Article

Iterative positioning algorithm of the target node based on distance correction in WSN

Jing Chen [1,2,*], Shixin Wang[1], Mingsan Ouyang [1,*] Yudi Chen[2] and Yuting Xuan[1]

[1] School of Electrical and Information Engineering, Anhui University of Science and Technology, No.168, Taifeng Road, Huainan 232001, China; 755520662@qq.com (S.W.); 2548039071@qq.com (Y.X.)
[2] Department of Electrical Engineering and Electronics, University of Liverpool, Liverpool L69 3BX, United Kingdom
[3] Department of Electrical and Electronics Engineering, Xi'an Jiaotong- Liverpool University, Suzhou 215123, China; 604219604@qq.com (Y.C.)
* Correspondence: jchen@aust.edu.cn (J.C.); msoy@aust.edu.cn (M.O.)

Received: date; Accepted: date; Published: date

Abstract: The node position information is critical in the wireless sensor network (WSN). However, the existing positioning algorithms commonly have low positioning accuracy because of noise interferences in communication. To solve this problem, this paper presents an iterative positioning model based on distance correction to improve the positioning accuracy of the target node in WSN. First, the log-distance distribution model of received signal strength indication (RSSI) ranging is built and the noise impact factor is derived based on the model. Second, the initial position coordinates of the target node are obtained based on the triangle centroid localization algorithm, thereby calculating the distance deviation coefficient under the influence of noise. Then, the ratio of the distance measured by the log-normal distribution model to the median distance deviation coefficient is taken as the new distance between the anchor node and the target node. Based on the new distance, the triangular centroid positioning algorithm is used again to calculate the target node coordinates. Finally, the iterative positioning model is constructed, and the distance deviation coefficient is updated repeatedly to update the positioning result until the set number of iterations is reached. Experiment results show that the proposed iterative positioning model can improve positioning accuracy effectively.

Keywords: iterative positioning algorithm; distance correction; RSSI; noise impact factor; distance deviation coefficient

1. Introduction

Wireless sensor network has been applied widely in various fields of defense, industry and social life due to its advantages of low power consumption, low cost, self-organization and so on. In order to provide effective monitoring services in engineering applications, the nodes own position information must be provided [1,1]. The node position information is the key to whether the information obtained is valuable or not in WSN, especially for the target reconnaissance and tracking in the field of military and anti-terrorism [3,4]. It can be said that perceived data are meaningless if no node position information are provided. However, in the actual physical environment, the wireless signals are inevitably interfered by noises such as multi-path fading [5,6], diffraction [7], antenna gain [8], non-line of sight [9] and so on in the process of propagating, and uncertain propagation loss is produced, which results in inaccuracy in ranging. The maximum ranging error is up to ±50% [10].

To solve this problem, the node positioning method in WSN should be explored deeply. An effective node positioning method must consider the following problems. (1) How to construct a mathematical model to fit the nonlinear relationship between the RSSI and the distance? (2) What

 doi:10.20944/preprints201905.0296.v1

kind of positioning algorithm should be used to obtain more accurate positioning accuracy? (3) What are the basic requirements to consider in terms of hardware resources and computational complexity when building a positioning algorithm?

Based on the above three problems, we proposed the target node iterative positioning algorithm based on distance correction in this paper. The motivation of this paper is reducing the positioning error of the target node to help users obtain accurate position information. The process of the target node iterative positioning model based on distance correction is shown as Figure 1.

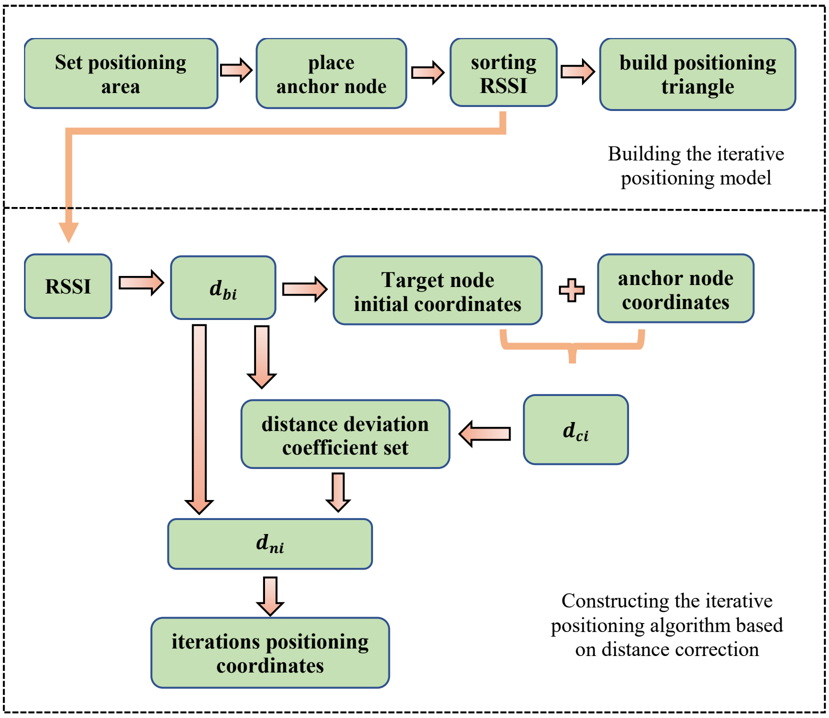

Figure 1. The process of the target node iterative positioning model based on distance correction

In our proposed algorithm, the median of the distance deviation coefficients is used to modify the measured distance during each iteration. The median of the distance deviation coefficients can more closely express the overall distance deviation characteristic. The log-distance distribution model is used to calculate the distance between unknown target nodes and connected anchor nodes in order to fit the nonlinear relationship between distance and RSSI more accurately, and reduce computational complexity. The iterative positioning model is constructed to ensure that the target node is in the area enclosed by the connected anchor nodes, which is also of great help to improve the positioning accuracy. In addition, the node iterative positioning algorithm based on distance correction can provide theoretical support for future research. Contributions are included in the following aspects.

