A Localization Algorithm for Mobile Sensor Navigation in Multipath Environment

Nehal M. Shyal and Rutvij C. Joshi

Abstract: In this paper new algorithm is proposed for localization of moving nodes in Wireless Sensor Networks (WSNs). Multipath is major challenge to find location for a moving node in WSNs. Proposed method combines several methods to overcome multipath error for finding position of a mobile node. Error is minimized based on threshold of RSS of each received channel. Simulation is done with Rayleigh channel and it enables to select the minimum error channel and finds accurate position with average error of 0.0691.

Keywords: **Localization, Multipath fading, RIPS, Lateration**

I. INTRODUCTION

There has been growing keen interest for research in Wireless Sensor Networks (WSNs) and utilizing its technology. One of the major applications of WSN is to find out the location of any object. The term *Localization* defines the process to find location of any object in the network. In wireless sensor Network, numbers of methods are available for the localization of static nodes but the same process becomes challenging and difficult for mobile nodes. In the case of mobile sensor node it generates Doppler shift and multipath fading effects, which are major sources of the localization error in wireless sensor network. In wireless sensor network, to describe characteristics of the fading channels mainly two channels may used Rayleigh channel and Rician Channel. Rayleigh and Rician fading channel includes multipath effects, time delays, and Doppler shifts that arise from relative motion between the transmitter and receiver during wireless communication. There are number of travelled paths due to delayed versions of the signal at the receiver. In addition, the radio signal undergoes scattering that are characterized by a large number of reflections by objects near the receiving mobile node. These components combine at the receiver and give *multipath fading effect*. Due to this, each major path behaves as a discrete fading path. The fading process is characterized by a Rayleigh distribution for a non line-of-sight path and a Rician distribution for a line-of-sight path. 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. All these effects generate error in localization of the sensor node, taking in account all above effects, new algorithm is required to be developed which can work robust in multipath environment.

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II. RELATED WORK

We are unable to accurately report the faulty position without localization capability of the WSN. In contrast to other type of networks, e.g., Internet, a prominent difference is that WSNs are location-based networks.

Several small-profile sensing devices that are able to control their own movement have already been developed. These sensors are large, expensive, have considerable power requirements, and/or require a powerful computing platform to analyze sensor data. In recent years, mote-sized mobile sensor platforms have been developed that are unable to use traditional navigation methods because of their small size and limited resources [1], [2], [3], [4]. For example, although GPS receivers are available for mote-scale devices, its relatively high cost often makes it not practical to apply GPS to all sensors in a network.

There are mainly two classes of localization approaches for WSNs: one is pre-localization and the other one is self-localization. The pre-localization method measures the position of sensors in the deployment stage. After the deployment and position measurement, the position is stored in the memory of the sensor. For this method, any movement of the sensors will result in errors in the location information. Differently, the self-localization method computes the locations of each sensor based on real-time measurements and therefore is robust to the variance of the environment [5]. However, the Non-GPS localization schemes are more practical for WSNs. There are main two categories. First category is Hardware-dependent algorithms need sensor hardware to provide information such as signal strength includes devices like received signal strength (RSS) and second category is Topology-dependent algorithms for localization do not need hardware support but do require support from special “seed nodes,” with exact knowledge of their location [6].

There are numerous methods for position finding, among them RIPS method is more popular in WSNs. RIPS do not require additional hardware support [7]. Position estimation is obtained using a localization technique developed that combines radio interferometric angle-of-arrival estimation [8] with least squares triangulation [9].

Now for navigation of mobile sensor control is done using PI controller presented in [10]. Both wheels will be set with an equal desired base speed. If heading error exists, the controller will minimize it by turning one wheel faster than the base speed, and the other wheel slower, which will result in the mobile node turning in the correct direction as it moves forward. This type of controller has low run-time complexity and does not require a substantial amount of memory. Error calculation shows with digital compass, even a compass heading error as high as 5^o does not contribute significantly to the position error. For a smaller range of angles between 0^o and 20^o in a rural area where no multipath effects are present other than ground reflections obtained data are similar to the predicted values [11].

II. PROBLEM STATEMENT

To set energy efficient schedule of a node, efficient localization algorithm is very important because of the limited resources like power, bandwidth and memory. This lead to develop new algorithm for localization of sensor node in multipath environment.

III. NETWORK MODEL

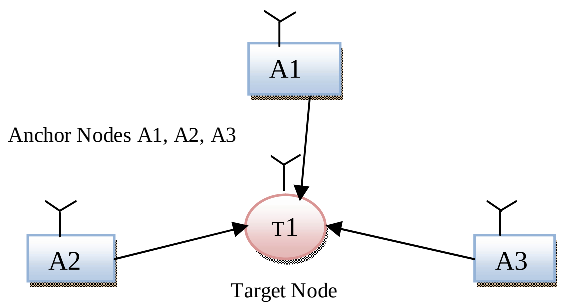

Figure.1. Network Model for Localization

As shown in figure 1, A1, A2 and A3 are anchor nodes which work as reference nodes in the network whose location is known and T1 is target node where location is to be find out.

