A Localization Protocol for Mobile Node Positioning in Wireless Sensor Network

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ABSTRACT: *In this paper a localization algorithm is proposed to find the location of mobile in presence of multipath effects. In proposed algorithm distance and angle of bearing are calculated of mobile node. Multipath fading generates the error to locate the mobile node. Scattering and diffusion are two major types of multipath that causes significant diversion in angle of received signal, hance it gives inaccurate position of the mobile node. So to overcome this error a localization algorithm is proposed here that reduces the error and gives position of the mobile node with average error of 0.5863.*

Keywords— Angle of bearing, Diffusion, Lateration, Multipath fading, RIPS, Scattering

I: Introduction

Wireless Sensor Network can be considered as an intelligent system which maintains its all movement itself to complete a task. Due to infrastructure less networks, nowadays from home appliances to high level application, military etc., WSNs are used very frequently worldwide. Wireless Sensor Networks (WSNs) are most useful networks to find out the location of any object. To find out location of the object many methods are available. They are limited to expense and multipath effect. In the case of mobile node it generates Doppler shift and multipath fading effect. Therefore an alternative algorithm is required that avoid the error.

Multipath arises from due to delayed versions of the signal and hence number of travelled paths available at the receiver. Scattering multipath and diffusion multipath are two main types of multipath. The radio signal undergoes scattering that are characterized by a large number of reflections by objects near the mobile node. Due to this, each major path behaves as a discrete fading path. In diffusion multipath signal reflects from smooth surface so received signal is totally out of phase of original signal so it makes significant error in positioning.

The relative motion between the transmitter and receiver causes Doppler shifts. Scattering typically comes from many angles around the mobile. These factors cause a range of Doppler shifts, known as the Doppler spectrum. The maximum Doppler shift corresponds to the scattering components whose direction exactly opposes the mobile's trajectory. Taking in account all above parameters new method is required to be developed.

II: BACKGROUND

All available methods for location finding has limitation like expense, large memory allocation, multipath effect etc. algorithm presented here is to avoid these limitations and that work for find location of moving node in presence of multipath fading in WSNs.

RIPS (Radio Interferometric Positioning System) method is RF ranging method in which three nodes are placed as shown in figure 1. Two node work as transmitter and transmits at very close frequency [5], [9]. The beat signal of these two signals can be measured by any low cost RF receiver. Third node and target node (moving node) work as receiver. This method measures distance by following formula,

$$d_{A_1}RM = \frac{\Delta\phi\lambda}{2\pi} \tag{1}$$

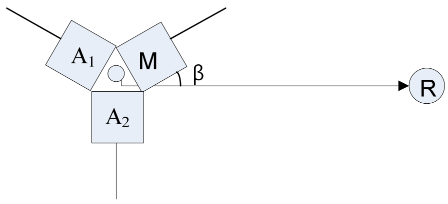

Fig 1. Array containing two transmitting nodes M and A_1 and two receiver nodes A_2 and R.

Where, $d_{A_1}RM$ is distance of target node R with respect to A_1 and M. $\Delta\phi$ is phase difference measured by the receivers. λ is wavelength of beat signal. This equation gives the distance parameter. Now to calculate angle of bearing β is estimated. Consider the above arrangement of figure 1 in t-range hyperbola as shown in figure 2 to find β [1], [4].

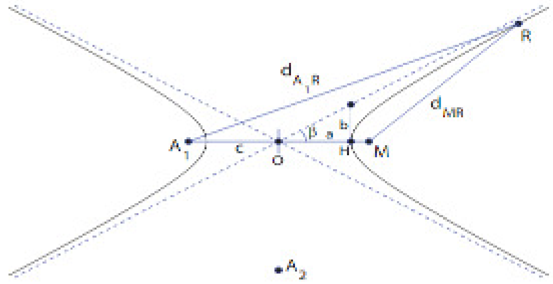

Fig 2. The t-range defines a hyperbola that intersects target node R, and whose asymptote passes through the midpoint of the two transmitters in the array, A_1 and M.

