The location technology of mobile nodes in wireless sensor network

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Abstract

The existing location method usually needs to establish network and the energy consumption is inequality. So it does not apply to a small number of mobile nodes in wireless sensor networks. Aim at the positioning of each node in wireless sensor network, clustered location algorithm is proposed on the premise of analyzing the computational complexity and the energy consumption of positioning. Using Receiving Signal Strength Indication (RSSI) combined with Centroid Localization Algorithm (CLA) to locate the mobile nodes in the cluster. The analysis and simulation results show that the improvement of clustering method can improve the positioning accuracy and reduce the network energy consumption effectively. Then the network life cycle can achieve the longest.

Keywords: wireless sensor network, clustering algorithm location, mobile node localization, energy consumption

1 Introduction

With the rapid development of the wireless communication and the electronics, the low cost wireless sensor network is also improved greatly, which gradually has been the research focus [1]. Wireless sensor network (WSN) is widely used in military medical health, remote monitoring, disaster relief and other fields. Therefore, the nodes without the position information are insignificantly for most the wireless sensor network. The positioning problem for the sensor nodes is a basic and key problem in the wireless sensor network.

Considering the cost, energy consumption and volume, it is not suitable for the requirements of the wireless sensor network by using the GPS receivers to connect the nodes. In this way, the nodes which can self-position are very important for the communication of the wireless sensor network [2-3]. Recently, the centralized and distributed methods are the two positioning ways which are mainly used in the wireless sensor network. And in the centralized positioning algorithm, the nodes' information is transferred to the some central node which can do the positioning calculation. The nodes which are closed to the central nodes may be quickly shut down because of the big traffic and large energy consumption. The interruption of the network and information exchange to the central nodes may be caused. What's more, the central positioning algorithm is not sensitive for the change of environment and the topology structure of the network. However, the network energy can be well optimized by the distributed positioning algorithm.

2 Clustering positioning algorithm

Clustering the wireless sensor nodes is one of the main design schemes for researching the distributed positioning algorithm. Based on the cluster of the wireless sensor network, the network sensor data can be transmitted after the data fusion which can reduce the energy consumption in the data transmission. And the nodes in the clusters can be managed uniformly. In this way, it is also very easy for the wireless sensor network to extend [4].

Considering the feature that most of the nodes are static, the clustering positioning method proposed by the design uses the clusters to collect the information, which is transmitted to the base based on the energy optimization. The positioning for mobile nodes is achieved by the inter communication between the nodes in cluster. Considering the positioning accuracy, the cluster structure can hold stability to avoid the energy consumption from the new built cluster for the wireless sensor network with little mobile nodes. The energy of the network can be optimized well to ensure the longest life cycle for the wireless sensor network.

The sensor network can be divided into several clusters, which are connected with each other. And a cluster node and several member nodes are included in every cluster. The member nodes are responsible for detecting and collecting the parameters' values and sending the results to the cluster node. And the cluster node is mainly responsible for receiving the data from the member nodes and processing the data, then sending the data to the base. The stability and the energy consumption of the network can be greatly improved. The single jump communication is used to ensure the lowest cost of the energy. The cluster structure is shown in Figure 1.

The cluster nodes collect the information from the member nodes and communicate with the base. Since the data amount processed by the cluster nodes is bigger than the normal nodes, the number of the cluster nodes should be limited. Aiming at the optimization for the network coverage and the network cluster nodes, the power of the nodes are regulated. In the design, the communication diameter of high power launch node is set to be twice as that of the low power launch node to meet the requirements of the network connectivity and the least cluster nodes [5]. The dormant node is inactive in some cycle to save the consumption of the network. The work mode in the next stage is selected by the rest energy of the nodes to keep the energy consumption average over the network.

