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An Approximate Sphere of the Four Anchor Nodes Positioning Method Based on RSSI

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Abstract: The utilizing of received signal strength indication (RSSI) in wireless sensor network (WSN) is a distance measurement method to compute the location of nodes, which needn't additional hardware equipment. However, large errors of measurement may cause by the disturbance of environmental noise and inherent factors of hardware. Through analyzing the location information of anchor nodes and adaptive acquire the uncertain factors of RSSI in WSN to estimate the coordinate of unknown node accurately. We use MATLAB and ZSTACK-CC2530 protocol stack as simulation and real experiments prove that the method to locate nodes is effective and practical than other usual RSSI based strategies. *Copyright © 2015 IFSA Publishing, S. L.*

Keywords: Spherical plane angle, RSSI location, Zstack-cc2530, Average position error.

1. Introduction

Positional information is indispensable part of [1-2] sensor nodes for data acquisition and monitoring information will be meaningless without its location information [3]. The localization technology in wireless sensor network has range based and range free technology. Among them, ranging method utilize location information of anchor nodes and the distance between anchor and unknown nodes to calculate the unknown node.

The popular range positioning technologies are [5-7] TOA method, TDOA method, AOA method and RSSI ranging method, ranging method which is commonly used is to estimate the unknown node by using RSSI information. General RF circuit has RSSI so it has ranging ability, but the reading of received signal strength indicator of wireless sensor node in same circumstance is quite diverse due to noise or other uncertain factors. Many researchers have done a lot of work to improve the accuracy of the RSSI positioning technology. Unfortunately, the uncertain factor is difficult to measure automatically. The fluctuation of RSSI readings usually is expressed in Gauss distribution, which is defined as shadowing model [8-9]. Because the instinct hardware factors of WSN node or environmental changing the concrete RSSI parameters is hard to demarcate. Therefore, it may lead to a subsequent calculation of distance become more unstable and uncertain, which will affect the ranging accuracy finally. Based on this background, this paper proposes one kind of positioning method that to use the deployed anchor nodes' coordinate information specifically calculate signal attenuation factor, by means of Gauss filter RSSI value to decrease unstable, low possible readings of RSSI. Consequently, it is automate that adjust four anchor nodes' coordination with a spherical found in the communication range of the unknown node, to estimate the unknown node position. Comparing with the traditional RSSI method, the experiments show that our strategy may improves the accuracy of location of nodes about 10 % and with less communication.

2. RSSI Ranging Theory and Related Research

According to the electromagnetic wave theory, with the increase of distance, the wireless signal strength from the emission source to its destination, which will nonlinearly decrease the attenuation process. The theoretical model of the widespread uses of wireless signal transmission for the Shadowing model. The Shadowing model is known in the signal transmitting theory and by using the signal propagation model, the propagation loss is converted to a [10] mathematical model of distance, this model is also known as the long-term fading model, by the Formula (1) said:

$$P(d)=P(d_0)-10\eta\times\log_{10}(\frac{d}{d_0})+N_\sigma, \qquad (1)$$

where d is the distance between nodes and beacon nodes; η is the path loss exponent. This type of parameter dependent on surrounding environment and buildings, said the path loss increases with the increase in distance. As for N_{σ_n} the unit db, and the standard deviation δ of zero mean Gaussian distribution of random variables; $P(d_0)$ is the received signal strength far from the sending node with d_0 meter [4]. Usually the d_0 is the set to be one unit meter, so the symbol $P(d_0)$ will have a standard strength value. We suppose the unit referenced RSSI under certain circumstance that is a constant number $P(d_0)$. The comparison of theoretical RSSI value and real RSSI value in different distance is shown in Fig. 1.

