

The Research of Positioning Measurement Based on Sensor Signal Strength

Mack Jianhua Du¹ and Roger Liu²

¹Shanghai Jianqiao University, Shanghai, China

²Honeywell(China)Co., Ltd., Shanghai, China

Abstract—Sensor positioning plays an important role in wireless sensor network (WSN). The sensor location information is indispensable to a lot of applications. This paper analyzes the wireless sensor node measuring algorithm and the principle of classification, focuses on analyzing the signal strength based ranging method of RSSI, puts forward an integration positioning method between theoretical and experience of the signal intensity values. This innovative method extends to most complicated positioning applications.

Keywords—sensor node; positioning measurement; Signal strength; Integration positioning method

I. INTRODUCTION

With the sensor technology rapidly development, WSN is used in the various industries. WSN consists of many sensors with sensing, computing and communicating functions and forms a self-organized wireless network. By the sensor collecting the object data in monitoring area, WSN processes these data into useful and accurate message and transmits them to the management center. WSN is the new generation network and will produce a profound effect on the human life and work[1].

In the many applications of WSN, the location message of sensor or object monitored is critical necessary.

II. SENSOR LOCALIZATION TECHNOLOGY

Generally because of the uncertainty of node position and important of data center, the sensor node becomes as the key point in the WSN. If adopting GPS method, the sensor positioning cost and complexity greatly increases because of tiny sensor device and crypticity factors. It is trend to positioning by sensor itself[2]. No matter what the positioning method, it must need the known-node to determine unknown-node, here the known-node is refer as Anchor Node.

Regarding to the positioning mechanism, there are two types: Range-based method and Range-free method[3].

The former needs to measure the distance or angle data between the unknown-node and anchor node, then calculates the node location data by trilateration measurement, triangle measurement or maximum estimation method. While later only needs the connection of network to determine the position of unknown-node in network.

Range-based method focuses to measure the Received Signal Strength Indicator (RSSI), Time of Arrived (TOA), Time Difference of Arrived (TDOA), and Angle of Arrived (AOA) etc., then fixes the position by suitable algorithm. This method

advantage is more accuracy. However the disadvantages are high quality need for node hardware, bigger power consumption and environment humidity which affects the precision.

Range-free method adopts the hop algorithm and connection of network to fix the node position such as DV-hop algorithm, APTI algorithm, and Amorphous algorithm etc., it does not need any infrastructure like base station and GPS. Above several algorithms, more or less, are with some insufficient factors. In general, the positioning precision and speed of convergence in this method basically depends on the estimation precision on the distance of per hop in the network. It is more suitable for simple topology in network [4]. The mixture using above algorithms realizes the better precision or is lower standard for certain measure data.

III. INDOOR WIRELESS POSITIONING BASED ON RSSI

This paper mainly researches the indoor sensor node positioning in WSN. In monitoring area, there are several allocated signal receivers, when the transmitter produces the electromagnetic signal, receivers get the signal and measure its signal strength as well as electromagnetic characteristic, and finally the accurate transmitter location is determined[5].

By the signal strength to fix the location in indoor environment, there are several negative factors such as obstacle, non-sight distance, multipath etc. for position precision. Moreover there is much workload for setting actual measure database. This paper provides an integration positioning method between theoretical and experience in the signal strength values. Meanwhile by combining the model of signal transmission and measure on site, it not only ensures the precision, but also highly reduces the workload on site. In the simple environment without any obstacle, it adopts the theoretical database which is deduced from model of signal transmission; in the complexity environment with many obstacles, it uses experience database which comes from measure value on site.

A. Building the Theoretical Value Database

It is critical that setting up the transmission model of RF signal because there is big difference of transmission loss in different environment. Hence it needs to build different signal transmission model based on the relevant environment.

1) Choosing the suitable transmission model

When the signal transmitting, there is negative effect from other types of signal such as reflection, refraction, and diffraction etc. The signal strength received is added from all

signal components, it is very strong in sometime, and weak in other time. From large quantity of engineering practice, the received signal strength obeys "Log-normal rule", its probability model of signal transmission is as following:

$$p(d)[dBm] = p(d_0)[dBm] - 10n_p \lg\left(\frac{d}{d_0}\right) + X_s \quad (1)$$

Here, $p(d)$ is signal strength received as d is two nodes distance between sending and receiving; d_0 is reference distance in two nodes; $p(d_0)$ is signal strength received as d_0 is distance in two nodes; n_p is path loss; X_s obeys average value 0. Standard difference is Gaussian distribution random variable, which is independent of transmission distance. It means that loss measured could be quite different as the same transmission distance. X_s is used to reduce the deviation of signal strength, that reduces positioning deviation as well.

