Obstacle based Range-Free Localization-Error Estimation for WSN

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Abstract

The projected paper considers a range-free localization protocols for the wireless sensor networks that highlights the localization irrationality problem in presence of obstruction. Here in our proposed research work the mobile anchor node is assumed to have the evidence of their position where an interaction protocol is considered. The proposed enables the presence of relay nodes with the beacon signals for the better optimization techniques by using the coordination ordinary sensor nodes and mobile anchor nodes simultaneously. The impediment consequence in the form of obstacle were studied with the transmission irregularities with the radical change algorithm for computation the localization errors in the range free localization. The significance of the current work considers the diversification of Sensor network topology. The performance analysis executed in various scenarios and our model was compared with DV-Hop, APIT, ROCRSSI, and Amorphous techniques. A simulation result in comparison with the existing system projected outperforms for minimizing localization error even in presence of obstacle.

Keywords: *Distance Vector-Hop, Localization, Mobile Anchor Node, Optimization, Range-based, Range-Free based, Wireless Sensor Networks.*

1. Introduction

Estimating the node localization is an extremely significant task in this field. Node localization consider as one of the complicated issues in wireless sensor network. Localization is consider as the fundamental services that is analogous to various operations such as cluster creation, routing, communication, coverage of network etc. With the aid of Cooperation [1], localization can be achieved with the help of sensor nodes itself without any involvement of humans. The critical issues in WSN operation is to determine the substantial locus of the sensor nodes as the position information will be deployed to find the locus at which the sensor reading originates as well as in any energy aware geographic routing. Various researches [2] towards application of sensor network also found that position estimation is information of interest.

There were many algorithms on localization which has been discussed in past to provide localization information for every node. The protocols used in localization is classified into two categories e.g. range-based and range-free method, in relation to the methodology deployed for estimation of the sensor nodes position information. The range based method is defined by protocols that deploy the absolute point-to-point range estimates or estimation for position. The range-free based method constructs no assumption about the availability or validity of such information. The range-free localization is being considered as a cost-effective alternative to range-based methods because of hardware limitation of deployment of WSN devices. Irregularity in transmission propagation as well as stringent restriction on cost of hardware has rendered localization a very challenging. The range free localization is more capable and promising to achieve higher localization accuracy without introducing any extra hardware in comparison to range-based technique of localization which depends on received signal strength to calculate absolute point-to-point distance.

Range free localization technique deploys information related to network topology as well as connectivity status for evaluating location. Low cost, no extra hardware, little communication traffic as well as flexible precision in position estimation is some of the advantageous features of range-free methods. Therefore range-free technique is considered to be most effective solution for the localization issues in wireless sensor network.

In comparison to range-based approach, the range-free techniques facilitates sensor nodes to evaluate their position without depending on parameters like distance or angles [19] [3]. Such methodology normally requires various anchor nodes, that enable position unknown sensor nodes to estimate their position by using the radio connectivity data among the nodes, or by comparing their RSS feeds with those supplied by neighbour nodes.

Various research techniques related to arrival time difference, received signal strength, arrival time etc, has been already proposed [4] which also discussed about trilateration, maximum likelihood measurements methods. DV-Hop localization, APIT, Centroid localization, amorphous positioning etc is some typical algorithms. Based on the algorithm of DV-HOP, sensor nodes estimate their position based on the anchor positions, number of hops from anchor, and also the average distance per hop [4]. Amorphous positioning algorithm uses offline hop-distance estimations, improving location through a neighbor-information exchange [5].

Many localization schemes have proposed solutions which are based on assumptions may not valid in certain scenarios. Some of such assumptions observed as symmetric radio connectivity, circular radio range, absence of any obstacle, no line-of-sight, poor multipath and flat terrain [6]. Another research loophole in this area is lack of consideration of important parameters like deployment method of WSN, presence of reference points or anchor nodes, cost of localization, energy consumptions etc. As the sensor network is normally of static nature, so obtaining location information by each sensor node is often a challenging task.

