An Improved Localization Algorithm for Error Minimization in Wireless Sensor Networks

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***Abstract*—Wireless sensor networks (WSNs) are comprised of huge number of resource constrained petite devices recognized as sensor nodes. Data collection and forwarding is an important function of WSN. In the majority of applications, the location of the data is of much significance. Such kind of info can be acquired by using localization schemes. So, node localization is extremely essential to determine the location of node by using localization algorithms. Hence, localization becomes a hot research issue in WSNs. Many localization algorithms have been projected to precisely locate nodes in WSNs. These algorithms are broadly classified into range based and range free categories. 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 while range free methods don't require any specific hardware. Range free methods use connectivity information between nodes in network. So range free methods are considered cost effective alternatives to range based methods. In this paper, we propose a novel range free localization algorithm for WSN on the basis of swarm intelligence. We perform the comparative analysis of proposed algorithm with DV-Hop algorithms on the basis of localization error and accuracy. Simulation results shows that proposed algorithm outperform the DV-Hop algorithm.**

Keyword- wireless sensor network, localization algorithms, DV Hop, error, accuracy

I. 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]-[3]. 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 sensor are needed to detect the events in monitored area [3]-[4]. So the location information is of much use in various applications and needed to build up context aware applications [4].

The majority of WSN applications used a model where some of the nodes are ware about their location (either manually placed or enabled with GPS) are known as anchors or beacon nodes. Remaining nodes are normal nodes, randomly deployed due to the hostility of the region to be kept an eye on. The nodes compute their locations with the help of information they received from the anchors [5]-[9]. But this model have some drawbacks: expensive method (due to cost of GPS), inaccurate in indoor environment and large scale deployment of WSN [10]-[11]. Many algorithms have been developed for node localization [12]-[16]. Based on the range's assessment, the localization algorithms are broadly categorizes as: range based and range free. The ranging methods used accurate value of distance or angle as range measurements. Several ranging methods are possible for range measurements like: signal strength based (RSSI), Time based (ToA/TDoA), and angle based (AoA) etc [14]-[15]. Because of certain hardware limitations and offset range errors, researchers designed range free schemes that are based on proximity or connectivity information measures [16]-[21]. The popular methods of these schemes are Centroid, APIT, Amorphous, and DV-Hop etc.

In this paper, we proposed a modified algorithm for localization on the basis of distance vector hop algorithm. The proposed method reduces the localization error and improves accuracy without raising the cost of the sensor node. Here the presented work contributes three most important things to localization problem. First, we propose a new modified algorithm that is easy to use and cost effective. Second, the proposed algorithm reduces the localization error as compared to DV-Hop. Third, we explore the impact of anchors and communication range on performance of new modified algorithm. The remaining part of paper is planned as; section 2 focused on a literature review. Section 3 focused on the DV Hop localization algorithms. The proposed algorithm is illustrated in section 4. Section 5 focused on the result and discussion of performance of algorithms. Finally, section 6 concludes the work.

II. RELATED WORK

Here, we assess the literature appropriate to the work. In recent past, many works propose the schemes for localization in WSNs. Since every method was designed to solve a dissimilar objective, they differ extensively in parameters includes size, cost, accuracy, and reliability. The examples are: RADAR, Active Bats, SpotON, and Calamari etc [14]-[15]. The range free algorithms are slightly influenced by some environmental factors but additional ranging hardware not required. Such types of characteristics make them appropriate for WSN applications. In range free category, the Niculescu et al. proposes a distance vector hop based schemes know as DV-Hop scheme [16]. In this method, the sensor nodes initially count the value of minimal hop from anchor nodes and afterward estimate the distance amid anchors and unknown nodes. At last, the sensor nodes find out their locations with help of angulations' or maximum likelihood estimation (MLE). He et al devised a new area based method known an APIT [17]. With help of three beacons, APIT (Approximate Point in Triangle Test) used a method based on area to compute the node positions. Centroid is an easy algorithm for localization. In this, nodes obtain the landmarks signals in its range and make its coordinate as centroid. Amorphous is alike to distance vector hop based method, however it likely to identify the node's density a prior with help of offline estimation of hop distance [20]. It is supposed to make a relatively accurate method via local information. The Centroid, APIT, Amorphous, and DV-Hop are distributed range free localization algorithms. So, they are outlined by low traffic and computational simplicity. In the recent past, based on various improved schemes were proposed on the basis of DV-Hop method.

III. DV-HOP LOCALIZATION ALGORITHM

All paragraphs must be indented. The DV-Hop method is designed by Niculesue [16]. The main idea behind this is that nodes exchange information from its neighbors. This algorithm requires that some nodes are aware about their location (either manually placed or enabled with GPS) and communication information between nodes. The nodes those are aware about their locations are recognized as beacons or anchors. The sensor nodes don't require measurement equipments so the DV-Hop is one of most applicable methods in node localization for large scale deployment of WSNs.

