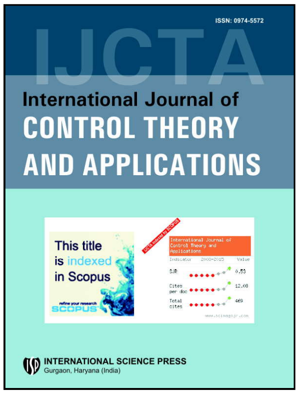

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A New Hop Based Algorithm for Localization in Wireless Sensor Networks

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Abstract: Wireless sensor network (WSN) is poised of enormous number of minute devices enabled with sensors to monitor the physical or ecological circumstances. In most of the WSN based applications, the node's location information is of much significance. Various localization algorithms have been proposed to precisely locate nodes in wireless sensor networks. These algorithms are broadly classified into range based and range free methods. The range based methods use exact computation measure (distance or time) among nodes in the network. So, range based methods needs some additional hardware for such computation. The range free methods use connectivity info among nodes in network. Hence, range free methods are regarded as cost efficient alternatives to range based methods. In this work, we proposed a hop based algorithms for localization in WSNs. We perform the comparative analysis of our algorithm with other hop based algorithms on the basis of localization error and accuracy. Simulation results shows that new hop based algorithm outperform the other existing algorithms.

Keywords: WSN, localization algorithms, connectivity, hop, performance evaluation

1. INTRODUCTION

Latest advancement in MEMS and wireless communication technologies allows the micro autonomous system comprised of small tiny devices known as sensors. These sensors can detect, compute and communicate via suitable sensor technology that gives birth to wireless sensor network [1,2]. Deployment ease and low cost sensors make wireless sensor network suitable for many applications like: health care, transportation, smart building, and environmental monitoring etc. For such applications the physical location of sensors are needed to detect the events in monitored area. Therefore, the location information is of much use in various applications and needed to build context aware applications [3,4].

Most of the WSN applications used a model where some of the nodes are ware about their location (either manually placed or enabled with GPS) are recognized as anchors or beacon nodes. The nodes other than anchors are normal nodes, randomly deployed due to the hostility of the area to be monitored. Anchors broadcast their locality info in the network. The nodes estimate their locations with the help of information they obtained from the anchors [5]. In this article, we proposed a novel hop based algorithm for localization based on DV-Hop method. This work makes three main contributions to the sensor network localization problem. First, we proposed a fast and user-friendly localization method with higher accuracy. Second, the proposed algorithm reduces the localization error and error variance as compared to traditional DV-Hop method. Third, we investigated the effect of number of anchors and communication radius on the performance of DV-Hop and our new hop based method.

The rest of the article is planned as follows. Section 2 gives the survey of related literature. In section3, PSO algorithm is discussed briefly. Section 4 describes the new hop based localization algorithm. In section5, simulation results are described. Lastly, Section 6 concludes the work.

2. RELATED WORK

In this part, we survey the literature relevant to our work. Lots of works reported in literature proposed techniques for sensor network localization for various uses. Since every method was built up to accomplish a special objective, they vary usually in many parameters [3-5]. The localization schemes are usually classified based on certain measures like: computational model, range measurements etc. Based on range measurements, localization techniques can be divided into range based and range free approaches. The range based methods needs to compute real distance among nodes while the range free schemes need only the connectivity info among nodes. The range based methods requires distance or angle info among nearby nodes to find out the position [5,6]. Some techniques to measure that are RSSI, ToA, TDoA, AoA based. The accuracy of range based approaches is higher as compared to range free schemes but needs extra hardware device. So, the overall cost becomes high in large scale deployment. In range free schemes, some restricted numbers of nodes are outfitted with GPS known as "anchors" or "beacons". Anchors broadcast their locality info into network, unknown nodes estimate their positions on the basis of hop values from beacons [7,8]. Distance estimation is vital in this scheme. In the range free schemes, the popular algorithms are DV-Hop, APIT, Amorphous, and Centroid. Niculesue et al. proposes the DV-Hop algorithm for localization that is alike to the conventional distance vector routing scheme [9]. In DV-Hop, node firstly counted the minimum hop value from beacons and after that calculates the distance among unknown node and anchor with help of minimum hop value and average hop distance. Lastly, node estimates its location with help of triangulation or maximum likelihood estimation (MLE) method. Additional device for localization is not required in this method. The range free methods are less influenced by environmental factors and additional ranging hardware is not required [10]. These characteristics make them suitable to sensor network localization.