(1) Derivation of noise impact factor based on log-normal distribution model

The expression of the noise impact factor FN is derived by reconstructing mathematical model, which is the corresponding numerical relationship between the noise impact factor FN and the measured distance. The noise impact factor proposed in this paper is used to describe the influence degree of noise on the measured values of RSSI.

(2) The selection of distance deviation coefficient on node measured distance

The distance deviation coefficient is used to evaluate the deviation degree of the distances calculated by the log-distance distribution model and the triangle centroid algorithm respectively, and a distance deviation coefficients set is established. The median of the distance deviation coefficient set is selected to characterize the deviation degree of the whole node measured distances, which can better reflect the overall distance deviation characteristic.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 May 2019 doi:10.20944/preprints201905.0296.v1

(3) Construction of the iterative positioning algorithm based on distance correction

The distance deviation coefficient median is used as an iteration factor for the iterative positioning algorithm. In the process of each iteration, the median of the distance deviation coefficients is used to correct the distance from the last positioning, obtaining a distance value closer to the true value. The triangle centroid localization algorithm is iteratively used to reduce the positioning fluctuation error and improve positioning accuracy.

The rest of the paper has been organized as follows: Section 2 will demonstrate a brief review of related works. The proposed iterative positioning algorithm will be provided in Section 3. The iterative positioning model will be constructed in Section 4. The experimental results and some analysis will be given in Section 5. Finally, key conclusions and the general discussion will be summarized in Section 6.

2. Related works

This section reviews two existing works which are the reference foundation theory for positioning of the target node in WSN. First is the measurement of the distance between the target node and the anchor node. Second is to determine the position coordinates of the target node.

2.1. The measurement of distance between the target node and the anchor node

The measurement of distance between the target node and the anchor node is an important research topic of the node positioning in WSN. Nowadays, most of the existing node positioning algorithms can be divided into two categories according to whether it is necessary to measure the distance or angle. One is the range-based measurement positioning algorithm and the other is range-free measurement positioning algorithm [11]. The distance measurement refers to calculating the distance or orientation between the unknown target node and the anchor node connected thereto through communication between them [12]. The classical distance measurement algorithms include based on signal time of arrival (TOA), signal time difference of arrival (TDOA) [13], Angle of Arrival (AOA) [14] and received signal strength (RSSI) [15,16] algorithms.

The first three algorithms need to accurately calculate the distance or angle between the unknown target node and the anchor node, thereby these three algorithms significantly improve the energy consumption of the node and the hardware equipment requirements of the network in the positioning process, and increase the calculation amount and communication cost of the network. The RSSI ranging method is often adopted in practical applications.

2.2. The target node positioning algorithm

The target node positioning algorithm can be built in several ways. A triangle centroid positioning algorithm based on the distance or relative angle information between the target node and the anchor node has been proposed in the document [17-19]. There are problems of the target node deviating effective locating area and the large positioning error in the positioning algorithm because the node distribution characteristics are not entirely considered. The weighted centroid positioning algorithm has been presented in the document [20-22] by introducing weight factor, which is related to the distance estimation. Therefore, if there is a large deviation in distance estimation, the positioning error will be large. A fingerprint database positioning algorithm has been constructed to improve the positioning accuracy in the document [23-25] by collecting the positioning samples in advance. The positioning algorithm highly relies on the fingerprint database data, if the environment changes, the positioning accuracy will become poor. The positioning algorithm based on the neural network has been put forward in documents [26,27], the input of the algorithm is the value of RSSI and the output is the distance between nodes. Due to the simple learning rules, the output of the neural network cannot be correct when the data is not sufficient. The positioning algorithm based on Bounding-Box has been proposed in the document [28,29]. The positioning accuracy of the algorithm depends on the number of anchor nodes. The positioning accuracy is not high if the number of anchor nodes is not enough.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 May 2019 doi:10.20944/preprints201905.0296.v1

For the above problems, an iterative positioning algorithm based on distance correction is proposed through correcting the estimated distance between the anchor node and the target node, and constraining the target node in the sub-triangular positioning area of the iterative positioning model in this paper. The algorithm calculates the target node coordinates iteratively and improves positioning accuracy effectively.

3. Iterative positioning algorithm for the target node based on distance correction

An iterative positioning algorithm for the target node based on distance correction is proposed in this paper to help users overcome the influence of noise on positioning accuracy. There are three main key problems presented in this paper for building iterative positioning algorithm based on distance correction. First，the log-normal distribution mathematical model should be constructed to measure RSSI, based on which the impact factor of noise on distance detecting can be derived. Second， a triangle centroid positioning algorithm should be built to determine the initial positioning coordinates of the target node. Finally, the distance deviation coefficient and its median can be determined. Therefore, the iterative positioning algorithm for the target node based on distance correction is constructed according to the median of distance deviation coefficient.

3.1. Basic concept

Definition 1. *WSN node positioning. WSN node positioning refers that the position of the unknown target node is calculated based on the communication between the anchor nodes whose position information are known in the network by certain techniques, algorithms and schemes* [30].
Definition 2. *Anchor node. The anchor node is the node whose coordinates or position information is known in WSN* [31].
Definition 3. *Target node. The target node refers to the node whose coordinates or positioning information is unknown in the WSN* [32].

3.2. The preprocessing of iterative positioning algorithm

Before the constructions of the iterative positioning algorithm, it is necessary to do some preprocessing tasks. First of all, the mathematical model of RSSI was constructed and used to calculate the initial measured distance. Then, analyzing the influence of noise on the measured distance and constructing the noise impact factor. Finally, the triangle centroid positioning algorithm is used to obtain the initial positioning coordinates of the target node.

3.2.1. RSSI ranging algorithm

The basic idea of the RSSI ranging algorithm is to calculate the distance between the transmitting signal node and the receiving signal node by measuring the received signal strength because there are varying degrees of losses in the propagation process of wireless signals. Therefore, it is very important to build an appropriate RSSI ranging model. At present, the model used commonly is the log-normal distribution model [33-35].

