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Implementation of a PSO Based Improved Localization Algorithm for Wireless Sensor Networks

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ABSTRACT

Wireless sensor networks (WSNs) are broadly employed in lots of applications. WSN is comprised of spatially dispersed sovereign devices enabled with sensors to examine some physical phenomenon. The node localization, which is to be responsive of nodes' location in the system, is a crucial component of numerous WSN functions and applications. Various localization algorithms have been proposed to precisely locate nodes in WSNs. The localization algorithms are normally categorized into range-based and range-free schemes based on range measurements. The range-based methods use exact computation measure (distance or time) among nodes in the network. So range-based methods need some additional hardware for such computation, thus expensive to be used in practice. Because of hardware constraints of sensor network devices, range-free methods are considered cost efficient alternatives. Though, these methods normally contain higher localization error in comparison with range-based methods. DV-Hop is an usual range-free method that use hop-based evaluation. In this article, we have modified DV-Hop method and applied a meta-heuristic (PSO) technique to overcome the positioning error. The algorithm has been implemented in MATLAB R2015a for the validation of results. The performance of implemented algorithm has been analyzed in terms of localization error, error variance, accuracy, and coverage. The results of modified algorithm confirm that our algorithm decreases the localization error and improved the localization accuracy as compared to DV-Hop and improved DV-Hop (IDV-Hop) algorithms.

KEYWORDS

Accuracy; Coverage; DV-Hop; Error; Localization algorithms; PSO; Wireless sensor network

1. INTRODUCTION

Nowadays, internet of things (IoT) for information sharing plays a vital role for improving the day-to-day life. In IoT, the multi-functional wireless sensors are installed in several applications. Wireless sensor network (WSN) is comprised of enormous amount of low-priced wireless nodes enabled with sensors [1,2]. These intelligent sensors can detect, compute, and communicate via suitable sensor technology. Ease of deployment and small price of sensors make WSN suitable for lots of applications like: health care, transportation, smart building, military affairs, reconnaissance, and environmental monitoring [3–6]. The forest fire forecast system based on WSN is shown in Figure 1. For such applications, the physical locations of sensors are needed to detect the events in monitored area. So, the node's location information in WSN is crucial and needed to develop context aware applications. Hence, position estimation (localization) of nodes is a key issue in WSNs.

The location assessment by adding global positioning system (GPS) to every wireless node is the easiest manner [7,8]. Lots of applications involve large number of nodes; thus usage of GPS in every node is costly as well as consumes more energy. Hence, such constraints suggest that use of GPS in localization is not feasible in sensor networks. Therefore, suitable localization algorithms are required.

Various localization schemes for sensor network have been used for position estimation of wireless nodes [9,10]. Based on range measurement, localization methods are partitioned into range-based and range-free schemes. Range-based schemes exploit absolute distance or direction info among neighbor node for the unknown nodes' location estimation. To determine the distance or direction, the subsequent measurement procedures have been utilized like: received signal strength indicator, time or time difference of arrival, and angle of arrival [11,12]. These schemes use added hardware, thus making it more costly. Conversely, range-free schemes do not require distance or orientation info. [13–15]. Thus, they do not need added expensive hardware, which makes it cost efficient and a good choice over range-based schemes. Because of ranging errors, range-free methods give less precise results as compared to ranging methods, which is, they be able to assure various applications requisites.

In this work, we focused merely on range free schemes particularly DV-Hop method and proposed a new