The problem of localization in wireless sensor networks has been studied and evaluated predominantly in simulators. Due to the severe hardware constraints imposed on wireless sensor nodes, real system implementations of the proposed simulated solutions have not produced encouraging results. Solutions that use the most tempting means of evaluating relative distances between sensor nodes - RF signal strength, have largely failed in practice, due to the unreliable nature and irregular pattern of the radio communication. Localization schemes that are based on the receive signal strength indicator (RSSI) have been, however, intensively studied in simulators [7]. Analysing from the above stated points about previous research results, therefore in this research journal, a framework for analyzing the mobility of mobile anchor assisted range-free algorithm for WSNs is proposed in presence of obstacles. Hence with deploying relay node, our proposed model can efficiently reduce the effects of obstacles on estimation of node localization.

Furthermore, our proposed model can compute the positions of infeasible points caused by a complex radio transmission environment that is accepted as a problem when the localization inequalities are empty for the feasible set. The rest of this paper is prepared as follows. Section 2 presents related work followed by proposed model description in Section 3. The method is discussed in Section 4. In the Section 5 highlight the algorithms deployed in this research work followed by Simulation results in Section 6 and finally Section 7 will conclude the research proposal.

2. Related Work

Tian He [8] present APIT, a novel localization algorithm that is range-free and revealed that proposed APIT scheme of ours performs excellent under an irregular radio pattern and random node placement, and this result in low communication overhead. The work is compared using the state of the art via extensive simulation; range-free localization schemes recognize the most suitable system configurations of each. In addition, the effect in the case location error of routing and tracking performance is also studied.

Huang [9] presented a complete description of standard DV-Hop and clarified some gaps in previous papers. The major source of errors in standard DV-Hop is identified and two enhancements are proposed: the anchor placement strategy and Weighted DV-Hop. With the anchor placement strategy, the research work had achieved an optimum result with less number of anchors. This will result in a cost-effective implementation. Chong Liu [10] propose a ring-overlapping, range-free approach using based on relationship of Received Signal Strength Indicator (ROCRSSI) which achieves more accurate location estimation than existing high performance Approximate Point in Triangle (APIT) method. Chong Liu [10] has performed thorough performance evaluation on two novel range-free localization methods, APIT and Ring Overlapping based on comparison of ROCRSSI. Evaluation results show that ROCRSSI outperforms APIT in terms of estimation accuracy and communication overhead under the same configuration, and it also greatly alleviates the inherent .uncertain node problem of APIT.

Chia [11] demonstrated that the range-free localization mechanism without using distance or angle information was also able to achieve fine-grained accuracy. The average location error (less than 1 meter) was also competitive to other range based approaches that typically require extra hardware for the deployed sensor node. Gideon Stupp [12] propose an estimate for the protocol based on arrangement which does not require any preliminary steps and prove that its expected accuracy converges protocol improves as the number of anchors increases. Keshtgary et. al. [13] review range-free localization methods to assess the performance of two important methods: “amorphous” and “DV-hop”.

In the proposed method we reflect some parameters like energy consumption, localization accuracy, and network overhead. In the recent papers localization methods is mostly concerted on localization accuracy where a consideration of a group of evaluation parameters, energy consuming, and network overhead in addition to the location accuracy is considered. Andrija e.t. al. [14] tackle the problem of RSS uncertainty, proposed a localization method based on fuzzy set with an improvement of the ring overlapping scheme. The deployed fuzzy set theory is to model relationship between localization regions and the RSS information available to the sensor node. The research paper has described a novel fuzzy set-based range-free localization scheme, which is termed as Fuzzy-Ring. Fuzzy-Ring requires a heterogeneous wireless sensor network composed of two sets of distributed static nodes across a planar sensing field: the position of anchors, i.e. the nodes whose locations are known, and the set of sensor nodes, whose locations are to be determined. The results obtained from simulations demonstrate that our solution improve localization accuracy in the presence of radio irregularity, but even for the case without radio irregularity. Wen-Yuan Liu [15] proposes an enhanced DV-Hop algorithm based on the selection of beacon nodes.