3. PSO ALGORITHM

The Particle swarm optimization is an optimization method, modeled after the societal behavior of a bird's flock [11]. In PSO, a swarm corresponds to the amount of prospective solutions to the problem, where every prospective solution is known as a particle. The objective of this method is to determine the particle location that fallout in the best estimation of a set fitness function. During the initialization stage, every particle is set initial parameters at random and is flown throughout the multidimensional search space. In every generation, every particle utilizes the info regarding its earlier person best position and globally best position to maximize the possibility of moving on the way to a better solution space that will results in a better fitness and update its candidate solutions as per the equations given as:

$$V_{id}(t) = \omega \times V_{id}(t) + C_1 \times \varnothing_1 \times (P_{id} - X_{id}(t-1)) + C_2 \times \varnothing 2 \times (P_{gd} - X_{id}(t-1)) \quad (1)$$

$$X_{id}(t) = X_{id}(t-1) + V_{id}(t) \quad (2)$$

Where, V and X are particle velocity and position respectively, t is time, C_1, C_2 are learning factors, ω represent inertia weight. ϕ_1, ϕ_2 are the numbers generated randomly amid 0and 1. P_{id} is the individual best position and P_{gd} is the global best position of particle. The flow chart of PSO is depicted in figure 1.

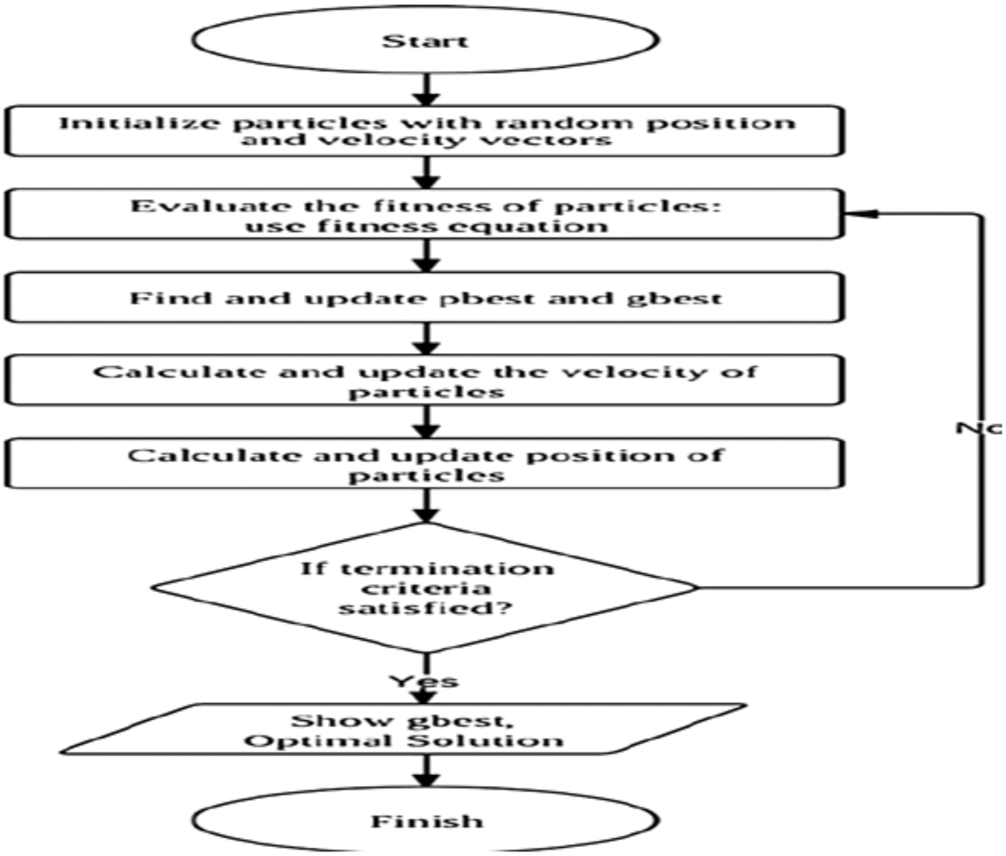

Figure 1: Flow chart of PSO ([18])