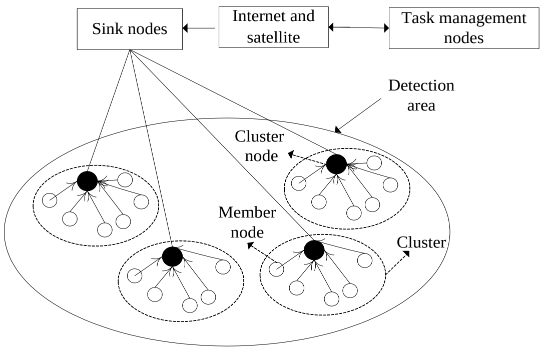

FIGURE 1 The cluster structure

3 Algorithm implementation

Assuming that the model of the wireless sensor network is a rectangle which contains a certain number of anchor nodes, and each sensor node is randomly distributed in the network, considering that the mobile nodes is little in the cycle, the unknown node is positioned by the cluster positioning algorithm. However, the wireless sensor network with the fixed anchor nodes and mobile nodes is positioned by positioning the cluster nodes through the little anchor nodes, and then the mobile nodes' position can be achieved by the feature of the inter connection between the nodes in wireless sensor network. And the high accuracy positioning and less energy consumption are realized by combining the Receiving Signal Strength Indication (RSSI) and Centroid Localization Algorithm (CLA).

3.1 THE SELECTION OF THE RSSI TRANSMISSION MODEL

Now most of the wireless transceiver chip has the measurement function. By analyzing the model of the radio transmission path loss, it can be found that the RSSI value can reflect the distance between the nodes. Since the technology is mainly to measure the signal intensity and it needn't to add additional equipments, it is a kind of low power consumption of cheap technology, which is used for the distance measurement [6]. But it is difficult to find the nearly linear relationship between the receiving signal strength intensity and the real distance. The focus of the research can be the signal transmission model.

There are three kinds of transmission models, which are commonly used in the simulation of the wireless sensor network, such as the free space model, the double electromagnetic model of surface reflection and the shadow model. As we know, since the multipath transmission of signals, the energy of the radio signals is random variation in the process of transmission. And the energy has parts of the random fluctuations in signal received from the other node between the two fixed unknown nodes. The free space model and the surface reflection model are used less in reality since the random factor is not taken into consideration. But the shadow model deals well with the random factor in the signal transmission.

The shadow model is better than the other two models since both the communication theory model and the signal random factor are taken into account. The model consists of two parts. The first part of the model expresses the relationship between communication distance and the receiving signal power, which also includes the reference d_0 that is the position of the sent node and set to be 1 meter in this research. Accordingly, the average signal power in the reference d_0 is set as the power $P_r(d_0)$, the calculation method for the power $P_r(d)$ in the position d is show in (1) as follows.

$$\frac{P_r(d)}{P_r(d_0)} = \left(\frac{d}{d_0}\right)^{\beta} . \tag{1}$$

In (1), the parameter β is the path loss indicator, which is decided by the reality experience in measurement and is proportional to the number of the obstacles. Accordingly, the acceleration of the average energy reducing will gradually become larger with the increase of the communication distance shown in table 1. The logarithmic operation is taken in both sides of (1). (2) Would be set as follows.

$$\left[\frac{\overline{P_r(d)}}{P_r(d_0)}\right]_{dB} = -10\beta\left(\frac{d}{d_0}\right) . \tag{2}$$

In (2), the reference signal receiving energy in the distance d_0 is used to calculate the distance d when the signal energy is $\overline{P_r(d)}$ in the model [7]. In the practical application, considering the application environment will not change, d_0 is set to 1 meter commonly. And the $P_r(d_0)$ can be achieved by the following (3).

$$P_r(d_0) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d_0^{\,2} L} . \tag{3}$$

In (3), the parameter P_t means the sending energy. And $P_r(d_0)$ is the receiving power in the distance d_0. G_t and G_r respectively represent the antenna gain of the sending and receiving nodes. What's more, λ is the wavelength of the communication signal and L is the system loss factor. In the research, it is assumed that $G_t=1$, $G_r=1$ and $L=1$.

