Difference Correction RSSI Location Algorithm of Double Reference Nodes

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Received: 16 December 2013 /Accepted: 28 February 2014 /Published: 31 March 2014

Abstract: In order to reduce the influence of measurement errors on the received signal strength of node localization of wireless sensor network, this paper presents a difference correction RSSI location algorithm of double reference nodes (DRN-RSSI). Firstly, DRN-RSSI selects two nearest beacon nodes away from the unknown node as differential reference node. Then, it measures the coordinate of reference nodes and unknown nodes through three edge positioning method. The calculated coordinates were corrected by a weighted coefficient. According to the error value between the actual differential reference node value and its measured value, the coordinates of the unknown nodes are corrected. These measures eliminate the problem of large positioning error. The simulation results show that the localization precision of DRN-RSSI is greatly improved in various conditions. Copyright © 2014 IFSA Publishing, S. L.

Keywords: Wireless sensor network, RSSI algorithm, Log-distance Distribution Model, Three edge positioning method, Double reference nodes.

1. Introduction

With the development of technology, application of wireless sensor network (WSN) is more and more widely. At present, there are many studies about WSN. Node localization technology is the focus of research on Sensor Networks. Node localization in WSN, in addition to report the incident location, can also be used for target tracking, aided routing and network management.

Jagoba Arias, Aitzol Zulo, etc. describes an algorithm, which computes the location of a node using noisy distance estimations. The restriction on distance exactitude can be relaxed and RF signal based distance estimations may be used to estimate the node location [1]. Radim Zemet, Daisuke Anzai describes a RSSI-based Localization algorithm. Each stage of the algorithm can be implemented using different estimation methods, such as maximum likelihood (ML) and least square (LS) estimation which provides four different combinations [2]. Fu Qing, Retscher, Guenther describes an algorithm that in the positioning phase these measurements are used together with the current measurements to obtain the current location of the user [3]. To some extent, these literatures consider the influence of environment on the RSSI value. However, only average or weighted method, reduce the transient disturbance, can't offset these effects.

Aiming at these problems, based on the analysis of the radio propagation path loss model, this paper proposes a double reference node differential RSSI positioning algorithm [4]. Firstly, the algorithm determines the minimum area of unknown node location. Then the distance is calculated between the unknown nodes and beacon nodes by the path loss model. Two beacon nodes are selected to use as the reference node and correct the coordinates.
of the unknown node. Finally, the coordinates of the unknown node is obtained. The algorithm does not need additional hardware. Simulation results show that the algorithm performance is better, node localization is more accurate, and the location error is small.

2. The Algorithm Model

According to the signal intensity of the transmitting node and receiving node received signal strength, the RSSI Location algorithm can calculate the propagation loss. Then transmission loss can be transformed into the distance using theory and empirical model. Finally, calculate the position with three sided measurement [5-8]. Finally, the position is calculated by three sided measurement.

2.1. Wireless Signal Attenuation Model

With the increase of distance, wireless signal will be regularly attenuated. This attenuation has great influence on the positioning accuracy of RSSI. So we should choose a suitable attenuation model of wireless signal. The commonly used wireless channel propagation attenuation model includes Free Space Propagation Model (Free-Space Model) and Log-distance Distribution Model [9-10].

The Free-Space model is shown in formula (1):

\[
Loss = 32.44 + 10k \log(d_o) + 10k \log(f),
\]

where Loss represents the channel attenuation (unit: dB), d said the distance between the test point and source distance (unit: km), f represents the signal frequency (unit: MHz), k said attenuation factor.

Because of the signal interference and the obstacle factors, the Log-distance Distribution model is often used to determine the relationship between signal strength and distance. The Log-distance Distribution model is shown in formula (2):

\[
PL(d) = PL(d_o) + 10k \cdot \log\left(\frac{d}{d_o}\right) + X_o
\]

In formula (2), d represents the distance between the current node and the source node. PL(d) is the path loss at the receiving node. X_o said Gauss distributed random variables, which average value is 0. The range of it is 4~10. k represents the attenuation factor, in different circumstances, its value is different, which range is 2~5.

Generally, known transmit node's signal strength, the receiving node's signal strength; the gain of the antenna, using formula (3) can get the channel attenuation value.

\[
RSSI = P + G - PL(d)
\]

In formula (3), P represents transmit power, G said antenna gain. By formula (3), PL (d) can be obtained. d_o is the reference distance, usually is taken as 1 m. Putting it into formula (1), PL (d_o) can be obtained. Putting PL(d) and PL(d_o) into the formula (2) can get the required distance d.