From large quantity practice, the probability model is better reflecting the signal transmission rule comparing to other model, moreover it is easy to use. This paper chooses the probability model as the basis for theoretical value database.

2) Dividing positioning area

In the simple square area without any obstacle, setting the signal node M_1, M_2, M_3, M_4 at the four corners, m is unit length for dividing area, as show figure 1. Then the distances from point $A_1(x_1 + m, y_1 + m)$ to four corners are respectively $\sqrt{2}m, \sqrt{26}m, 5\sqrt{2}m, \sqrt{26}m$. Based on the experience, setting m length is 2~4 m (it depends on the measure precision and real time positioning calculation).

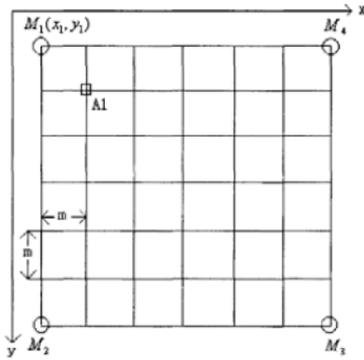


FIGURE 1. DIVIDING AREA SHOW.

3) Creating the "location~signal strength" relation characteristic

Generally the "Location~Signal Strength" Relation Characteristic contains three elements: location coordinate, average value of signal strength, and standard difference of signal strength. There is example for setting point A_1 .

Location coordinate: $(x_1 + m, y_1 + m)$

Average value of signal strength: by signal transmission model, transferring the four distances from A_1 to M_1, M_2, M_3, M_4 (respectively $\sqrt{2}m, \sqrt{26}m, 5\sqrt{2}m, \sqrt{26}m$) into average values of signal strength of P_1, P_2, P_3, P_4 (Transfer formula as above (1)).

Standard difference of signal strength: It expresses deviation degree between measure value and average value in signal strength, as below formula:

$$f_i = \sqrt{E\{\Pi - \Pi_i\}}, (i=1,2,3,4) \quad (2)$$

P is measure value in signal strength, E is average value. Thus it creates the relation of location coordinate and signal strength between the A_1 and each M point:

$$(x_1 + m, y_1 + m) \sim \begin{bmatrix} P_1 & \sigma_1 \\ P_2 & \sigma_2 \\ P_3 & \sigma_3 \\ P_4 & \sigma_4 \end{bmatrix} \quad (3)$$

By the same way, getting the relation of location coordinate and signal strength characteristic in other cross points. Its formula is as below:

$$(x, y) \sim \begin{bmatrix} SAVG_1 & SDEV_1 \\ SAVG_2 & SDEV_2 \\ SAVG_3 & SDEV_3 \\ SAVG_4 & SDEV_4 \end{bmatrix} \quad (4)$$

Here $SAVG_i$ is average value of signal strength, $SDEV_i$ is standard difference value, $i=1, 2, 3, 4$.

Thus it produces the theoretical value database in signal strength.

4) Checking correction theoretical value database

By the actual measurement value checks the correction theoretical value database. It is the concrete method that selects equally several points and measures their signal strength in the positioning area. If the difference is little between actual measuring value and theoretical value in database, there is no correction; otherwise, the actual measure value is used instead of theoretical value in database for the test point. Finally it creates one complete theoretical value signal strength database.

B. Building the Experience Value Database

Because of many walls, bodies, obstacles in indoor, there are various other signals such as reflection, refraction, and diffraction etc. The signal strength received is added by all signal components via multipath. Hence the RF signal strength distribution is closely related to the indoor environment. In order to realize the positioning based on signal strength in this complicated environment, it is the feasible method to use experience value database.

There are four beacon nodes in positioning system. The indoor plane graph, beacon node location, and transmitted power of unknown-node are known. The monitoring area is divided into multi units. The sample value of signal strength is collected many times at different location in per unit, and then the average value of signal strength and standard difference value can be calculated. Meanwhile these values are as the basis of experience value database. When the signal strength value measured is near to the certain value in the unit of database, this center location of unit is as unknown-node location.

