International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 8, August - 2013

Fuzzy RSSI Based Localization in Wireless Sensor Networks

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***Abstract* – In the past decade the problem of Localization i.e location estimation in Wireless Sensor Networks (WSNs) has been an inevitable challenge and an unsolvable research problem. Localization plays an indomitable role as having a Global Positioning System (GPS) receiver on every sensor node increases the cost and hence cannot provide a feasible solution. Localization is broadly classified as range-based and range-free schemes. We have used Received Signal Strength Indicator (RSSI) based ranging localization technique which is distributed. The objective of this work is to find the position of unknown sensor nodes over the sensing region in a sensor network using three reference nodes known as anchors or beacons. We have developed an Fuzzy logic based Multilateration Scheme Localization (FLMSL) for finding the position of the sensor nodes that is randomly deployed over a 1000 * 1000 m^2 sensor area. Through simulation it is observed that FLMSL approach minimizes the positional errors and improves the Localization accuracy**

***Keywords*: Localization; Wireless Sensor Networks (WSNs); GPS; Fuzzy Logic based Multilateration Localization (FLMSL); mobile anchors; beacons;**

I. INTRODUCTION

In the recent years, the advent of Micro-Electronics and Wireless Communications proliferated to the development of multi-functional sensor nodes in a Wireless Sensor Network (WSN). A sensor node has the ability to sense, process and communicate over a shorter distance. Basically a wireless sensor network (WSN) consists of a number of sensor nodes that are densely deployed over the region of interest. The position information of a node is essential practically because sensing the data without knowing the location information of a node becomes meaningless. In a wireless sensor network, the location information of a node is significant as it has gained significant momentum especially for the applications such as tracking the position of an object, pollution monitoring, surveillance etc.

The Node Localization problem is viewed as finding the positional information i.e. spatial coordinates of all the nodes over a region of interest in a network. Localization becomes very critical when there is an uncertainty about the position of the nodes. Location information of a node lays the foundation [1] for all other applications such as routing, topology control, reporting the origin of events, coverage, node life-time control and target tracking. Node localization was initially done by adding Global Positioning System(GPS) to the nodes but it is quite unfortunate that adding GPS to all the nodes in a WSN environment leads to the following demerits:- (i) Cost factor increases. (ii) GPS cannot work in indoor environments or during the obstacles such as Line of Sight(LOS) obstructing the GPS satellites.(iii) GPS consumes more power thereby decreasing the battery power of individual nodes and hence reducing the life time of nodes in a sensor network.

In order to overcome these demerits, Node localization was done by configuring few nodes as reference nodes either manually or using GPS in order to determine the location of the remaining unlocalized nodes in the network. Basically there are three set of nodes namely anchor nodes, unlocalized nodes and localized nodes. The first set of sensor nodes whose positions are known i.e. reference nodes are termed as anchor (or) beacon (or) location aware nodes [2]. The second set of sensor nodes whose

positions are unknown are termed as unlocalized nodes. The third set of nodes contains nodes which were in the second set but subsequently had their positions estimated are termed as localized nodes. Localization algorithms are usually classified into range based and range free. Range based algorithms are based on distance or angle estimation techniques of unknown nodes to anchor nodes in the network. Then the anchor nodes will use this distance or angle estimate in order to find the position of unlocalized sensor nodes. The commonly adopted range based localization approaches [3] are Received Signal Strength (RSS), Time of Arrival (ToA), Time Difference of Arrival (TDoA) and Angle of Arrival (AoA).Range based schemes has higher location precision and for achieving fine accuracy, range based schemes allow the use of hardware, which is expensive. Range free approaches are based on the content of received messages [4] as they support coarse accuracy. Range free approaches use proximity or connectivity information for finding the position of unknown nodes in the network. The commonly adopted range free localization approaches are Centroid, Amorphous, Distance Vector (DV) - Hop and Approximate Point-in-Triangulation Test (APIT). Range free schemes do not involve the use of expensive hardware and has lower location precision, less accurate and less complexity.

In this paper, we describe a novel RSSI based range dependent localization algorithm, by placing the nodes and described the node movements by random waypoint algorithm,. Our objective is to determine the positioning of nodes based on RSSI using the rules formed by all the anchor nodes. The remainder of the paper is organized as follows. Section II provides a brief survey of the related works based on range based and range free localization. Section III explains the Fuzzy Multilateration Scheme RSSI based localization algorithm with regard to random (dynamic) WSN environment. Section IV provides the performance analysis of RSSI based Fuzzy Multilateration Localization Technique (FLMSL) for the WSN environment in comparison with Bayesian Filtering Technique (BFT). Section V provides the concluding remarks and discusses future directions.