Angle of bearing is defined as,

$$\beta = \tan^{-1}\left(\frac{b}{a}\right) \qquad (2)$$

Where, $a = \frac{d_{A_1RM}}{2}$, $b = \sqrt{c^2 - a^2}$ and $c = \frac{d_{A_1M}}{2}$

t-range defines the arm of a hyperbola that intersects the position of target node M, and whose asymptote passes through the midpoint of the line $\overline{A_1M}$, connecting the primary and assistant nodes.
RIPS method is limited to find distance and angle of bearing of mobile node and there is no mechanism to overcome error in case of wrong distance is measured. So another method is used to that is able to calculate error. This method is Lateration method. there are n anchors with known positions (x_i, y_i), i = 1,..., n, a node at unknown position (x_u, y_u), and perfect distance values r_i , i = 1,..., n. From the Pythagoras theorem, a set of three equations follows:

$$(x_i - x_u)^2 + (y_i - y_u)^2 = r_i^2 \qquad \text{for } i = 1,..,n \qquad (3)$$

For particular case of three nodes arrangement is shown in figure 3.To solve this set of equations, it is more convenient to write it as a set of linear equations in x_u and y_u. To do so, the quadratic terms x_u^2 and y_u^2 have to be removed. This can be achieved by subtracting the third equation from the two previous ones, resulting in two remaining equations:

$$(x_1 - x_u)^2 - (x_3 - x_u)^2 + (y_1 - y_u)^2 - (y_3 - y_u)^2 = r_1^2 - r_3^2 \qquad (4)$$
$$(x_2 - x_u)^2 - (x_2 - x_u)^2 + (y_2 - y_u)^2 - (y_2 - y_u)^2 = r_2^2 - r_3^2 \qquad (5)$$

Rearranging of terms results in

$$2\times (x_3 - x_1)\, x_u + 2(y_3 - y_1)\, y_u = (r_1 - r_3)^2 - (x_1 - x_3)^2 - (y_1 - y_3)^2 \qquad (6)$$

$$2(x_3 - x_2)\, x_u + 2(y_3 - y_2)\, y_u = (r_2 - r_2)^2 - (x_2 - x_3)^2 - (y_2 - y_3)^2 \qquad (7)$$

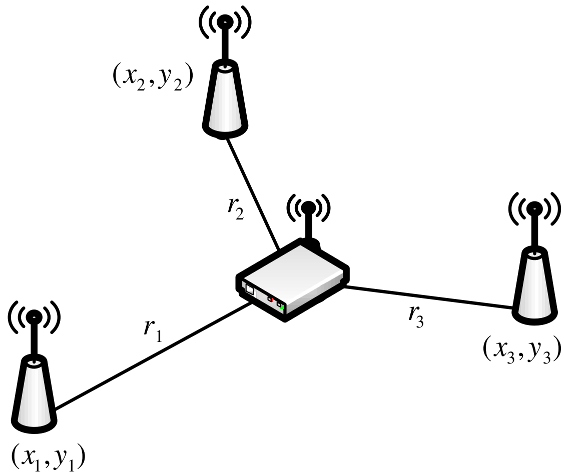

Fig.3. Lateration method using three anchor nodes

Rewriting as a linear matrix equation,

$$2\times\begin{bmatrix}(x_3 - x_1) & (y_3 - y_1)\\ (x_3 - x_2) & (y_3 - y_2)\end{bmatrix}\begin{bmatrix}x_u\\ y_u\end{bmatrix} = \begin{bmatrix}(r_1 - r_3)^2 - (x_1 - x_3) - (y_1 - y_3)\\ (r_2 - r_3) - (x_2 - x_3) - (y_2 - y_3)\end{bmatrix} \qquad (8)$$

Using these equations we can find the position of unknown node. Now due to multipath effects, distance measured will be not accurate, this makes error in position of the target node. Therefore to overcome this problem, Lateration method is used that minimizes the mean square error for such error. The square of the 2-norm is taken and denoted by $\left\|Ax - b\right\|_2$.

Where,
A is an n-1×2 matrix of value 2 × [$(x_n - x_j)$ $(y_n - y_j)$],

b is an n-1 row matrix with value,
$\left[(r_j^2 - r_n^2) - (x_j^2 - x_n^2) - (y_j^2 - y_n^2)\right]$.