4. PROPOSED ALGORITHM

Here in this part of work, we propose a new hop based localization algorithm that is comprised of four steps. The various improved DV-Hop localization algorithms are reported in literature [12-17]. The step 1 and step 2 of the proposed method are same as of traditional DV-Hop algorithm. In step 3, unknown node positions are determined with help of 2D hyperbolic algorithm. The 2D hyperbolic location algorithm improves the estimated location precision. In step 4, we correct the estimated positions with help of PSO. So the step 3 of the new modified algorithm is same like the improved DV-Hop method [13]. However, in the step 4 of proposed algorithm, we use PSO for correction the position estimation.

Step1: Determine the minimal hop value between unknown and each anchor node.

In this step, every anchor broadcast a message all over the network comprised the location of anchor with value of hop count i.e. initially one. Every node that obtains the message records the each node's minimal hop count although ignoring the bigger one from same anchor and then hop count value is incremented by one and pass on to neighbor nodes.

Step2: Determine the actual distance among unknown node and anchor node.

In this step, every anchor estimate the average hop distances by the following equation:

$$HopSize_i = \frac{\sum_{i \neq j} \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2}}{\sum_{i \neq j} h_{ij}} \tag{3}$$

Where (x_i, y_i) is the coordinate or position of anchor i and (x_j, y_j) is the coordinate or position of anchor j. h_{ij} is the hop value among anchors i and j.

Anchor disseminates the average hop value. Unknown node evidence the first collected average hops distance and pass on it to neighbors. Then unknown node determines the distance to every beacon in accordance with hop counts.

Step3: Determine the position of unknown nodes.

An unknown node makes use of trilateration or MLE method to determine the coordinate of these nodes.

The distance from all beacon nodes to unknown node $P(x_u, y_u)$ are given by the formula:

$$\begin{aligned} (x_1 - x_u)^2 + (y_1 - y_u)^2 &= d_1^2 \\ &\vdots \\ (x_n - x_u)^2 + (y_n - y_u)^2 &= d_n^2 \end{aligned} \tag{4}$$

Meantime formula (4) can be stated as:

$$\begin{aligned} x_1^2 - x_n^2 + 2(x_1 - x_n)x_u + y_1^2 - y_n^2 - 2(y_1 - y_n)y_u &= d_1^2 - d_n^2 \\ &\vdots \\ {x_{n-1}}^2 - x_n^2 + 2(x_{n-1} - x_n)x_u + {y_{n-1}}^2 - y_n^2 - 2(y_{n-1} - y_n)y_u &= {d_{n-1}}^2 - {d_n}^2 \end{aligned} \tag{5}$$

Formula (5) steps the right equation for

$$AX = B \tag{6}$$

Where

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

$$B = \begin{bmatrix} x_1^2 - x_n^2 + y_1^2 - y_n^2 + d_1^2 - d_n^2 \\ {x_{n-1}}^2 - x_n^2 + {y_{n-1}}^2 - y_n^2 + {d_{n-1}}^2 - d_n^2 \end{bmatrix}$$

$$X = \begin{bmatrix} x_u \\ y_u \end{bmatrix}$$

The geographic coordinate of unknown node P can be find out with help of the following formula:

$$P = (A^T A)^{-1} A^T B \tag{7}$$

Step 4: We will apply PSO to find the correct position of unknown nodes.

Let (x, y) is the geographical position of the unknown node, the distance d_i can be obtained as described in second step of improved DV-HOP method.

Thus the positioning error may be described as:

$$f_i(x,y) = \left\| (x - x_j)^2 + (y - y_j)^2 - d_i^2 \right\| \tag{8}$$

$$fitness(x,y) = \sum_{j=1}^{n} \left(\frac{1}{Hop\ value_j} \right)^2 f_j(x,y) \tag{9}$$

Particle's updations are done with the help of (1) and (2), and (9). Equation (9) is the fitness function to estimate the fitness of particles. The total no of iterations is set accordingly. After these iterations, the optimal solution is treated as the final estimated location of the unknown node. The flow chart representation of our new algorithm is depicted in figure 2.