II. RELATED WORK

Mayuresh M.Patil et.al [1] has proposed a distributed localization scheme based on Received signal strength Indicator (RSSI) by the three masters. The distance from three masters is determined and the unknown nodes can compute its location by using circular triangulation concept. Based on the simulation results, with regard to the localization error and power consumption, they have proposed and verified that the three master approach performs relatively much better than two master and one master approaches.

Frankie K.W.Chan, H.C.So et.al [6] has proposed a novel subspace approach of deterministic type for positioning the nodes in a WSN with the use of the node-to-node distance estimates, deduced from Received Signal Strength **(**RSS) or Time of Arrival (ToA) measurements. They have developed three versions of subspace algorithm for positioning the nodes in a WSN. They are full-set subspace algorithm, minimum-set subspace algorithm and distributed subspace algorithm.

Ji zeng Wang et.al [7] has proposed an improved Approximate Point-in-Triangulation Test (APIT) algorithm for location estimation in WSN. The improved APIT algorithm that is proposed in this work performs best when compared to the original APIT algorithm, based on the metrics such as high Node Packet Loss Rate and Node Density etc.

Wojciech Zajdel, Ben J.A. Krose et.al [8] has proposed a probabilistic framework designed for solving complex problems. From the series of noisy high-dimensional observations these problems recover meaningful low-dimensional state information. For the design of algorithms which deals with noisy data, the presented framework set a general pattern. They focus on on-line inference techniques i.e. Bayesian filtering.

III. FUZZY MULTILATERATION SCHEME

In this section, we describe the Fuzzy logic based Multilateration scheme for Localization (FLMSL) [1] with regard to mobile anchors in WSN environment. This algorithm is typically a range based distributed algorithm. FLMSL Localization algorithm works based on the following steps:-

1. Calculate the Received Signal Strength(RSS) of the signal send from the sensor node to the sink node. This gives the distance of the sensor node from the anchor node. Distance calculation from RSS is given by the Friis free space Transmission equation namely,

Pr = Pt Gt Gr λ^2 / (4πd) 2L, where Pr and Pt indicate the Received power and Transmitted power respectively in Watts. Gt and Gr indicate the gains of the transmitting and receiving antenna respectively. L indicates the system loss in dB, d indicates the Distance in metres and λ indicates the Wavelength in metres. The distance from the three anchors is found and the sensor node can then find its location.

2. Define the fuzzy input and output linguistic variables. The fuzzy input variables used here are { Weak , Medium , High}. The fuzzy output variables are { Far , Intermediate , Near}.

3. Once the Variables are defined, Fuzzy Rule is formed. The Rules contains an IF – THEN part where the IF part contains the INPUT linguistic variables and THEN part contains the OUTPUT linguistic variables. The Fuzzy Rules are listed below,

I. If RSSI is Weak then Distance is Far.

II. If RSSI is Medium then Distance is Intermediate

III. If RSSI is High then Distance is Near.

```
Node ID:3 Source ID:0 RSS STATE : WEAK
Distance: FAR(0.35 mtrs and Above)
Node ID:1 Source ID:0 RSS STATE : WEAK
Distance: FAR(0.35 mtrs and Above)
Node ID:4 Source ID:0 RSS STATE : HIGH
Distance: SHORT(Lesser than 0.25 mtrs)
```

The rules are framed based on the relation, “Signal strength Reduces as the distance increases”. This is due to the noise and interference present in the environment.

4. Once the Fuzzy Rules are framed, the next step is fuzzification. Bins are constructed using the fuzzy rules formed. Bins are represented in the form of a matrix where columns represent the fuzzy output variables and the rows represent the number of trials to consider for taking the average.

```
FUZZIFICATION Bins at Node:3
FAR RULE   MEDIUM RULE       WEAK RULE
0.477495    0.824751          0.931808
1.283515    1.790267          1.700715
1.037936    1.790118          1.912010
0.824680    2.376838          1.036349
1.151176    1.789935          0.825806
center of gravity
0.954961    1.714382          1.281338
```

5. Once the bins are constructed, the defuzzification process is carried out. Here we use Jacobi's defuzzifier technique. The value Dk for each anchor node is calculated using the formula.

$$D_k = (a,b,c) = \left(\left(\frac{\sum L_n}{|L|} \right)_x, (P_c)_x, \left(\frac{\sum G_n}{|G|} \right)_x \right) \quad \ldots(1)$$

Where the points P,L,G represent the fuzzy distance.