Pd is used to indicate the power measurement corresponding to the distance between two nodes as d, Pd_0 is used to indicate the power measurement corresponding to the distance between two nodes as d_0. The relationship between Pd and d can be expressed as

$$Pd = \frac{Pd_0}{\left(d_0 / d_0 \right)^n}, \tag{1}$$

where n is a signal propagation factor, which is usually obtained by empirical value or actual calibration.

The logarithmic processing is performed on both sides of the formula (1), and after arranging, the formula (2) can be obtained:

$$\lg Pd = \lg Pd_0 - n\lg(\frac{d}{d_0}), \quad (2)$$

And because the relationship between RSSI value and power can be expressed as:

$$RSSI = 10\lg p, \quad (3)$$

Thus, a mathematical model of RSSI ranging can be obtained:

$$P(d) = P(d_0) - 10n\lg(\frac{d}{d_0}), \quad (4)$$

where $P(d)$ $P(d)$ is the RSSI value when the distance between two nodes is d, and $P(d_0$ $P(d_0)$ is the RSSI value when the distance between two nodes is d_0.

3.2.2. The effect of noise on RSSI ranging

The loss of the wireless signal during propagation has a great influence on the accuracy of the RSSI ranging algorithm and must be considered in practical applications. Next, we will analyze the effect of signal propagation loss on RSSI ranging. In the formula (4), the measurement value $P(d)$ is composed of the true signal strength value and noise signal strength value, denoted as $P_T(d)$ and $P_N(d)$ respectively. $P(d_0)$ is the RSSI value when the distance between two nodes is d_0. To simplify the calculation, d_0 is usually taken as 1, and $P(d_0)$ is denoted as A.

Thus, the actual mathematical model of the log-normal distribution model is as follows:

$$P_T(d) - P_T(d) = A - 10nlg(d), \quad (5)$$

From the formula (5), the distance between two nodes can be calculated as follows:

$$d = 10^{\frac{A - [P_T(d) - P_N(d)]}{10n}}, \quad (6)$$

Equation (6) can be calculated as follows by further mathematical transformation:

$$d = 10^{\frac{A - P_T(d)}{10n}} 10^{\frac{P_N(d)}{10n}}, \quad (7)$$

Assume that $K_1 = \frac{A - P_T(d)}{10n}$, $K_2 = \frac{P_N(d)}{10n}$ $K_1 = \frac{A - P_T(d)}{10n} K_2 = \frac{P_N(d)}{10n}$.

Formula (7) can be expressed as

$$d = 10^{K_1}(1 + 10^{K_2} - 1), \quad (8)$$

Formula (8) can be expanded further as:

$$d = 10^{K_1} + 10^{K_1}(10^{K_2} - 1), \quad (9)$$

Assume that $d_T = 10^{K_1}$, $F_N = 10^{k_2} - 1$ Therefore, the calculation of distance d can be simplified as follows:

$$d = d_T + d_T F_N, \quad (10)$$

where $d_T = 10^{K_1}$ $d_T = 10^{K_1}$ is the true distance between the anchor node and the target node, $F_N = 10^{k_2} - 1$ $F_N = 10^{K_2} - 1$ is the impact factor of noise on distance measurement. F_N is referred to as noise impact factor in this paper.

3.2.3.The triangular centroid positioning algorithm

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 May 2019 doi:10.20944/preprints201905.0296.v1

The basic principle of the triangle centroid positioning algorithm is as follows: the three circles are determined by treating the three anchor nodes as their respective circle centres, by treating the distances between the anchor nodes and the target node as their respective radiuses. The intersection of the three circles can obtain six intersection points, a triangle is constructed by treating the three closer intersection points as vertexes, the centroid of the triangle is taken as the coordinates of the node to be positioned. The schematic diagram of triangular centroid positioning is shown in Figure 2.

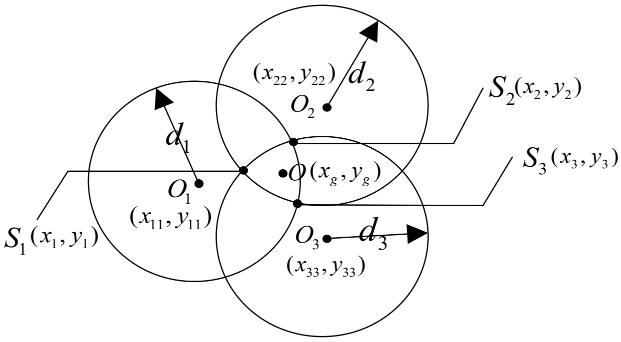

Figure 2. Schematic diagram of triangular centroid positioning

In Fig. 2, and O_1, O_2 and O_3 are defined as the positions of three anchor nodes with coordinates of $O_1(x_{11}, y_{11})$, $O_2(x_{22}, y_{22})$ and $O_3(x_{33}, y_{33})$, which radius are d_1, d_2, and d_3 respectively. Point $S_1(x_1, y_1)$, $S_2(x_2, y_2)$ and $S_3(x_3, y_3)$ are the three closer intersections points, that is, the three vertices of the triangle centroid positioning algorithm.

The intersection point coordinates of the circle O_1 and the circle O_2 can be obtained by equation (11).

$$\begin{cases} (x-x_{11})^2+(y-y_{11})^2=d_1^{\,2} \\ (x-x_{22})^2+(y-y_{22})^2=d_2^{\,2} \end{cases}, \tag{11}$$

In the 2 sets of coordinates solved by equation (11), the intersection S_3 (x_3, y_3) closer to the center of the positioning triangle. The solution of the remaining two points $S_1(x_1, y_1)$ and $S_2(x_2, y_2)$ is similar to that of point $S_3(x_3, y_3)$.

Thus, the initial coordinates $O(x_g, y_g)$ of the target node can be calculated by equation (12).

$$\begin{cases} x_g = \dfrac{1}{m}\sum_{i=1}^{m} x_i \\ y_g = \dfrac{1}{m}\sum_{i=1}^{m} y_i \end{cases} (m=3), \tag{12}$$

where m=3, i = 1, 2, 3.