DV-Hop algorithm is comprised of following three steps:

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 beacon and then hop count value is incremented by one and pass on to nearby 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:

$$HopSize_i = \frac{\sum_{i \neq j} \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2}}{\sum_{i \neq j} h_{ij}} \quad (1)$$

Where (x_i, y_i) is the location of anchor i and (x_j, y_j) is the location of anchor j. h_{ij} is the hop value amid anchor i and anchor j.

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

Step3: Determine the position of unknown nodes.

The unknown node use trilateration or MLE scheme 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:

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

Meantime formula (2) can be expressed as:

$$\begin{aligned}
&x_1^2 - x_n^2 + 2(x_1 - x_n)x_u + y_1^2 - y_n^2 - 2(y_1 - y_n)y_u = d_1^2 - d_n^2 \\
&x_2^2 - x_n^2 + 2(x_2 - x_n)x_u + y_2^2 - y_n^2 - 2(y_2 - y_n)y_u = d_2^2 - d_n^2 \\
&\qquad \ldots\ldots\ldots\ldots\ldots \\
&x_{n-1}^2 - x_n^2 + 2(x_{n-1} - x_n)x_u + y_{n-1}^2 - y_n^2 - 2(y_{n-1} - y_n)y_u = d_{n-1}^2 - d_n^2
\end{aligned} \tag{3}$$

Formula (3) steps the right equation for

$$AX = B \tag{4}$$

Where

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

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

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

The coordinate of the unknown node P are obtained with help of the following formula:

$$P = \left(A^T A\right)^{-1} A^T B \tag{5}$$

IV. PROPOSED METHOD

Here in this part of work, we propose a new algorithm by making some modification in original DV-Hop algorithm with help of PSO.

A. PSO

Particle swarm optimization (PSO) is a branch of heuristic techniques that optimizes a complex problem via repetitively attempting to get better candidate solution with respect to a specified measure of quality [22]. The flow chart representation of this method can be shown by Fig.1.

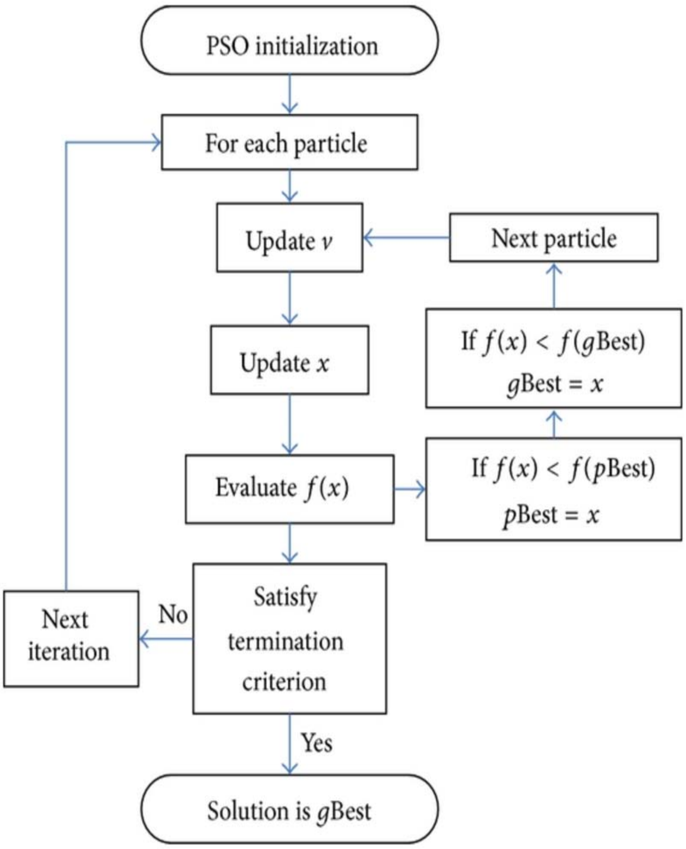

Fig. 1. Flow sheet of PSO algorithm ([31])

Updating behavior of particles can be defined as:

$$v_i(t+1) = \omega v_i(t) + c_1 r_1 (pbest_i - x_i) + c_2 r_2 (gbest - x_i) \quad (6)$$

$$x_i(t+1) = x_i(t) + v_i(t+1) \quad (7)$$

Where, v_i is the velocity of particle; x_i is position of particle; c_1 and c_2 are the acceleration coefficients and also known as learning factors; r_1 and r_2 are the positive integers between 0 &1 chosen randomly and ω is the inertia weight; *pbest* is individual extreme (optimal solution position of individual); *gbest* is global minimum (group optimal solution position of group

B. Proposed Algorithm

Title must be in 24 pt Regular font. There are various improvements on DV-Hop algorithm is reported in literature [23-30]. Here, our modified DV-Hop algorithm at is comprised of four steps. The initial two steps of the proposed algorithm are same as of traditional DV-Hop algorithm. In step3, 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 use PSO to improve the estimated positions. So the step3 of the new modified algorithm is same like the improved DV-Hop algorithm. However, in the step 4 of proposed algorithm, we use PSO for correction the position estimation.