Where, j=1 to n-1 and $x = \begin{bmatrix}x_u\\ y_u\end{bmatrix}$

Observe that for any vector t, $\left\|t\right\|_2^2 = t^T t$. Hence,

$$\left\|Ax - b\right\|_2^2 = (Ax - b)^T (Ax - b) = x^T A^T A x - 2x^T A^T b + b^T b \qquad (9)$$

It can be simplified as below:

$$A^{T}Ax = A^{T}b \qquad (10)$$

This equation is called normal equation and solved using QR factorization. It gives some value for x_u and y_u which is later used to calculate mean square error. If x_{ur} and y_{ur} are true position coordinates than error is obtain by following equation,

$$\left((x_u - x_{ur})^2 + (y_u - y_{ur})^2 \right)^{1/2} \qquad (11)$$

Now it seen that as increasing the number of anchor node error is minimized. Using this algorithm error is minimized [2].

III: PROBLEM FORMULATION

There are number of method to find localization for mobile node but some method required expensive devices and due to lack of resources in WSNs it is necessary to develop new method for localization that is robust and work in all the environment like multipath fading, Doppler shift etc.

IV: PROPOSED METHOD

In proposed method several methods are combined and new algorithm is developed to calculate accurate position of mobile node in multipath environment. Algorithm shown in figure 4 is used to calculate reference parameters.

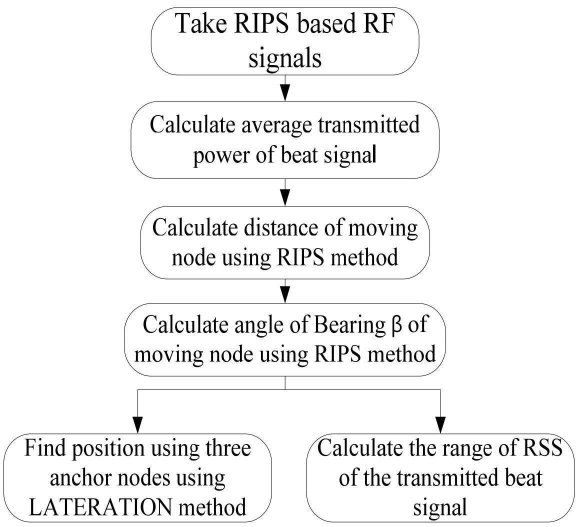

Fig.4. Algorithm to calculate reference parameters

In this algorithm first RIPS method based signals are taken. This method is described in above section. Second stage is to calculate the average transmitted power of the signal. This parameter is used later to calculate the Received Signal Strength (RSS) of the signal.

Then distance from mobile node is obtained from equation (1) and angle of bearing from equation (2). Last step is to find position of mobile node using Lateration method with the use of three anchor nodes. RSS of received signal is given by Friss' transmission formula it is given in following equation [3],

$$P_r = \frac{P_t}{\left(\frac{4\pi R}{\lambda} \right)^2} \qquad (12)$$

Where, Pr is received signal strength, Pt is transmitted power, λ is wavelength of the signal and R is distance measured by RIPS method. Range of RSS is defined so that other signal having RSS of outside of defined range are rejected and counted as wrong signal. Thus figure 4 is summary to calculate reference parameters like distance, angle of bearing, RSS range and position.

Now signal with multipath effect is shown here by passing it to Rayleigh channels. Therefore due to the multipath fading there will be error to find distance and hence error in position of mobile node. So here algorithm is such designed to reduce this error. It combines several methods and have several steps to find accurate position in multipath environment. This is shown in figure 5.

Here algorithm starting with taking n number of anchor nodes. These anchor nodes are set of two transmitters and one receiver as described in RIPS method. In next step pass all signals through Rayleigh channel. Then average RSS of that particular channel is obtained. If obtained RSS comes in the range of reference RSS then only that channel will be taken account, otherwise that channel will be rejected and assumed that this channel is highly affected by noise or multipath fading effect. So that channel will not be used to calculate position of mobile node and algorithm switch to next Rayleigh channel and check for RSS range of it and same process will be repeated. So here threshold for channel selection is given in the proposed algorithm.