3.3. The iterative positioning algorithm

In the actual physical environment, signals are easily disturbed by noise in the transmission process. Therefore, there is a large deviation between the distance obtained by the log-normal distribution model and the real distance value. In order to reduce the positioning error further, a node iterative positioning algorithm based on distance correction is introduced in the paper.

The basic principle of the iterative positioning algorithm based on distance correction is as follows: the distance deviation coefficient is introduced to evaluate the degree of deviation of the measurement distance between the log-normal distribution model and based on the triangle centroid positioning algorithm. The distance between the anchor node and the target node is recalculated based on the distance deviation coefficient. By constantly updating the distance between the anchor node and the target node, the target node coordinates are iteratively calculated.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 May 2019 doi:10.20944/preprints201905.0296.v1

3.3.1. The calculation of the distance deviation coefficient

The distance between the anchor node and the target node, which is calculated by the log-normal distribution model, is denoted as d_{bi} d_{bi} The distance between the anchor node coordinates and the coordinates, which are calculated by the triangle centroid positioning algorithm, is denoted as d_{ci} d_{ci} In order to indicate the deviation of the two distances, the distance deviation coefficient C_{dev} C_{dev} is defined as equation (13).

$$C_{dev} = \frac{d_{bi}}{d_{ci}} \quad (i=1, 2, 3), \tag{13}$$

Many distance deviation coefficients can be solved by the formula (13), and it is important to determine a characteristic quantity to represent the degree of deviation of the overall node measurement distance. The two statistical parameters, the average value and the median of distance deviation coefficients, can both closely be used to express the overall distance deviation characteristics.

The average value of distance deviation coefficients can be expressed the average level of the overall measurement distance deviation. However, its fatal disadvantage is that if the extremum at both ends is too low or too high, the final calculation result will greatly deviate from the real situation.

Therefore, the median distance deviation coefficients are usually used to express the overall distance deviation characteristic. The median is not affected by the extreme values of both ends, and can better reflect the overall distance deviation characteristics, making the final calculation result closer to the real situation.

The distance deviation coefficients are calculated by the formula (13), the median C_{dev} C_{dev} can be obtained after sorting.

The distance between the anchor node and the target node can be recalculated based on the median C_{dev} C_{dev} as shown in equation (14).

$$d_{ni} = \frac{d_{bi}}{C_{dev}} \quad (i=1, 2, 3), \tag{14}$$

The new distance d_{ni} d_{ni} is obtained by the formula (14), and the triangular centroid positioning algorithm is iteratively conducted to obtain the positioning result (x_G, y_G).

3.3.2. The iteration termination criteria for algorithm.

If the termination condition of the iterative positioning algorithm is set correctly, the higher positioning accuracy can be obtained with only a small number of iterations, and the algorithm is prevented from falling into an infinite loop. In general, the iteration termination condition is defined as:

$$P_{\hat{O}_n} - P_{\hat{O}_{n-1}} < \varepsilon, \tag{15}$$

Where $P_{\hat{O}_n}$ $P_{\hat{O}_n}$ is the RSSI value between the centroid of the *n*th iteration and the unknown target node, ε is the set threshold.

Under different environmental conditions, if formula (15) is used as the iterative termination condition, its computational complexity is very high, even higher than the complexity of the iterative positioning algorithm itself. In this way, the hardware complexity of the system will increase significantly and the algorithm become almost infeasible. In practical applications, as the number of iterations increases, the positioning error has the following cases: fast convergence, slow convergence, and periodic oscillation. By simulation analysis, it is found that, when the number of iterations is between 0-10 times, the iteration error varies with different regular pattern, the iteration error basically unchanged when the number of iterations is between 10-20 times.

The flow chart of the iterative positioning algorithm is shown in Figure 3.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 May 2019 doi:10.20944/preprints201905.0296.v1

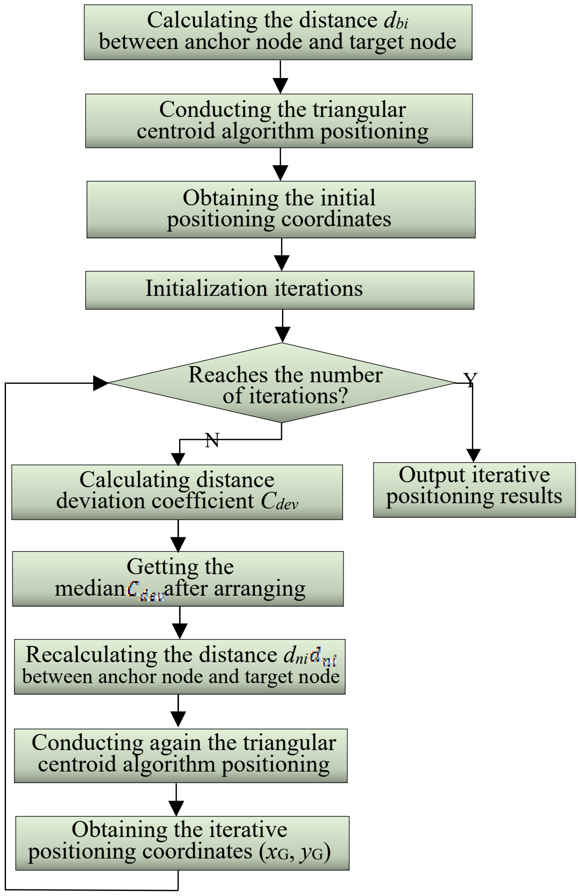

Figure 3. The flow chart of the iterative positioning algorithm

4. The construction of iterative positioning model

In the procedure of iterative positioning, whether the target node is in the positioning triangle area has great influence on its positioning accuracy. The positioning error of the target node located in the positioning triangle area is much smaller than that of the target node outside the positioning triangle area. In order to improve the positioning accuracy, an iterative positioning model is established in the paper, as shown in Figure 4.