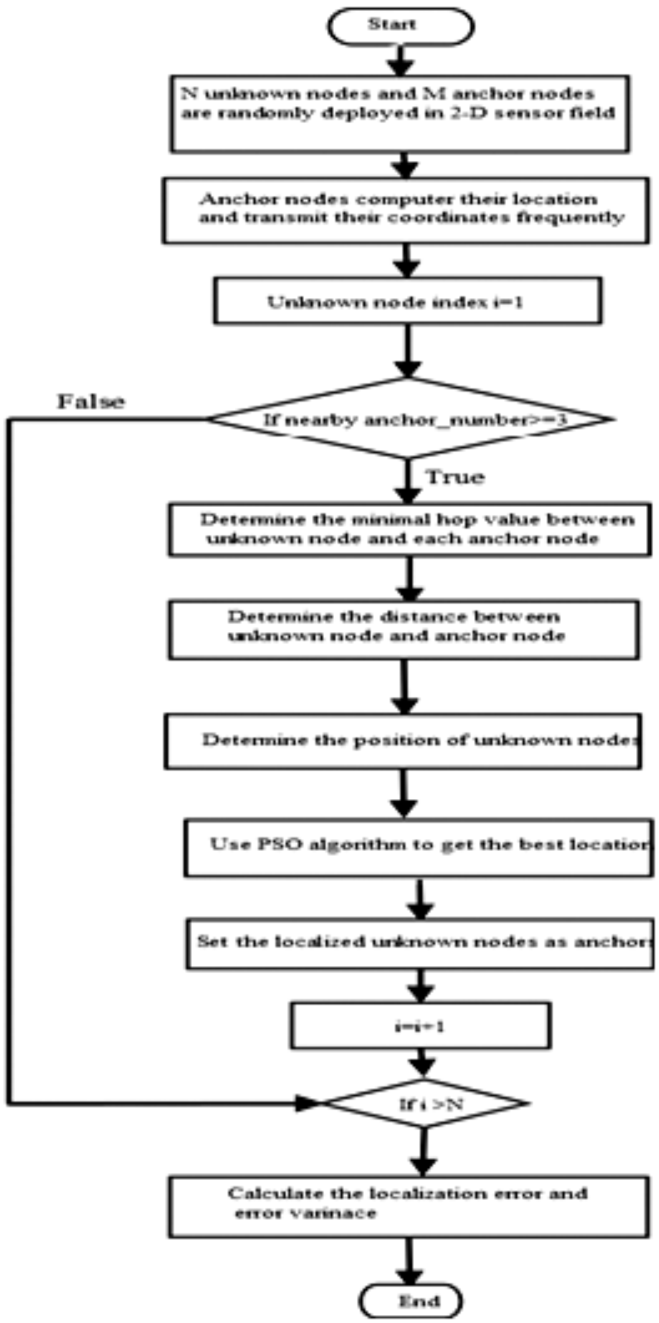

Figure 2: Flow Chart of Proposed Algorithm

5. SIMULATION RESULTS AND ANALYSIS

For the performance analysis of our modified algorithm, we use Matlab2015a as a simulator for implementation of the scenario of networks and determination of final results. Parameter setting for simulation be as: initially, few beacon nodes are fixed in 100 × 100 m^2 area then rest anchors and unknown nodes are distributed randomly in that area. We analyze the impact of total no of nodes, impact or anchor nodes and impact of communication range on the localization results.

The parameters in PSO algorithms are $c_1 = c_2 = 2.05$, $\omega = 0.9$, no of particles = 20, $V_{max} = 10$ and we use 20 iterations. The stability and accuracy of localization are analyzed by localization error and error variance and these performance parameters are calculated by the following formula:

$$Error_i = \sqrt{\left(x_i^{eval} - x_i^{real}\right)^2 + \left(y_i^{eval} - y_i^{real}\right)^2} \quad (10)$$

Average localization error is considered as localization error and computed as:

$$Localization\ Error\left(LE\right) = \frac{\sum_{i=1}^{n} Error_i}{n \times R} \quad (11)$$

The variance of localization error is computed as:

$$Localization\ Error\ Variance = \frac{\sum_{i=1}^{n}\left(LE_i - LE\right)^2}{n-1} \quad (12)$$

Wherever n represent the value of unknown nodes. x_i^{real}, x_i^{eval} be the real and evaluated positions of unknown node i respectively. The sensor node's radio range is represented by R.