Step1: It is same as of DV-Hop method; in this step the smallest value of hops between every unknown and anchor nodes are calculated.

Step2: It is same as of DV-Hop method; in this step actual distance among unknown and anchor node is determined.

Step3: It is same as of Improved DV-Hop method; in this step, a general model for 2-D source position estimation is developed with help of anchors. Let (x_u ,y_u) be the location of unknown node and (x_i, y_i) is the location of the i^{th} anchor node and distance among them is denoted by d_i.

d_i can be given as:

$$d_i = \sqrt{(x_i - x_u)^2 + (y_i - y_u)^2} \quad (8)$$

In this improved localization system, instead of conventional triangulation method, the 2-D hyperbolic location algorithm is utilized.

By the definition of above equation of d_i, we have the following expression:

$$x_i^2 + y_i^2 - 2x_i x_u - 2y_i y_u + x_u^2 + y_u^2 = d_i^2 \quad (9)$$

$$d_i^2 - E_i = -2x_i x_u - 2y_i y_u + K \quad (10)$$

Where $E_i = x_i^2 + y_i^2$

$K = x_u^2 + y_u^2$

$Z_c = [x_u, y_u, K]^T$

Let

$$G_c = \begin{bmatrix} -2x_1 & -2y_1 & 1 \\ -2x_2 & -2y_2 & 1 \\ . & . & . \\ & & \\ -2x_i & -2y_i & 1 \end{bmatrix}$$

And

$$H_c = \begin{bmatrix} d_1^2 - E_1 \\ d_2^2 - E_2 \\ . \\ . \\ d_i^2 - E_i \end{bmatrix}$$

We can have

$$G_c Z_c = H_c \quad (11)$$

With the help of least square method, we obtain

$$Z_c = \left(G_c^T G_c\right)^{-1} G_c^T H_c \quad (12)$$

After that the coordinate of unknown node (x_u ,y_u) is given as:

$$\begin{aligned} x_u &= z_c(1) \\ y_u &= z_c(2) \end{aligned} \quad (13)$$

Step4: In this step, we will apply PSO to find the correct location of unknown nodes.

Let X_u is the geographical locality of the unknown node, B_i is the position of i^{th} beacon 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:

$$f\left(X_u\right)=\left(d_i-\left|X_u-B_i\right|\right)^2 \quad (14)$$

$$fitness\left(X_u\right)=\sum_{j=1}^{n}\left(\frac{1}{Hop\ value_j}\right)^2 f\left(X_u\right) \quad (15)$$

Particle's updations are done with the help of (6) and (7), and (15). Equation (15) 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 considered as the final estimated locality of the unknown node. The flow sheet representation of proposed algorithm is revealed in Fig. 2.