Now we have selected the proper channel so in next step distance from mobile node to each anchor node is calculated using equation (12) it gives wrong distance due to multipath effect. Further from equation (2) angle of bearing will be obtained which is affected by multipath effect so it has not accurate measurement but due to less error channel is selected angle of bearing here will be close to original angle of bearing.

In next step Lateration method is used to calculate position of mobile node. Formula given in equation (3) and (10) calculates the position and is later compared to original position of the mobile node. Error in positioning can find with the equation (12). Now error must be negligible due to channel is selected with less error. If it error is not negligible than just increase the number of anchor nodes and repeat whole process again as described above. When error is negligible then algorithm is ended.

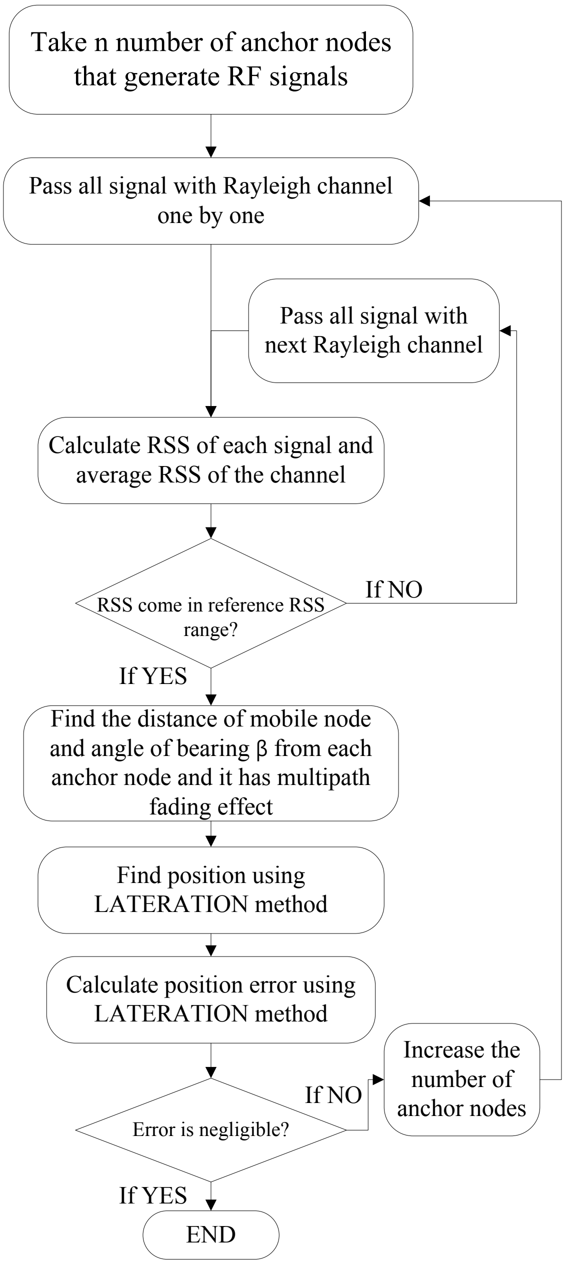

Fig.5. Proposed algorithm for accurate positioning

V: SIMULATION RESULTS

For simulation three anchor nodes are taken which generates signal of 2.4GHz and its near frequencies. First reference parameters are calculated from algorithm shown in figure 3. Values are shown in table 1. A1, A2 and A3 are reference anchor nodes with x and y coordinate (2, 1), (5, 4) and (8, 2) respectively. RSS and position are measured in ideal condition.

Now, same signals are passed through Rayleigh channel and gets multipath fading. So measured distance is not correct and hence there is error in finding position. Here, four Rayleigh channels are used and all anchor nodes are passed through each Rayleigh channel one by one. For each channel distance and position are measured. Error in positioning is calculated summarized in table 2. As we increase the number of anchor nodes error in positioning is decreased summarized in table 3.