2.2. Three Edge Measurement Location Method

Three beacon nodes A(x_a, y_a), B(x_b, y_b), C(x_c, y_c) are known. d_a, d_b, d_c said the distance between them and the unknown node M(x, y). The coordinates of unknown nodes of M can be obtained by formula (4).

\[
\begin{align*}
\sqrt{(x-x_a)^2 + (y-y_a)^2} &= d_a \\
\sqrt{(x-x_b)^2 + (y-y_b)^2} &= d_b \\
\sqrt{(x-x_c)^2 + (y-y_c)^2} &= d_c
\end{align*}
\]

Through formula (4), the results are calculated as shown in equation (5):

\[
\begin{bmatrix}
  x \\
  y
\end{bmatrix}
= \begin{bmatrix}
  2(x_a-x) & 2(y_a-y) \\
  2(x_b-x) & 2(y_b-y)
\end{bmatrix}^{-1}
\begin{bmatrix}
  x_a^2 - x^2 + y_a^2 - y^2 + d_a^2 - d^2_a \\
  x_b^2 - x^2 + y_b^2 - y^2 + d_b^2 - d^2_b
\end{bmatrix}
\]

In the formula, x, y are the value of the coordinates of unknown node M.

3. Algorithm Design

3.1. The Traditional Differential Correction Algorithm

The distance that base d on RSSI Measurement will produce error. The error should be appropriately modified, and the modified value calculated by formulas. The difference correction algorithm is often used to solve this kind of problem [11-12].

Firstly, the algorithm selects three beacon nodes A(x_a, y_a), B(x_b, y_b), C(x_c, y_c) to measure the positions of the unknown nodes M(x, y). Then selects a beacon node D(x_4, y_4) which is closest to the M. Using three points, the measurement coordinates of D(x'4, y'4) is obtained by three edge measurement method. Comparing with the actual coordinates D, the offset (△△x, △△y) can be drawn. Locating the point M in the same way, the coordinates of point M(x', y') can be got. Finally, the offset of point D is approximated to the offset of unknown node M, and the coordinates of M is calculated by the offset. Coordinate as shown in formula (6):
There are some problems in this difference divided correction. How to choose the three measurements of beacon nodes? Because of the node deployment, D point may be far distance from M point. These factors will affect the accuracy of M point positioning [13-15].

This paper presents the DRN-RSSI algorithm that uses two beacon nodes respectively as a point of reference for differential correction. To a certain extent, the algorithm can avoid such problems.

3.2. DRN-RSSI Algorithm

Firstly, according to the received RSSI value, three beacon nodes A, B and C are determined which have nearest distance with the unknown node M. The three beacon nodes determine a triangle. The centroid of the triangle can be calculated through the centroid algorithm. We can obtain the fourth beacon node D which has shortest distance from it.

Then, the two beacon nodes are chose which have shorter distance from unknown node M. These two points are indicated by A and B. Taking node A as the differential correction reference point, B, C, D as the beacon node, M coordinates is calculated by formula (6), expressed as \( x = x_n^\prime + \Delta x \) and \( y = y_n^\prime + \Delta y \).

\[
\begin{align*}
  x &= x_n^\prime + \Delta x \\
  y &= y_n^\prime + \Delta y
\end{align*}
\]  

(6)

In the traditional differential correction algorithm, because of ignoring the influence of other beacon node to node position, the positioning accuracy error is large. In DRN-RSSI Algorithm, the beacon node reflects to node location decision rights through the weighted factor. According to the difference of the reference point from the unknown node, the coordinate is weighted correction. Finally, the coordinates of unknown node M is calculated which is shown in the formula (7).

\[
\begin{align*}
  x &= \frac{x_m + x_{mb}}{d_1^d + d_2^d} \\
  y &= \frac{y_m + y_{mb}}{d_1^d + d_2^d}
\end{align*}
\]  

(7)

In the formula (7), \( d_1 \) and \( d_2 \) said the distance between the beacon nodes and the unknown node; \( k \) is the natural number, represents the weighted coefficient. Factor \( 1/d_1^d \) and \( 1/d_2^d \) reflect the distance of unknown nodes and beacon nodes is closer; the position of influence is greater. This interrelationship can improve the positioning accuracy.

3.3. DRN-RSSI Algorithm Steps

According to the above description, algorithm implementation steps are as follows:

Step 1: Beacon nodes periodically send its information to other node within the communication scope. This information includes ID number, Coordinate position information and so on. Each node spreads in turn.

Step 2: According to different beacon nodes, the unknown nodes classifies the received information. When the received signal exceeds a certain threshold, the average value of same beacon node RSSI is calculated.

