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Research on ZigBee Indoor Technology Positioning Based on RSSI

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Abstract

Because in the indoor environment, GPS and other navigation satellite signals can not penetrate the building well, making the satellite signal weaker and unable to use the satellite for positioning. A received signal strength indication (RSSI) -based wireless ZigBee sensor network is proposed based on ranging and indoor positioning technology. The module CC2431 is used as the core chip to design ZigBee nodes which are used to form a ZigBee positioning network. According to the receiver RSSI model, the distance d is estimated between the unknown node and the reference node. By introducing the average filtering model and the Gaussian filtering model, then the measured formula of RSSI ranging is obtained, which is RSSI=-34.3-24×lgd. The field test experiment shows that under the condition of quickly locate and low accuracy, the proposed method does not require additional hardware and software, meanwhile is simple to be implemented.

Keywords: *ZigBee technology, RSSI, CC2431, average filtering model, Gaussian filtering model;*

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1. Preface

ZigBee is an emerging wireless network technology that has developed rapidly in recent years and is widely used for indoor navigation and positioning. As a short-range wireless communication technology, ZigBee has the advantages of high communication efficiency, low power consumption, low cost and high security. In this paper, the RSSI algorithm is used to measure the received reference node signal strength1-3, and the measured data is averaged by the model and the Gaussian filter model to estimate the distance between the nodes4-5. Some positioning algorithms calculate the coordinate position of the node6. As a supplementary technology based on the wireless communication, a relatively coarse positioning function can be realized, which can be used when some positioning requirements are not too high.

2. Introduction to RSSI Positioning Algorithm

The RSSI-based ranging technique measures the distance between nodes by the principle that the radio signal is regularly attenuated as the distance increases. During the propagation of the signal, the complexity of the external environment will cause the signal to weaken to a certain extent, and the greater the propagation distance is, the greater the signal attenuation is. According to this law, the relationship between the attenuation of the signal strength and the distance can be obtained. The relationship between the received signal strength RSSI and the transmission distance d is shown below7

$$\mathrm{RSSI} = A - 10n\lg d \tag{1}$$

where n represents a signal propagation constant, also called a propagation coefficient. A represents the signal strength when the distance A from the sender is 1 m from the sender. A is an empirical parameter that can be obtained by measuring the RSSI value at 1 m from the sender.

Because RSSI is susceptible to multi-path and obstacles, it is weakened in different environments. Therefore, in order to obtain a precise ranging model, it is necessary to stabilize the RSSI value by designing various filters.

3. Improved Model Algorithm

In the actual environment, the RSSI value is greatly affected by the specific environment, and has great volatility and randomness. Here, an average filtering model and a Gaussian filtering model pairs can be introduced to improve the parameters accuracy.

3.1 Average filtering model

Due to the complexity of the environment and the instability of the RF signal, it is necessary to measure the RSSI value multiple times. When using the RSSI value, it is not suitable to select any one of the multiple measured RSSI values. The method of average fibltering provides a basis for the selection of the RSSI value. Mean filtering refers to collecting a set of m positioning node RSSI values, and then taking the arithmetic mean of these data, as shown in equation (2).

$$\mathrm{RSSI} = \frac{1}{m}\sum_{i=1}^{m}\mathrm{RSSI}_i \tag{2}$$

Although the average filtering model can effectively solve the randomness of the data, the model can balance the real-time and accuracy by adjusting the value of m. However, the communication cost will increase accordingly, and the effect is not ideal when dealing with large fluctuations.

3.2 Gaussian filtering model

The introduction of Gaussian filtering model can reduce the volatility. The data processing principle of Gaussian filter model is a positioning node receives n RSSI values at the same position, and there must be some small probability events with very small frequency of RSSI values. The Gaussian filter model rejects the small probability RSSI values, selects the RSSI value of the high probability occurrence region, and then takes the geometric mean to obtain the final RSSI value. The Gaussian distribution function is as follows

$$f(x)=\frac{1}{\sqrt{2\pi}\sigma}e^{\frac{(x-u)^2}{2\sigma^2}} \tag{3}$$

where $u=\frac{1}{n}\sum_{i=1}^{1}x_i$ and $\sigma^2=\frac{1}{n-1}\sum_{i=1}^{n}(x_i\text{-}u)^2$.

