Precision optimization of node localization centroid algorithm for WSN

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Abstract

Aiming at the problems that the traditional centroid algorithm in WSN node positioning precision is not high and the error is very large, this paper proposed a adaptive centroid algorithm based on weighted factor, first of all, determined the weighting factor according to the influence of different beacon node to the unknown node, with weights to reflect the impact of each beacon nodes for centroid position and then all the beacon nodes in the network were conducted with adaptive optimization, translated adaptive optimization of coordinate error into the distance error. The experimental simulation results showed that the proposed adaptive centroid algorithm based on weighted factor was effective in reducing the error of traditional centroid algorithm in wireless sensor network node location, the location precision was improved.

Keywords: centroiding algorithm, WSN, weighting factor, adaptive optimization, location precision optimization

1 Introduction

Wireless Sensor Network (WSN) is a multiple hops self-organizing network system formed with a large number of sensor nodes assigned in monitoring area by Wireless communication mode. Its purpose is collaboration to perceive, collect and process information of monitoring object in network coverage area, and sent to the observer [1]. It combines sensor technology, embedded computing technology, distributed information processing technology, communication technology and micro-motor technology, it has huge application value in military, industrial, medical treatment, traffic, environmental protection and many other aspects [2]. Node localization technology is one of the core support technology of WSN. For WSN applications, the location information of nodes is very important. It can be used to identify the location of the monitoring data, the network topology management, routing protocols based on node location and storage technology based on location data, etc. [3].

As a new technology, WSN has many challenging research topic among which is localization. Localization is the foundation of most applications [4]. Localization mechanism and algorithm of WSN consists of two parts: the node self-localization and the external target [5]. Node localization algorithm is a more prominent topic in WSN research as a key technology in WSN node localization technology which has considerable research achievements both at home and in abroad. N.Bulusu etc. put forward the distance of center algorithm which estimates the position coordinate of the sensor nodes by N the center of the reference nodes. D.Niculescu et al. put forward such as DV-distance algorithm which is similar to DV-hop, but the former improves the localization accuracy, but has a certain request for hardware effect of a greater error of beacon nodes and improve the localization precision [9]. Aiming at the problem that the incremental localization easily to be accumulated and concentrated trial computation overhead in the process of localization. Wei Yehua etc. put forward a node localization algorithm of support vector regression, the algorithm reduced the communication overhead, but also improved the precision of positioning [6]. And convex programming localization algorithm, cooperative ranging algorithm and MDS-MAP algorithm, etc. [7]. At home, there are also many researches on wireless sensor positioning, the main research is to improve the localization accuracy, such as Zhang Jia etc. put forward to combine the least-square method with sampling algorithm to realize the node localization. The algorithm has good robustness and its localization precision is not susceptible to the influence of the external environment condition and has good stability [8]. On the basis of trilateral localization algorithm, Qiu Meng et al. proposed a WSN localization algorithm based on fuzzy clustering, the algorithm uses the clustering of data mining technology. Based on the precision requirement of WSN node localization, the traditional centroid algorithm was improved and optimized, the adaptive centroid algorithm based on the weighted factor was proposed and its simulation is carried out by comparing with traditional centroid algorithm.

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2 Traditional centroid algorithm

2.1 TRADITIONAL CENTROID ALGORITHM

Centroid algorithm is a kind of coarse precision localization algorithm, the idea is to regard polygon centroid constituted by neighbour beacon nodes as its estimated location. Its advantage is not to measure distance, completely based on the network connectivity, low cost, low power consumption, simple algorithm, the disadvantage is that the density and distribution of beacon nodes have a requirement, the larger the density of beacon node is, more uniform the distribution and the higher the positioning accuracy will be. A lot of subsequent research tried to improve this algorithm, or used certain conditions to obtain location area and regarded the centroid of localization area as estimated position. So the centroid algorithm is laid the cornerstone of the localization mechanism which has nothing to do with distance.