Step 3: According to RSSI from strong to weak order, the mapping of RSSI value and the distance between unknown node and the beacon node is established. Establish the following three sets:

- The beacon node set: \( B = \{a_1, a_2, ..., a_m\} \);
- The distance set between beacon nodes and the unknown nodes:
  \( D = \{d_1, d_2, ..., d_m\}, d_1 < d_2 < ... < d_m \);
- The beacon node location set:
  \( P = \{(x_1, y_1), (x_2, y_2), ..., (x_m, y_m)\} \);

Step 4: Four beacon nodes are selected which match condition. The two reference beacon node are located by DRN-RSSI Algorithm. According to the positioning error, the position of unknown node is modified. Finally, the coordinates of the unknown node is obtained by the formula.

Step 5: Calculate the location error:

\[
ER = \sqrt{(x - x_r)^2 + (y - y_r)^2}
\]

\( (x_r, y_r) \) is the true location of the unknown node.

4. The Simulation Results and Analysis

MATLAB 2008 is used to simulate the DRN-RSSI algorithm and RSSI algorithm, and each influence factors on positioning precision are compared.

4.1. Parameter Settings

Starting parameters are set as follow:

1) The range of measured region: the square area of 100 m \( \times \) 100 m

2) Communication radius: Communication radius of node is 10-100 m; the starting value is set 50 m.

3) The total number of nodes is 200. Among them, the beacon nodes are respectively 15, 20, 25, 30, 35, 40, 45 and 50. The positions of the unknown nodes are randomly generated by MATLAB 2008. The simulation runs 200 times.

4) The weighted coefficient is initially set to 1.
All the simulation data are average values, obtained through many simulations.

### 4.2. Influencing Factors

We observe the performance of two algorithms on the location error through different weighted correction coefficient, number of beacon nodes and communication radius. In order to improve the simulation accuracy, this paper uses statistical methods. The following are 200 measurement results [16-18].

#### 1) Effects of weight coefficient on positioning precision

By changing the weighting coefficient, two algorithms simulation results are shown in Fig. 1. Because the RSSI algorithm has not the weighted coefficient, so no matter how the coefficients change, there are not any changes in location error. DRN-RSSI algorithm changes along with the increase of weighted correction coefficient. When the weighted correction coefficient is 1, the location error is max. When its value is 4, the location error is min. The min error is 2.8 m. At this point, the algorithm's accuracy is the best. It can be seen that no matter how the weighted coefficient change, the positioning error of DRN-RSSI Algorithm is less than RSSI Algorithm.

![Fig. 1. Effects of weight coefficient on positioning precision.](image1)

#### 2) Effects of beacon node number on positioning precision

Parameter settings are as follows: the communication radius: 50 m, the path loss coefficient: 4, the weighted coefficient k: 2. With different number of beacon nodes, we observe the effect of two kinds of algorithms for positioning error. The results are shown in Fig. 2.

With unchanging the total number of nodes in the network, both RSSI algorithm and DRN-RSSI algorithm, are increased with the number of anchor nodes, and the positioning precision is higher. Thus, in a certain range, by increasing the number of beacon nodes can improve the positioning precision, reduce positioning errors. But beyond a certain range, this change does not have too big effect.

![Fig. 2. Effects of beacon node number on positioning precision.](image2)

#### 3) Effects of communication radius on positioning precision

Changing the communication radius of node, the performance of two different algorithms is compared. The number of beacon nodes is set to 30; the weighted coefficient k is set to 2. Communication radius change in the range of 25 m-60 m, and the amplitude is 5 m. The simulation results are shown in Fig. 3. With increasing communication radius, it can be seen that the average positioning error are presented a decreasing trend, and gradually tends to be steady. When the node communication radius is small, the trend is very obvious. Under the same conditions, the average position error of DRN-RSSI algorithm is less than RSSI algorithm, its positioning accuracy is significantly improved.

![Fig. 3. Effects of communication radius on positioning precision.](image3)
In summary, in the change process of 3 factors, the performance of DRN-RSSI algorithm is better than RSSI algorithm.

5. Conclusions

Combined with the analysis of radio propagation path loss model, this paper has proposed a difference correction RSSI location algorithm of double reference nodes. The algorithm firstly selects two beacon nodes as differential reference node, and then calculates the location of the unknown node. Taken distance between reference node and unknown node as the weight, it better reflects the decision of each differential reference node of unknown node position. Through large-scale simulation, this paper has analyzed various different situations such as the weighted coefficient, beacon node number, radius of communication. The results have proved that the DRN-RSSI algorithm can improve the positioning precision than RSSI algorithm, reduces the positioning error, worthy of promotion.

References