In this paper the proposed range-free and convex optimization approach ensures the minimum localization error. The result of simulation shows that this method can choose a better combination of beacon nodes to locate unknown nodes in the network, and can greatly improve the localization accuracy of the unknown nodes. The Table 1 highlights the comparative analysis of previous research work in localization areas carried out the wireless sensor networks.

TABLE 1: COMPARATIVE ANALYSIS OF PREVIOUS WORK

Authors	Considerations	Target of Research	Results Obtained
Tian He [8]-2003	RF Localization, Irregular radio patterns, random node placement	Effect of localization on routing & tracking [Simulation]	Good Accuracy but slight performance degradation observed
Huang [9]-2008	RB localization, Probabilistic Technique	Security issues in localization process [Simulation]	Location of node is estimated on Beacon instead of sensor, obtain less than 50% localization error, 80% coverage on very sparse network of density 4
Chong Liu [10]-2007	RF localization, RSSI, overlapping rings and their intersection, irregular radio patterns	Real time implementation using Mote Sensor [Real-Time]	Enhance performance than Tien He [5] work.
Chia [11]-2008	RF localization, anchor broadcasting its location information in its movement, Mobile sensor network	Localization for mobile sensor network [Simulation]	No dependency from Hardware, interaction between nodes, and network densities.
Gideon Stupp [12]-2005	RF-localization, random sensor distribution, Anchor broadcasting position info, positioning uncertainty	Localization improvement of basic intersection protocol [Simulation]	Less Network overhead in localization process
Keshtgary [13]-2011	Hop based RF-localization, localization accuracy, energy consumption, N/W overhead	Comparative analysis of localization w.r.t Amorphous and DV-Hop [Simulation]	Amorphous is more accurate than DV-Hop in non-uniform and high diffusion network, Amorphous consumes less energy; DV-hop has better accuracy than amorphous if Anchor nodes are increased.
Andrija [14]-2010	RSS-based RF localization, fuzzy set theory	Enhancement of Chong Liu [8] [Simulation]	Fuzzy rings perform better than ROCRSSI, no consideration of level of fuzzification.
Wen-Yuan Liu [15]-2010	Physical location relationship between beacon nodes, relative position relationship between unknown nodes and beacon triangle	Improved DV hop Algorithm [Simulation]	Improved localization accuracy of unknown nodes.
Lutful Karim e.t. al [18]-2010	RF energy efficient localization technique	Implement Range-free Energy efficient, Localization technique using Mobile Anchor Comparative analysis with Neighbour-info-based Localization System [Simulation]	RELMA is more energy aware and accurate than that of NBLS - an existing Neighbouring information based localization approach.

3. Proposed Model

The proposed model presents a unique localization framework considering the presence of obstruction in environment of wireless sensor network with random node placement and irregular radio patterns for minimizing estimates of range free localization errors. The mobile anchor nodes [19] are those nodes which are in frequent movement in the wireless network and periodically broadcast beacon message, including their current location approach.

The sensor node of different anchors, which may show various patterns [20], is considered to be disturbed by various anisotropic factors. The framework will include mobile anchor evaluation, distance evaluation as well as location estimation. One of the significance of the current work may be formulated considering diversification of Sensor network topology which was not considered in the previous research work (See Table 1). The network topology might be isotropic where the properties of the proximity measurements are identical in all direction where as Anisotropic network condition is just opposite of isotropic network. When the mobile anchor node is in listening mode from the normal sensor node based on this scenario of classification of sensor, the framework will estimate the distance of mobile anchor for each types of classification.

Assumptions made for this proposed networks is:

i. Anchor nodes are mobile in the network over complete runtime.
ii. The nodes are having omnidirectional communication range.
iii. Obstruction can be deployed in any position in the networks
iv. All sensors are deployed randomly.