According to actual experience, setting a high probability occurrence area is a range with a probability greater than 0.6, which is written by

$$0.6\le f(\mathrm{x})\le 1 \tag{4}$$

Combined with the function (4), it can be proposed, that is, $0.15\sigma+u\le x\le 3.09\sigma+u$.
Therefore after Gaussian filtering, the RSSI range is $\left[0.15\sigma+u\le x\le 3.09\sigma+u\right]$, where

$$\sigma=\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(\mathrm{RSSI}_i\text{-}\frac{1}{n}\sum_{i=1}^{n}\mathrm{RSSI}_i)^2} \quad \text{and} \quad u=\frac{1}{n}\sum_{i=1}^{n}\mathrm{RSSI}_i .$$

Gaussian filtering can reduce the impact of some small probability and large interference events on the overall sample measurement, thereby improving the accuracy of parameter estimation, and even the accuracy of ranging and positioning.

4. Triangulation Method of Distance Measurement

After performing average filtering and Gaussian filtering on the measured RSSI values, the distance between the nodes can be estimated by (1). According to the distance between the unknown node and the reference point, the position information of the unknown node can be obtained. As shown in Figure. 2, the location information of the unknown node can be obtained by measuring the location of the distance d1, d2, and d3 between the nodes N1, N2, and N3. The principle is shown in Figure. 1.

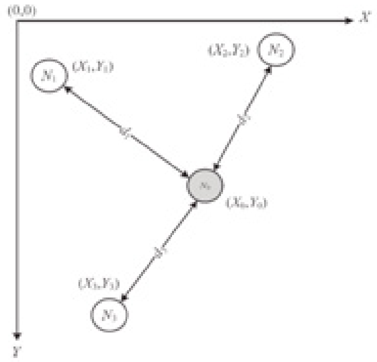

Figure.1 Trilateral measurement diagram

The principle of the trilateration positioning method is to find the coordinates of the intersection point of the circle of the three known radius and the coordinate centre 8. It is known that the coordinates of the three reference nodes N1(x1, y1), N2(x2, y2), and N3 (x3, y3) .Their distances to the unknown node N0(x, y) are respectively d1, d2, and d3 can establish the following equation to obtain the N0 point.

$$\begin{cases} \{(x-x_1)^2+(y-y_1)^2=d_1^{\,2} \\ \{(x-x_2)^2+(y-y_2)^2=d_2^{\,2} \\ \{(x-x_3)^2+(y-y_3)^2=d_3^{\,2} \end{cases} \tag{5}$$

5. Platform based on CC2431

As Fig. 2 shown, the CC2431 chip has high-performance data processing capability and can handle data resolution of a large number of nodes. A system-on-chip for IEEE 802. 15. 4/ZigBee applications integrates a 2.4 GHz RF transceiver with a low-power 8051 MCU core, 128 KB programmable Flash ROM and 8 KB RAM, and A/D Converters, timers, etc.

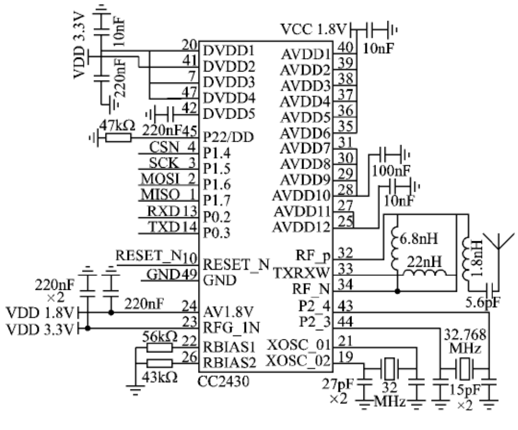

Figure.2 CC2431 chip

As Fig. 3 shown, the CC2431 system-on-chip consists of a wireless location engine based on the IEEE 802. 15. 4 standard9. The positioning engine supports the positioning operation of 3~16 reference nodes, the highest precision is up to 0.5 m, the positioning time is less than 40 μs, the positioning area is 64 m, the positioning error is 3~5 m, and the general software positioning compared with the characteristics of fast positioning, high positioning accuracy and low CPU consumption10.

