Study on Positioning System Based on Wireless Sensor Network

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***Abstract*— The positioning technology of wireless sensor is the premise in the application of wireless sensor network and has high application prospect and research value. The positioning technology based on received signal strength (RSSI) and the working principle were studied in the paper. The error and compensation method based on the RSSI positioning technology have been analyzed in the paper. The positioning function of wireless sensor network has been realized by CC2431. the expected goal has reached through the experiment testing.**

Keywords-;RSSI localization; CC2431; Location Error Wireless Sensor Network

I. INTRODUCTION

In the wireless sensor network positioning system, the physical address of the network node must be known.in the condition that the address of reference node physical has been known. The relative position of the anchor node must be measured by a variety of algorithms. The positioning technology wireless sensor network is mainly divided into two categories：localization algorithm based on distance and localization algorithm which is not related with distance. Compared with the technologies, the former has high positioning accuracy, the latter has low requirements of node hardware. but the latter has the poor positioning accuracy. Positioning algorithm based on distance are included the positioning mechanism of the received signal strength (RSSI),time of arrival (TOA), time difference of arrival (TDOA), angle of arrival (AOA)[1]. AOA techniques are influenced by the external environment, such as noise, NLOS problems which have different effects on the measurement results. At the same time, AOA requires additional hardware, which is not used for sensor nodes in the hardware size and power consumption. Communication overhead of TOA and TDOA algorithm has high requirement, which does not apply to low-power wireless sensor[2]. In the paper positioning algorithm based on the received signal strength RSSI (received signal strength indicator) is used. Known transmit power, received power is measured at the receiving node to calculate the propagation loss. The propagation loss is converted into distance using the theory or experienced signal propagation model. The RF signal is mainly used by the technology. Because the sensor node itself has wireless communication capability, which is a low power and inexpensive technology[3].

II. THE RSSI RANGING PRINCIPLE

A. *The RSSI ranging Model:*

The received signal strength RSSI is the function of the transmission power and transmission distance, which is the distance between the transmitting node and the receiving node. RSSI value diminishes as the distance increases, as shown below:

$$RSSI= - (10N\times lgd+A) \qquad (1)$$

The standard parameters A is 1m away RSSI absolute from the transmitter(CC2430/CC2431); N is attenuation RSSI absolute when the distance increase 1m from the transmitter; RSSI value is signal strength of CC2430/CC2431 and the unit is dBm, d is the distance and the unit is m.

B. *RSSI test*

Test environment: The actual testing has been made by the reference node in outdoor empty Spaces. The power of the transmitting node is 0dBm and sending and receiving nodes are in the same horizontal plane. The average of 100 continuously collected RSSI values is RSSI value in each position. A was set 18.75 and N is set 3.75 in the testing experiment. The broken line in Figure 1 is the relationship of the measured value and the RSSI changed distance.

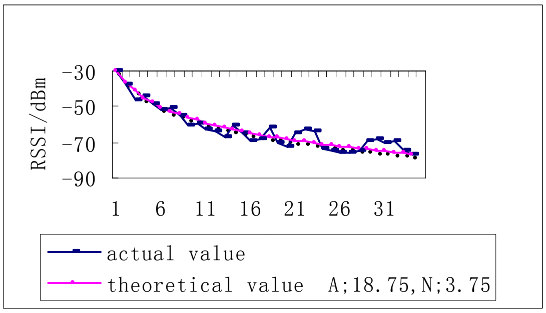

Figure 1. The relationship of RSSI and distance

The certain actual value has deviation with the theoretical value in the figure1.If the the distance became larger, the deviation became bigger.

C. RSSI sources of error and correction method

In the wireless sensor positioning network ,the method based on RSSI location has the feature of low cost and easy implement. But the RSSI value is not only related to the distance, but also the environmental impact of the signal transmission. Shown in Figure 1, when the distance is within the range of less than 15m, the distance and RSSI value have relatively good linear relationship. The result has a good consistency with the theoretical model. when the distance is more than 15m, a certain randomness appears, because signal multipath fading could be leaded by obstructions and environmental changes caused by signal transmission could be leaded by Anchor node moving. Therefore, the result has a great difference with theoretical model[4]-[5]. In the paper, the measured distance could be corrected by the least square method, as follows:

Given a set of the first network node position coordinates (M_i, N_i) and other anchor node level position coordinates (M_j, N_j), the actual distance could be calculated according to two coordinates, $x_i = \sqrt{(M_i - M_j)^2 + (N_i - N_j)^2}$. According to formula (1),the distance of the anchor node yi is estimated. the relationship of xi and yi could be fitted by the least square. Assumed the relationship of two variables is $y_i = ax_i + b$. To make squared deviations sum of all the data be the minimum, we should regard R2 as the variables a and b from the binary function, assumed $R^2 = \sum_{i=1}^{m}(y_i - ax_i - b)^2$ .The variables could be derivate respectively to make R^2 be zero.

