Wireless Sensor Network Node Location Based on Improved APIT

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***Abstract*-As the support technology of most applications of wireless sensor network represented by ZigBee, the location technology has been extensively studied. This paper, based on the commonly used APIT positioning algorithm, aims at studying its shortcomings, and using RSSI ranging method to improve APIT location algorithm. The experimental result shows that the improved algorithm reduces the location error significantly and improves the positioning accuracy effectively.**

Keywords- ZigBee; Node Localization; APIT; RSSI

I. INTRODUCTION

Wireless sensor network (WSN) is composed by a large number of sensor nodes that are deployed in the monitoring region through wireless connection component, which is called multi-hop self-organizing network system [1]. The information of node position is not only the basic perceptive information, but also the basis of wireless sensor network application [2]. Thus the node location technology is one of the key technologies of wireless sensor network. This paper uses the RSSI (Received Signal Strength Indication [3]) and APIT (Approximate Point in Triangulation) algorithm in combination [4] to improve APIT algorithm.

II. NODE LOCATION TECHNOLOGY

In the wireless sensor network node location system, the node with known location information is called an anchor node, and the one without is called an unknown node. Depending on whether the node location algorithm measures the distance of anchor nodes, location algorithm can be divided into the location algorithm based on distance measurement and the one not based on distance measurement. The prior algorithm estimates the unknown node's position by the measurement of the distance from the unknown node to the anchor node [5]. This algorithm has high location precision, but requires additional hardware, leading to cost increase in the system deployment. The latter algorithm measures the location of nodes by network connectivity and other methods [6]. There is no need to measure the distance between nodes, and the node hardware requirement is low. Therefore the cost is low but position error is large.

However, because the nodes of wireless sensor network are deployed massively, the cost is very sensitive to node price. Meanwhile, the location algorithm not based on ranging can meet most of the requirements of application environment, and it is currently the research focus [7] of location algorithm. Commonly used non-range-based location algorithms are center of mass algorithm [8], DV-Hop algorithm [9], and APIT location algorithm. This paper studies on the APIT location algorithm, analyzes the methodological shortcomings, and proposes ways to improve APIT algorithm.

III. APIT LOCATION ALGORITHM

A. Principle of APIT Location Algorithm

The principle of APIT location algorithm is that the unknown nodes in a network obtain the adjacent anchor nodes' information first, and then three nodes are randomly selected as a group [10] among the collection of those adjacent anchor nodes. Each group forms a triangle, and the overlapping region of all the triangles is a polygon. The geometric center of mass of the polygon will be the position of the unknown node. As shown in Fig. 1, the black spot in the figure is the calculated position of the unknown node.

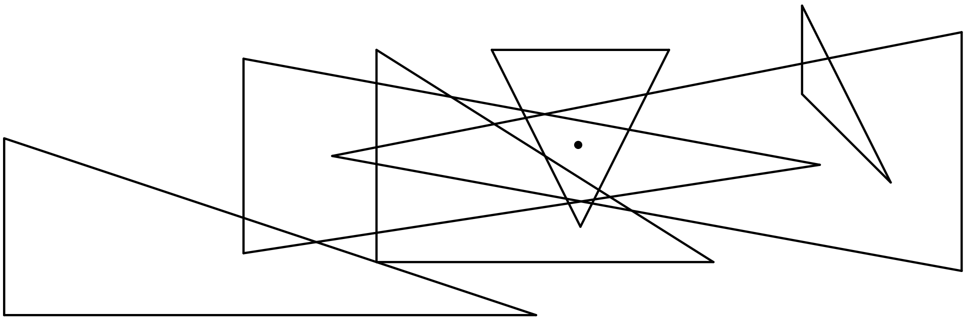

Fig. 1 Schematic diagram of APIT location algorithm

The key technique of APIT location algorithm is the way to judge whether the unknown node is in the triangle composed by anchor nodes or not. At present, this problem mainly adopts PIT (Point-In-Triangulation Test) method. The principle of this method is shown in Fig. 2, assuming that unknown node M is moving in the shown direction. If the M in the process of movement is moving either away from or close to the apex of A, B and C altogether at the same time, then M is at the outside of △ABC, otherwise M is in △ABC.

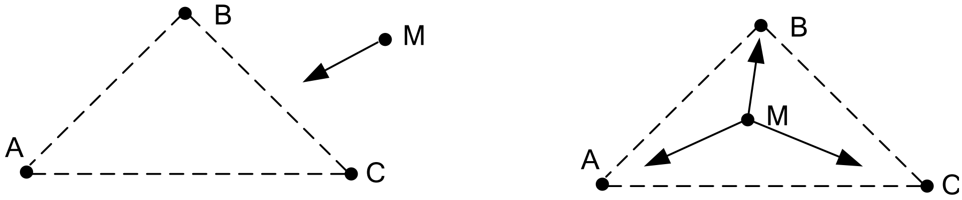

Fig. 2 Principle diagram of APIT

B. Analysis of APIT Location Algorithm Defect

In order to obtain higher location precision, the number of anchor nodes should be as many as possible. But it is also affected by the deployment cost. In the wireless network sensor, unknown nodes of certain regions cannot be located under the following two circumstances:

(1) An unknown node (such as M node) finds less than three nodes. According to the principle of location [11], this information cannot have an APIT test, nor determine its location, as shown in Fig. 3.