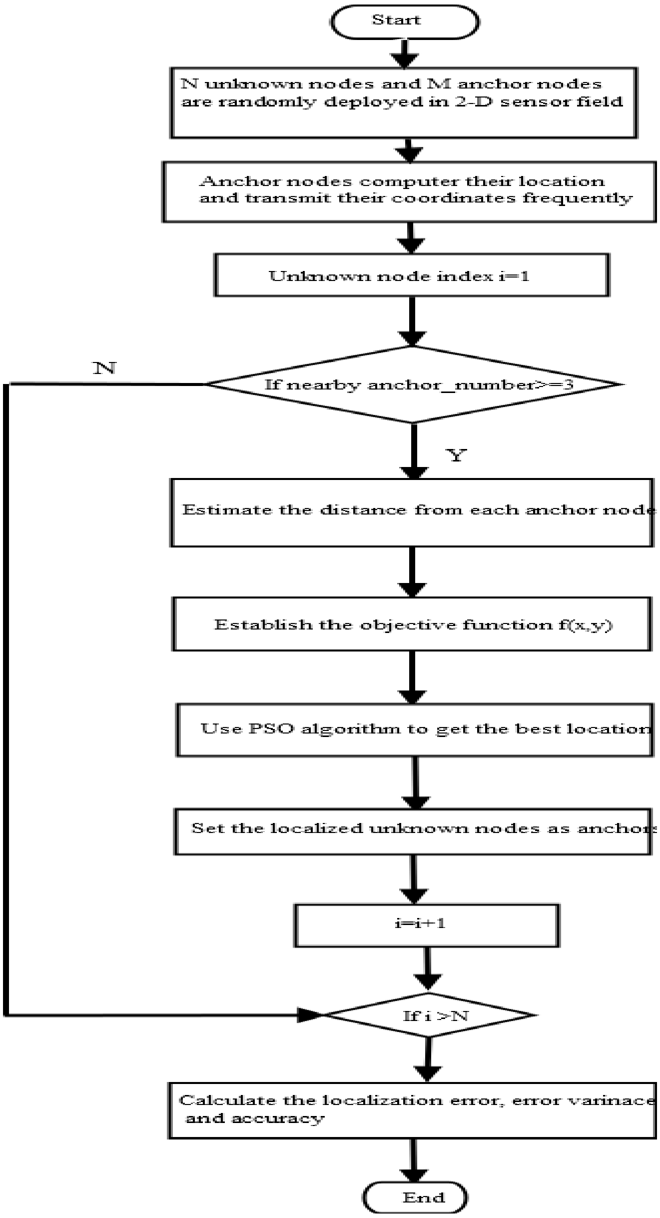

Fig. 2. Flow chart of proposed algorithm

V. RESULTS AND DISCUSSIONS

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 100x100 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, 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:

$$Error_i = \sqrt{\left(x_i^{eval} - x_i^{real}\right)^2 + \left(y_i^{eval} - y_i^{real}\right)^2} \quad (16)$$

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

$$Localization\ Error\left(LE\right) = \frac{\sum_{i=1}^{n} Error_i}{n \times R} \quad (17)$$

The variance of localization error is computed as:

$$Localization\ Error\ Variance = \frac{\sum_{i=1}^{n}\left(LE_i - \overline{LE}\right)^2}{n-1} \quad (18)$$

The localization accuracy is computed as:

$$Localization\ Accuracy = \frac{\sum_{i=1}^{n}\sqrt{\left(x_i^{eval} - x_i^{real}\right)^2 + \left(y_i^{eval} - y_i^{real}\right)^2}}{n \times R^2} \quad (19)$$

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 X100 $m^{2.}$ The node's distribution is shown in Fig. 3.

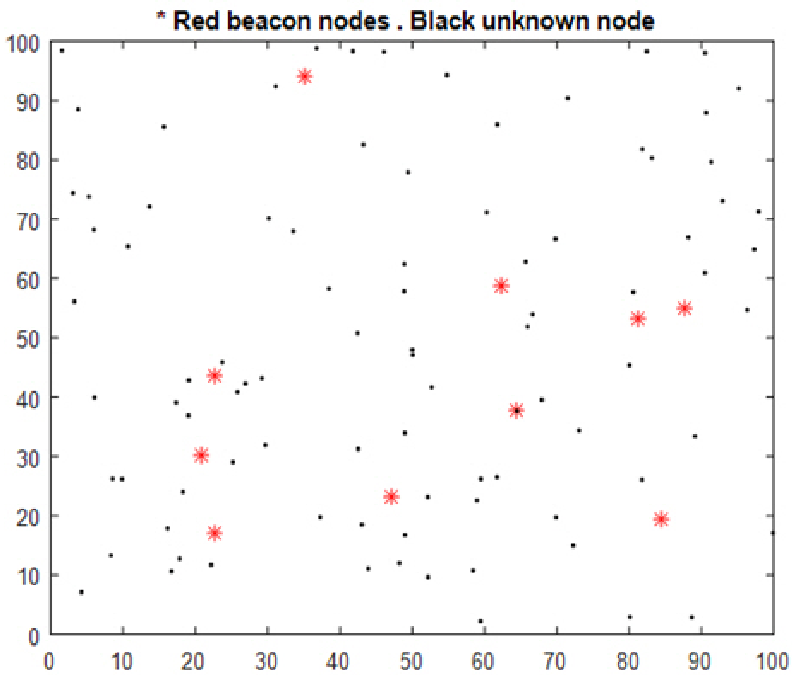

Fig. 3. Distribution of nodes

1) Impact of number of sensor nodes on localization results

The impact of total nodes on localization parameters like error, error variance and accuracy is given away in Fig. 4, Fig.5, and Fig. 6 respectively.