All anchor nodes sends beacon signal to the target node from which target node may calculate its position by considering distance from respective anchor nodes. As discussed, due to multipath fading effect during wireless communication signal may undergo fading effect and proper data signal power may not reach to the target node and due to which exact position may not obtain. To overcome this problem diversity method is used. All available methods for location finding has limitation like expense, multipath effect etc. Localization protocol presented here is to avoid these limitations and that work for find location of moving node in presence of multipath fading in WSNs.

This model is combination of several methods like RIPS and Lateration Method. **RIPS** (Radio Interferometric Positioning System) method is RF ranging method in which three nodes are placed as shown in figure 2. A_1 and M are transmitting nodes and transmits RF signals with nearly close frequency. A_2 and R are receiving nodes. Average transmitted power of beat signal is calculated as reference power. Two node work as transmitter and transmits at very close frequency [13]. 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,

$$d_{A_1RM} = \frac{\Delta\phi\lambda}{2\pi} \qquad (1)$$

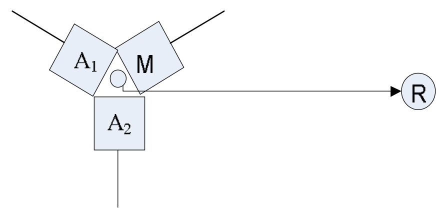

Figure.2. Array containing two transmitting node M and A1 and two receiving node A2 and R.

Where, d_{A_1RM} 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.

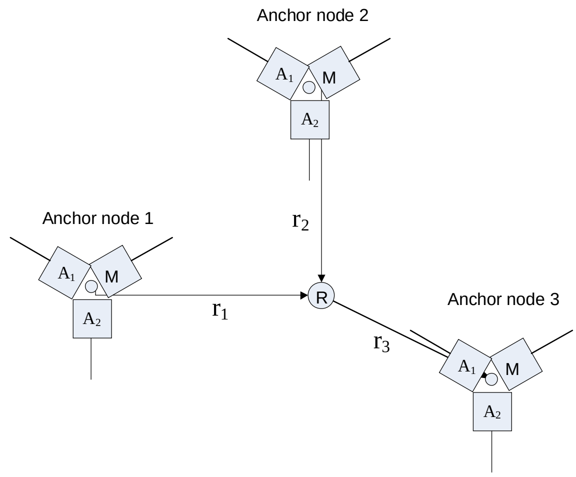

Figure.3. Network Model to calculate location of target node R using three anchor nodes.

RIPS method is limited such that it finds distance of the node only. Another method is used here which finds the coordinates of the node based on some anchor nodes. An anchor node is set of array of three nodes as shown in figure 3. Using this model distance from each node is measured. In Lateration method, position of anchors is predefined, and its distance from the node is calculated in above step. So, for find position, **Lateration** method uses following formula to find the target node position [12],

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

Where, x_i and y_i are x and y coordinate of i^{th} anchor node respectively, x_u and y_u are x and y coordinate of target node respectively and r_i is the distance from i^{th} anchor node to target node. So this whole algorithm gives reference parameter like average transmitted power, distance, and range of RSS (Received Signal Strength) and position of the target node. Figure 4 shows the summary of steps for finding reference parameters.

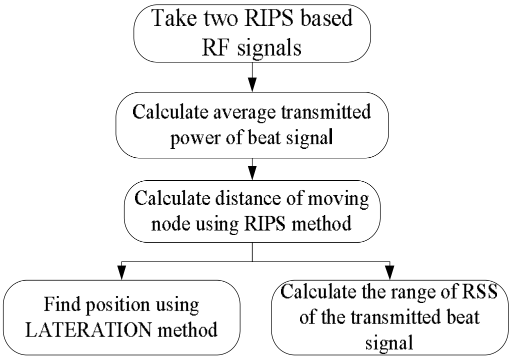

Figure.4. steps flow for calculating reference parameters

IV. PROPOSED METHOD

In figure 5 proposed algorithms for location finding is shown. Number RF signals are taken that is equal to double of the reference anchor nodes. The set of beat signal is generated from n anchor nodes that are passed through n number of Rayleigh channel to characterized multipath effect in transmitted signal. This scenario is shown in figure 5.