TABLE 1 The value β in different environment

Position	Environment	β
Indoor	Freedom space	2
	Covered urban space	2.7~5
Outdoor	Within space of vision	1.6~1.8
	Space with obstacles	4~6

The other part of the model is the path loss model which is used to describe the relationship between the path loss and the communication distance. The parameter of the path loss is a logarithmic normal random variable. The variable satisfies the Gaussian distribution with the unit of dB. And the second part of the shadow is as follows in (4).

$$\left[\frac{\overline{P_L(d)}}{P_L(d_0)}\right]_{dB} = -10\beta\left(\frac{d}{d_0}\right) + X_{dB} . \tag{4}$$

$P_L(d)$ and $P_L(d_0)$ respectively the loss after transmission when the signal gets path through d and d_0. And X_{dB} is a Gaussian random variable of which the average value is 0. And the variance is decided by the reality experience which is commonly set to be about 5.

3.2 THE OPTIMIZATION FOR THE RSSI

The dynamic adjustment is used between the receiving signal strength and the distance. In applications, compared with the previous RSSI value, if the new received RSSI value is far from the actual movement of the target significantly, it is considered to be environmental interference and the corresponding data should be weeded out. If the RSSI value varies within a certain range, the data can be stored for further processing. Since the node movement speed is limited in the process of positioning, the appropriate threshold set based on the specific situation, can effectively inhibit the larger fluctuation in the wireless channel interference by comparing the RSSI difference between the two RSSI values with the threshold. The RSSI value which is received and stored is used to make a comparison with the next RSSI value. Considering the first receiving RSSI values in node may be interfered data, the RSSI value as a comparison is get by the average RSSI values in the two receiving RSSI value.

In order to achieve a better positioning accuracy, the combination of RSSI measurement and centroid localization algorithm is adopted in the design to locate the nodes. And the original centroid localization algorithm does not reflect the degree of the influence on the unknown nodes caused by different anchor nodes. The research shows that, the closer the distance of the unknown nodes to anchor nodes, the greater the influence of the anchor nodes on its positioning. The weight factor is used to reflect the influence degree of the anchor nodes to the unknown node and the intrinsic relationship between them in the combination algorithm of RSSI measurement and centroid localization algorithm [8]. The RSSI values of the unknown nodes are sorted in the algorithm to reduce the complexity of the calculation, and the anchor nodes with bigger RSSI values are selected to arbitrary triangle collection. And the weighted centroid algorithm is adopted to calculate three of the triangles further.

$$x_{ki} = \frac{\frac{x_1}{d_1+d_2}+\frac{x_2}{d_2+d_3}+\frac{x_3}{d_3+d_1}}{\frac{1}{d_1+d_2}+\frac{1}{d_2+d_3}+\frac{1}{d_3+d_1}}, i=1,2,3, \quad (5)$$

$$y_{ki} = \frac{\frac{y_1}{d_1+d_2}+\frac{y_2}{d_2+d_3}+\frac{y_3}{d_3+d_1}}{\frac{1}{d_1+d_2}+\frac{1}{d_2+d_3}+\frac{1}{d_3+d_1}}, i=1,2,3. \quad (6)$$

In (5) and (6), the coordinates (x_{ki}, y_{ki}) is calculated by the weighted centroid algorithm. And the (x_1, y_1), (x_2, y_2) and (x_3, y_3) respectively the coordinates of the three anchor nodes. The d_1, d_2 and d_3 are the distances from the symbol nodes to the unknown node [9]. And the coordinates of the unknown node can be achieved by the following equation.

$$x = \frac{\sum_{i=1}^{3} x_{ki}}{3}, i=1,2,3, \quad (7)$$

$$y = \frac{\sum_{i=1}^{3} y_{ki}}{3}, i=1,2,3. \quad (8)$$

The RSSI localization algorithm combined with centroid algorithm is used to solve the problem of anchor node information based on the random centroid localization. Through three times' localization, the final coordinates can be calculated by adopting the way of centroid algorithm. The way cannot only improve the positioning precision but also reduce the computational complexity.