$$\frac{\partial}{\partial a}\sum_{i=1}^{m}(ax_i + b - y_i)^2 = 2(a\sum_{i=1}^{m}x_i^2 + b\sum_{i=1}^{m}x_i - \sum_{i=1}^{m}x_i y_i) = 0 \quad (2)$$

$$\frac{\partial}{\partial b}\sum_{i=1}^{m}(ax_i + b - y_i)^2 = 2(a\sum_{i=1}^{m}x_i + bm - \sum_{i=1}^{m}y_i) = 0 \quad (3)$$

By formulate(2)and(3), $a = \frac{\sum_{i=1}^{m}(x_i - \bar{x})(y_j - \bar{y})}{\sum_{i=1}^{m}(x_i - \bar{x})^2}$, $b = \bar{y} - a\bar{x}$

Where $\bar{x} = \sum_{i=1}^{m}\frac{x_i}{m}$, $\bar{y} = \sum_{i=1}^{m}\frac{y_i}{m}$

According to formulate(1) derive

$$Y_{corrected} = a \times 10^{\frac{-(RSSI+A)}{10n}} + b \quad (4)$$

III. Positioning functions and principles based on CC2431

A. Positioning system

Positioning system is composed by the reference node and positioning node. The reference node is the static node in the known location. when the node know its position, the node will send a data packet to notify other reference nodes(using CC2430). Positioning node receive the packet signals from reference node to obtain position coordinates and the corresponding RSSI value of reference nodes and send it to the positioning engine. The self-position could be calculated by reading out the positioning engine[6]. The packet which the reference node send the positioning node includes at least the horizontal position coordinates X and the vertical position Y of the reference node. The RSSI value is calculated by the receiving node.The each part function of positioning system are as follows：

1) Host An ordinary PC is used by host.

Host connected gateway to achieve the work schedule of the entire network .The written positioning software could observe the operation of each positioning node and the reference node.

2) Gateway

The gateway is used to build a ZigBee WSN network and acts as a coordinator.The gateway sends the coordinates and the external environment parameters of the positioning node to the host.

3) The reference node

The reference node is acted as the role of router in the network.It specified fixed coordinate by the user and offered the coordinate and the average of RSSI by the positioning node in the positioning system. The reference node is a known static nodes whose coordinate(x,y) is fixed. but does not participate in position calculation. The device of CC2430 or CC2431 can achieve the calculation. A positioning reference area is usually composed of eight nodes and the system requires at least three to four reference nodes to be positioned. In the paper CC2430 is used as the reference node..

4) The positioning node

There is a positioning engine in the positioning node. The precise location of its own could be calculated according to a fixed node and the average RSSI of the reference node., then send coordinates and identification node number to the gateway. In the paper the core device CC2431 is implemented.

B. Positioning Workflow

Positioning nodes are a type of mobile nodes and can move freely in the surrounding area of the reference node. The location of the coordinates could be calculated by the positioning algorithm when the positioning node received RSSI values of all the reference nodes. The device CC2431 can be implemented by the positioning node. With the device, the positioning resolution of 0.25 m can be realized and the positioning accuracy of 3m can be realized. The positioning time is less than 40 μs. The flowchart of the reference node is shown as Figure 2. The flowchart of positioning nodes is shown as Figure 3.