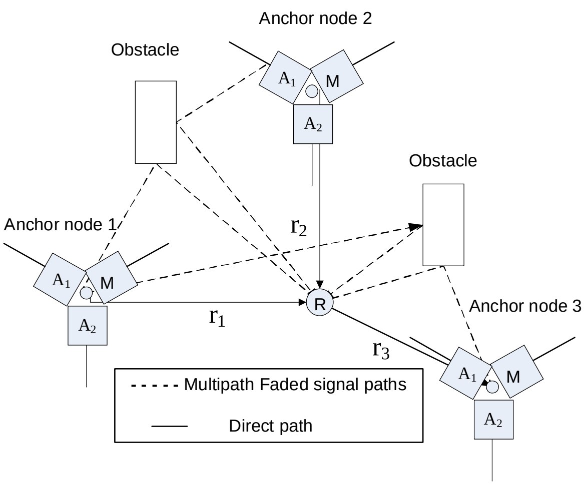

Figure.5. Network Model that generate multipath fading environment

After giving multipath effect, calculate the Received signal strength of all the signals at that channels from Friss' transmission formula,

$$P_r = \frac{P_t}{(4\pi R/\lambda)} \qquad (3)$$

Where, P_r is received signal strength, P_t is transmitted power, λ is wavelength of the signal and R is distance measured by RIPS method. If RSS comes in the range of reference RSS then that channel only will be selected for further process and other channels will be rejected. After selecting channel, position of the sensor node is calculated using Lateration method from equation (2). 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 $\|Ax - b\|_2$.

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

b is n-1 row matrix with value $[(r_j^1 - r_n^2)(x_j^2 - x_n^2)(y_j^2 - y_n^2)]$.
Where, j=1 to n-1 and $x = \begin{bmatrix} x_u \\ y_u \end{bmatrix}$.

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

$$\|Ax - b\|_2^2 = (Ax - b)^T (Ax - b) = x^T A^T A x - 2x^T A^T b + b^T b \qquad (4)$$

It can be simplified as below:

$$A^T A x = A^T b \qquad (5)$$

This equation is called normal equation and solved using QR factorization. Using this algorithm error is minimized. If error that is calculated in last step is not negligible than increase the number of anchor nodes from three to four and so on and repeat the whole process until error become negligible.

Figure 6 shows the summary of steps of the proposed algorithm.

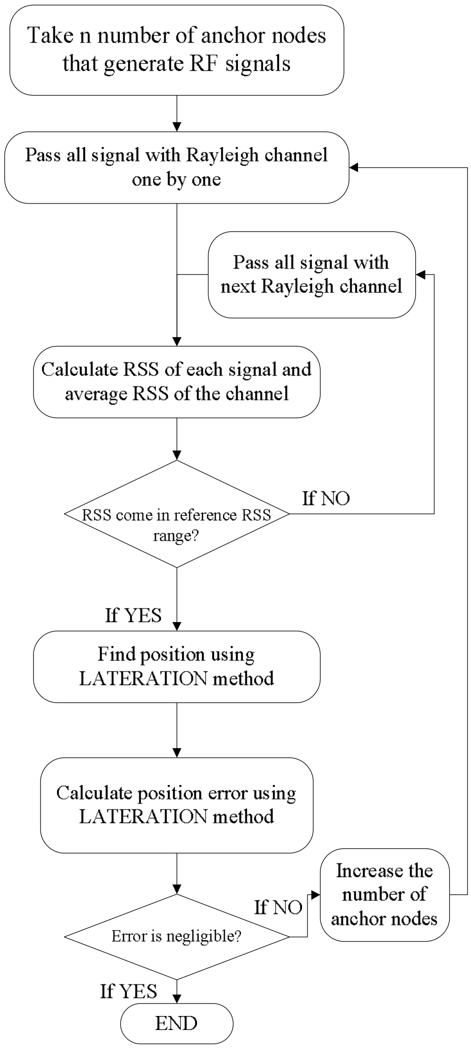

Figure.6. steps flow for calculating position of moving node in multipath environment

V. SIMULATION RESULTS

For simulation three anchor nodes are taken which generates signal of 2.4GHz and its near frequency. First reference parameters are calculated from algorithm shown in figure 4. 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.

Parameter name	Value		
Distance	A1	A2	A3
	1.41	0.67	2.89
RSS (dB)	0.0173		
Average transmitted power (dB)	27.01		
Position of target node	xu		yu
	4.4074		1.8502

TABLE.1 Reference parameters

channel		1	2	3	4
Distance	a1	1.2245	1.2021	1.4177	2.1835
	a2	0.6882	0.7383	1.2260	1.0951
	a3	2.9569	3.4739	5.3506	3.1328
Position	x	4.3414	4.0077	2.4212	4.4764
	y	1.8295	2.1423	3.6633	2.1183
Error		0.0691	0.4951	2.6893	0.2769

TABLE.2 Distance, Position and Error measurement in various channels

This error must be overcome for accurate positioning. Therefore extension in this algorithm is given such that 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 0.0691 with mobile node x and y coordinate 4.3414 and 1.8295 respectively.

VI. CONCLUSION AND DISCUSSION

Frequency Diversity is the best method to overcome multipath fading effect. The proposed method of localization is the combination of Diversity method, RIPS method and Lateration method, so works in almost all type of noisy and harsh conditions.

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 may achieve.

The only problem with this method is near-far field effect when transmitter and receiver is very much nearer then diversity mechanism may fail and generate wrong information about the signal strength and localization method may fail.

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