Localization equation of centroid algorithm is shown in Equation (1):

$$(X_{est}, Y_{est}) = \left(\frac{X_1 + X_2 + ... + X_n}{n} + \frac{Y_1 + Y_2 + ... + Y_n}{n} \right). \quad (1)$$

Centroid algorithm usually uses localization error to reflect localization precision, it is divided into absolute error (AE) and the relative error (RE), as Equations (2) and (3) shown:

$$AE = \sqrt{(X_{est} - X_a)^2 + (Y_{est} - Y_a)^2} . \quad (2)$$

$$RE = \frac{AE}{R} = \frac{\sqrt{(X_{est} - X_a)^2 + (Y_{est} - Y_a)^2}}{R} . \quad (3)$$

(X_{est}, Y_{est}) reflect the estimated location of the unknown node, (X_i, Y_i) reflects the coordinate of *N*-th beacon node, *n* reflects the number of beacon node, (X_a, Y_a) reflects the real location of unknown node, *R* reflects the communication radius. In order to improve the accuracy of localization, localization need beacon nodes can be set a threshold value, for example, beacon nodes greater than *m* can be located.

2.2 DISADVANTAGES OF TRADITIONAL CENTROID ALGORITHM

Centroid algorithm process can be divided into following steps:

1) The beacon node send their neighbouring nodes which contain their data package with coordinates and the ID in the same power periodically.

2) The unknown nodes accept the packetages from beacon nodes, then parse the ID in data packages and set statistics on which beacon nodes the data package come from. When the statistics on the number of beacon nodes is equal to or larger than 3, or when waiting for a certain time, the unknown node can calculate the coordinates by the maximum likelihood method or the trilateral measurement method.

The following unknown nodes will stop accepting packages from beacon nodes, and send to the adjacent node which has sent its estimated coordinates and the ID packages with the same power as beacon node periodically. The estimated coordinates of the unknown node can be obtained by Equation (4):

$$(X_{est}, Y_{est}) = \left(\sum_{i=1}^{n} \frac{x_i}{n}, \sum_{i=1}^{n} \frac{y_i}{n} \right). \quad (4)$$

Due to the unknown node may be surrounded by multiple localization polygon, so one unknown node may have more than one estimated coordinates. Then it can estimate the unknown node coordinate through statistics, and calculate the average estimated coordinate for who have more than one estimated coordinates of the unknown node.

As the propagation model we used in the centroid algorithm is the ideal spherical radio propagation model, the reality is not so. The nearer the target sensor is, the stronger the corresponding signal intensity will be; the farther from the target sensor, and its corresponding signal strength is smaller. So the strength of wireless signal is inversely proportional to the distance. But the centroid algorithm ignores this influence on the result which will introduce some error and because the accuracy of centroid algorithm localization is not high, it can not meet the requirements of the localization precision.

3 Centroid algorithm optimization

3.1 WEIGHTING FACTOR OPTIMIZATION

In order to overcome the defect of centroid algorithm, weighted centroid algorithm was proposed in this paper, the main idea was according to the influence of different beacon node to the unknown node, and then determine the weighting factor, with weight to reflect the impact of each beacon node on centroid position, its basis is usually the Received Signal Strength Indicator (RSSI) between the unknown node and beacon node. Particular way is that after the unknown node receives the information of beacon node, translate the RSSI value into distance value, with the function of distance as the weight, the coordinates of each beacon node weighted, then locate on the basis of the centroid algorithm.

Assuming that the distance between the unknown node and beacon node is d_i, weight is u_i, the weighted centroid calculation equation are:

$$x = \frac{\sum_{i=1}^{n} u_i x_i}{\sum_{i=1}^{n} u_i}, \quad (5)$$

$$y=\frac{\sum_{i=1}^{n}u_i y_i}{\sum_{i=1}^{n}u_i}. \quad (6)$$

The method of weighting is not the only, choose according to the different application and environment, it is usually a function of the distance. This article adopted $u_i=\frac{1}{d_i}$. If the unknown node cannot communicate with A_i, then $u_i=0$.

In WSN, the RSSI ranging is highly affected by the environmental factors, such as noise, obstacles and multipath reflection and even some people's malicious attack lead to the inaccuracy of RSSI ranging. Distance measured between the unknown node and beacon node is often not the real distance, it may cause the large localization error and need to introduce other correction method.