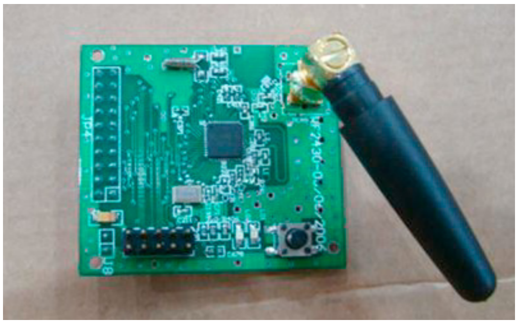

Figure.3 CC2431 circuit diagram

6. Experimental test

In order to testify the validity of the proposed method, the experiment is selected in the football field. A CC2431 ranging positioning module sends data to another CC2431 ranging positioning module. Each position point is tested 10 times then to average the value, and the RSSI data is sent to the RS-232 serial port. The laptop and laptop installation data processing software stores the RSSI data and the distance data into the database, and finally uses the Matlab software to analyze and calculate the information stored in the database.

First, we must first determine the value of A. In order to measure the A value, a CC2431 chip is placed in the middle of the playground as a reference node, a circle with a radius of one meter is drawn with the reference node as the centre of the circle, and the circle is equally divided into eight parts, starting from a starting position, incrementing each time. The distance was measured at a 45-degree angle, which is listed in Table 1, and each angle was measured 10 times, then the average value was used to obtain the A average value, that is, A = -34.3.

Tabel 1 RSSI values measured at different angles

Angle	0	45	90	135	180	225	270	315	360
The average value of RSSI	-33.8	-34.2	-35.1	-33.5	-33.6	-34.3	-33.7	-33.8	-33.9

Second, The RSSI value of the distance measurement is changed below, and the unknown node is placed at different distances and different angles of the reference node to measure the RSSI value, and 10 measurement data are respectively performed, which is listed in Table 2, and then the data is filtered, and finally, n=2.4 is obtained.

Tabel 2 RSSI values measured at different distances

Distance	1	2	3	4	5	10	15	20	25	30
RSSI	-33.5	-40.6	-43.4	-49.2	-49.3	-58.7	-62.3	-66.7	-70.2	-74.7

Combining the stable values of n and A, it can be inferred that the model is

$$\mathrm{RSSI} = -34.3 - 24\lg d \tag{6}$$

Simulating with matlab, it can be seen from the Figure. 4 :

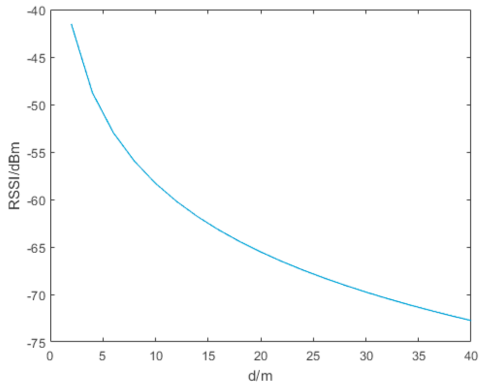

Fig.ure4 Matlab simulation diagram

In the experiment, the model parameters measured due to less data collection will always have errors with the standard model parameters, resulting in low accuracy in the next distance measurement. Therefore, it is necessary to perform error compensation and accurately correct the parameters.

7. Conclusion

In this paper, a wireless ZigBee sensor network ranging and positioning technology is proposed based on RSSI value. The algorithm of node ranging and positioning is proposed based on RSSI, theoretically. After average model filtering and Gaussian filtering model processing, the RSSI range is obtained. Although, the RSSI value-based ranging positioning method can only be used in some simple environments, it has a place in the positioning field because it does not require additional hardware and software and is simple to be implemented.

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