We deploy 100 nodes out of these, few are beacon nodes and others are unknown ones, randomly in 2D area of 100 × 100 $m^{2.}$ The node's distribution is shown in figure 3.

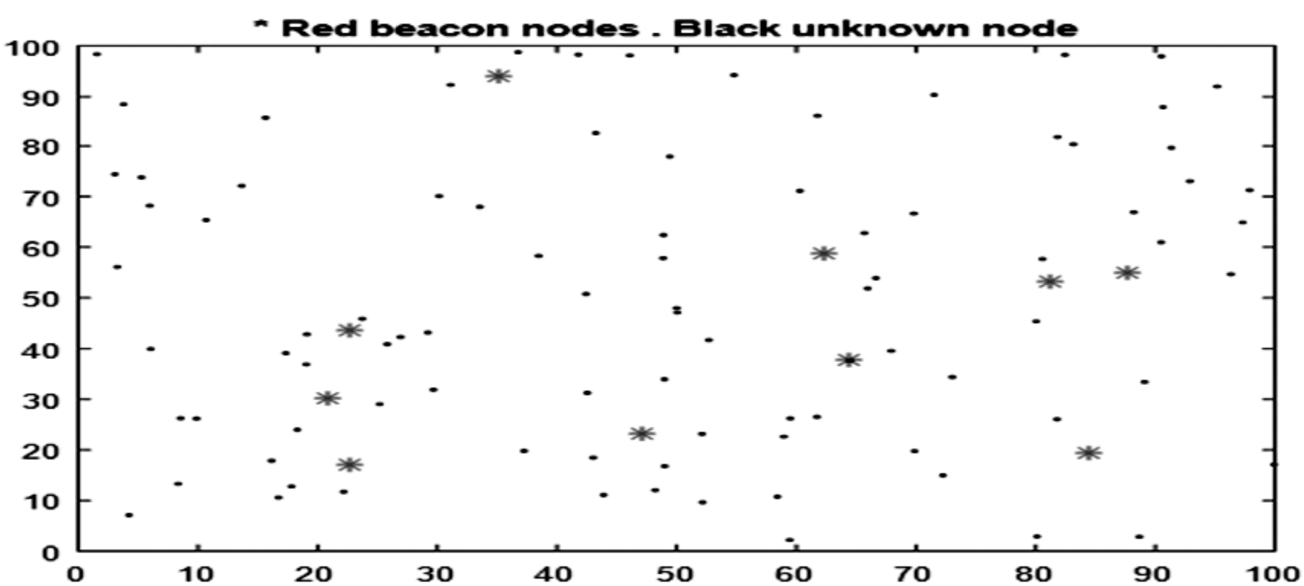

Figure 3: Distribution of nodes

5.1. Impact of no. of anchor nodes on localization results

The impact of beacons on the localization parameters like error and error variance is given away in figure 4 and figure 5.