3.2 ADAPTIVE OPTIMIZATION OF WEIGHT

Aiming at the defects of centroid algorithm of weighting factor optimization, this paper proposed an adaptive weighting optimization strategy, in order to improve the accuracy of localization.

The basic idea of algorithm as follows: all the beacon nodes in the network were carried on adaptive optimization, translated the error of coordinates in adaptive optimization into range error, identified the credibility of beacon nodes with function made up of range error, and then combined with RSSI weighted centroid algorithm to complete the localization of unknown node.

The so-called adaptive optimization is to regard all the beacon nodes in the network one by one as the unknown node, used the remaining beacon node information, through some algorithm to locate itself, the result of localization was compared with the real location node, to calculate the adaptive error.

The process of beacon nodes self-correcting as follows: N fixed beacon nodes are $A_1(x_1,y_1)$, $A_2(x_2,y_2)$,…, $A_N(x_N,y_N)$, the distance between unknown node $M(x,y)$ and each beacon nodes is d_i, $1\le i\le N$.

For some beacon node $A_i(x_i,y_i)$, through Equations (5) and (6), it could use other beacon nodes to calculate the location information, and then compared with the actual location, you could get the localization error of beacon nodes. In that way, $A_1(x_1,y_1)$ was the real location of beacon node, $A_{ci}(x_{ci},y_{ci})$ was the estimated location. In the same way, all the beacon nodes could get a location error. The equation of coordinate location error as follows:

$$\begin{cases} e_{ix}=x_i-x_{ci} \\ e_{iy}=y_i-y_{ci} \end{cases}. \quad (7)$$

In the Equation (7), x_i was the real coordinate of i-th beacon node in x coordinate value, x_{ci} was the measured coordinate of i-th beacon node in x coordinate value, e_{ix} was the localization error of i-th beacon node in x coordinate value. y_i was the real coordinate of i-th beacon node in y coordinate value, y_{ci} was the measured coordinate of i-th beacon node in y coordinate value, e_{iy} was the localization error of i-th beacon node in y coordinate value.

Translated the coordinate error into the distance error is:

$$e_{id}=\sqrt{e_{ix}^2+e_{iy}^2}. \quad (8)$$

In the Equation (8), e_{id} was the self-correcting optimization range error of beacon node $A_i(x_i,y_i)$. Credibility of beacon node was inversely proportional to the e_{id}, the larger the e_{id} was, the lower the credibility of beacon node was. Named:

$$Cr=\frac{1}{e_{id}}. \quad (9)$$

In the Equation (9), Cr represented the credibility of beacon node.

When the process of adaptive self-correcting optimization finished, combined with RSSI weighting centroid algorithm, introduced the credibility of beacon node, common definition of a weighting:

$$\mu=Cr\cdot e_{id}=\frac{1}{e_{id}}\cdot\frac{1}{d_i}. \quad (10)$$

Then it could get the equation of unknown node based on beacon node by weighted centroid algorithm since, which as follows:

$$x=\frac{\sum_{i=1}^{n}\frac{1}{d_i e_{id}}x_i}{\sum_{i=1}^{n}\frac{1}{d_i e_{id}}}, \quad (11)$$

$$y=\frac{\sum_{i=1}^{n}\frac{1}{d_i e_{id}}y_i}{\sum_{i=1}^{n}\frac{1}{d_i e_{id}}}. \quad (12)$$

4 Simulating example

In MATLAB, using traditional centroid algorithm and improved centroid algorithm to conduct simulation respectively. Simulation environment and the parameter settings were as follows: the area for the square area of side length of 100m, there was random distribution of 100 node

in the area (including anchor node and ordinary node), the communication range of all types of nodes is equally to set as 20 m.

All the results of simulation were through 100 experiment to get the average value. The calculation equation of average localization error as followed:

$$\varepsilon = \frac{\sum_{i=1}^{n}\sqrt{(x_i - x_i')^2 + (y_i - y_i')^2}}{n \cdot R}. \quad (13)$$

In the Equation (13), n was the located sum of the ordinary nodes, R was the radius of the node communication, (x_i, y_i) was the real location of the node, (x_i', y_i') and was the estimated location of node through localization algorithm. Localization rate is defined as the ratio of the total number of nodes and initial average total number of nodes which were through algorithm to locate the location.