3.1 Aim of the Proposed Work

To design a new approach towards localization scheme that localizes the randomly deployed sensor nodes and evaluates the performance for minimizing the localization error. Ultimately, the proposed model will analyse the location of sensors by estimating the position of a target object by evaluating the temporal difference of advent of a signal released from that target object to multiple receivers. The proposed framework consists of two different types of input. The first input will be estimation of location or hop counts resulting from mobile anchor initiating flooding and the second input will be broadcasting of first input to its entire respective neighbourhood giving the final output which is estimation of location. Nodes are evaluated with respect to the location of boundary nodes for the estimation of location error. The proposed localization scheme can also be mapped as distributed elucidation as both flooding and local broadcast is exceptional cases of restricted flooding.

4. Methodology

The proposed approach discusses about issues in localization which is based on mobile anchor nodes with diversified transmission energy in presence of any obstructions. Therefore this issue can be effectively altered to problem of solving a set of quadratic inequalities. In such previous research work [16] [17], majority of the methodology considers that set of quadratic inequalities must have solutions, which is not always feasible while majority of the consideration are in range-based localization. Another significance of the current research work is that the previous researches have not considered the analysis with existence of obstruction in wireless sensor network.

Let us assume that the network of n non-anchors and m anchors nodes are present, where for every pair of dual nodes, the framework has introduced (based on measurements) the upper bound $d^{kj}_{\max}$ and lower bound $d^{kj}_{\min}$ to the Euclidean distance between a_k and x_j, and upper bound $d^{ij}_{\max}$ and lower bound $d^{ij}_{\min}$ to the Euclidean distance between x_i and x_j. Then, the model of the localization problem can be defined as per equation no. 1, 2 & 3.

$$\min_{x}\{J = \sum_{k=1}^{m}\sum_{j\in N_k} e_{kj} + \sum_{i=1}^{n}\sum_{j\in N_g} e_{ij}\} \tag{1}$$

With a condition that

$$(d_{ij}^{\min})^2 - e_{ij} \le \| x_i - \hat{x}_j \|^2 \le (d_{ij}^{\max})^2 + e_{ij}, \tag{2}$$

$$\forall i \ne j, \quad j \in N_i$$

$$(d_{kj}^{\min})^2 - e_{kj} \le \| a_k - \hat{x}_j \|^2 \le (d_{kj}^{\max})^2 + e_{kj}, \tag{3}$$

$$\forall j, j, \quad j \in N_k$$

Where $e_{kj} \ge 0$ and $e_{ij} \ge 0$ represents localization errors in sensor position estimations, $\hat{x}_i$ and $\hat{x}_j$ are estimated positions of nodes i and j, respectively, and N_i, N_k are groups of neighboring nodes. Let X = [x1, x2 . . . xn] be the 2 × n matrix that needs to be evaluated where the issue of localization may be transformed and formulated in matrix form.

5. Algorithm Description

The proposed framework assumes that the sensor node can identify the boundary node as only such nodes can relay beacons from mobile anchor nodes based on boundary location algorithm [18]. Using distributed contention process, the boundary node will tend to retrieve the coordinates of the position of the node. Node density as well as transmission energy will play a vital role in localization.

Node density as well as transmission energy will play a vital role in localization. Boundary node sets a stay timer after receiving a beacon from mobile anchor node, which defines the temporal factor where the node must stay before retransmitting the current position co-ordinates. The stay timer T_S will be estimated by following equation no 4:

$$T_s = \{C_1\left(\frac{consumed\ energy}{initial\ energy}\right) + \left(\frac{C_2}{neighbor\ node\ density}\right) x\ maximum\ holdup\ period\} \quad (4)$$

C_1 and C_2 are coefficients which provide diverse cost for different parameters. The specific values of C_1 and C_2 can be configured based on which characteristics are more significant for users: power equilibrium or coverage effectiveness. In total, $C_1 + C_2 = 1$ which shows that greater remaining transmission energy and a neighbor node density will result in a shorter stay time. The candidate boundary node will broadcast beacon signals in case they don't receive any beacon signals from the other sensor nodes during its stay timer. Not only this, the contention will be terminated by the other boundary nodes in case they hear retransmitted of the beacon. Therefore, node with highest priority will retransmit first and serve as a relay for mobile anchor node's beacon signal. This technique ensures that guaranteed delivery of mobile anchor node's location co-ordinates to certain areas that cannot directly receive mobile anchor communication. So, the unidentified-location sensor node in these specific areas can obtain a set of inequality constraints on x:

$$r_i < \| x - a_i \| \le R_i + R_{relay}, \text{ i=1, 2, 3. . . n} \quad (5)$$

Where, R-relay is the current transmission radius for the relay node as per equation no 5. Depending upon this methodology, the application can efficiently decrease the impact of the obstruction on node localization and thereby enhance the location accuracy and minimize errors in its estimation. The algorithm can be given as:

5.1 Pseudo code for finding intersection points

```
for (every node)
        initialize creation of Sensor Network topology (ST);
        declare total nodes, length, width;
        simulation area (SA) = length x width;
for (every ST)
        initialize Transmission radii (RT) and Transmission Area (AT);
        if (RT<SA)
                RT = 2 x AT;
  while (inside AT)
        plot Sensor Node;
Declare obstacle size;
        initialize obstruction position coordinates [Obx and Oby];
                plot network topology (ST`);
for (every ST`)
        estimate Mobile anchor path;
        for (every mobile anchor path)
                compute one-by-one mobile anchor position;
        while (inside AT)
                plot dynamic readings for positions captured by interface
        plot network trajectory set of each node which receives beacon from mobile anchor node.
                dx,y=cal_dist[X, Y] for both anchor and normal node.
 if (dx,y<AT && d>RT)
        plot intersection point
```

5.2 Pseudo code for Estimating Localization Error

```
if (dx,y<AT && d>RT)
dx,y= sqrt {(x-aix(i))^2+(y-aiy(i))^2}
        sum= (dx,y- r)^2+(dx-R)^2
        sum= sqrt {sum}
for (every ST)
        for (every ST`)
                while (inside AT)
                        x1= newBoundaryNode.x;
                        y1=newBoundaryNode.y;
        plot nodes which receive beacon from anchor nodes;
                relay the co-ordinates from the neighbor nodes;
        identify obstacle and estimate location error LE=1/N {Actual Position-estimated position} x 1/RT;
        compute Error for localization;
```

6. Performance Evaluation

In this section, we evaluate the proposed model in terms of localization accuracy and the error estimate in the presence of obstacle and without obstacle considering neighborhood size and compared with the DV-Hop [9], APIT [8], ROCRSSI [10], and Amorphous techniques [13]. We first present the simulation model along with the performance result as follow.

6.1 Simulation Model and Performance Measures

In this section the proposed framework simulation has been carried on Intel Pentium Dual Core E2160 CPU with 1.8 GHz and 2 GB RAM. The architecture is designed in Matlab 7.2 considering, where 100 sensor nodes will be distributed randomly in a two dimensional simulation area of size 100 m x 100 m with specific transmission radii (R) and transmission area (r) deployed for mobile anchor nodes. We evaluated the performance of the proposed framework with many empirical tests in various scenarios by changing the sensing transmission range radius and obstacle orientation. The simulation is considered both with obstacle as well as without obstacle.

- Network initialization size:-
- Node dimension size 100 X 100 m
- Node size: 100 X 100;
- Obstacle size: 20 to 90;
- R= 2 X r; where r is the maximum transmission radius

$$\text{Error} = \frac{1}{N}\sum_{i=1}^{N} ||x_i\text{-}\bar{x}_j||*1/r \qquad (6)$$

Figure (1) and Figure (2) shows the simulation results in both scenarios of without and with obstacle respectively.

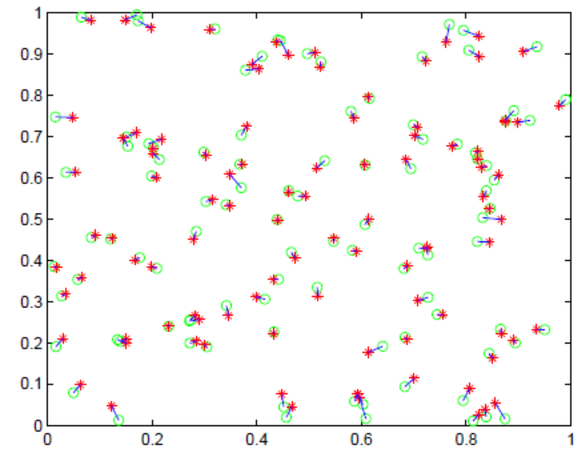

Fig 1. Simulation Results considering without Obstruction

The actual node is shown by circle and the estimated node is shown by asterisk. The line joining the actual and the real node position represent the estimation error as per equation no 6.