(2) An unknown node (such as M node), because of its location, although it can be found more than or three nodes, it is still unable to determine its location, as in Fig. 4.

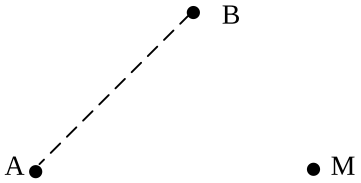

Fig. 3 APIT positioning

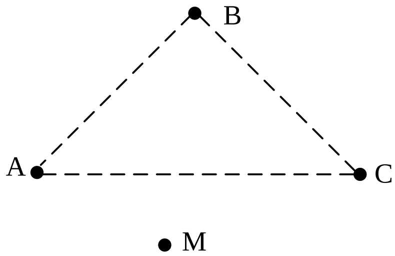

Fig. 4 APIT positioning

IV. IMPROVED APIT LOCATION ALGORITHM

To solve the problem of location precision that exists in the APIT location algorithm, RSSI is introduced to revise the location precision. For the anchor nodes within one unit of the unknown node, use RSSI to measure the distances between the unknown nodes and the anchor nodes. Select three anchor nodes with smaller distances, and calculate the estimated position 1 by trilateration measurement. Then according to APIT algorithm, we calculated the center of mass of the overlapping region as estimated position 2. Finally we can calculate the average value of these two positions as the final position coordinates.

For those unknown nodes that are unable to be located by APIT algorithm, use RSSI ranging quantitative model to assist location and find the estimated coordinates of the unknown node.

A. Principle of RSSI Ranging

The principle of RSSI is that, in free space, assuming no energy transmission loss in signal transmission, at every moment, the total signal energy is equal which means that at any moment the product of the signal coverage area multiplied by the signal strength on this area is equal. That is to say, the RSSI will reduce as the transmission distance increases [12]. Therefore, the distance of RSSI sent to receiver can be calculated if the signal transmission power and the RSSI of a point are known. In free space, the path loss model [13] can be expressed as:

$$P_{\mathrm{r}} = \mathrm{C_f} \frac{P_t}{d^2} \tag{1}$$

Wherein, P_{r} is received signal power; $\mathrm{C_f}$ is a constant dependent on the receiving end; P_t is the power of transmitting signal; *d* is distance from the receiving node to the sending node. If P_{r}, $\mathrm{C_f}$ and P_t are known, then *d* can be expressed as:

$$d = \sqrt{C_f \frac{P_t}{P_f}} \tag{2}$$

But in actual transmission process, due to the presence of multipath, barriers and other factors, the loss in wireless communication path is usually different fromthe theoretical value, so it is necessary to establish a reasonable path loss model. Wireless communication path loss usually adopts the following statistical model [14]:

$$\mathrm{P_r} = \mathrm{P(d_0)} - 10\eta \log_{10}(\mathrm{d/d_0}) + \mathrm{A}_\sigma \tag{3}$$

in which: *Pr* is the received signal power;

d is the distance from the receiving node to the sending node;

d_0 is the reference distance;

P(d_0) is the received signal strength value with distance d_0 from the receiving node to the sending node;

η is the path attenuation index;

A_σ is the normal random error with standard deviation of *σ*.

When obstacles are few, such as in open outdoor environment, path attenuation index η is normally from 1.6 to 1.8. In the presence of obstacles, path attenuation index η is normally from 2 to 4, with d_0 10 meters.

Therefore, knowing the power of sending nodes, measuring the signal power of the receiving node (read from the CC2431 RSSI register) and in accordance with the formula (3) model, we can calculate the distance of the signal transmission, which is the distance from the sending node to the receiving node. Assuming that d_i is the distance from anchor node(x_i , y_i) to the unknown node, the calculation process is shown as formula (4), (5) below:

$$\log_{10}(\mathrm{d/d_0}) = (\mathrm{P(d_0)} - \mathrm{P_r} + \mathrm{A}_\sigma)/10\eta \tag{4}$$

$$\mathrm{d} = \mathrm{d_0} * 10^{(\mathrm{P(d_0)} - \mathrm{P_r} + \mathrm{A}_\sigma)/10\eta} \tag{5}$$

B. The Node Location Estimation

By measuring the received signal strength of the anchor nodes, the location of the unknown node can be estimated according to the path loss model. Assuming there are m anchor nodes, where the anchor node N_i (i =1,2......m) has coordinate (x_i , y_i). D is the unknown node that needs location estimation.

