effectively reduces the localization errors, and adopts the improved two-dimensional hyperbola algorithm in the distance estimation to make the estimated distance more accurate. The simulation results show that the presented algorithm has been significantly improved compared to the algorithms in literature, and enhanced the localization accuracy to a certain extent.

2. DV-HOP Algorithm

The main idea of DV-HOP algorithm is to determine the distance between unknown nodes and anchor nodes through the network average hops and the product of hops, and then get the node location through likelihood estimation.

The algorithm consists of three stages:

(1) Information Broadcast and Correction Value Calculation. In WSN, each node will broadcast its location information in the form of data grouping. The initial hop is set to 0, when the unknown nodes are recorded to the minimum hop of each anchor node, compare with the existing hop. If it is greater than the existing hop, just neglect, add 1 to the hop value, continue forward the rest unknown nodes, and each unknown node will get the minimum hop of anchor nodes.

(2) Correction Value Broadcast. Each anchor node will broadcast its correction value in the form of broadcast, and the non-located unknown nodes get the correction value of each anchor nodes.

(3) Localization of unknown nodes. By calculating the correction value of anchor nodes and the hop from itself to anchor nodes, unknown nodes calculate the distance to anchor nodes. Afterwards, the coordinates for unknown nodes will be calculated through the coordinate information of anchor nodes and the distance information to anchor nodes.

3. DV-HOP Localization Algorithm based on Improved Weighted Centroid and Two-Dimensional Hyperbola

3.1 Improved Weighted Centroid Algorithm

To solve the inaccurate correction value caused by the localization error of unknown nodes in DV-Hop algorithm, this paper takes the received signal strength (RSS) as a weight value to improve the localization of unknown nodes. Take Figure 1 for example, there are different anchor nodes {A,B,C,D,E,…..K} around an unknown node N, the coordinates fort anchor node is set to A(x_A, y_A), B(x_B, y_B), C(x_C, y_C)…..K(x_K, y_K), so the unknown node N adopts the method of Table 1 to record the strength of related unknown nodes receiving RSSI signals sent by the surrounding anchor nodes, the path distance between unknown nodes and anchor nodes as well as the coordinate information of anchor nodes.

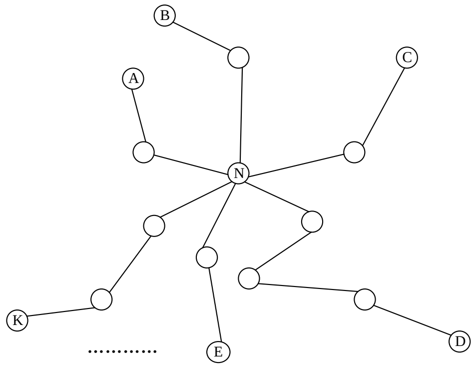

Figure 1. Example Distribution Diagram for Unknown Nodes and Anchor

Nodes

According to the characteristics of the channel transmission model, the following results can be obtained: the farther the signal transmission distance is, the weaker its RSSI value is, so the anchor nodes have greater impact on the solution of unknown node coordinates. Since the location of unknown location nodes cannot be arbitrarily changed, it is very important to take the distance between unknown nodes and anchor nodes and RSSI value as a reference. This paper considers from the above two factors, compares the the size of RSSI strength values as specific values, adopts the ratio of RSS values and path distance as the reference coefficient, and determines the coordinates for unknown nodes through the product of anchor node coordinates. It is calculated as follows (1)

$$\begin{cases} x_N = x_A * \dfrac{RSSI_{N\to A}}{S_{N\to A}} + x_B * \dfrac{RSSI_{N\to B}}{S_{N\to B}} + x_C * \dfrac{RSSI_{N\to C}}{S_{N\to C}} \cdots\cdots x_K * \dfrac{RSSI_{N\to K}}{S_{N\to K}} \\ y_N = y_A * \dfrac{RSSI_{N\to A}}{S_{N\to A}} + y_B * \dfrac{RSSI_{N\to B}}{S_{N\to B}} + y_C * \dfrac{RSSI_{N\to C}}{S_{N\to C}} \cdots\cdots y_K * \dfrac{RSSI_{N\to K}}{S_{N\to K}} \end{cases} \quad (1)$$

Where, $RSSI_{N\to R}$ represents the signal strength between unknown nodes to the anchor node R, and $S_{N\to R}$ represents the path distance between unknown node to the anchor node.

3.2 Improved Two-dimensional Hyperbola Localization Algorithm

According to the previous estimation algorithm, DV-HOP algorithm often adopts the likelihood estimation method to calculate the node location, and this method of subtracting three equations has certain losses over the coordinate information. To prevent such errors, this paper adopts the improved hyperbola location algorithm, and introduces an error value ε in order to better improve the localization accuracy of nodes.