P – centroid of all points in a column C.
L – Centroid of all points in column C whose value is less than P.
G - Centroid of all points in column C whose value is greater than P.

```
Fuzzy distance
Dk(6.541133,6.584467,6.637800)
```

6. With the Dk value the fuzzified location of nodes (x , y) is found using Jacobi equation

X = { (P+(L-P) r , G-(G-L) r } ……… (2)
where r is the random value that ranges between 0 to 10.

7. Value of X = {x, y} obtained in step 6 is passed through series of iterations until it converges. The converged value gives the location of the sensor node.

```
Node ID:19
Round:1,14.000000
Parametric Form X(272.772608,99.224029)
Round:2,12.000000
Parametric Form X(284.772608,111.224029)
Round:3,11.000000
Parametric Form X(295.772608,122.224029)
Round:4,5.000000
Parametric Form X(300.772608,127.224029)
Round:5,1.000000
Parametric Form X(301.772608,128.224029)
```

IV. PERFORMANCE EVALUATION

We simulated the energy efficient localization technique on Network Simulator (version 2) widely known as NS2 [11], a scalable discrete-event driven simulation tool.

A. Simulation Model

The distributed coordination function (DCF) of IEEE 802.11 is used as the MAC layer in our experiments. It uses RTS and CTS packet. The values of the parameters used for simulation are as shown in Table1

Table 1: Simulation Parameters

Parameters	**Value**
Topology Size	1000 m X 1000 m
No. of sensor nodes	100,200,300,400,500
No. of anchor nodes	10 , 20 , 30 and 40
MAC layer	IEEE 802.11
Simulation Time	50 sec
Traffic Source	Constant bit rate(CBR)
Node Placement	Random waypoint
Packet Size	512 bytes
Transmit Power	360 mW
Receive Power	395 mW
Idle Power	1 mW
Initial Energy	5.1 Joules
Transmission Range	500m
Routing Protocol	Adhoc on-Demand Distance Vector (AODV)
Speed	10 m/sec

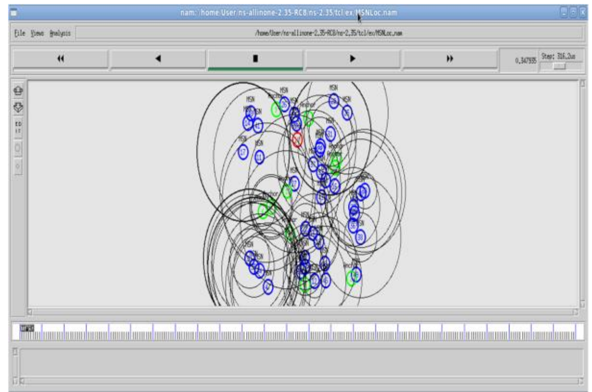

Fig 1. NAM window simulation showing the deployment of sensor nodes in WSN environment

V. RESULTS

The FLMSL is applied for the WSN environment as mentioned in the simulation parameter table and the result is obtained as follows.

Average end-to-end delay: The end-to-end delay is determined by calculating the average over all the surviving data packets from the source to the destination.

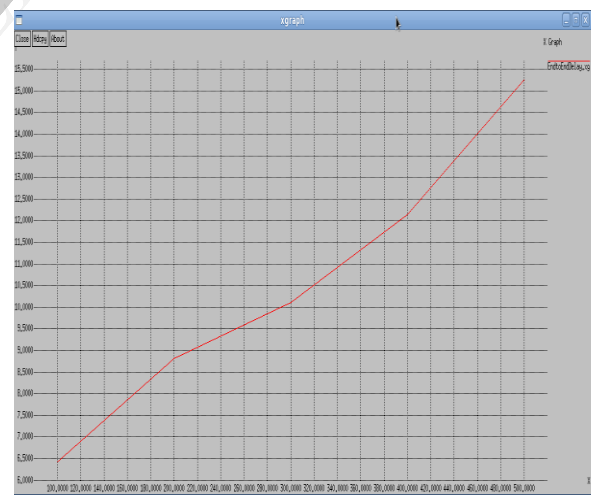

Fig 2. End-to-End Delay(ms)

Average Energy Consumption: The energy consumed by the nodes while receiving and sending the packets is noted and the average is taken and plotted.