Parameter name	Value		
Distance from mobile node to particular anchor node	A1	A2	A3
	1.41	0.67	2.89
RSS (dB)	0.0173		
Angle of bearing (β)	41.8730		
Average transmitted power (dB)	27.01		
Position of target node	x_u	y_u	
	4.0397	3.8918	

TABLE.1 Reference parameters

Channel		1	2	3	4
Distance	a1	1.2243	1.9764	1.9950	2.1822
	a2	0.6786	1.0955	1.1057	1.2095
	a3	2.9958	4.8362	4.8816	5.3399
Position	x	6.0365	5.5755	5.5613	5.4115
	y	4.5086	3.8612	3.8414	3.6310
Angle of bearing (β)		38.6120	42.8589	42.9012	43.2673
Error		**2.0899**	**1.5361**	**1.5225**	**1.3964**

TABLE.2 Distance, Position, Angle of bearing (β) and Error measurement in various channels

channel		1	2	3	4
Distance	a4	11.0018	17.8997	17.6839	18.6533
	a5	4.4499	7.2399	7.1526	7.5447
Position	x	4.3107	3.4076	3.4424	3.2829
	y	4.4117	1.7594	1.8616	1.3929
Angle of bearing (β)		37.9647	42.7122	42.6512	42.9069
Error		**0.5863**	**2.2241**	**2.1163**	**2.6110**

TABLE.3 Distance, Position, Angle of bearing (β) and Error measurement with four and five anchor nodes.

This error must be overcome for accurate positioning. Therefore in this algorithm only such channel will be consider which has RSS in range of reference RSS range. So on giving threshold it is possible to achieve channel that transmit with minimum error of 0.5863 with mobile node x and y coordinates 4.3107 and 4.4117 respectively.

VI: CONCLUSION AND DISCUSSION

The proposed method of localization is the combination of Diversity method, RIPS method and Lateration method such that it works in almost all environmental condition. It is also low cost localization algorithm.

With the more number of anchor node it gives better result for positioning. When Received signal strength not coming in the range of reference RSS repetitively that means, number of anchor nodes are not enough in the network or the distance is too large. By increasing number of anchor nodes more accurate results are achieved.

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REFERENCES

[1] I. Amundson, X. Koutsoukos, J. Sallai, and A. Ledeczi, "Mobile Sensor Navigation using Rapid RF-based Angle of Arrival Localization," IEEE 17th conference on Real-Time and Embedded Technology and Applications Symposium (RTAS), 2011 .

[2] Holger Karl and Andreas Willig, "Protocols and Architectures for Wireless Sensor Networks", John Wiley & Sons Ltd, 2005.

[3] Guoqiang Mao and Barış Fidan, "Localization Algorithms and Strategies for Wireless Sensor Networks", Information Science Reference, 2009.

[4] I. Amundson, J. Sallai, X. Koutsoukos, and A. Ledeczi, "Radio interferometric angle of arrival estimation," in Proceedings of the 7th European Conference on Wireless Sensor Networks (EWSN), vol. LNCS 5970. Springer, 2010.

[5] M. Mar´ oti, B. Kus´ y, G. Balogh, P. V¨ olgyesi, A. N´ adas, K. Moln´ ar, S. D´ ora, and A. L´ edeczi, "Radio interferometric geolocation," Proceedings of the 3rd International Conference on Embedded Networked Sensor Systems (SenSys), 2005.

[6] Amundson, X. Koutsoukos, and J. Sallai, "Mobile sensor localization and navigation using RF doppler shifts," in Proceedings of the 1st ACM International Workshop on Mobile Entity Localization and Tracking in GPS-less Environments (MELT), 2008.

[7] Mohammad A. Matin, "wireless sensor networks technology and protocols", Institut Teknologi Brunei, Brunei Darussalam.

[8] Kazem Sohraby, Daniel Minoli and Taieb znati, "Wireless Sensor Networks - Technology, Protocols, and Applications", John Wiley & Sons Ltd, 2007.

[9] B. Kusy, A. Ledeczi, M.Maroti and L.Meertens, "Node-Density Independent Localization", In Proc. of IPSN/SPOTS,Apr. 2006.