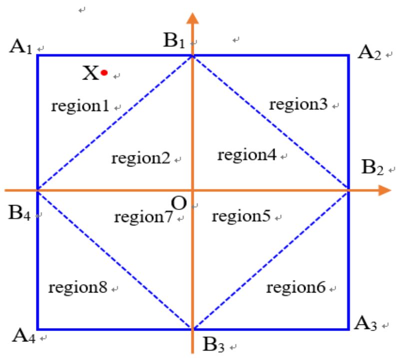

Figure 4. A schematic of the positioning model

In Figure 4, the quadrilateral $A_1A_2A_3A_4$ is a square, the point O is its center, the points B_1, B_2, B_3 and B_4 are the midpoints of the respective sides. According to the connection shown in Figure 4, the square $A_1A_2A_3A_4$ is subdivided into eight triangular regions: region 1 to region 8. The anchor nodes (9 in total) are placed at points A_1, A_2, A_3, A_4, B_1, B_2, B_3, B_4 and O.

There is a target node X in the quadrilateral $A_1B_1OB_4$ in Figure 4, the points closest to the point X are points A_1, B_1, O, B_4 in turn. The node X is included in both $\triangle A_1B_1B_4$ and $\triangle A_1B_1O$. In the $\triangle A_1B_1B_4$, the coordinates (x_{G1}, y_{G1}) is calculated by iterative positioning algorithm. In order to reduce effectively the positioning error caused by noise, the other coordinate (x_{G2}, y_{G2}) is calculated by the iterative positioning algorithm in ΔA_1B_1O. The weighted average of these two coordinates can be taken as the final coordinates (x_{G3}, y_{G3}). Obviously, the closer the distance between the anchor node and the target node is, the more reliable the calculation result is. Hence the weight of the former coordinate should be greater than the weight of the latter coordinate.

The various proportion of weight value are compared by the simulation experiment, the results show that when the weight of the former coordinate is 0.75 and the weight of the latter coordinate is 0.25, the positioning result better than others.

The final positioning results can be expressed as follows in equation (16).

$$\begin{cases} x_{G3} = 0.75x_{G1} + 0.25x_{G2} \\ y_{G3} = 0.75y_{G1} + 0.25y_{G2} \end{cases}, \quad (16)$$

In actual positioning progress, the RSSI values of the 9 anchor nodes are recorded and arranged in descending order of their values. The first four larger *RSSI* values are denoted as $RSSI_1$, $RSSI_2$, $RSSI_3$ and $RSSI_4$. The first positioning coordinates (x_{G1},y_{G1}) is calculated by $RSSI_1$, $RSSI_2$, $RSSI_3$ and their corresponding coordinates. The second positioning coordinates (x_{G2},y_{G2}) is calculated by $RSSI_1$, $RSSI_2$ and $RSSI_4$ and their corresponding coordinates. The weighted average of two coordinates according to the weights mentioned above is the final positioning result (x_{G3},y_{G3}).

The positioning process of the iterative positioning algorithm is shown in Figure 5:

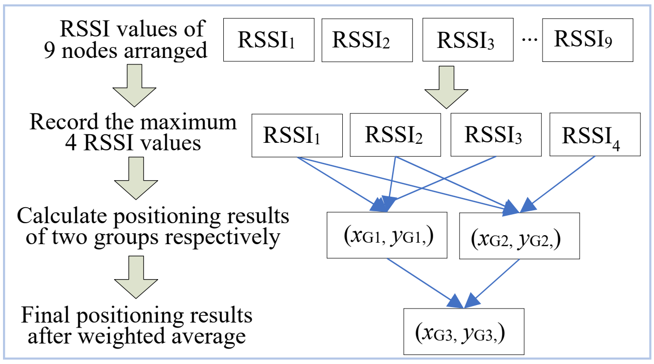

Figure 5. The specific implementation process of iterative positioning

5. Experiment

5.1. The experimental method

In order to verify the performance of the algorithm proposed in the paper accurately and quantitatively, without loss of generality, the positioning experimental area is set as a square of 40m*40m. There are nine anchor nodes in the positioning experimental area, which are located at the vertices of the square, the middle of each edge and the center of the square. Now, 50 target nodes are generated in the square area by random, and calculating their positioning results in turn.

In the experiment, for different noise impact factors F_N, positioning error is discussed by three methods of the centroid positioning algorithm, the weighted centroid positioning algorithm and the iterative positioning algorithm based on distance correction. The value of F_N is taken into account in two situations: constant value and random value.

5.2. Experimental analysis

According to the above experimental method, two experiments have been conducted.

5.2.1. The first experiment: F_N is constant

When F_N is a constant value, considering the effects of the actual noise on the signal, three

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 May 2019 doi:10.20944/preprints201905.0296.v1

typical F_N values are taken for experiments, which are 0.1, 0.2 and 0.3 respectively.

The experiments for three parameters are shown as follows:

- F_N=0.1

The positioning error is shown as Figure 6 in the case of the noise impact factor of 0.1.

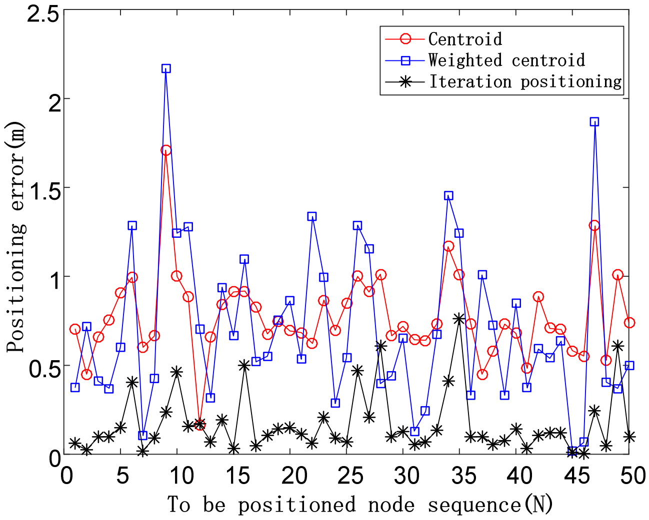

Figure 6. The positioning error of the three positioning algorithms in the case of the noise impact factor of 0.1

The *x*-coordinate represents the target node sequence, the unit is the number of nodes. The *y*-coordinate represents the positioning error, the unit is meter.