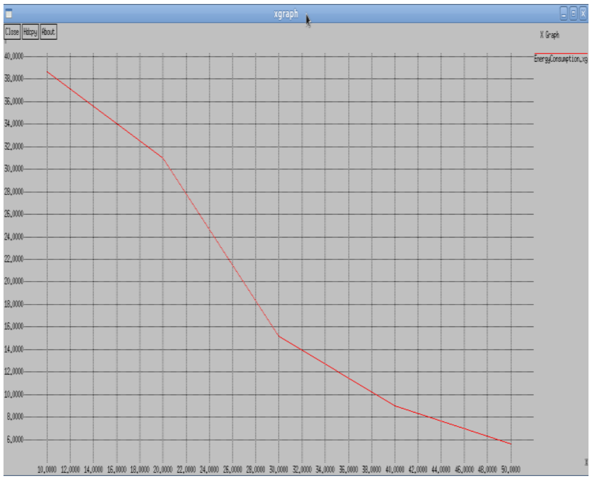

Fig 3.Energy Consumption per node(J)

Estimation Error: The difference between the actual location and calculated location of all the nodes is known as estimation error. The average is taken and plotted.

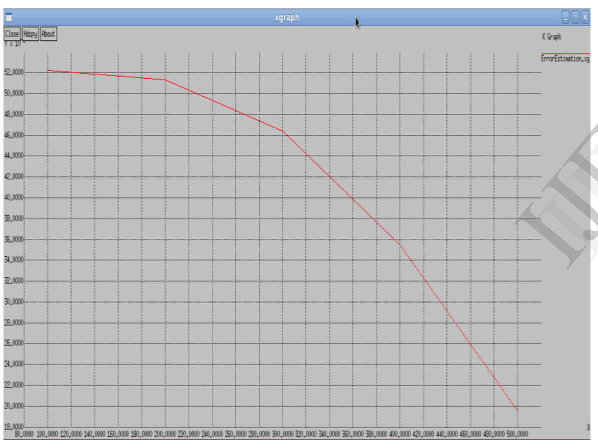

Fig 4. Error estimation analysis

No. of Sensor Nodes	No. of Anchor Nodes	Error Estimation
100	10	0.0540
100	20	0.0338
100	30	0.0311
100	40	0.0289

Table. 2. Error Estimation Calculation

Table 2 shows the error estimation calculation with the varying number of anchor nodes. Error estimation decreases, while increasing the anchor node which gives better centroid result and better convergence.

No. of Sensor Nodes	No. of Anchor Nodes	Error Estimation
100	20	0.0522
200	40	0.0513
300	60	0.0464
400	80	0.0355
500	100	0.0196

Table 3 Error Estimation with varying Sensor and Anchor Nodes

Control overhead: The total number of control packets exchanged is known as the control overhead.

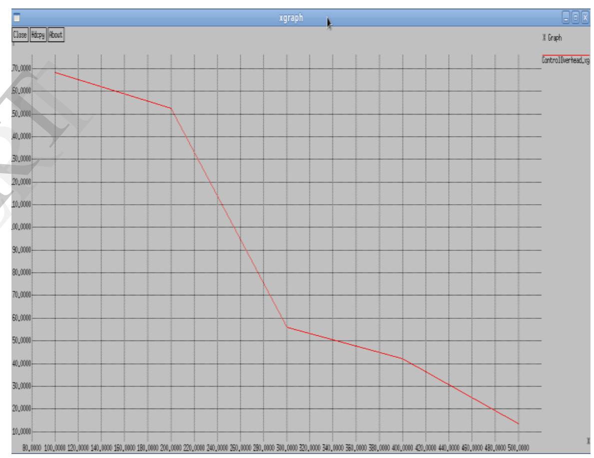

Fig 5.Control Over Head(Kbps)

V. CONCLUSION

In WSNs the localization has become an inevitable challenge [12] with regard to sensor nodes and is an emerging research as it is an unsolvable problem. The main goal of this work is finding the position of nodes at an unknown location using Location Aware or Anchor nodes. The analysis and simulation studies validate the effectiveness of our solution in incorporating sensor capacities of RSSI for the randomly deployed distribution of sensor nodes. This work can be further enhanced by applying optimization schemes [13] or using hybrid localization schemes with mobility models [14]. From the simulation results, we observe that the Fuzzy Logic Based Multilateration Scheme (FLMSL) gives better result in terms of increased localization accuracy by minimizing the positional errors with reduced energy consumption and control overhead.

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