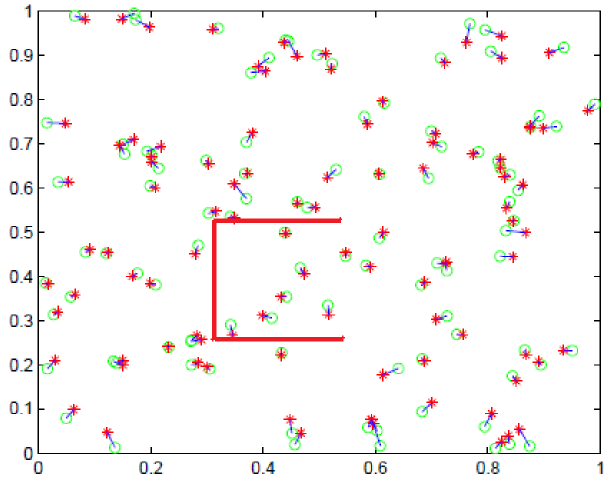

Fig 2. Simulation Results considering in presence of Obstruction

6.2 Simulation Results

In this section simulation results are presented and analyzed. The simulation was then analyzed for both mobile anchor nodes as well as normal nodes. The motive behind this is to evaluate the correctness of our approach of deployment of nodes in wireless sensor network where localization accuracy strongly depends on location of the node in the network. The error percentage indicates the percentage of maximum transmission radius.

TABLE 2: COMPUTING TIME AND LOCALIZATION ERROR—VARIOUS DEPLOYMENT OF ANCHOR NODES

Mode	Average Localization Error [%]	Average Computation Time [s]
Even distribution	2.76	3.04
Random distribution	14.996	5.26

The above Table (2) represents average localization error estimation (%) along with reading of Average Computation time (s) for various passes of simulations. It can be easily observed that the results are quite varying for which it will not be recommended to deploy distance based localization methods to networks with randomly distributed mode of deployment of mobile anchor and normal nodes. Estimating along with computation time will be required as in case of very large scale of sensor network area, computation time can restrict the application for centralized localization techniques.

The performance of the designed application is evaluated using different numbers of mobile anchor nodes which gives various result sets for location error.

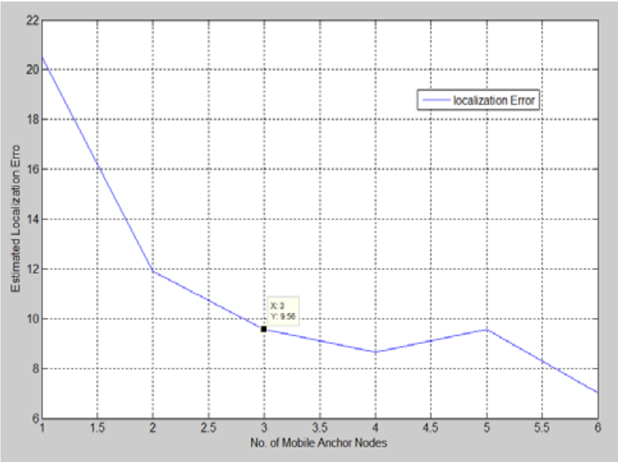

Fig. 3. Impact of the network size on localization accuracy

This evaluation as shown in Figure (3) shows that the when the quantity of mobile anchor nodes are increased, the feasibility of location errors decreases. This represents that increase in mobile anchor node-density will make the localization more accurate.

The localization accuracy is analyzed with varying the values of transmission range to evaluate impact of transmission value on estimating localization errors on range free based techniques.

