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Improvement of Centroid Location Algorithm for Wireless Sensor Networks

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Abstract. In this paper, the radio propagation path loss is analyzed and the previous weighted centroid location algorithm is improved. The weighted factor in the algorithm is optimized, which makes positioning error and positioning accuracy of the unknown nodes better. Firstly, the paper uses three-point location to calculate location of unknown nodes approximately. Secondly, the paper uses a modified weighted centroid location algorithm to calculate the unknown nodes precisely. Finally, the algorithm is simulated. Compared to the previous weighted centroid localization algorithm, the simulation results show that the improved centroid positioning algorithm has better positioning performance.

Keywords: wireless sensor networks; location algorithm; unknown nodes.

1. Introduction

Wireless sensor network[1-2] is a powerful tool and effective way to get information. Because of its wide coverage, strong adaptability, layout convenience and flexibility, it plays an important role in the development of traditional sensing technologies and has broad application prospects in many areas. With the continuous development of wireless sensor networks, domestic and foreign researchers pay more and more attention to node localization algorithm of key technology node positioning.

The node localization algorithms can be divided into two broad categories by the positioning means: range-based localization algorithm[3] and range-free positioning algorithm. Range-based algorithms have such as TOA[4] (time of arrival), AOA (angle of arrival), TDOA (time difference of arrival) and RSSI[5]. These methods are by measuring the distance between nodes or the angle information and using the triangular measurement, triangulation, or maximum likelihood estimation to calculate the location of unknown nodes. Range-based algorithms are in need of dedicated hardware which enlarges the cost and size of sensor nodes, and limits its availability. The non-Range-based algorithm doesn’t have to know the distance of unknown nodes to the beacon nodes or doesn’t have to measure the distance directly. It has certain advantages in cost and power consumption to the range-based approach. The non-range-based algorithms have such as: APIT algorithm, DV-hop algorithm, DV-distance algorithm.

In this paper, weighted centroid localization algorithm in wireless sensor networks[6] is improved and the weighting factors are optimized. The improved weighted centroid localization algorithm has greatly improved in terms of accuracy and location error.

2. Algorithm model

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A. *Analysis of radio propagation path loss model*

The different degrees of radio signal loss in propagation process will affect the positioning accuracy of the algorithm, so the selection of the appropriate transmission path loss model is very important. There are many common propagation path loss models: the log-distance distribution model, the log-distance path loss model, the free space propagation model, Hata model and so on. Choose the free space propagation model and the logarithmic-normal distribution model for simulation in the complex field environment.

The free space propagation model is as follows:

$$Loss = 32.44 + 10 \times n \times \lg(d_0) + 10 \times n \times \lg(f). \quad (1)$$

The *LOSS* is the path loss of radio signal which is transmitted the distance of d_0. d_0 is the distance to the beacon node. *n* is the signal attenuation coefficient of the environment which is usually taken the values 2 to 5. f is the frequency of the transmitted signal.

Because of the effect of varieties of factors in environment, using the log-normality distribution model, which calculates the path loss of a node receiving beacon messages, is more reasonable.

$$PL(d) = \overline{PL}(d_0) - 10\lg(\frac{d}{d_0}) - \partial. \quad (2)$$

P(*d*) is the path loss of radio signal which is transmitted the distance of d . P(d_0) is the path loss of radio signal which is transmitted the distance of d0. PL(d_0) can be calculated by the equation(1). Where the value of d_0 is 1 meter, the value of LOSS is the PL(d_0). ∂ is the Gaussian random variable with average value of 0, and its standard deviation ranges from 4 to 10. According to the above analysis, received RSSI values of the sensor satisfies the following relationship:

$$RSSI = P_{send} + P_{amplify} - PL(d). \quad (3)$$

RSSI is the received power. Psend is transmitting power. Pamplify is the antenna gain. PL (*d*) is the path loss.

According to the above analysis and experiments, it is Logarithmic relationship between the received RSSI and the transceiver distance *d*. The distance error which is calculated from the larger value of the RSSI is small. The distance error which is calculated from the smaller value of the RSSI is large.