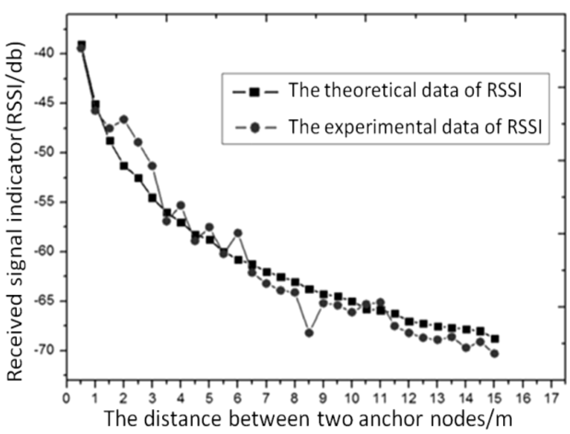

Fig. 1. The comparison of theoretical RSSI value and real RSSI value in different distance.

$$P(d_0)=[\sum_{i=1}^{N}\sum_{j=1}^{N}\overline{RSS(P_i,P_j)}]\Big/\sum_{i=1}^{N}\sum_{j=1}^{N}d(P_i,P_j), \qquad (2)$$

where, $RSS(P_i,P_j)$ is the average value of RSSI measurement for the anchor node P_i and P_j. Consequently, we can set one meter as the unit measurement of RSSI. $P(d)$ can be seen as a Gauss distribution model. It is a mean of μ and standard deviation δ as the Gauss distribution. For a certain received signal strength indication value $RSSI_i$, the measurement results comply with the density function $f(x)=\frac{1}{\delta\sqrt{2\pi}}e^{-\frac{(x-\mu)^2}{2\delta^2}}$. The density function in sensor network localization environment will be changed in different deployment. Therefore, by deploying real deployment of the anchor node coordinate information, so it can be trained and learned so as to get parameters μ and δ in Gauss distribution function. In the use of the maximum likelihood estimation method as shown in Equation (3):

$$L(\mu,\delta)=\prod_{i=1}^{N}\frac{1}{\delta\sqrt{2\pi}}e^{-\frac{(x-\mu)^2}{2\delta^2}} \qquad (3)$$

The Formula (3) on both sides of the partial derivative of the logarithm formula obtained:

$$\begin{cases}\frac{\partial ln(L(\mu,\delta))}{\partial\mu}=0\\ \frac{\partial ln(L(\mu,\delta))}{\partial\delta}=0\end{cases} \qquad (4)$$

The parameters μ and δ can be calculated from the following equations:

$$\mu=\frac{1}{N}(\sum_{i=1}^{N}RSSI_i),\quad \delta=\sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(RSSI_i-\mu)^2}$$

where N is the number of measurement. According to the principle 3δ, probability, range 97 % is concentrated in the range of high probability of occurrence in the range $[\mu-3\delta,\mu+3\delta]$. The calculation RSSI value that is filtered by the range of signal intensity $[\mu-3\delta,\mu+3\delta]$ and finally we get Formula (5) with unknown variable d:

$$\underbrace{P(d)}_{\mu}=\underbrace{\left(\frac{\sum_{i=1}^{N}\sum_{j=1}^{N}\overline{RSS(P_i,P_j)}}{\sum_{i=1}^{N}\sum_{j=1}^{N}d(P_i,P_j)}\right)}_{P(d_0)}-10\eta\log_{10}(d)+\delta \qquad (5)$$

Consolidation Formula (5) to deduce as follows:

$$d=10^{[\frac{P(d_0)-\mu+\sigma}{10\eta}]} \qquad (6)$$

3. Description of Spherical Adjusting Three-dimensional Positioning Method Based on RSSI

3.1. The Basis of Localization Scheme of Measuring in WSN

The basic measuring methods to get the location of unknown nodes are Trilateral Measurement and Maximum Likelihood Estimation. The standard equation $(x-x_1)^2+(y-y_1)^2+(z-z_1)^2=(d_1)^2$ and radius d_1 can be expressed as sphere having its center at (x_1,y_1,z_1) .0 The location calculation is shown in Fig. 2.

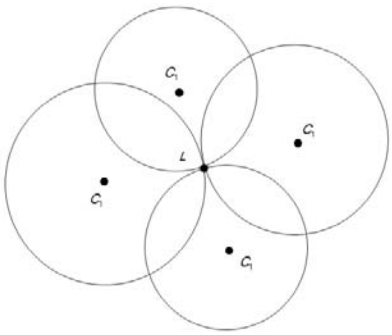

Fig. 2. Location calculation through anchors is at the surface of connectivity range of unknown node.