If the node D can find n anchor nodes signal intensities and the signal strength is P_i, select three anchor nodes with smaller distances and use formula (5) to calculate the distance d_i from node D to an anchor node. According to trilateration measurement, find the estimated position $D_1(x_1, y_1)$. Then by APIT algorithm, find the center of mass of the overlapping region as the estimated position $D_2(x_2, y_2)$. Finally calculate the average of the two positions, and obtain the estimated node D coordinates (x_i , y_i). Fig. 5 and Fig. 6 correspond respectively to the above two kinds of circumstances.

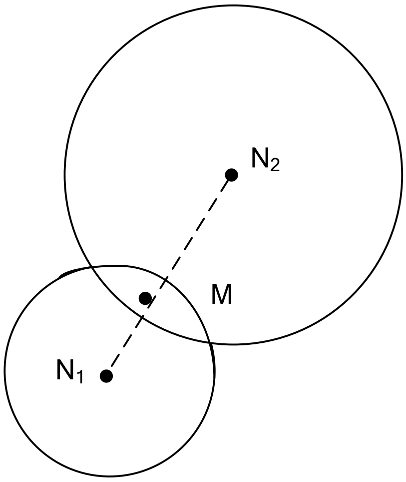

Fig. 5 APIT positioning 1

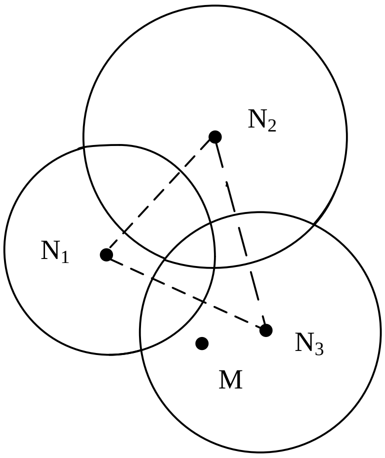

Fig. 6 APIT positioning 2

C. *Improved APIT Location Algorithm*

APIT location algorithm calculation process:

(1) The anchor node sends location signal of fixed power periodically (signal contains the anchor nodes' numbers and location information). Assuming that the number of anchor node received by the unknown node D (x, y) is n (i = 1, 2, 3 ... n), the anchor node coordinates are N_i (x_i , y_i).

(2) If $i \geqslant 3$ and APIT algorithm location can be used, select three anchor nodes with smaller distances and calculate the position coordinates 1 of the unknown node by trilateration. Then use APIT to estimate the position coordinates 2 of the unknown node, and finally obtain the position coordinates of the unknown node.

(3) If $i \geqslant 3$ and APIT algorithm location cannot be used, select three anchor nodes with smaller distances and calculate the position coordinates of the unknown node by trilateration.

(4) If $i < 3$, then the position coordinates of the unknown node cannot be located.

V. EXPERIMENTAL VERIFICATION AND ANALYSIS

In the experiment, the nodes are placed in a circle with radius of 200m. Let the origin be (0, 0). The total number of nodes is 50, among which 20 are anchor nodes. ZigBee chip of the anchor node module uses CC2430 chip produced by TI company and the node locations are fixed; The quantity of unknown nodes that are placed randomly in the interval is 30, and ZigBee chip in the node module uses CC2431 chip produced by TI company, which contains the RSSI engine that can read out the value of RSSI signal directly.

Fig. 7 shows how location error changes when the communication radius of the unknown node varies from 1.5m to 6m. In the figure, location error reduces as communication radius increases, and with the same communication radius, the improved APIT algorithm has higher location precision than the original APIT algorithm.

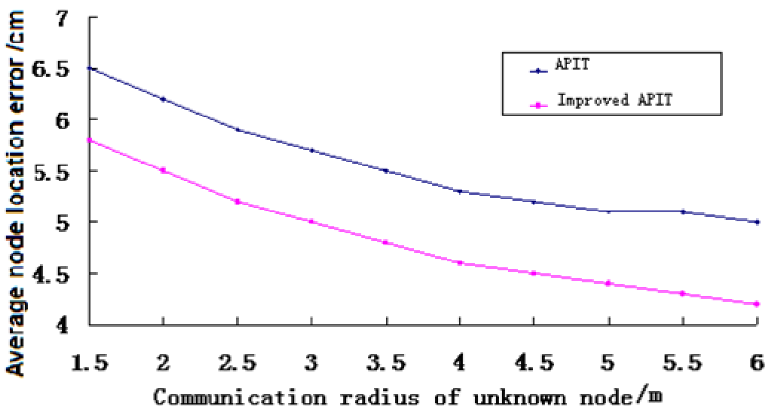

Fig. 7 Comparison of location error

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