- F_N=0.2

The positioning error is shown as Figure 7 in the case of the noise impact factor of 0.2.

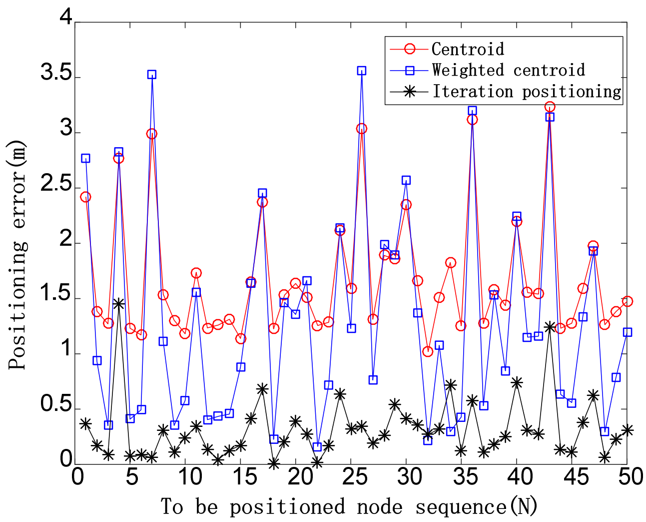

Figure 7. The positioning error of the three positioning algorithms in the case of the noise impact factor of 0.2

- F_N=0.3

The positioning error is shown as Figure 8 in the case of noise impact factor of 0.3.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 May 2019 doi:10.20944/preprints201905.0296.v1

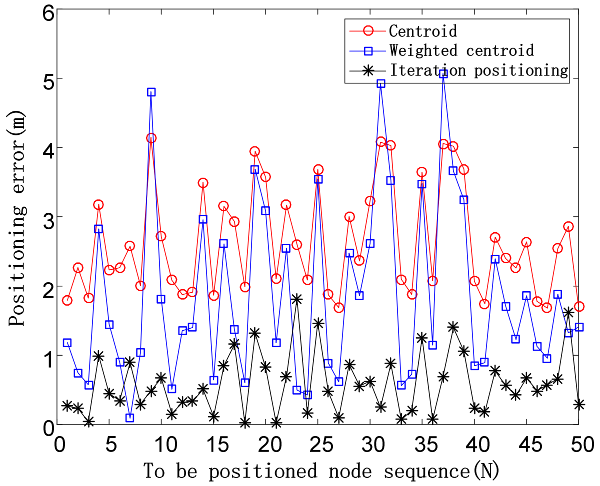

Figure 8. The positioning error of the three positioning algorithms in the case of noise impact factor of 0.3

5.2.2. The second experiment: FN is a random value

When F_N is a random value, considering the effect of the actual noise on the signal, the random value is 0.3 times of random function.

The positioning error is shown as Figure 9 in the case of the noise impact factor of random value.

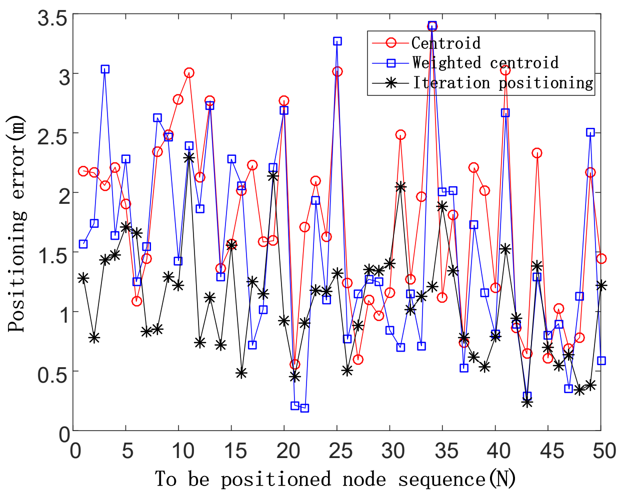

Figure 9. The positioning error of the three positioning algorithms in the case of the noise impact factor of random value

In the case of different noise impact factors, the positioning errors of the three positioning algorithms are shown in Table 1.

Table 1. The positioning error of the three positioning algorithms in the case of different noise impact factors

Noise impact factor	Average positioning error (m)		
	Centroid	Weighted centroid	Iterative positioning
F_N=0.1	0.77	0.70	0.17
F_N=0.2	1.68	1.30	0.32
F_N=0.3	2.63	1.85	0.59
F_N=random	1.75	1.53	1.09

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 24 May 2019 doi:10.20944/preprints201905.0296.v1

As can be seen from Table 1, when FN is a random value, the positioning accuracy of the iterative positioning algorithm is improved by 38% compared with the centroid algorithm, and the positioning accuracy of the iterative positioning algorithm is improved by 29% by comparing with the weighted centroid algorithm.

The positioning error of the three positioning algorithms for different values of noise impact factors is shown in Figure 10.

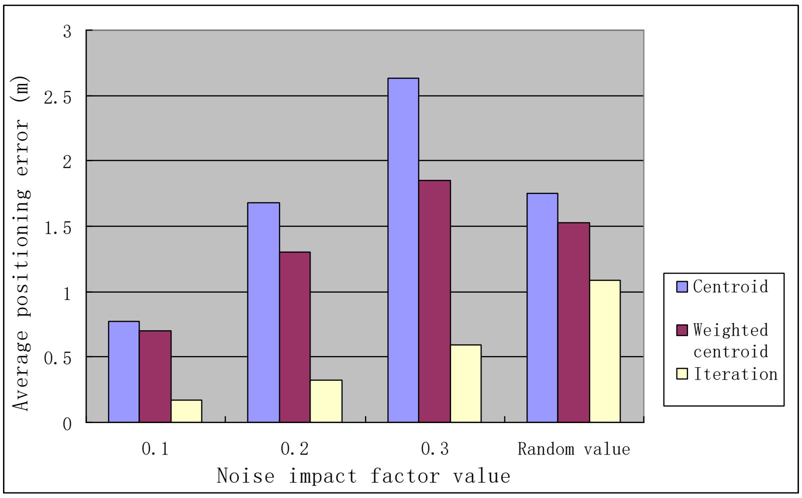

Figure 10. The positioning error of the three positioning algorithms under different noise influence factors

As can be seen from Figure 10, the positioning error of the iterative positioning algorithm is smaller than that of the centroid positioning algorithm and the weighted centroid positioning algorithm in the case of different noise impact factors F_N.