We pick up the four anchor nodes: (x_1,y_1,z_1) , (x_2,y_2,z_2) , (x_3,y_3,z_3) , (x_4,y_4,z_4) near to the unknown node in the range of signal connection with coordination (x,y,z) . We can utilize following group of equations to transform them to localize the unknown nodes' position (x,y,z) .

$$
\begin{aligned}
(x-x_1)^2+(y-y_1)^2+(z-z_1)^2&=(d_1)^2\\
(x-x_2)^2+(y-y_2)^2+(z-z_2)^2&=(d_2)^2\\
(x-x_3)^2+(y-y_3)^2+(z-z_3)^2&=(d_3)^2\\
(x-x_4)^2+(y-y_4)^2+(z-z_4)^2&=(d_4)^2
\end{aligned}
$$

We can obtain Unknown Node's coordinate (x,y,z) :

$$
\begin{bmatrix} x\\ y\\ z \end{bmatrix} = \begin{bmatrix} 2(x_1-x_4) & 2(y_1-y_4) & 2(z_1-z_4)\\ 2(x_2-x_4) & 2(y_2-y_4) & 2(z_2-z_4)\\ 2(x_3-x_4) & 2(y_3-y_4) & 2(z_3-z_4) \end{bmatrix}^{-1}
\begin{bmatrix} x_1^2-x_4^2+y_1^2-y_4^2+d_4^2-d_1^2\\ x_2^2-x_4^2+y_2^2-y_4^2+d_4^2-d_2^2\\ x_3^2-x_4^2+y_3^2-y_4^2+d_4^2-d_3^2 \end{bmatrix}
$$

By utilize the all location of anchors to calculate the unknown node's location. We use method of Maximum Likelihood Estimation to compute the location. The whole process is as following Fig. 3.

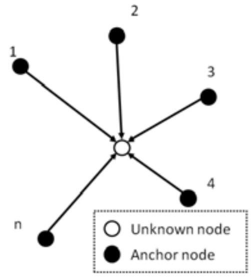

Fig. 3. Maximum Likelihood Estimation for calculation of location of unknown nodes.

The coordination of WSN nodes are as follows: (x_1,y_1,z_1) ,…, (x_n,y_n,z_n) ; and

$$
\begin{cases}
(x_1-x)^2+(y_1-y)^2+(z_1-z)^2=d_1^2\\
\dots\\
(x_n-x)^2+(y_n-y)^2+(z_n-z)^2=d_n^2
\end{cases}
$$

From the above equations, each one minus the final equation, we can get

$$
\begin{cases}
x_1^2-x_n^2-2(x_1-x_n)x+y_1^2-y_n^2-\\
2(y_1-y_n)y+z_1^2-z_n^2-2(z_1-z_n)=d_1^2-d_n^2\\
\dots\\
x_{n-1}^2-x_n^2-2(x_{n-1}-x_n)x+y_{n-1}^2-y_n^2\\
-2(y_{n-1}-y_n)y+z_{n-1}^2-z_n^2-2(z_{n-1}-z_n)=d_{n-1}^2-d_n^2
\end{cases}
$$

The linear equations can be expressed as follows:

$$
A=\begin{bmatrix} 2(x_1-x_n) & 2(y_1-y_n) & 2(z-z)\\ \dots & & \\ 2(x_{n-1}-x_n) & 2(y_{n-1}-y_n) & 2(z-z) \end{bmatrix},
$$

$$
b=\begin{bmatrix} x_1^2-x_n^2+y_1^2-y_n^2+z_1^2-z_n^2+d_n^2-d_1^2\\ \dots\\ x_{n-1}^2-x_n^2+y_{n-1}^2-y_n^2+z_{n-1}^2-z_n^2+d_n^2-d_{n-1}^2 \end{bmatrix},
$$

$$
X=\begin{bmatrix} x\\ y\\ z \end{bmatrix}
$$

Now we can use the least squares equation to calculate out the unknown node's coordinate. That is: $\hat{X}=(A^TA)^{-1}A^Tb$. The process of RSSI three-dimensional positioning is to utilize the anchors' location to calculate the unknown nodes' location with the help of Trilateral Measurement and Maximum Likelihood Estimation.