B. *Weighted centroid algorithm*

According to analysis radio propagation path loss model in A, the common centroid algorithm doesn't reflect the affection of beacon node to centroid location and the positioning accuracy is affected by a certain extent. In the paper, the weighted factor is adopted to reflect the affection of the beacon nodes to coordinates.

In this paper, following method is used to calculate the location of unknown nodes. As shown in Figure:

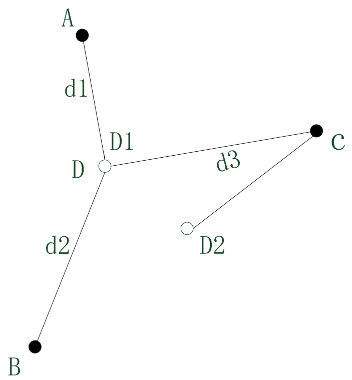

Figure 1. Three-point positioning method.

Three beacon nodes are: A (x_A,y_A),B(x_B,y_B),C(x_C,y_C). D is the unknown node. The distance from D to the A, B and C separately is d_1, d_2 and d_3.From the distance from D to the beacon node A and B, the following equations are obtained:

$$\begin{cases}(x_A-x_D)^2+(y_A-y_D)^2=d_1^2\\(x_B-x_D)^2+(y_B-y_D)^2=d_2^2\end{cases} \tag{4}$$

Solve the equations (4). When $L_{AB} \leq d_1+d_2$, the real solutions is obtained to get two places points D_1, D_2 (two points D_1, D_2 coincide when D_1 is equal to D_2). In the real environment, *RSSI* values will be randomly distributed. The situation of $L_{AB} > d_1 + d_2$ may appear. Two complex solutions are obtained when the equations (4) are chosen to solve in the complex domain. In order to calculate, the real parts of the two solutions are taken to get the two points D_1, D_2 in real field. The distance from C point to D point is d_3. The position of D is determined by comparing $\left|d_3-L_{CD_1}\right|/L_{CD_1}$ with $\left|d_3-L_{CD_2}\right|/L_{CD_2}$ .The small absolute value is the approximate location of the unknown node D (x_1, y_1). Similarly, combine the distance from the known node D to the beacon node B and C and the distance to the beacon node C and A to obtain one equation. Make use of the equation to get the other two points (x_2,y_2),(x_3,y_3) Use a modified centroid algorithm is used to get the centroid of these three points which makes location of the point D (x_D,y_D) more precise, the following equations:

$$x_D=\frac{x_1\times(\frac{1}{d_1^n}+\frac{1}{d_2^n})+x_2\times(\frac{1}{d_2^n}+\frac{1}{d_3^n})+x_3\times(\frac{1}{d_3^n}+\frac{1}{d_1^n})}{2\times(\frac{1}{d_1^n}+\frac{1}{d_2^n}+\frac{1}{d_3^n})}$$

$$y_D=\frac{y_1\times(\frac{1}{d_1^n}+\frac{1}{d_2^n})+y_2\times(\frac{1}{d_2^n}+\frac{1}{d_3^n})+y_3\times(\frac{1}{d_3^n}+\frac{1}{d_1^n})}{2\times(\frac{1}{d_1^n}+\frac{1}{d_2^n}+\frac{1}{d_3^n})}$$

$\frac{1}{d_1^n}+\frac{1}{d_2^n}$, $\frac{1}{d_2^n}+\frac{1}{d_3^n}$ and $\frac{1}{d_3^n}+\frac{1}{d_1^n}$ are the improved weighting factors. The improved weighting factors avoid the phenomenon of the secondary data's playing the major role. n is the correction factor. Adjust n to adjust the degree of correction.

3. Algorithm steps

The steps of the algorithm:

- The beacon node sends information to the surrounding environment periodically. These information include the node ID, location information and other information.
- After the unknown node receives the messages sent by the beacon nodes, the RSSI means of the same beacon node is record.
- After the unknown nodes receive a certain number of beacon nodes (above the threshold m), beacon node information is stop receiving. The received beacon node information is sort by size value of the RSSI and three collections are established. The collection of beacon node is B_set={b_1,b_2,…,b_m}.The collection of the distance of unknown node to the beacon node is D_set={d_1,d_2…,d_m},$d_1<d_2<\ldots<d_m$. The collection of the position of the beacon node is P_set={(x_1,y_1), (x_2,y_2),…, (x_m,y_m)}.
- According to the analysis conclusion of radio wave propagation loss model in Ⅱ.A, the positioning accuracy is improved. *B_set* is combined into the following triangle set.
- To arbitrary triangle on the *T_set*, the weighted centroid algorithm Ⅱ.B is used to duplicate calculations, which makes the unknown node have more accurate coordinates (x, y).