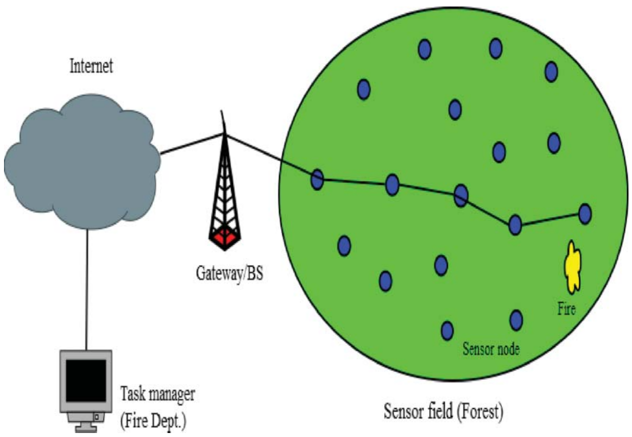

Figure 1: Structure of forest fire forecast system

modified DV-Hop method for sensor network localization. To overcome the localization error, we have implemented the improved algorithm with PSO. The implemented algorithm improves accuracy of localization with no increase in hardware and network traffic. In this paper, we make an effort to lessen positioning error in range-free localization scheme. The localization error is minimized in two manners. First, error in node localization is eased through solving a structure of equations with our process. Second, upgradation in node localization is advised to decrease the localization error. The simulation section confirms that the proposed algorithm performs better to original DV-Hop along with improved DV-Hop method.

The rest of the paper is structured in the following sections: Section 2 demonstrates the related work on range-free methods; DV-Hop method. Section 3 illustrates the DV-Hop scheme along with its error analysis and mathematical formulation of WSN localization problem. The outline of PSO technique and development of improved DV-Hop (IDV-Hop) algorithm using PSO are described in Section 4. In Section 5, results are revealed and performance analysis of the proposed algorithm with DV-Hop as well as improved DV-Hop methods is performed. Finally in Section 6, conclusions are expressed.

2. RELATED WORK

This part of paper focuses on research literature which is mainly related to our work. The usual range-free methods are centroid, approximate point-in triangle test (APIT), amorphous, DV-Hop, etc. In such methods, a few nodes, named anchor (beacon) nodes, are furnished with GPS device to identify their position. By means of these beacons, the position of normal (unknown) nodes is evaluated.

In centroid method [16], unlocalized node obtains signals from anchors within its communication region as well as estimates its position like centroid of such beacon nodes. APIT [17] makes use of the area-based scheme to evaluate the unknown node's position. Amorphous [18] method needs prior info of net density as it exploits offline hop distance evaluation.

DV-Hop [19] method is alike to conventional routing methods derived from distance vector scheme. Some benefits of DV-Hop scheme are ease, cost efficacy, feasibility, and large coverage area. In DV-Hop, a normal (unknown) node finds out the minimum hop count of it along with average hop distance. Finally, the nodes estimate their positions with help of triangulation method or maximum likelihood estimation (MLE) scheme. The main shortcoming of DV-Hop is poor positioning. Various schemes are reported in literature to get better accuracy of DV-Hop method [20–28]. Some of them are as follows.

Chen et al. [21] utilized average hop size on the setup instead of personal hop size of beacon in Distance Vector-Hop to determine distance among unknown and beacon node.

Chen et al. [22] offered the improved DV-Hop method wherein the hop distance be advanced via determining approximate positioning error. Node location is evaluated with the 2D hyperbolic algorithm in preference to triangulation method.

Hou et al. [23] presented the new DV-Hop method to symmetrically distributed sensor networks that improve location via improvements in the hop-size. The improvement in hop-size is achieved as a result of utilization of range's differential error term like weight coefficient.

Li [24] developed an improved method of localization using local assessment of hop-size in addition to vigorously correcting the ranging error on the basis of allocation of the unknown nodes just around a beacon node.

3. POSITION ESTIMATION AND ANALYSIS OF ERROR IN DV-HOP ALGORITHM

The implementation of present schemes consists of two steps.

3.1 Position Estimation

The DV-Hop method is developed by Niculescu and Nath [19] and is used for position estimation of nodes.

This method is comprised of three steps. In the first step, every node calculates the value of minimal hop-count to each anchor node. During second step, average hop distance may be evaluated with an easy procedure and afterward will be broadcasted. Once the unknown one gets it, then recipient evaluates its distance to anchor. In the last step, once the unknown attains three or more evaluated values from anchors, its position can be worked out with trilateration method.

