Study on Localization Algorithm of Mine Personnel Positioning System Based on Zigbee

Chen Yanli¹, Xu Xiaoling², Liu Xiaoyan¹

¹School of Computer Science and Technology, Henan Polytechnic University, Jiaozuo, China
E-mail: {yanlichen,xyanli}@hpu.edu.cn
²School of Mechanical and Electrical Engineering, Maoming University, Maoming, China
E-mail: xiaolingxu@163.com

Abstract—For the demand of lower localization costs, less communications costs and higher accuracy of objects tracking under mine pit, weighted centroid localization algorithm based on RSSI is introduced to localize the node. This algorithm shows relatively high accuracy by simulation and is suitable for the localization of mine personnel.

Index terms—weighted centroid localization algorithm, RSSI, mine personnel localization

I. INTRODUCTION

For the poor working conditions, complexity of the tunnel and being prone to happen of malignant events such as the gas explosion, water inrush, landslides under mine pits, lives of the staff are seriously threatened, and the development of mining enterprise and social stability are also restricted. With stricter safety production requirement in the domestic coal mine, it is most practically important to establish reliable personnel positioning system under mine pit for improving safety management. With the mine personnel positioning system based on Zigbee, we can know each person’s real-time location and activity scope[1,2,3]. Location information, such as events occurred and sensor nodes, is very important for mine personnel positioning system, and monitoring information is unimportance without location information for monitoring. Therefore, it is crucial for mine personnel positioning system to ascertain accident position or acquire location node position.

Special nodes are arranged under coal mine in network in proportion, which energy is powerful and equipped with GPS system, or acquire themselves coordinate by other specific way. These special nodes announce their own position information to other nodes, and offer information to ascertain location for others. Calculate unknown node coordinate by measuring distance or angle between special nodes and other nodes, or the relative location for each other, and network connectivity.

II. MEASURING METHODS OF DISTANCE BETWEEN NODES OR ANGLE

Measuring methods of distance between nodes are TOA, TDOA, AOA, RSSI and so on. Although the first three methods have high measuring precision in theory, because of constraints in hardware, it is difficult to use under coal mine. Wireless transceiver is wireless sensors node own resources, by adopting the method of measuring RSSI to measure distance, and need not to add extra hardware. This is realistic and feasible method of sensor node positioning in mine personnel positioning system.

Based on RSSI positioning, firstly, test received power of receiving node, together with launching power of the launching node, convert propagation loss into the distance between nodes by signal propagation attenuation model, and then ascertain unknown node location by using localization algorithm. This technology mainly use RF signal [4]. For example, in free space, the antenna, which far from transmitter is d, receive signal intensity is illustrated by (1) as below:

\[ P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} \]  

\[ P_r \] is launching power; \( P_r(d) \) is receiving power on the distance of d point; \( G_t, G_r \) separately refers to gain of transmitting antenna and receiving antenna; \( d \) refers to distance, its unit is meter; \( L \) is system loss factor that is nothing to do with propagation; \( \lambda \) is wavelength, its unit is meter. Like this, by measuring receiving signal power and using formula (1), we can calculate approximate distance between receiving and launching node.

But the RSSI measured distance shows great instability by the analysis of RSSI localization algorithm, and it maybe arise location error in \( \pm 50^\circ \)[4]. Therefore, we need to choose appropriate node localization algorithm aiming at its shortcoming, and improve in order to reduce localization error.

III. NODE LOCALIZATION ALGORITHM

Usually use connectivity to approximately estimate distance, among node localization algorithm of low cost priority. Measuring based on connectivity only simply show that whether two nodes are very near or connecting. Although receiving successfully data packets are random variation given received signal power and noises, to some extent connectivity provide node locations messages through binary variable.
Localization algorithm base on centroid is a simple centroid location algorithm base on connectivity.

Centroid location algorithm is an outdoor location algorithm based on network connectivity [5]. It used all beacon nodes in unknown node communication range as geometric centroid to measure unknown node position. Location process is as follows: beacon nodes transfer a beacon signal at intervals, and this signal includes its ID and location messages. When signal quantity which unknown node received from beacon nodes at a period of time is extend some presupposed threshold, the node will locate in a polygon centroid net which is consist of these connected beacons.

The most merit of centroid location algorithm absolutely base on the connectivity of network. It carries out simply and little calculation, but it needs more beacon nodes. In the large WSN distributing dense beacon nodes, this algorithm has these advantages. The distributing dense beacon nodes can increase probability of forming polygon between beacons and unknown nodes. It diminish location granularity and then improve of the accuracy of location estimation. In addition, little calculation can save power dissipation, and increase the effectiveness of network nodes.

IV. WIRELESS SENSOR LOCATION ALGORITHMS BASED ON ZIGBEE

Combining denotation based on receiving signal intensity with weighted centroid localization algorithms to locate object, it make location very precise. Position of determinate event occurs or localization of acquiring node takes vital effect for the effectiveness of sensor network application.

Weighted centroid algorithms, mainly based on RSSI figure between fixed beacon nodes and unknown nodes, calculate weights of each fixed beacon node. Show the degree that fixed beacon node decision for centroid coordinate by weights, also speak influence that fixed beacon node for centroid localization, and reflect inner relationship between them.