3.2. Spherical Adjusting Three-dimensional Positioning

Based on the RSSI three-dimensional positioning method, the positioning method is first anchor node to node broadcasts data in the coverage area of signal, signal strength on the statistics of the anchor nodes each unknown node to the unknown node values in each unknown node using Gauss filter to calculate all anchor nodes in the signal covering cap values and coordinates anchor nodes, anchor nodes S_i Can be expressed in a broadcast signal with a four tuples $A^{(i)}(id, RSSI, X, Y, Z)$, the information of anchor nodes all are sorted according to the signal intensity value and choose to anchor node signal strength values of the four anchor nodes, i.e.

$$\underset{1\le i\le N, N=4}{\arg\min}\{\frac{1}{N}\sum_{j=1}^{N}[RSSI_{ij}-(\frac{1}{N}\sum_{j=1}^{N}RSSI_{ij})]^2\}$$

Finally calculated selected four unknown node signal strength value expectations $E(D)$, selection algorithm (ASA) are as follows:

1) Firstly as for unknown nodes received form RSSI in the scope of $[\mu-3\delta, \mu+3\delta]$, the use gossans filtering to filter to get serial $S(A)$;

2) To rank signal serial $S(A)$ in a descending order, successively to pick four value of RSSI as group of subseries:

$$RSSI_{i1} \le RSSI_{i2} \le RSSI_{i3} \le RSSI_{i4};$$

3) To compute $\theta \leftarrow \frac{1}{N}\sum_{j=1}^{N}[RSSI_{ij}-\frac{1}{N}\sum_{j=1}^{N}RSSI_{ij}]^2, N=4$;

4) Do $i \leftarrow i+1$, if the end of the sequence is to Formula (6), recalculate the parameter θ;

5) If $old(\theta) > \theta$, then $old(\theta) = \theta$;

6) To compute the sequence of $S(A)$ and get the expectation $E(D)$.

The computing time is closest with spherical anchor node algorithm complexity is $O(n)$, because of the unknown node outward radiation radio signal in the ideal case, so in the three-dimensional space positioning method of [11-16] ideally can use in the sphere of four non coplanar anchor node coordinates to determine the coordinates of the unknown nodes. The unknown nodes to find four dimensional space in the approximation in a spherical four points $P_1(x_1, y_1, z_1)$, $P_2(x_2, y_2, z_2)$, $P_2(x_2, y_2, z_2)$, $P_4(x_4, y_4, z_4)$ to adjust. The coordinates of nodes adjusted to meet the following core p_0, q_0, r_0, Spherical equation:

$$\begin{cases} S_0 : x^2+y^2+z^2+2p_0x+2q_0y+2r_0z+d_0=0 \\ (x,y)=x_1,y_1 \\ (x,y)=x_2,y_2 \\ (x,y)=x_3,y_3 \\ (x,y)=x_4,y_4 \end{cases} \quad (7)$$

A general equation is derived from the spherical center can express as Equation (8)

$$S_j : (x-p_j)^2+(y-q_j)^2+(z-r_j)^2 = \left\{\underbrace{(p_j^2+q_j^2+r_j^2-d_j)^{\frac{1}{2}}}_{R}\right\}^2 = R^2 \quad (8)$$