3.3 POSITIONING PROCESS OF THE CLUSTER STRUCTURE

When wireless sensor network node is moving, the moving situation can be gotten from the receiving RSSI value by the cluster nodes. Normally, signal strength can basically satisfy the law of the monotone decreasing with the increase of distance. So through the change of the received signal strength in adjacent nodes, the node mobile information can be gotten without calculating the actual distance. The error caused by the inaccurate model can be effectively reduced. The method of cluster structure of nodes is adopted to locate in the network. The communication nods have the most energy consumption in the network. So in order to reduce the energy consumption and improve the positioning accuracy, the localization process in the cluster nodes is as shown in figure 2 (a).

When the position of the mobile node 2 changes, the receiving RSSI values of the nodes in the communication within the scope will increase or decrease. The induced changes of the two nodes are the observer as shown in figure 2 (b). After knowing the changes, the nodes at the same time as like as the base station send information. And the base station tags the sending node after accepting this information. If it is assumed as (S_i, S_j), one of them should be the mobile node. Since the fixed observation nodes are contained in the network, thus a start value $f(0)$ is set up. In the same period, when the number of a node in the base station is less than the start value $f(0)$, the node can be taken as a normal value. If the received nodes by the base station will set as S_i for several times, S_i would be set as mobile node. At the same time, considering the situation that more than one node is moving, the situation for the other node is moving cannot be excluded. The real-time positioning for the mobile nodes is achieved by other fixed nodes in the cluster.

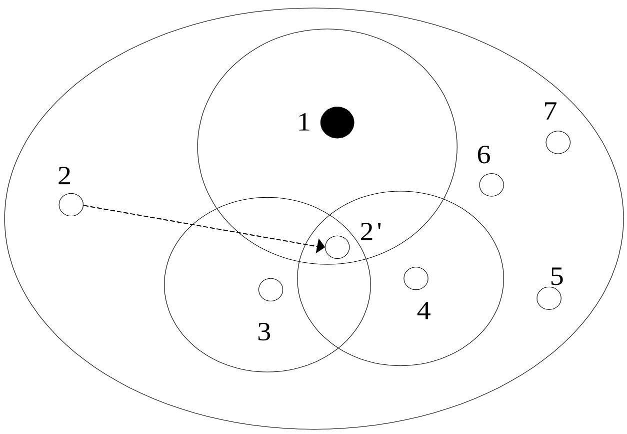

FIGURE 2(a) The relative position for the cluster nodes

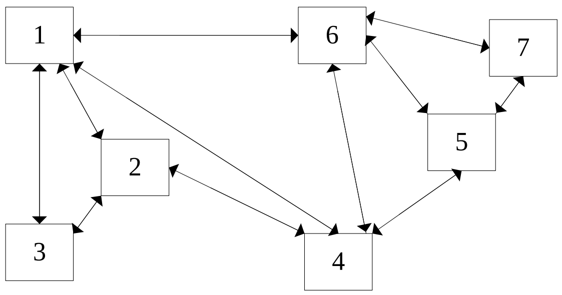

FIGURE 2(b) The relative observation for the cluster nodes

Through cluster positioning technology, the positioning of the mobile node will be limited within the cluster. The distance measurement for the mobile nodes can be only done. This may reduce the computational complexity, save the network energy consumption, and overcome the long distance measurement error caused by relying on the mobile anchor nodes to positioning. As only a small number of nodes are moving in the network, and the cluster structure is relatively stable, the node working mode is changed in a certain period of time based on the principle of the average energy consumption, which can optimize the energy consumption for the whole network.