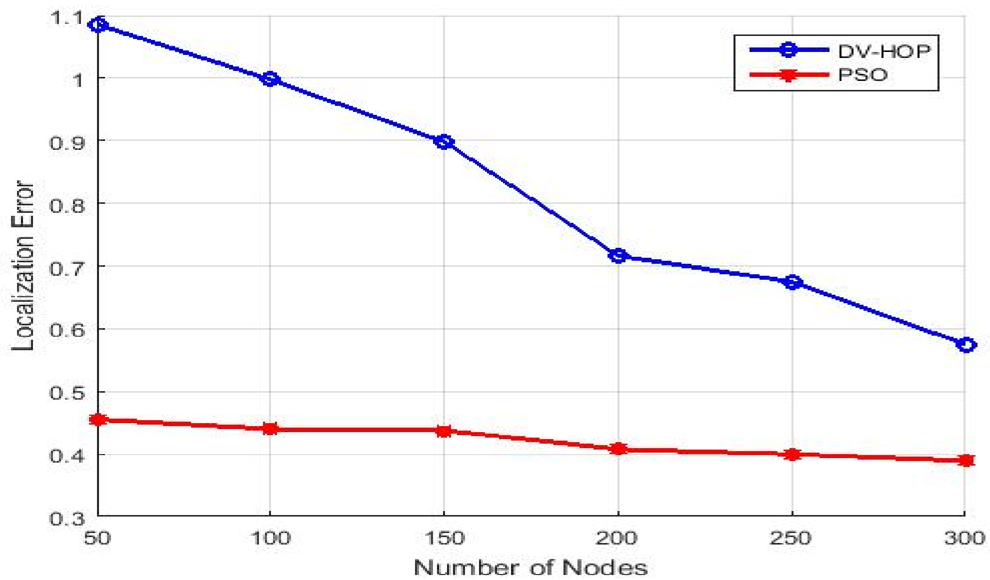

Fig. 4. Localization error with changing no. of nodes

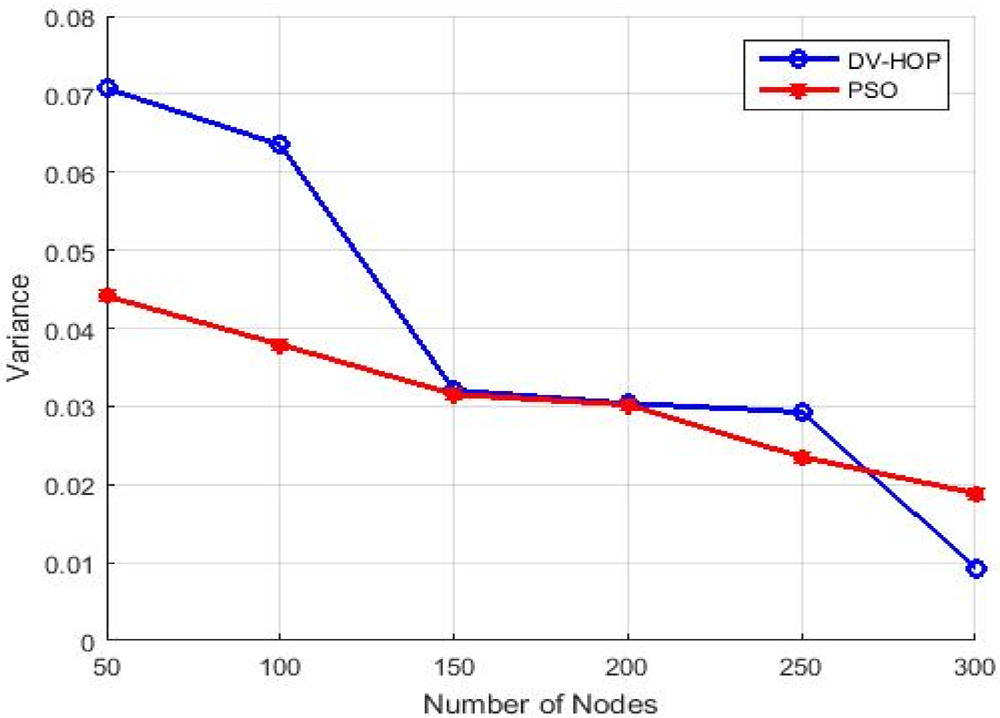

Fig. 5. Localization error variance with changing no. of nodes

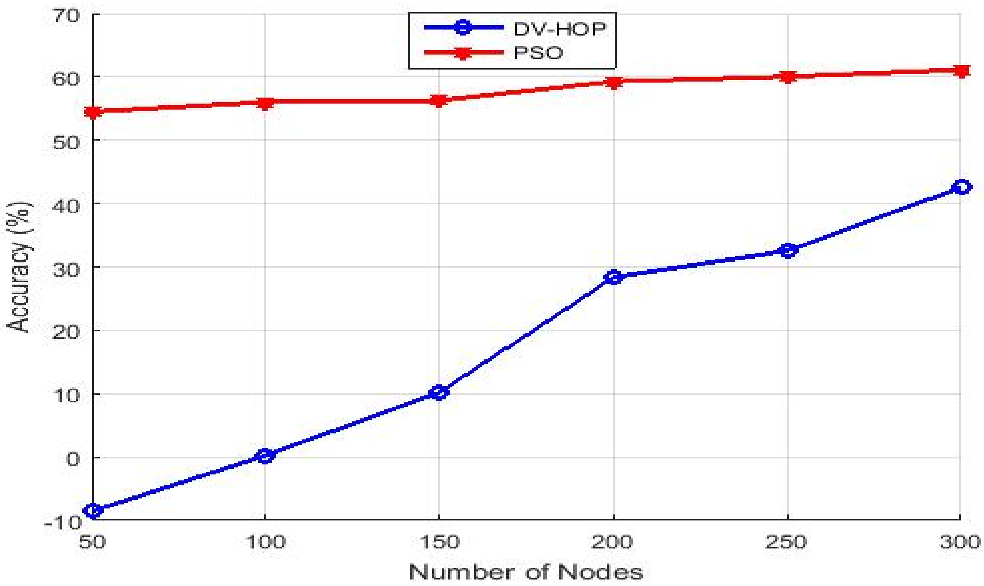

Fig. 6. Localization accuracy with changing no. of nodes

2) Impact of number of anchor nodes on localization results

The effect of beacons on the localization parameters like error, error variance and accuracy is given away in Fig. 7, Fig. 8, and Fig. 9 respectively.