By the Formula (8) center p_j, q_j, r_j coefficient in the spherical equation for the sphere S_j. Adjust the desired distance equal to four anchor nodes to the unknown node for each approximation at the point on the sphere. The process of the adjustment is to each anchor node will coordinate adjusted to the unknown node $P_0(x_0, y_0, z_0)$ as the core, $E(D)$ as the radius to a distance function accepts the signal values of $d=10^{(\frac{P(d_0)-E(D)+\delta}{10\eta})}$, and four non coplanar node coordinates S_0, large spherical $\widehat{P}_1(x_1, y_1, z_1)$, $\widehat{P}_2(x_2, y_2, z_2)$, $\widehat{P}_3(x_3, y_3, z_3)$, $\widehat{P}_4(x_4, y_4, z_4)$, and by Equation (8) method to determine the unknown node $P_0(x_0, y_0, z_0)$ is more difficult to coordinate. We can through the Equation (7) the relationship between the general equations of S_i and S_i sphere, which is the four ball surface S_1, S_2, S_3, S_4 coordinates and a spherical S_0 tangent relationship indirectly the unknown node, and because two spherical S_i and the cosine of the angle between the cutting surface of S_j (9). The 3D positioning adjustment based on RSSI is simply shown in Fig. 4 and detailed algorithm is described in SAA method in the end of this section.

$$Cos(S_i, S_j) = \frac{2p_ip_j+2q_iq_j+2r_ir_j-d_i-d_j}{2\sqrt{p_i^2+q_i^2+r_i^2-d_i}\sqrt{p_j^2+q_j^2+r_j^2-d_j}} = 1 \quad (9)$$

First to analyze the S_1 and S_0, S_2 and S_0 between the tangent equation, consolidation type (9) to get:

$$\begin{cases} 2p_1p_0+2q_1q_0+2r_1r_0-d_1-d_0= \\ 2\sqrt{p_1^2+q_1^2+r_1^2-d_1}\sqrt{p_0^2+q_0^2+r_0^2-d_0} \\ 2p_2p_0+2q_2q_0+2r_2r_0-d_2-d_0= \\ 2\sqrt{p_2^2+q_2^2+r_2^2-d_2}\sqrt{p_0^2+q_0^2+r_0^2-d_0} \end{cases} \quad (10)$$

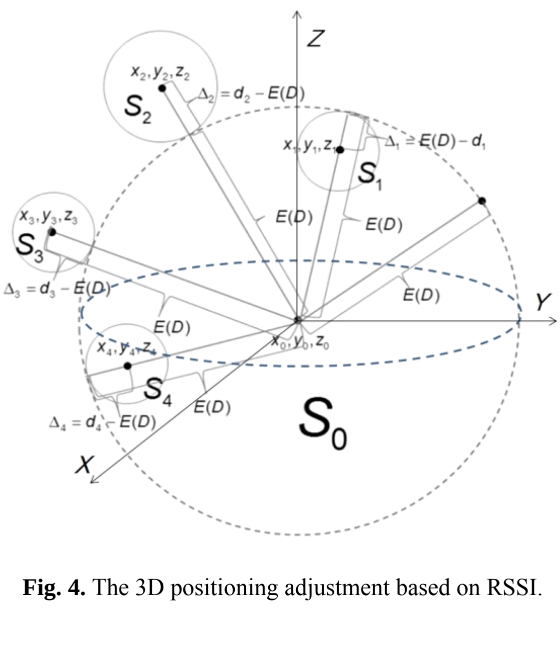

Fig. 4. The 3D positioning adjustment based on RSSI.

Consolidation type (10) to get (11):

$$(2p_1p_0+2q_1q_0+2r_1r_0-d_1-d_0)\times\underbrace{\sqrt{p_2^2+q_2^2+r_2^2-d_2}}_{A_2}=$$
$$(2p_2p_0+2q_2q_0+2r_2r_0-d_2-d_0)\times\underbrace{\sqrt{p_1^2+q_1^2+r_1^2-d_1}}_{A_1} \quad (11)$$