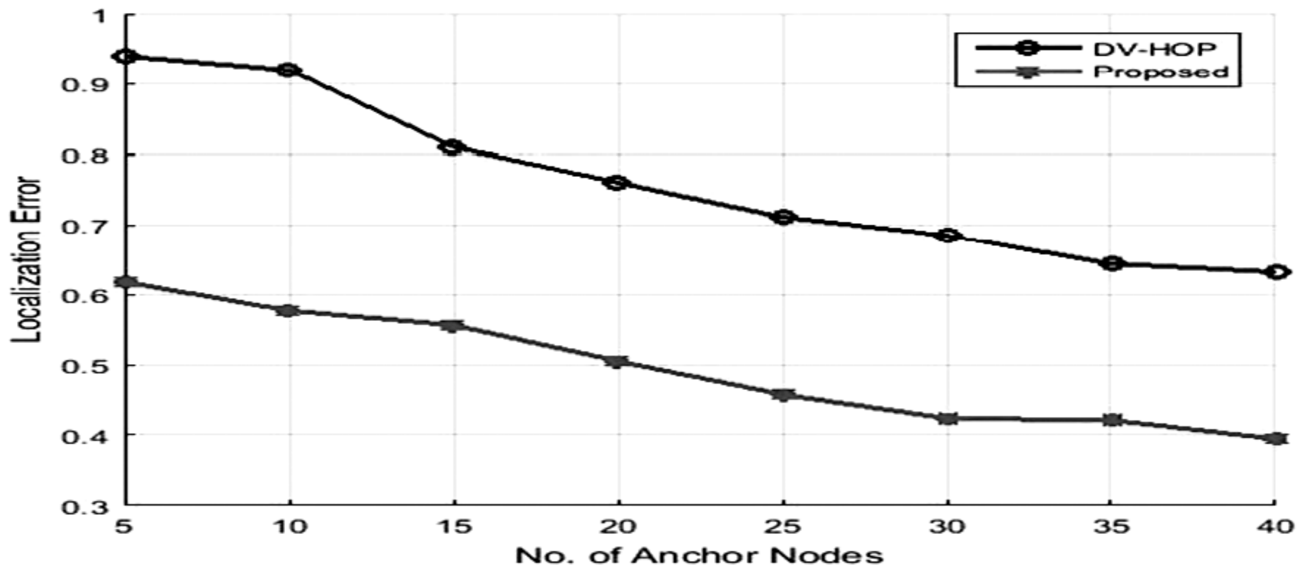

Figure 4: Localization error with changing number of anchor nodes

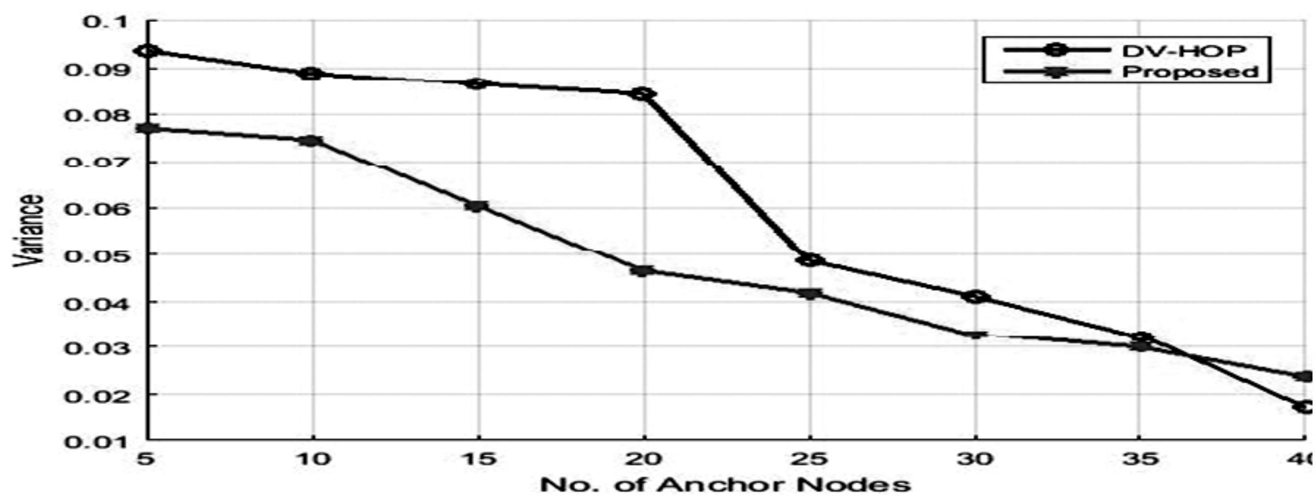

Figure 5: Localization error variance with changing number of anchor nodes

5.2. Impact of radio range on localization results

The effect of nodes' radio range on the localization parameters like error and error variance is given away in figure 6 and figure 7.

6. CONCLUSION

We presented a new hop based algorithm, which improves the traditional DV-Hop algorithm considerably. The analysis of simulation result section states that our modified algorithm betters the localization error and error variance as compared to basic hop based localization algorithm. As revealed in the simulation section of this