4. Simulation results

A 8m×8m free space environment is assumed. Nine beacon nodes and twenty unknown nodes are set. The locations of unknown node are generated functions by the Matlab randomly and distributed randomly. The locations of the beacon nodes are installed in the four vertices, the regional center and the four sides of the center. Then there are (1),(2),(3) to generate RSSI data. Gaussian noise (mean 0, variance 7.5) is added in the RSSI data instead of the impact of various factors in the actual environment. The attenuation coefficient is set to 4. Following steps of the algorithm, free-space propagation model and logarithmic-normal distribution model are simulated to position. Figure 2 is the simulation results of positioning error.

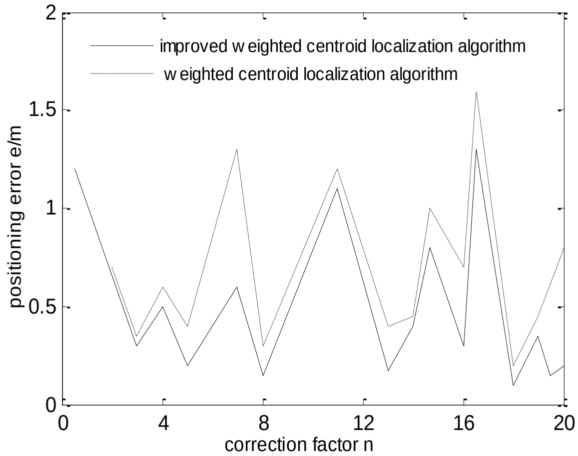

Figure 2. When n = 4, the average error curve of the unknown nodes of two algorithms.

From the above figures, the positioning error of the improved weighted centroid location algorithm is significantly smaller than the weighted centroid location algorithm.

The improved algorithm is used to repeat 500 tests and average the simulation data. Figure 3 is the two algorithm's average positioning error.

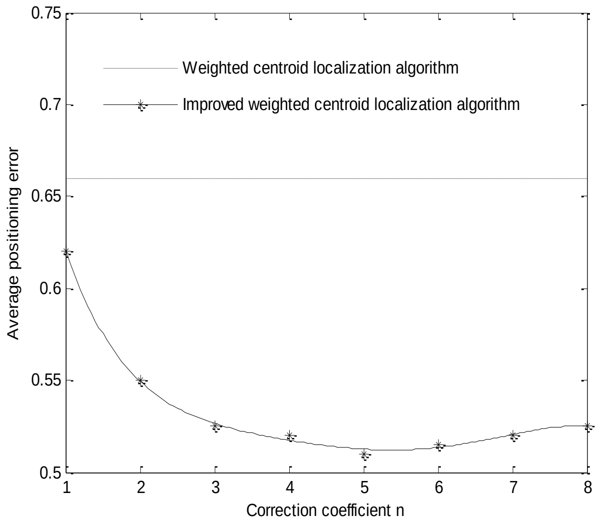

Figure 3. The two algorithm's average positioning error.

It can be seen from the figure that the improved algorithm is better than the weighted centroid location algorithm in average positioning error. Average location error of the weighted centroid location algorithm is 0.6625 m, and average location error of the improved method in correction factor n=5 is 0.5125 m. The relative weighting centroid location algorithm is greatly improved with the accuracy is highest.

5. Conclusion

Basing on the previous weighted centroid localization algorithm, this paper replaces the weight with the sum of the distance reciprocals and makes full use of the RSSI data, which makes the positioning error and positioning accuracy improved greatly. The results are further verified by means of simulation. However, the algorithm can not achieve precise positioning to the unknown nodes, which needs to have further improvement.

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