The spherical tangent in spatial four nodes S_1, S_2, S_3, S_4, and the unknown node S_0 and the equations is:

$$\begin{cases} 1:\begin{cases}(2p_1p_0+2q_1q_0+2r_1r_0-d_1-d_0)\times\underbrace{\sqrt{p_2^2+q_2^2+r_2^2-d_2}}_{A_2}\\ =(2p_2p_0+2q_2q_0+2r_2r_0-d_2-d_0)\times\underbrace{\sqrt{p_1^2+q_1^2+r_1^2-d_1}}_{A_1}\end{cases}\\ 2:\begin{cases}(2p_2p_0+2q_2q_0+2r_2r_0-d_2-d_0)\times\underbrace{\sqrt{p_3^2+q_3^2+r_3^2-d_3}}_{A_3}\\ =(2p_3p_0+2q_3q_0+2r_3r_0-d_3-d_0)\times\underbrace{\sqrt{p_2^2+q_2^2+r_2^2-d_2}}_{A_2}\end{cases}\\ 3:\begin{cases}(2p_3p_0+2q_3q_0+2r_3r_0-d_3-d_0)\times\underbrace{\sqrt{p_4^2+q_4^2+r_4^2-d_4}}_{A_4}\\ =(2p_4p_0+2q_4q_0+2r_4r_0-d_4-d_0)\times\underbrace{\sqrt{p_3^2+q_3^2+r_3^2-d_3}}_{A_3}\end{cases}\\ 4:\begin{cases}(2p_4p_0+2q_4q_0+2r_4r_0-d_4-d_0)\times\underbrace{\sqrt{p_1^2+q_1^2+r_1^2-d_1}}_{A_1}\\ =(2p_1p_0+2q_1q_0+2r_1r_0-d_1-d_0)\times\underbrace{\sqrt{p_4^2+q_4^2+r_4^2-d_4}}_{A_4}\end{cases}\end{cases}$$

Comprehensive calculation of four related equations above gets the following equations:

$$\underbrace{\begin{pmatrix} p_1A_3-p_3A_1 & q_1A_3-q_3A_1 & r_1A_3-r_3A_1\\ p_2A_4-p_4A_2 & q_2A_4-q_4A_2 & r_2A_4-r_4A_2\\ p_3A_1-p_1A_3 & q_3A_1-q_1A_3 & r_3A_1-r_1A_3\end{pmatrix}}_{B}\begin{pmatrix}p_0\\ q_0\\ r_0\end{pmatrix}=$$
$$\underbrace{\begin{pmatrix}\dfrac{[(d_1+d_0)A_3-(d_3+d_0)A_1]}{2}\\ \dfrac{[(d_2+d_0)A_4-(d_4+d_0)A_2]}{2}\\ \dfrac{[(d_3+d_0)A_1-(d_1+d_0)A_3]}{2}\end{pmatrix}}_{C} \quad (12)$$

When the condition of the establishment of the

$$\begin{cases}\begin{vmatrix} p_1A_3-p_3A_1 & q_1A_3-q_3A_1 & r_1A_3-r_3A_1\\ p_2A_4-p_4A_2 & q_2A_4-q_4A_2 & r_2A_4-r_4A_2\\ p_3A_1-p_1A_3 & q_3A_1-q_1A_3 & r_3A_1-r_1A_3\end{vmatrix}\neq 0\\ \begin{vmatrix} x_1-x_2 & y_1-y_2 & z_1-z_2\\ x_2-x_3 & y_2-y_3 & z_2-z_3\\ x_3-x_4 & y_3-y_4 & z_3-z_4\end{vmatrix}\neq 0\\ A_i=\sqrt{x_i^2+y_i^2+z_i^2-d_i}\end{cases},$$

can be used to calculate the coordinates of unknown nodes

$$\begin{pmatrix}p_0\\ q_0\\ r_0\end{pmatrix}=B^{-1}C \quad (13)$$

In there, $\begin{vmatrix} x_1-x_2 & y_1-y_2 & z_1-z_2\\ x_2-x_3 & y_2-y_3 & z_2-z_3\\ x_3-x_4 & y_3-y_4 & z_3-z_4\end{vmatrix}\neq 0$, representation of spatial 4 nodes location is not coplanar, the signal strength *E(D)* is adjusted to the center, four node adjusting distance:

$$d_j=10^{\left(\frac{P(d_0)-\left|RSSI_j-E(D)\right|+\delta}{10\eta^*}\right)},1\le j\le 4 \quad (14)$$