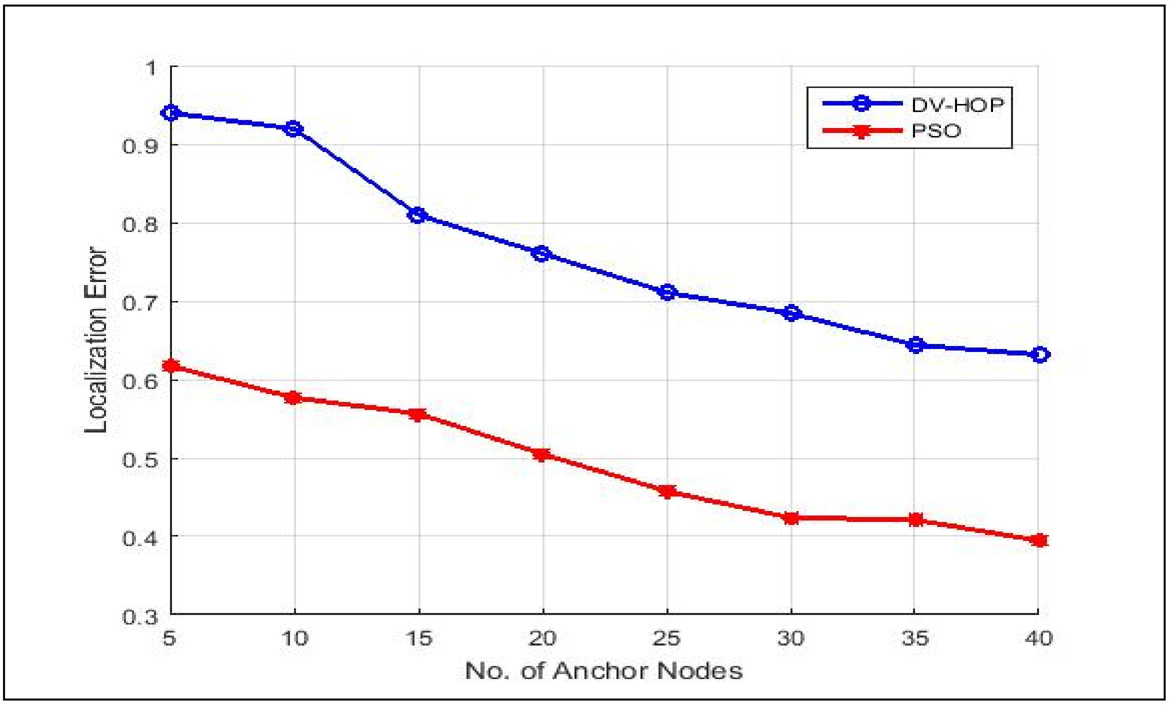

Fig. 7. Localization error with changing no. of anchor nodes

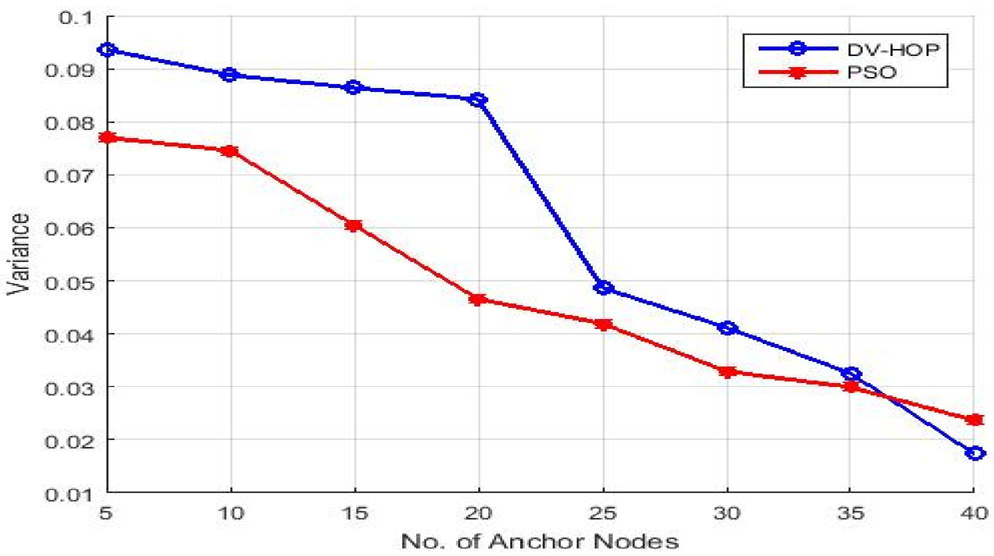

Fig. 8. Localization error variance with changing no. of anchor nodes

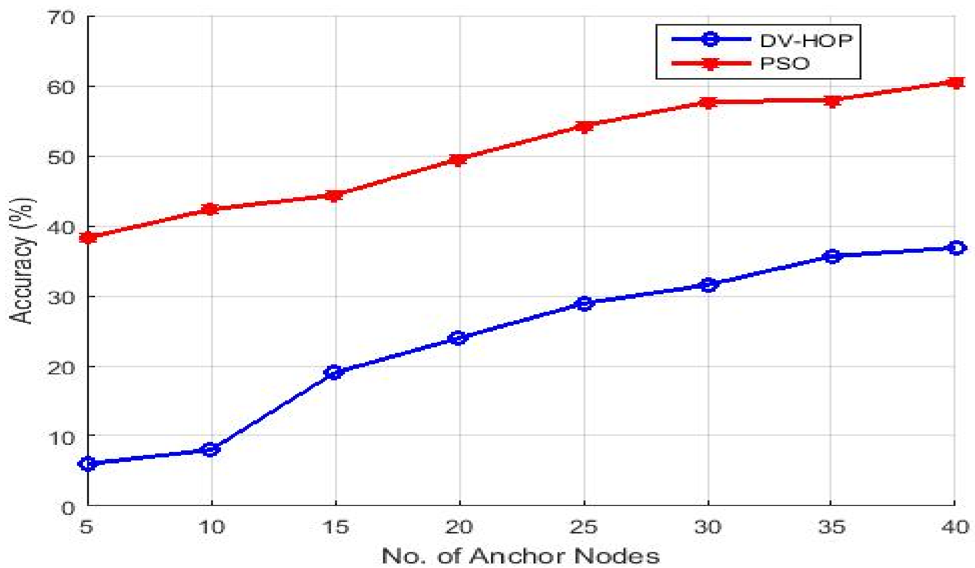

Fig. 9. Localization accuracy with changing no. of anchor nodes

3) Impact of radio range of sensor nodes on localization results

An effect of node's radio range on localization error, error variance and accuracy is given away in Fig. 10, Fig. 11, and Fig. 12 respectively