6. Conclusions

With the development of wireless communication technology, the position information of data is playing an increasingly important role. There are errors in node positioning due to various interferences in the data transmission process. To solve this problem, a node iterative positioning algorithm based on distance correction is proposed in this paper to help users obtain accurate position information. Contributions include the following aspects.

(1) The noise impact factor FN has been derived on the basis of the original log-distance distribution model, which is used to describe the corresponding relationship between the noise impact factor FN and the measured distance. Proposing of noise impact factor provides a novel method for analyzing the influence of noise on the distance measurement between nodes in WSN.

(2) The median of the distance deviation coefficient has been constructed to characterize the deviation degree of the whole measured distances, and used to correct the distance from the last positioning. The triangle centroid localization algorithm has been iteratively conducted based on the corrected new distance value to improve the node positioning accuracy.

The experimental results show that the node iterative positioning algorithm based on distance correction can effectively reduce the positioning error of unknown target nodes in wireless sensor networks, and help users obtain more accurate node coordinates. In the future, based on the node iterative positioning algorithm proposed in the paper, we will do some related researches such as real-time tracking and path planning of moving nodes in WSN.

Author Contributions: Conceptualization, J.C., S.W., and M.O.; Methodology, all authors; Software, J.C. M.O., and Y.C.; Validation, J.C and Y.X.; Formal Analysis, J.C., S.W., and Y.X.; Investigation, J.C, and M.O.; Resources, J.C., S.W. and Y.C.; Data curation, S.W.,Y.C. and Y.X.; Writing—Original Draft Preparation, J.C. and M.O.; Writing—Review & Editing, J.C., S.W., and M.O.; Visualization, J.C. and Y.C.; Supervision, J.C. and M.O.; Project administration, J.C. and M.O.; Funding acquisition, J.C.

Funding: This research was funded by Natural Science Fundation of Education Department of Anhui province (KJ2018A0087) and Natural Science Foundation of China (51874010).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. S. Pandey, S. Varma. A Range-Based Localization System in Multihop Wireless Sensor Networks A Distributed Cooperative Approach. *Wireless Personal Communications* **2016**, *86*, 615-634. [DOI: 10.1007/s11277-015-2948-3]
2. S. Safavi, U. A. Khan. Localization in mobile networks via virtual convex hulls. *IEEE Transactions on Signal and Information Processing over Networks* **2018**, *4*, 188-201. [DOI: 10.1109/TSIPN.2017.2673238]
3. M. A. Benatia, M. Sahnoun, D. Baudry, A. Louis, A. El-Hami, B. Mazari. Multi-Objective WSN Deployment Using Genetic Algorithms Under Cost, Coverage, and Connectivity Constraints. *Wireless Personal Communications* **2017**, *94*, 2739-2768. [doi.org/10.1007/s11277-017-3974-0]
4. M.R. Senouci and H.E. Lehtihet. Sampling-based selection-decimation deployment approach for large-scale wireless sensor networks. *Ad Hoc Networks* **2018**, *75-76*, 135-146. [DOI: 10.1016/j.adhoc.2018.04.002]
5. P. Raja1, P. Dananjayan. Game Theory Based Cooperative MIMO Routing Scheme for Lifetime Enhancement of WSN. *International Journal of Wireless Information Networks* **2015**, *22*, 116-125. [DOI 10.1007/s10776-015-0268-x]
6. R. Rai, P. Rai. Survey on Energy-Efficient Routing Protocols in Wireless Sensor Networks Using Game Theory. *Advances in Communication, Cloud, and Big Data* **2019**, *31*, 1-9. [DOI: 10.1007/978-981-10-8911-4_1]
7. S. Halder1, A. Ghosal1. A survey on mobile anchor assisted localization techniques in wireless sensor networks. *Wireless Networks* **2016**, *22*, 317-2336. [DOI: 10.1109/COMST.2016.2544751]
8. Alletto S, Cucchiara R, Fiore G D, et al. An Indoor Location-Aware System for an IoT-Based Smart Museum. *IEEE Internet of Things Journal* **2016**, *3*, 244-253. [DOI: 10.1109/JIOT.2015.2506258]
9. ZHANG X. R, XIONG W. L, XU B. G. A Whole Process Optimization Distributed Localization Strategy Based on RSSI in Wireless Sensor Networks. *Chinese Journal of Sensors and Actuators* **2016**, *29*, 1875-1881.
10. Tomic S, Beko M, Rui D. Distributed RSS-AoA Based Localization with Unknown Transmit Powers[J]. *IEEE Wireless Communications Letters* **2016**, *29*, 3-395. [DOI: 10.1109/LWC.2016.2567394]
11. P. K. Sahu, E. H.-K. Wu, and J. Sahoo. DuRT: Dual RSSI Trend Based Localization for Wireless Sensor Networks. *IEEE Sensors Journal* **2013**, *13*, 3115-3123. [DOI: 10.1109/JSEN.2013.2257731]
12. F. Yaghoubi, A.-A. Abbasfar, and B. Maham. Energy-efcient RSSI-based localization for wireless sensor networks. *IEEE Communications Letters* **2014**, *8*, 973-976. [DOI: 10.1109/LCOMM.2014.2320939]
13. S. Tomic, M. Beko, and R. Dinis. RSS-based localization in wireless sensor networks using convex relaxation: on cooperative and cooperative schemes. *IEEE Transactions on Vehicular Technology* **2015**, *64*, 2037-2050. [DOI: 10.1109/TVT.2014.2334397]
14. Y. Hou, X. Yang, and Q.H. Abbasi. Efficient AoA-Based Wireless Indoor Localization for Hospital Outpatients Using Mobile Devices. *Sensors* **2018**, *18* 3698. [Doi.org/10.3390/s18113698]
15. X. H. Zhang, T. J. Wang, J. L. Fang. A node localization approach based on mobile beacon using particle swarm optimization in wireless sensor networks. *International Journal of Embedded Systems* **2017**, 9, 112-118. [https://doi.org/10.1504/IJES.2017.083731]
16. C. Ke, M. Wu, Y. Chan, K. Lu. Developing a BLE Beacon-Based Location System Using Location Fingerprint Positioning for Smart Home Power Management. *ENERGIES* **2018**, *11*, 3464. [doi.org/10.3390/en11123464]
17. T. J. S. Chowdhury, C. Elkin, V. Devabhaktuni, D. B. Rawat, and J. Oluoch. Advances on localization techniques for wireless sensor networks: A survey. *Computer Networks* **2016**, *110*, 284-305. [doi.org/10.1016/j.comnet.2016.10.006]
18. Z. Wang, H. Zhang, T. Lu, T. A. Gulliver. Cooperative RSS-Based localization in wireless sensor networks using relative error estimation and semidefinite programming. *IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY* **2019**, *8*, 483-497. [DOI: 10.1109/TVT.2018.2880991]
19. G. Sharma, A. Kumar. Improved range-free localization for three-dimensional wireless sensor networks using genetic algorithm. *Computers & Electrical Engineering* **2018**, *72*, 808-827. [doi.org/10.1016/j.compeleceng.2017.12.036]