The unknown nodes around the closest common spherical four anchor nodes coordinate information, with the help of angle equation of spherical, indirect equivalent to adjust the four anchor nodes to the unknown nodes on the surface of the sphere, used to adjust the positioning algorithm to calculate the coordinates of the unknown node information. The following to the adaptive adjustment of three-dimensional localization algorithm for calculating interference spherical (SAA):

1) The cluster coordinator command to each anchor node to multicast location

2) Each anchor node to the other anchor nodes multicast environment noise test signal, using the position of anchor nodes to obtain environmental parameters $P(d_0)$ and environmental signal attenuation coefficient η;

3) In the communication range of each anchor nodes S_i broadcast signal $A^{(i)}$;

4) In the communication range of each anchor nodes broadcast signal;

5) The anchor node information signal $A^{(i)}(id,RSSI,X,Y,Z)$ each unknown node records at the maximum communication range;

6) The unknown nodes calculate and record the related non coplanar 4 anchor node information sequence;

7) The unknown node based on ASA algorithm, get four space closest anchor node spherical information and distance expectations $E(D)$, adjustment calculation of each anchor node value $\Delta_i=\left|E(D)-d_i\right|$;

8) Based on the spherical tangent, use the Formula (13), (14) adjusting and positioning the unknown node position.

If the execution of positioning at the beginning of the process, there has not four anchor nodes within the communication scope around the unknown nodes, then sleep for a period of time, waiting for the anchor nodes or positioned nodes in communication range to achieve four, then the implementation of the above algorithm.

4. The Results of Experiment and Theory Analysis

The method effectively through the matlab7.0 programming tool for WSN network 3D orientation data analysis and precision comparison experiment. Space simulation test for the hypothesis is $100m \times 100m \times 100m$. In this region are respectively according to the proportion of anchor nodes and unknown nodes generate. Because of the anchor nodes and unknown nodes are randomly distributed, and the communication radius R, 25 m, 35 m, in the space of 200 sensor nodes randomly deployed, of which the proportion of anchor node number by 10 % to 80 % density is calculated to get the location of the unknown. We can measure the quality of positioning using normalized localization error AVG_ER .

$$AVG\_ER = \frac{\sum_{i=1}^{N} \sqrt{(\tilde{x}_i - x_i)^2 + (\tilde{y}_i - y_i)^2 + (\tilde{z}_i - z_i)^2}}{N \times R} \times 100\% \tag{15}$$

It is the estimated coordinates of an unknown node values $\tilde{x}_i, \tilde{y}_i, \tilde{z}_i$, and $x_i y_i z_i$ is the real coordinates of unknown node S_i . N is required for positioning a number of unknown node, R node communication radius. In addition, the use of VAR repeatedly said positioning standard deviation: $VAR = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(E_i - AVG\_ER)^2}$ used to show the degree of consistency of algorithm. The use AVG_ER and VAR analysis of positioning methods, the average localization error AVG_ER is small, the positioning accuracy is higher; the positioning standard difference VAR is small, consistent better positioning method. The Fig. 5 and Fig. 6 analyze the sparse anchor node (less than 10 %) when the positioning error of SAA method compared with the use of RSSI positioning accuracy by means of maximum likelihood estimation and Trilateral Measurement difference.

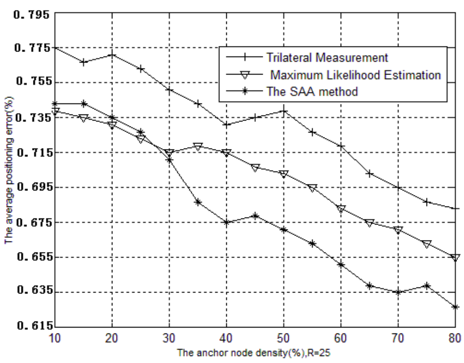

Fig. 5. The average position error compared with different positioning method (R=25).

After analyzing the results we know when the anchor nodes is sparse the error of SAA method is less accuracy than RSSI methods because where is not enough anchors to directly calculate the unknown nodes. When the anchor node density is greater than 30 % (density R=35) and 40 % (density R=25), the average localization accuracy than the RSSI method increased 10 %, Trilateral Measurement and Maximum Likelihood Estimation is improved about 9 %, 12 %.