The method of building experience database is as below:

1) *Dividing the minimum positioning unit*

The monitoring area is divided into multi units, and the each unit is same, e.g. one space (1.5m x 4m) is as a unit. It is considered on the workload and permissible positioning error. One unit square is limited within 6~ 16 m².

2) *Actual measure signal strength value*

In unit 1, one transmitting node with known power is located randomly, beacon node 1 collects signal strength value for 100 times from this transmitting node, Unit 1, corresponding to the beacon node1, gets the vector value of signal strength $\vec{RS}_1 = (RS_{1,1}, RS_{1,2}, \dots, RS_{1,100})$. By the same way, unit1 gets vector values corresponding to other three beacon nodes.

3) *Getting signal strength characteristic*

From large quantity collections, it is discovered that signal strength is disturbed from white noise X_s . The white noise is $X_s \sim N(0, S^2)$. Thus it is efficient to express the signal strength characteristic by getting the average value and standard difference in signal strength. By $\vec{RS}_1 = (RS_{1,1}, RS_{1,2}, \dots, RS_{1,100})$, unit 1, corresponding to the beacon node1, gets the average value $SAVG_{1,1}$ and standard difference $SDEV_{1,1}$ in signal strength. By the same way, unit1 gets average values $SAVG_{1,i}$ and standard difference $SDEV_{1,i} = (2,3,4)$ in signal strength corresponding to other beacon nodes $i = (2,3,4)$.

4) *Building the "location ~ signal strength" relation characteristic*

The unit1 (center location coordinate (x_1, y_1)) builds the collected signal strength relation characteristics with each beacon node. Its formula is as below:

$$(x_1, y_1) \sim \begin{bmatrix} SAVG_{1,1} & SDEV_{1,1} \\ SAVG_{2,2} & SDEV_{2,2} \\ SAVG_{3,3} & SDEV_{3,3} \\ SAVG_{4,4} & SDEV_{4,4} \end{bmatrix} \quad (5)$$

Hence the other unit (center location coordinate (x_j, y_j)) in area collected signal strength relation characteristic with other each beacon node is set up as well. Its formula is as below:

$$(x_j, y_j) \sim \begin{bmatrix} SAVG_{j,1} & SDEV_{j,1} \\ SAVG_{j,2} & SDEV_{j,2} \\ SAVG_{j,3} & SDEV_{j,3} \\ SAVG_{j,4} & SDEV_{j,4} \end{bmatrix} \quad (6)$$

Thus one complete experience value signal strength database sets up.

By combining the theoretical value database and experience value database, that creates one theoretical- experience value database. It is as real time positioning base.

The integrated positioning method of theoretical- experience value database, the advantage is very obvious: when being in complicated environment, multi obstacle area, the experience value database is adopted; when being in simple environment, area without any obstacle, the theoretical value database is used. This method reduces the multipath effect, promotes the

positioning precision and decreases the actual workload in the experience value database. Meanwhile it solves the problem which changes the positioning algorithm when monitored object moves from simple area to complicated area.

IV. CONCLUSION

Today the wireless network covers more and more large area, location message is becoming one of key basic information. Wireless positioning technology rapidly development, the related services is stepping into people 's life. As the basic technology of WSN, this positioning measurement technology based on signal strength is of lower cost, less equipment, ease to use and so on benefits. It is especially suitable for wireless positioning system in low power and cost properties.

The innovation of this paper is integration positioning method by theoretical and experience value database, it covers most application fields based on signal strength.

REFERENCE

- [1] A.Dan, S. Halder, S. Dasbit "Localization with Enhanced Accuracy Location Using RSSI in WSN," IEEE Inter'l Conference on Advanced Networks & Telecommunication Systems, 011,34(17):1-6
- [2] Zhou Lijun, Liu Yu. "Study on Node Self-Localization Based on RSSI in WSN," Electronic Measurement Technology, Vol.33, No.8, August, 2010
- [3] Andy Harter, Andy Hopper. A distributed location system for the active office. IEEE Network, 1994, 8(1):62 — 70.
- [4] C.henXijian, Cheng Lianlun. "Study and Implementation of Power Match Algorithm Based on RSSI," Chinese Journal of Sensor and Actuators Vol.26, No.5, May, 2013
- [5] Roy want, Andy Hopper, VernieaFaleao and Jon Gibbons. "The Active Badge Location System," ACM Transsation on Information System January 1992, 10(1):91-102