4 Simulation results

Data marts are usually smaller and focus on a particular subject or department. Some data marts, called department data marts, are subsets of larger data warehouses. Each data mart is used for a direct analysis, for instance; selling analysis, product analysis, etc. Compare with the node warehouse, the data marts and the node warehouse are two different concepts.

Assuming that the number of anchor nodes is more than three in wireless sensor network, the experimental results show that the positioning of the mobile node can be well realized based on RSSI measurement and centroid localization algorithm combining with the clustering localization algorithm. And the energy consumption over the network is leaded to the average. And the energy consumption of cluster nodes is as shown in figure 3. And the number of the cluster nodes and dormant nodes are about 10% of the number of all the nodes. The cluster head nodes, the launch of high power and low power emission energy loss ratio is 20:2:1. Under the condition that the number of dormant node is zero, among the consumption of localization algorithm curve, the system energy consumption of communication is kept under 300 in the 15 cycles, and the operation energy consumption will also be able to maintain below 3.8.

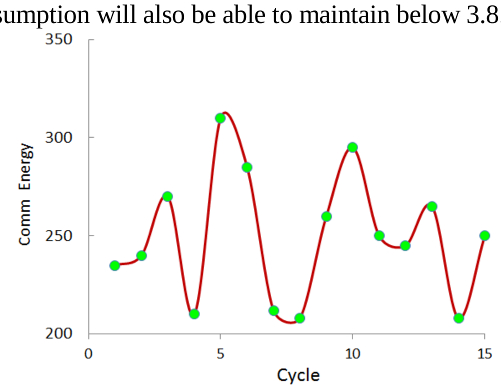

FIGURE 3(a) The energy consumption

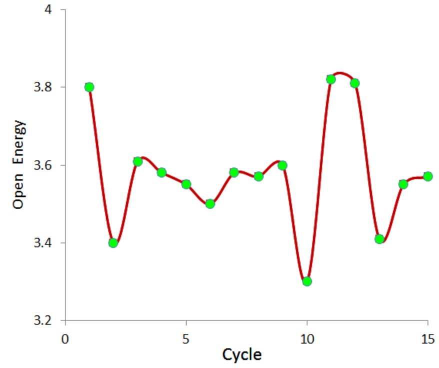

FIGURE 3(b) The energy consumption

For locating mobile node, the method of the tracking is adopted, which is to track every moving node. The result is shown in figure 4. In the same conditions, as the change of time random mobile nodes, the positioning error based on RSSI is obviously less than the original positioning error after correction with higher positioning accuracy. The adaptive of node is enhanced and the reliability of the system is also improved.

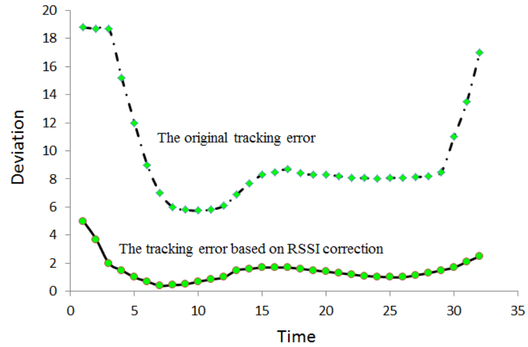

FIGURE 4 The comparisons of positioning error for mobile nodes

5 Conclusion

The dynamic characteristics of wireless sensor network and all kinds of mobile node localization requirements are the hot and difficult problem with smaller energy consumption to achieve high positioning accuracy. This research proposes a localization algorithm based on clustering, to overcome the long distance positioning error, save the energy consumption in the process of transmission. The RSSI and centroid localization algorithm, is used to not only effectively reduce the positioning error caused by error of RSSI values, but also effectively improve centroid localization algorithm. The Matlab simulation results show that the location accuracy of anchor nodes and energy balance are both achieved well in the design based on RSSI and centroid localization clustering localization algorithm. On the premise of guaranteeing the high accuracy, the communication overhead is reduced to achieve the longest life-time of network.

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