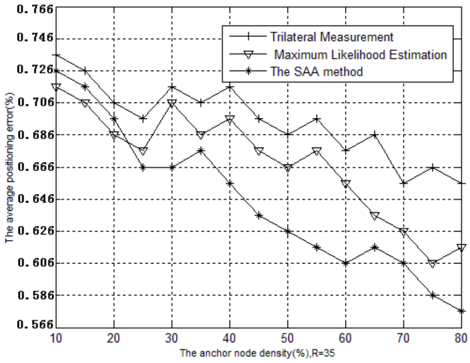

Fig. 6. The average position error compared with different positioning method (R=35).

With the increasing communication radius, SAA method has a significant improvement in positioning accuracy. In the positioning error consistency on the SAA method than the other three methods have obvious advantages, the anchor node density increases more stable and consistent; and the RSSI methods are sensitive to noise, Maximum Likelihood Estimation has improved, but in contrast to the SAA method, consistency needs further improvement. The different standard positioning method of contrast is shown in Fig. 7.

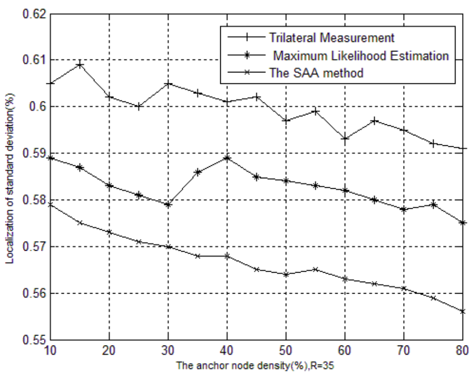

Fig. 7. Different standard positioning method of contrast.

After comparison with other methods in measuring location in simulation, the implementation of positioning test this method in a real environment with precision, $zstack-cc2530$ protocol stack for embedded software development environment of wireless sensor network node, the experimental equipment using Wuxi FanTai technology company as the test tool. Wireless sensor network will take GPS hardware sensors, router and coordinator, according to cluster topology deployment of three-dimensional space $20m \times 20m \times 10m$ on the hillside environment, the deployment of 10 sensor nodes are all anchor nodes, in all anchor nodes choose the 5 node A, B, C, D, E as the unknown node positioning experiment, the estimated value of the corresponding with the actual value error rate $error$ is expressed by the following equation:

$$error = \frac{1}{R}\sqrt{(\hat{x}-x)^2+(\hat{y}-y)^2+(\hat{z}-z)^2} \times 100\% \qquad (16)$$

The error rate $error$ of the smaller the better, different location error rate comparison table as shown in the following Table 1.

Table 1. Positioning of different positioning method of error rate.

No.	Node coordinates	Trilateral Measurement	Maximum Likelihood Estimation	The SAA method
1	A(2,3,6)	0.451	0.356	0.202
2	B(7,9,10)	0.567	0.423	0.283
3	C(7,8,7)	0.432	0.415	0.358
4	D(5,1,10)	0.787	0.702	0.622
5	E(9,9,3)	0.852	0.839	0.742

By comparing Table 1 results found Gauss filtering method of SAA positioning method in practical environment than RSSI method, Bayesian methods, increase the improvement.

5. Conclusions

This paper proposes the use of three-dimensional positioning method for adjusting range and calculation of node coordinates two step adaptive anchor node spherical measuring intensity signal based on RSSI, the location phase using the existing location information of anchor nodes adaptively obtained signal disturbance attenuation and other factors, using Gauss filtering to obtain more accurate distance between unknown nodes and anchor nodes. In the positioning stage calculation node position, the unknown nodes around the closest co spherical four anchor nodes coordinate information, adjust the four anchor nodes to the same spherical coordinates using the equation, and adjust the positioning algorithm to calculate the coordinates of the unknown node information. From the theoretical and experimental analysis, has been significantly improved in the positioning accuracy, in the actual application is feasible. We will work to further improve the positioning precision of the method, communication and computation cost reducing the localization process.

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