The variation of the estimated localization error is shown in Figure (4) when the transmission range increases with various obstacles or noises.

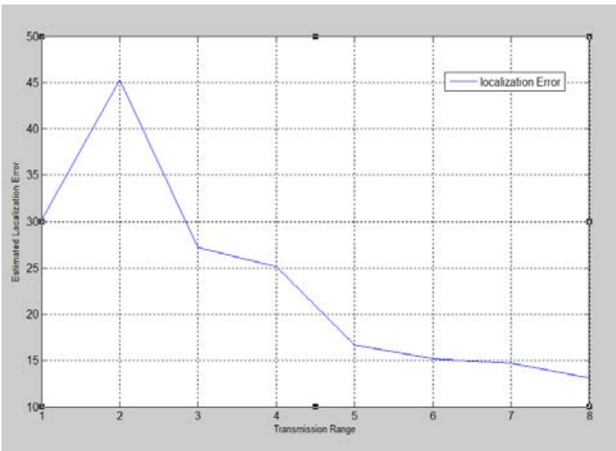

Fig. 4. Impact of the radio range on localization accuracy

The higher transmission level benefits will reduce beyond a specific point. The graphs explain that localization error estimation is minimized or to some extent render it uniform with the increase of transmission range.

The next phase of evaluation is done by considering magnitude of nodes in presence of obstructions which affects the accuracy of localization techniques as shown in Figure (5).

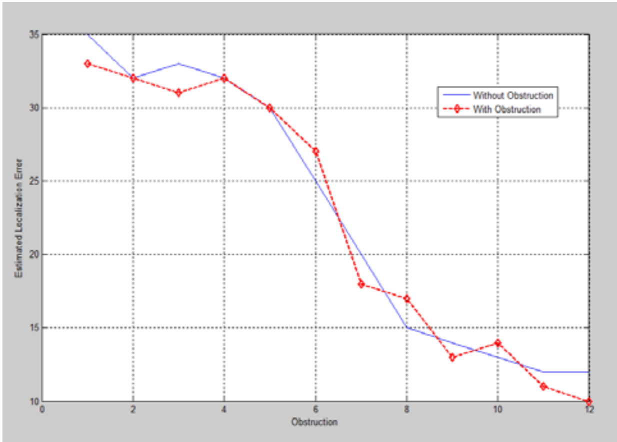

Fig. 5 Impact of Obstacles on localization accuracy

The next performance analysis is done by comparing the proposed technique with previous DV-Hop [9], APIT [8], ROCRSSI [10], and Amorphous techniques [13].

The Figure (6) represents the performance of the proposed technique with the previous research technique of localization. For this evaluation, the APIT scheme is modified for which each mobile anchor and node requires broadcasting once to see that APIT performance shows higher peak.

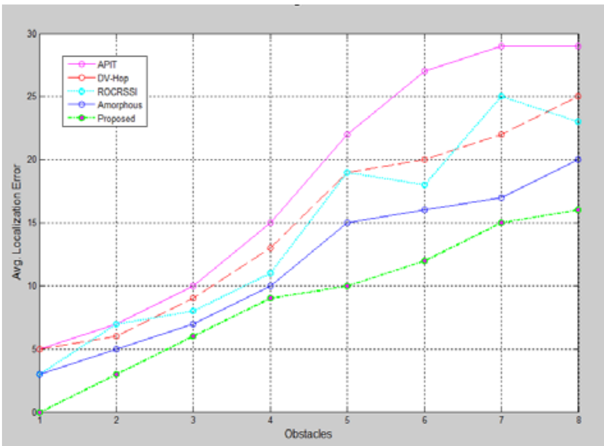

Fig 6. Average Localization Error Vs Obstacle

When the same evaluation is repeated with DV-Hop, ROCRSSI, and Amorphous, it can be observed that performance of Amorphous is comparatively better for estimating localization in presence of obstruction. In order to convert hop counts to Euclidean's distance; the program will compute average distance per hop considering range free techniques. Mobile anchor conduct the location and hop count information inside the network topology. So it can easily seen that performance for reducing localization errors is relatively reduced in our proposed system in comparison to tradition range free localization techniques.