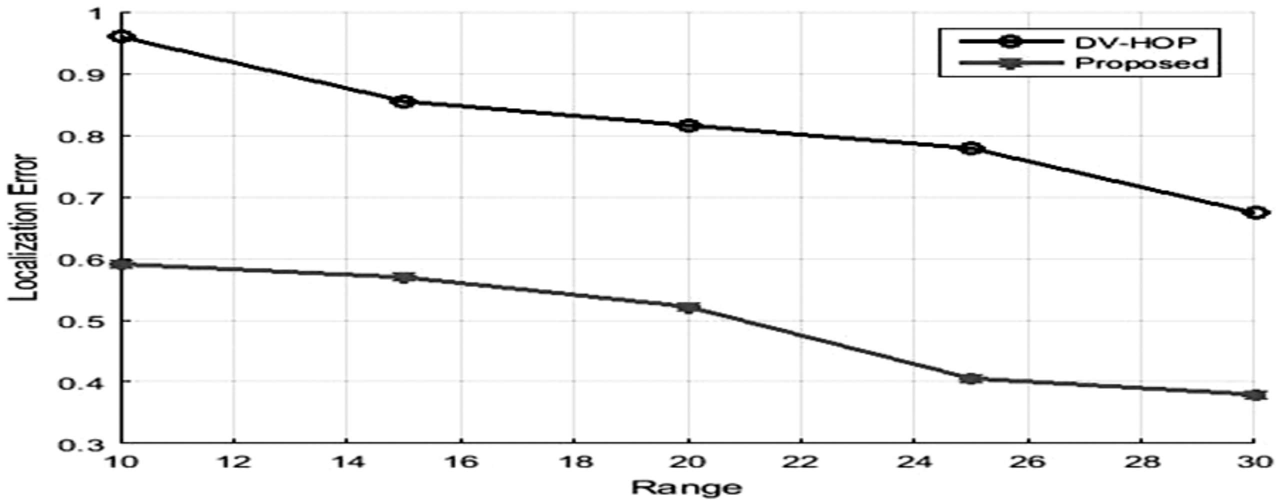

Figure 6: Localization error with changing radio range

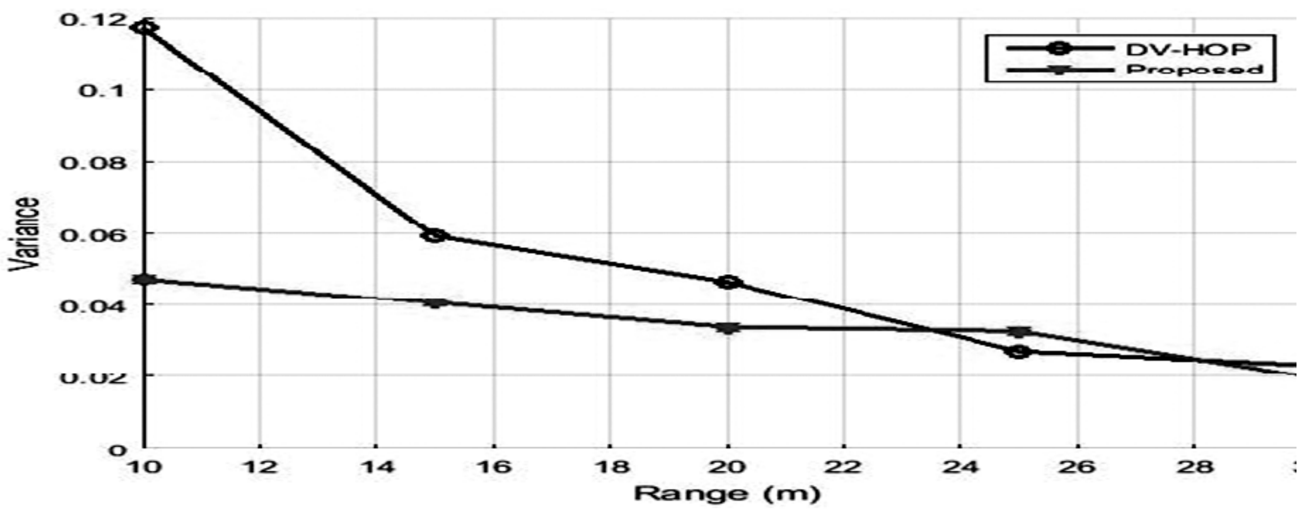

Figure 7: Localization error with changing radio range

paper, it can be stated that proposed method is efficient and have excellent application forefront. We also investigated the impact of anchor nodes and radio range on the localization error as well as on variance. In proposed algorithm, we correct the position estimates with help of PSO. It is clear that modified algorithm boost the precision and stability of localization method. But due to the use of PSO, little increase in computation time.

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