There are \( n \) fixed beacon nodes in the network, and the \( i \) fixed beacon node of \( B_i \) with known coordinate \((x_i, y_i)\), \(1 \leq i \leq n\). Then, estimated coordinate of unknown node \( M \) is \((x_e, y_e)\). Thus, the formulas of weighted centroid algorithm are illustrated by (2):

\[
\begin{align*}
x_e &= \frac{\sum_{i=1}^{n} w_i \times x_i}{\sum_{i=1}^{n} w_i} , \quad y_e = \frac{\sum_{i=1}^{n} w_i \times y_i}{\sum_{i=1}^{n} w_i}
\end{align*}
\]

(2)

\( w_i \) refers to weight of each fixed beacon node, which usually should be a function of distance between unknown node and fixed beacon node. If the unknown node cannot connect with beacon node \( B_i \), \( w_i \) is zero.

For wireless sensor network, RSSI is affected by environment in a great degree, even RSSI are very different for the same node at same position in different environment. In addition, at the same circumstance, RSSI may be different if the node is at a different region or different direction although the distance is equal .This means that distance during different node is different at the same RSSI in the same network topology distribution. Corresponding weight should be also different. If calculate unknown node location just consider RSSI from unknown node to some fixed beacon node, without adding other modified method, it may lead to algorithm in a great error because RSSI is influenced greatly by environment. Therefore, we must consider distance of fixed beacon node and signal intensity information, and take the both kinds of information as reference to revise weight of each fixed beacon node.

V. EXPERIMENTAL ANALYSIS

The function of algorithm is verified by changing the density of beacon nodes to verify the location error and comparing with the algorithm of the weighted centroid localization. Using Matlab integrated mathematics tools of software as the basic plate form of algorithm simulation, and using it can evaluate the performance of the wireless sensor network’s location algorithm. Simulation area is a rectangle by \( 30m \times 40m \).

(1) Influence on the location error in limited areas by increasing the number of beacon nodes

First, by a fixed unknown node \((20, 20)\), through increase the number of beacon nodes gradually in rectangular areas to detect the location error between the weighted centroid algorithm based on RSSI and the weighted centroid algorithm.

![Fig.1 Localization error comparison on the increasing number of beacon node](image)

In Fig. 1, it shows the location error of the weighted centroid algorithm based on RSSI less than the location of the weighted centroid algorithm. Moreover, when the number of the beacon nodes greater than two nodes,
the error of nodes location below 5m. Therefore, during the actual measurement, it requires the unknown nodes to maintain communication with less than three beacon nodes at least thus improving the position accuracy.

(2) Influence on the location error by changing the position of the fixed number of the beacon nodes

In reality, it is impossible to increase the beacon nodes arbitrarily within the restricted scope to improve the accuracy. Thus, it is necessary to get a balance between the number of beacon nodes and the location accuracy. By using a fixed number of beacon nodes and changing the location of the beacon nodes, the influence on location error can be got as following.

In the simulation processing, through fixing two beacon nodes (0, 0), (40, 30), moving two beacon nodes (0, 30) and (30, 40), meanwhile, changing the position of the beacon nodes (0, 30) to the beacon nodes (-10, 30), (-20, 30), …, (-60, 30) towards the left. Meanwhile, changing the position of the beacon nodes (40, 0) to the beacon nodes (50, 0), (60, 0) …, (100, 0) toward the right. That is to say, the beacon nodes composed a chart which changes from the rectangle into the serration, when it extends without restriction, it will change into a straight line. With the density of a fixed number of beacon nodes changes, finally we will get the location error of the unknown beacon nodes through the Matlab simulation as in Fig. 2.

Fig.2 Localization error comparison on the increasing beacon node density

Fig.2 shows that the locating error increases gradually with the distance of the beacon nodes increases. By comparison, the accuracy of the algorithm of the Moreover, when the number of the beacon nodes weighted centroid based RSSI is better than the algorithm of the weighted centroid. Especially, in coal mine well, the environment is abominable, and the arrangement of the beacon nodes of is very difficult, the advantage of the algorithm of the weighted centroid based on RSSI is more prominent. In the practical application, adjusting the arrangement of the beacon nodes properly within the scope of the error permitted can reduce the use of the beacon nodes.

(3) Influence of the unknown nodes location on the nodes locating error

Fixing the beacon nodes on the apex of rectangles which is 40m by 30m, in this area we select six vertex at random which are (10, 20), (20, 20), (30, 20), (10, 10), (20, 10) and (30, 10) as the location of the unknown nodes, and calculate. Figure 3 shows the relationship of the location error where fixing the unknown nodes on the six vertex.

When the number of the beacon nodes is unchanged, the centroid algorithm has bigger influence on the location error of unknown nodes at different positions. Contrasting improved algorithm to the algorithm of the weighted centroid, for increase field density of the fixed beacon nodes as weighting, which makes the algorithm become more stable and accurate after improving.

By analysis on localization error from the above three aspects, we realize that weighted centroid algorithms based on RSSI has better localization precision than weighted centroid algorithm. For localization tracking applications in mine pit, weighted centroid algorithms based on RSSI introduces a logarithmic function with a normal distribution to describe electromagnetic wave propagation under mine, which is more suitable to practical surrounding of application. At the same time, when we select localization algorithms, we directly adopt receiving field density denotation of node itself to location measuring and localization calculation by weighted centroid algorithms; it is simple and easy to satisfy the requirement of wireless sensor network tracking.

VI. CONCLUSION

According to targets tracking requires location for lower costs and lower communications costs and higher accuracy, for miner personnel positioning methods making detailed study, raising the algorithm of the weighted centroid localization based on RSSI. It has a higher precision, which is a lower costs of locating solution suitable for miner personnel location and proved the advantages of the algorithm by stimulation experiments.
REFERENCE