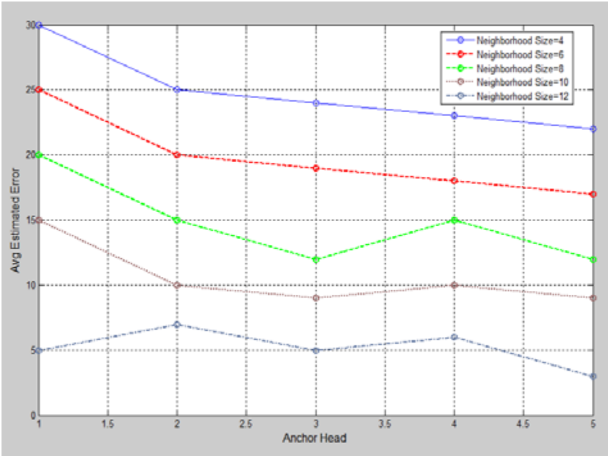

Fig 7. Average Estimated Error Vs Anchor Head

The final performance analysis we shown in the Figure (7) an idea about the consequence of neighbor nodes in estimating localization under various mobile anchor head. In this operation, once the mobile anchors quantity is computed, the hop displacement will be estimated using local averaging.

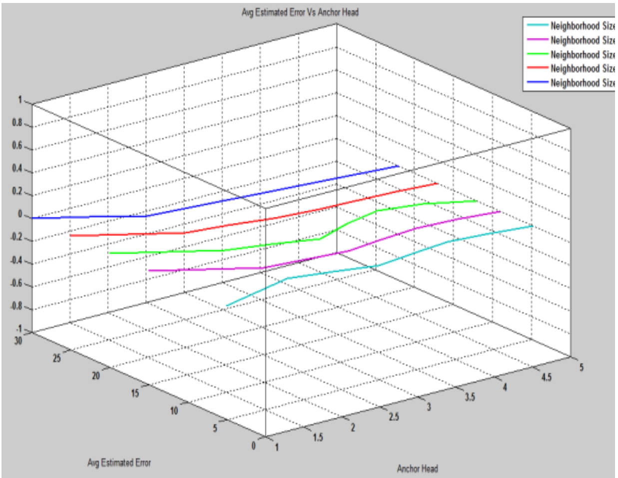

Fig 8. 3D Plot of Average Estimated Error Vs Anchor Head

From the 3D plot of the Figure (8) represents the 3D plot of average estimation for error is increased when the numbers of neighborhood increases. But it can be stated that mobile anchor nodes should not be incremented exponentially or else it will increase the network overheads much for seeking much better localization estimates result. Our result is better than the average localization error computation method.

The idea behind this localization performance evaluation is to find the best possibilities range free localization technique. The existing range free schemer fails in anisotropic wireless sensor networks. By consideration of geometrical feature of the network with the neighboring nodes hop the estimated position could able to compute which can minimize the localization error. The aim of this localization methodology is to create novel energy efficient architecture for the future wireless sensor network that can include the optimum performance factor with respect to proposed localization method and the other research characteristics that is about to propose.

7. Conclusion and Future Works

In this paper, the proposed model analyzed localization errors for wireless sensor nodes in the presence as well as absence of obstacles in anisotropic networks. The model was initially simulated in sensor network environment in absence of any obstacle, where records show that estimation of exact position is very satisfactory. The efficiency of the proposed system is experimented in various scenarios of previous range free localization techniques. In this paper we compare the result with the APIT, DV-Hop, ROCRSSI, and Amorphous methods. The performance analysis shows that our proposed technique has better results for localization estimation even in less node density which is a contrast version of amorphous techniques. The interesting part of the simulation is that when the test is conducted in various pattern of obstacle orientation within the network, the proposed approach shown minimum localization error. We believe that our design will make the range free scheme more practical for large-scale WSNs. The future work will consist of modeling the same with multiple obstructions under the same simulation.

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