20. Zhang Y, Xu X. L, Xu K. Y. Algorithm based on weighted centroid method for WLAN indoor positioning. *Journal of Electronic Measurement and Instruments* **2015**, *29*, 1036-1041.
21. S. Phoemphon, C. So-In, N. Leelathakul. Fuzzy Weighted Centroid Localization with Virtual Node Approximation in Wireless Sensor Networks. *IEEE Internet of Things Journal* **2018**, *5*, 4728-4752. [DOI: 10.1109/JIOT.2018.2811741]
22. S. B. Shah, Z. Chen, F. Yin, I. U. Khan, S. Begum, M. Faheem, F. A. Khan. 3D weighted centroid algorithm & RSSI ranging model strategy for node localization in WSN based on smart devices. *Sustainable Cities and Society* **2018**, *39*,298-308 [doi.org/10.1016/j.scs.2018.02.022]
23. H. Huo, H.H. Yang, D.Y. Zhen, L. Liu, W. Zhang. Advanced indoor position algorithm based on RSSI fingerprint. *Application Research of Computers* **2017**, *24*, 2786-2790.
24. X. Fang, Z. Jiang, L. Nan, L. Chen. Optimal weighted K-nearest neighbour algorithm for wireless sensor network fingerprint localisation in noisy environment. *IET COMMUNICATIONS* **2018**, *12*, 1171-1177. [DOI: 10.1049/iet-com.2017.0515]
25. C. Panarat, S. Pitikhate. Soft-clustering Technique for Fingerprint-based Localization. *SENSORS AND MATERIALS* **2018**, *30*, 2221-2233. [doi.org/10.18494/SAM.2018.1844]
26. M. Gholami, N. Cai, R. W. Brennan. An artificial neural network approach to the problem of wireless sensors network localization. *Robotics and Computer-Integrated Manufacturing* **2013**, *29*, 96-109. [doi.org/10.1016/j.rcim.2012.07.006]
27. B. S. Saber, A. Fazlollah, S. Mehdi A. A New Range-Free and Storage-Efficient Localization Algorithm Using Neural Networks in Wireless Sensor Networks. *Wireless Personal Communications* **2018**, *98*, 1547-1568. [Doi:10.1007/s11277-017-4934-4]
28. Sun X, Yao H, Zhang S, et al. Non-Rigid Object Contour Tracking via a Novel Supervised Level Set Model. *IEEE Transactions on Image Processing* **2015**, *24*, 3386-3399. [DOI: 10.1109/TIP.2015.2447213]
29. K. G. Qian, Y. J. Wang, X. M. Li, Z. C.Dai. An Improved Bounding Box Localization Algorithm Based on Optimum Node Selection. *Applied Mechanics and Materials* **2014**, 668-669, 1359-1362. [doi.org/10.4028/www.scientific.net/AMM.668-669.1359]
30. S. Saunhita, M. S. Optimized Relay Nodes Positioning to Achieve Full Connectivity in Wireless Sensor Networks. *WIRELESS PERSONAL COMMUNICATIONS* **2018**, *99*, 1521-1540. [Doi:10.1007/s11277-018-5290-8]
31. P. Singh, A. Khosla, M. Khosla, A. Kumar. Computational intelligence based localization of moving target nodes using single anchor node in wireless sensor networks. *Telecommunication Systems* **2018**, *69*, 397-411. [doi:10.1007/s11235-018-0444-2]
32. P. Singh, A. Khosla, A. Kumar, M. Khosla. Optimized localization of target nodes using single mobile anchor node in wireless sensor network. *International Journal of Electronics and Communications* **2018**, 91, 55-65. [DOI: 10.1109/IC3TSN.2017.8284493]
33. E. Goldoni, A. Savioli, M. Risi, and P. Gamba. Experimental analysis of RSSI-based indoor localization with IEEE 802.15.4. *IEEE Proc. of European Wireless Conference* **2010**, 71-77. [DOI: 10.1109/EW.2010.5483396]
34. TIAN Z. J, LI Z. W, LIU X. Y, et al. A Positioning Method in Mine Tunnel Based on Joint Electromagnetic Wave and Ultrasonic Distance Measurement. *Transactions of Beijing Institute of Technology* **2014**, *34*, 1177-1185.
35. Zheng X. L, Fu J. Q. Research on Indoor Location Algorithm Based on PDR and RSSI', *Journal of Instrumentation* **2015**, *36*, 1177-1185.