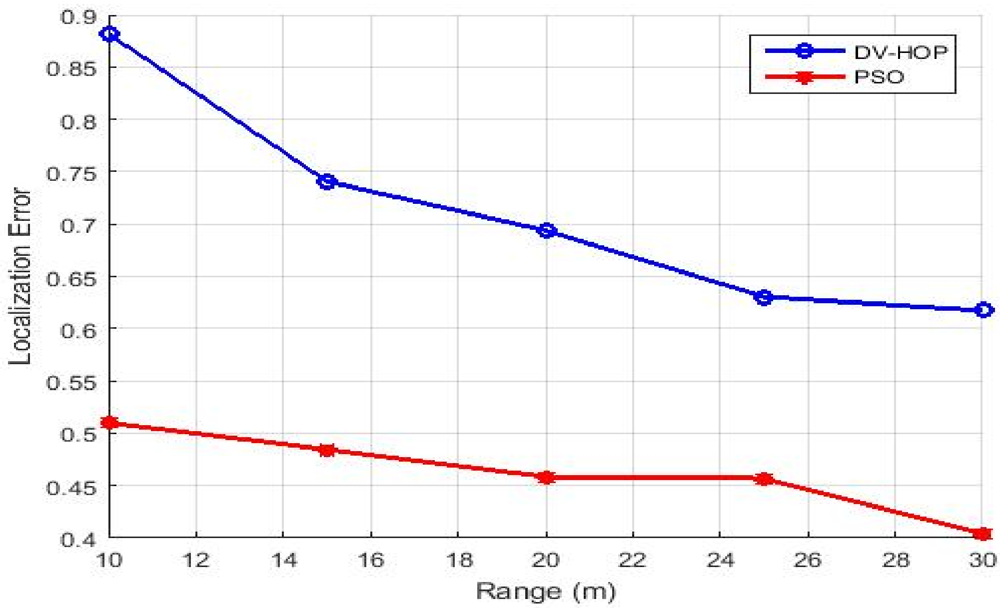

Fig. 10. Localization error with changing communication range

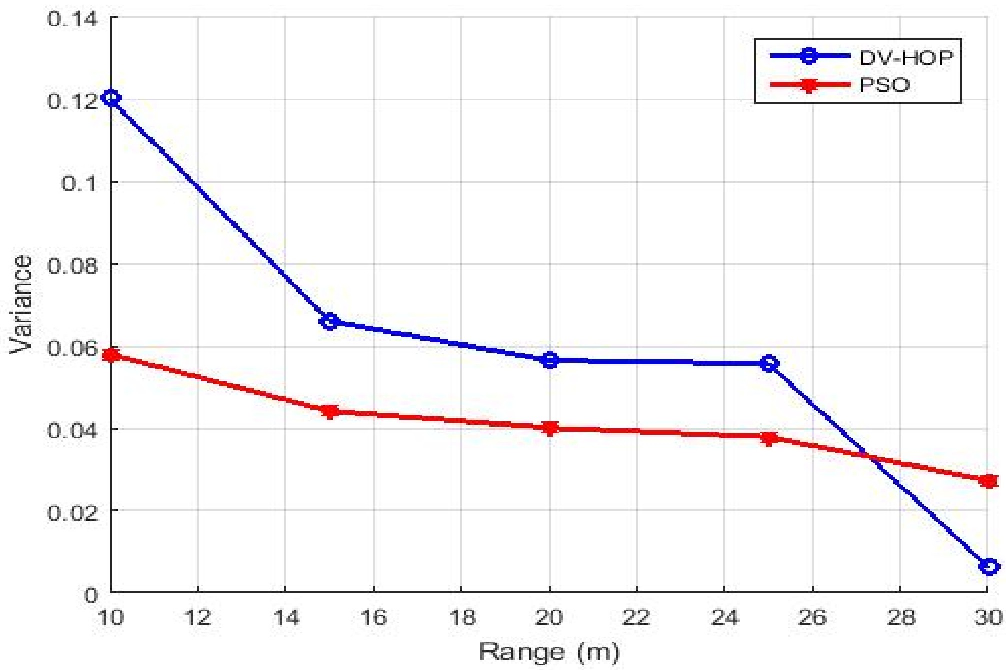

Fig. 11. Localization error variance with changing communication range

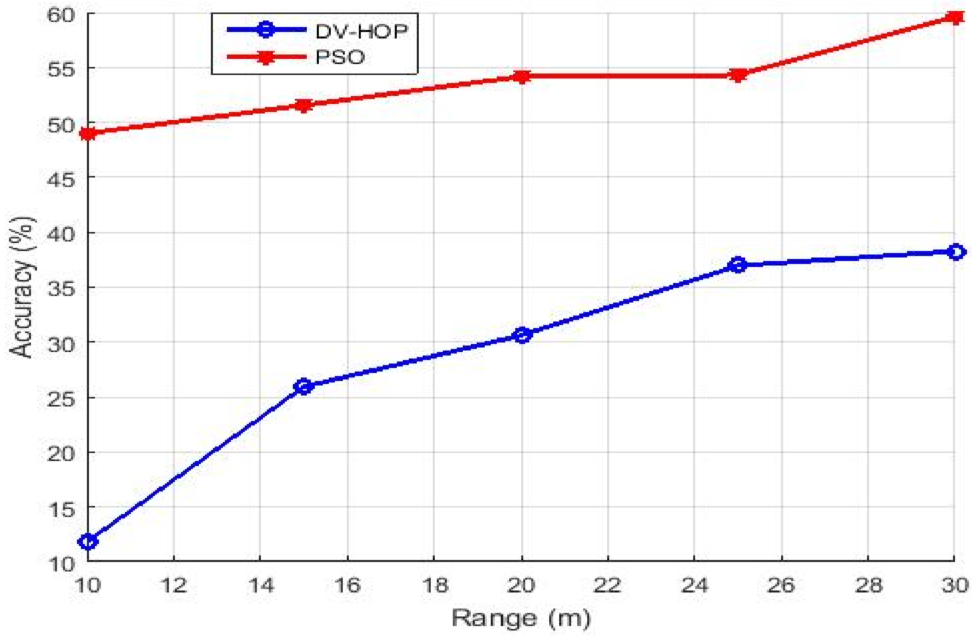

Fig. 12. Localization accuracy with changing communication range

VI. Conclusion

We presented a new algorithm i.e. modified DV-Hop algorithm, which improves the traditional DV-Hop algorithm considerably. The analysis of simulation result section states that our modified algorithm betters the localization error, error variance, accuracy as compared to basic hop based localization algorithm. As revealed in the simulation section of this paper, it can be stated that proposed method is efficient and have excellent application forefront. We also explored the effect of no of sensor nodes, no of anchor nodes, and radio range on the localization error as well as on accuracy. 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.

Acknowledgment

This work is supported by human resource development (MHRD) ministry under research grant scheme for doctoral work.

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He has successfully completed several major research projects independently funded by various Govt. Agencies like AICTE, CSIR, MHRD, DST, and DRDO Profile about the first author of the manuscript should be updated here.