Assumed the coordinates for unknown node is (x, y) and the coordinates for anchor node is $K(x_K, y_K)$, the distance between unknown nodes and anchor nodes is:

$$length_{N\to i|i\in K} = \sqrt{(x-x_i)^2 + (y-y_i)^2}\,(i=1,2\ldots K) \quad (2)$$

Step 1: An approximate distance $length'_{N\to i}$ is obtained in the process of distance measurement through Section 2.1.

$$length'_{N\to i} = length_{N\to i|i\in K} + \varepsilon_{N\to i} \quad (3)$$

Step 2: Combine with Equation (2) and (3) to get

$$length'_{N\to i} - \varepsilon_{N\to i} = \sqrt{(x-x_i)^2 + (y-y_i)^2}\,(i=1,2\ldots K) \quad (4)$$

Step 3: Expand the formula to get

$$(length'_{N\to i})^2 - 2length'_{N\to i}\varepsilon_{N\to i} + \varepsilon^2_{N\to i} - x_1^2 - y_1^2 = x^2 - 2xx_1 + y^2 - 2yy_1 \quad (5)$$

Step 4: Assumed $S = x^2 + y^2$, $T = x_1^2 + y_1^2$ are substituted into Equation (5) to get Equation (6)

$$(length'_{N\to i})^2 - 2length'_{N\to i}\varepsilon_{N\to i} + \varepsilon^2_{N\to i} - T = S - 2xx_1 - 2yy_1 \quad (6)$$

Step 5: Expand Equation (6) by the matrix to get Equation (7)

$$A = \begin{bmatrix} -2x_1 & -2y_1 & 1 \\ -2x_2 & -2y_2 & 1 \\ \cdots\cdots & \cdots\cdots & \cdots\cdots \\ -2x_n & -2y_n & 1 \end{bmatrix}, \quad K = \begin{bmatrix} x \\ y \\ S \end{bmatrix}, \quad B = \begin{bmatrix} (length'_{N\to 1})^2 - 2length'_{N\to 1}\varepsilon_{N\to 1} - T_1 \\ (length'_{N\to 2})^2 - 2length'_{N\to 2}\varepsilon_{N\to 2} - T_2 \\ \cdots\cdots\cdots\cdots \\ (length'_{N\to i})^2 - 2length'_{N\to i}\varepsilon_{N\to i} - T_n \end{bmatrix}$$

$$\varepsilon = \begin{bmatrix} \varepsilon_{N\to 1}^2 \\ \varepsilon_{N\to 2}^2 \\ \cdots \\ \varepsilon_{N\to i}^2 \end{bmatrix}$$

$$AK - B = \varepsilon \quad (7)$$

Step 6: Use the maximum error ε to set the anchor node weight. Seek the anchor nodes having the farthest distance to unknown nodes from the received anchor nodes, and denote as $length_{\max}$. Error must be greater due to the farthest distance, set the weight to be 1, calculate the distance between unknown nodes and anchor nodes, and set the weight value set by different paths. Therefore, the weight value of each anchor node is calculated by Equation (8)

$$\tau_i = \frac{length'_{N\to i}}{length_{\max}} \quad (8)$$

Step 7: Use the least squares to solve Equation (10) and obtain $K = (A^{-T}A')^{-1}(A^{-T}B')$, where,

$$A' = \begin{bmatrix} -2\tau_1 x_1 & -2\tau_1 y_1 & \tau_1 \\ -2\tau_2 x_2 & -2\tau_2 y_2 & \tau_2 \\ \ldots.. & \ldots.. & \ldots. \\ -2\tau_n x_n & -2\tau_n y_n & \tau_n \end{bmatrix} \quad K = \begin{bmatrix} x \\ y \\ S \end{bmatrix}$$

$$B' = \begin{bmatrix} \tau_1^2 (length'_{N\to 1})^2 - 2\tau_1 length'_{N\to 1}\varepsilon_{N\to 1} - T_1 \\ \tau_2^2 (length'_{N\to 2})^2 - 2\tau_2 length'_{N\to 2}\varepsilon_{N\to 2} - T_2 \\ \cdots\cdots\cdots\cdots \\ \tau_n^2 (length'_{N\to i})^2 - 2\tau_n length'_{N\to i}\varepsilon_{N\to i} - T_n \end{bmatrix}$$

4. Simulation and Analysis of Algorithms

To further prove the effectiveness and practicality of the algorithm, the paper carries out in the Windows platform and conducts the simulation experiment by using Matlab2010. Simulation environment selects the 100*100 area, selects 500 nodes including 100 anchor nodes and 400 unknown nodes, and all nodes are randomly distributed.

4.1 Localization Error of Correction Value

This paper compares the presented algorithm with the Literature [8] algorithm in terms of localization error of correction value, and conducts 100 simulation experiments, as shown in Figure 3.