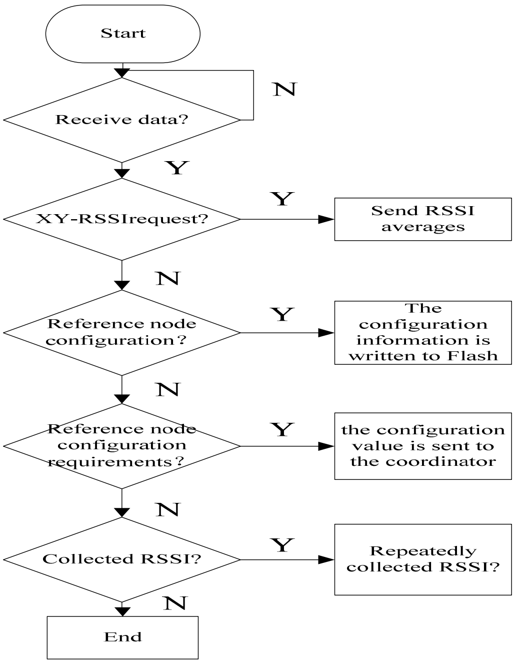

Figure 2. The flowchart of the reference node

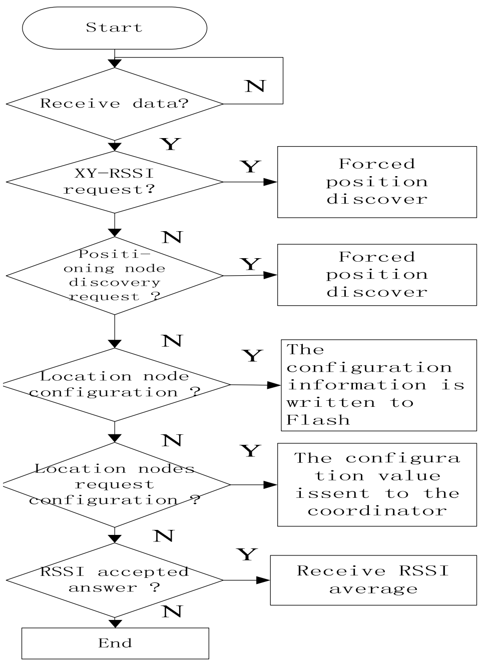

Figure 3. The flowchart of positioning node

IV. EXPERIMENTAL RESULTS AND ANALYSIS

Reference nodes are arranged in the region of 35m x 35m.100 data packets can be collected through repeated adjustments. The positioning works best when A is taken 43 and n is taken 15.The relationship of corrected distance and estimated distance can be fitted by the least square method. a = 1.0781 and b = 0.1955 are obtained. Therefore, the corrected distance and the estimated distance can be obtained by formula (4). $Y_{corrected} = 1.0781 \times 10^{\frac{-(RSSI+43)}{10\times 15}} + 0.1955$ The fixed correction value and the unfixed correction value are listed in table 1. Estimated errors of positioning node coordinates are listed in table 2.Compared with the fundamental flaw from table, the adjusted distance by least-square method is more close to the actual distancewhich has smaller error.The positioning node coordinates can be more accurately estimated .From table 2,the corrected distance by modified trilateration method has samller error than un-corrected estimation error.

V. CONCLUSION

The RSSI ranging principle has been analyzed briefly in the paper, the least square method is combinated to estimate the distance of the modification and core design based on CC2430 / CC2431 Zigbee nodes on the network experiment. Through test validation, in the range of about 10 m x 10 m, under the condition of its positioning accuracy can reach within 2 m, this result also with RSSI test results is consistent, namely in less than 10 m, within the scope of the RSSI values and distance relationship and the theory model has good consistency, and in terms of positioning coverage, just make sure each positioning node centered 64 m x 64 m range includes at least three reference nodes, can be programmed to achieve its positioning coverage arbitrary large. Experiments show that after the adjusted distance accuracy is higher, the positioning node positioning more accurate, the coordinates of the revised location accuracy in accordance with some general positioning system

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TABLE I. THE FIXED CORRECTION VALUE AND THE UNFIXED CORRECTION VALUE

Coordinates of RealNode	Estimation of uncorrected coordinates	Uncorrected Estimation error	Uncorrected Estimation error	Corrected coordinates estimation
(1.25,2.25)	(1.58,2.76)	(0.33,0.51)	(1.15,2.46)	(-0.10,0.21)
(3.25,3.25)	(3.98,3.85)	(0.73,0.60)	(3.60,3.68)	(0.35,0.43)
(5.50,4.50)	(6.29,3.76)	(0.79,-0.74)	(5.07,4.96)	(-0.43,0.46)
(8.80,9.85)	(7.79,11.23)	(-1.01,1.38)	(9.32,9.14)	(0.52,-0.71)
(12.25,10.65)	(11.02,9.56)	(-1.23,-1.09)	(11.46,11.37)	(-0.79,0.72)
(15.55,18.45)	(13.91,19.96)	(-1.64,1.51)	(14.52,17.36)	(-1.03,-1.09)

TABLE II.
THE UNCORRECTED ESTIMATION ERROR OF POSITIONING NODE COORDINATES AND THE CORRECTED ESTIMATION ERROR OF POSITIONING NODE COORDINAT ES

Actual distance	3.73	5.53	8.75	12.66	18.65	21.89	25.97	31.12
Estimated distance	3.45	5.18	7.95	10.88	16.25	19.33	23.25	28.01
The error of estimated distance	0.28	0.35	0.80	1.78	2.40	2.56	2.72	3.11
Corrected distance	3.85	5.66	8.55	11.64	17.36	20.45	24.85	29.66
The error of corrected distance	-0.12	-0.13	0.20	1.02	1.29	1.44	1.12	1.46