First of all, simulating indoor and outdoor environment, in both simulation environment, the number of anchor nodes by 10 intervals increased to 50 (increase by every 10 nodes). In MATLAB, adopting the centroid algorithm and improved centroid algorithm to localization simulation. The simulation results were shown in Figure 1 and Figure 2.

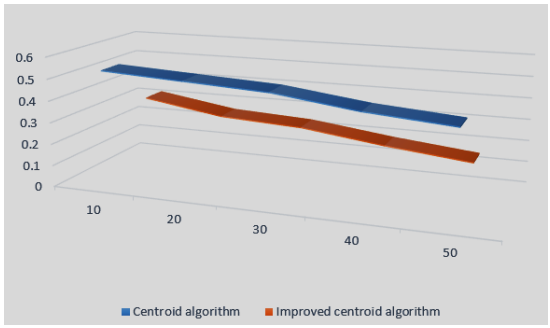

FIGURE 1 Indoor positioning error contrast simulation environment

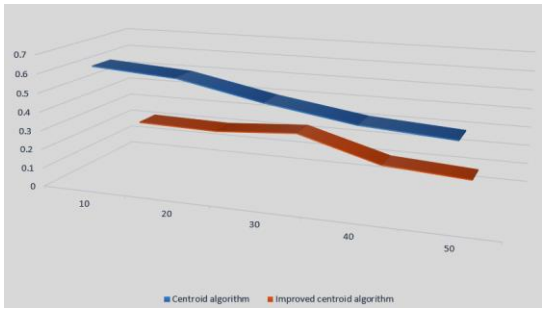

FIGURE 2 Outdoor compare simulated environment positioning error

From the transverse comparison between Figure 1 and Figure 2, it could be found, in the two kinds of different environment, the changes of average localization error of centroid algorithm were not so large. The reason was that the improved centroid algorithm adopted signal intensity ratio method to locate which could effectively reduce the effects of the environmental changes on the localization results, so the localization was more accurate, localization error will not fluctuate obviously.

Then, set 10 nodes for example, actual localization test was given to the improved centroid algorithm, the results as shown in the figure below.

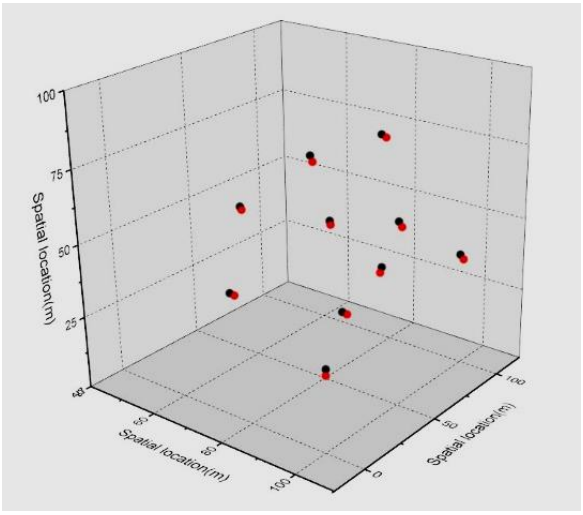

FIGURE 3 The actual node localization test

The black node in the Figure 3 were the actual location, red nodes were calculated location through improved centroid algorithm, it could be seen from the figure, there was small difference between the calculated location through improved centroid algorithm and the actual location, it had achieved the accuracy requirement.

5 Conclusions

WSN is the network based on node location technology to complete data collection, processing, communication and management function. The node localization can monitor the location events happen and still can real-time monitor the movement and track of targets, as well as assist in network management, etc. In this paper, the WSN localization algorithm was studied, aiming at the defects of traditional centroid algorithm, and proposed adaptive centroid algorithm based on weighted factor. The experimental simulation results showed that the changes of the average localization error of improved centroid algorithm as very little and could effectively reduce the effects of environmental changes on the localization results, thus to made the localization more accurate, the localization error would not fluctuate obviously.

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