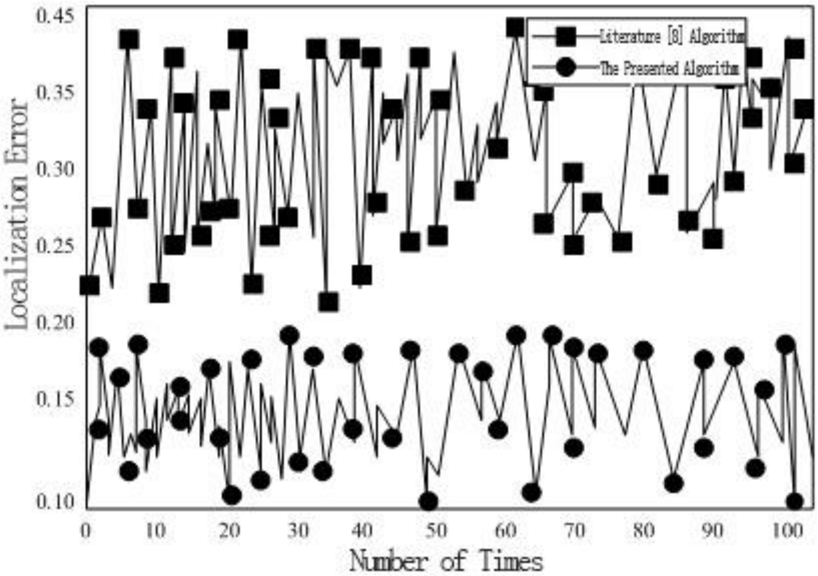

Figure 2. Correction Value Comparison of Two Algorithms

According to Figure 2, the error range of the presented algorithm is about 10%, whereas the Literature [8] algorithm is nearly 20%, so the error range is narrowed after adopting an improved weighted centroid algorithm in the selection of the correction value calculation.

4.2 Localization Error of Maximum Estimation

This paper compares the presented algorithm with the algorithm in Literature [8] in terms of localization error of maximum estimation, as shown in Figure 3

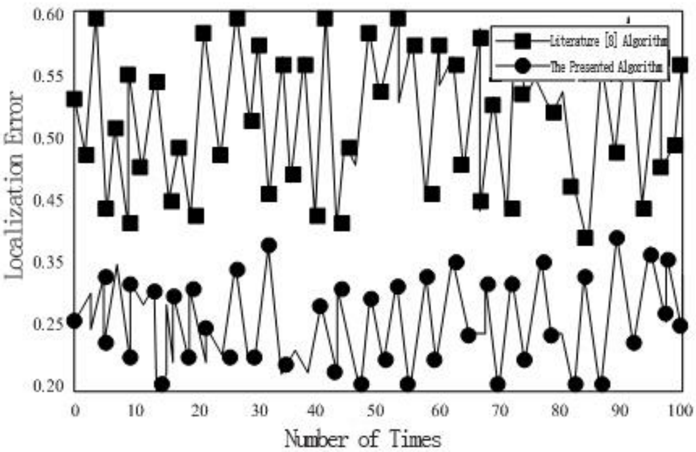

Figure 3. Maximum Estimation Localization Error Comparison of Two Algorithms

According to Figure 3, the error range of the presented algorithm is about 15%, whereas the Literature [8] algorithm is nearly 21%, so the error range is narrowed after adopting the improved hyperbola algorithm in the selection of maximum estimation localization.

4.3 Results of the Improved Algorithm

The above two methods respectively distinguish from the error localization of correction value and maximum estimation localization algorithm, and this paper compares the presented algorithm with the algorithms in Literature [7] and Literature [8], as shown in Figure 4:

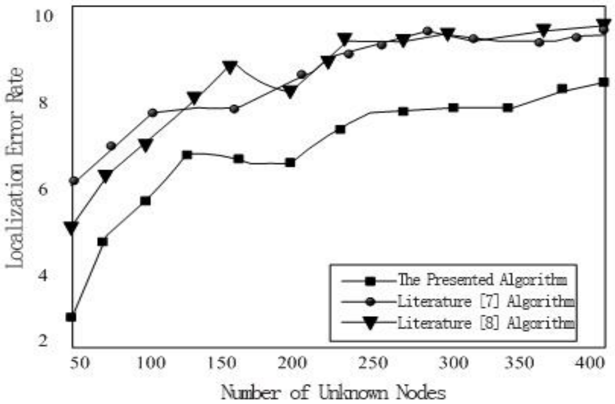

Figure 4. Localization Error Comparison of Three Algorithms

5. Conclusion

Unknown node localization in WSN has always been a research focus in WSN, and the unknown node localization will have a direct impact on the efficiency of WSN. In order to solve the errors of correction value in DV-HOP algorithm, inaccurate estimation of the distance between unknown nodes and the maximum estimation errors, this paper analyzes and adopts the improved weighted centroid algorithm for the problems of correction value, takes the improved two-dimensional hyperbola method in the maximum estimation algorithm, and the improved algorithm has significantly improved the localization accuracy.

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