Step 1: Calculating the minimum hop-count value

In this step, all anchor nodes broadcast a packet with their positions, along with a hop-count assessment initially set to zero, to its neighbors. The structure of packet is $\{id, x_i, y_i, h_i\}$, including the identifier *id*, coordinate of anchor *i*, (x_i, y_i) and the minimal hop-count value h_i as of anchor *i*, initially h_i is zero. Once neighbor nodes take delivery of the message with smaller hop-count to the specific anchor, they keep the position of the beacon node as well as raise the value of hop-count by one prior to spreading it to further nearby nodes. The packets that contain higher values of hop-count to a specific beacon are termed as stale info and will be overlooked. During this method, every node obtains the minimum hop-count assessment en route for each anchor.

Step 2: Distance estimation between nodes

In this step, we evaluate distance among all nodes. Initially, every anchor computes the average size per hop, HopSize, by Equation (1), which is specified as

$$\text{HopSize}_i = \frac{\sum_{i \neq j}^{m} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{\sum_{i \neq j}^{m} h_{ij}} \tag{1}$$

where (x_i, y_i) and (x_j, y_j) denote the geographic position of anchor *i* and *j*, h_{ij} denotes the smallest amount of hop among anchor *i* and *j*, and *m* represents the number of anchors.

Subsequent to computing HopSize_i, every anchor broadcasts its HopSize_i in the system via controlled flooding. As unknown node *j* gets the HopSize_i info from anchor, it determines the distance among itself and the anchor with Equation (2), which is specified as

$$d_i = \text{HopSize}_i \times h_{ij} \tag{2}$$

where h_{ij} represents the minimum hop-count assessment among anchors *i* and *j*.

Step 3: Determining the location

In this step, we find out the position of all unknown nodes. In accordance with the coordinates of beacon nodes along with the distance to them, which has been acquired in step 2, an unknown node computes its coordinate with use of multi-lateration method.

Let (x_u, y_u) be the location of an unknown node *U* and (x_i, y_i) be the coordinate of anchor *i*. Thus, distance among unknown node *U* and *m* anchors is specified via the following equation:

$$\begin{cases} (x_1 - x_u)^2 + (y_1 - y_u)^2 = d_1{}^2 \\ (x_2 - x_u)^2 + (y_2 - y_u)^2 = d_2{}^2 \\ \quad \cdots\cdots \\ (x_m - x_u)^2 + (y_m - y_u)^2 = d_m{}^2 \end{cases} \tag{3}$$

Equation (3) can be expanded as

$$\begin{cases} x_1{}^2 - x_m{}^2 - 2(x_1 - x_m)x_u + y_1{}^2 - y_m{}^2 - 2(y_1 - y_m)y_u = d_1{}^2 - d_m{}^2 \\ x_2{}^2 - x_m{}^2 - 2(x_2 - x_m)x_u + y_2{}^2 - y_m{}^2 - 2(y_2 - y_m)y_u = d_2{}^2 - d_m{}^2 \\ \quad \cdots\cdots\cdots\cdots\cdots \\ x_{m-1}{}^2 - x_m{}^2 - 2(x_{m-1} - x_m)x_u + y_{m-1}{}^2 - y_m{}^2 - 2(y_{m-1} - y_m)y_u = d_{m-1}{}^2 - d_m{}^2 \end{cases} \tag{4}$$

Equation (4) can be expressed in matrix form $AX = B$, where

$$A = \begin{bmatrix} 2(x_1 - x_m) & 2(y_1 - y_m) \\ 2(x_2 - x_m) & 2(y_2 - y_m) \\ \cdots\cdots & \\ 2(x_{m-1} - x_m) & 2(y_{m-1} - y_m) \end{bmatrix} \tag{5}$$

$$B = \begin{bmatrix} x_1{}^2 - x_m{}^2 + y_1{}^2 - y_m{}^2 + d_m{}^2 - d_1{}^2 \\ x_2{}^2 - x_m{}^2 + y_2{}^2 - y_m{}^2 + d_m{}^2 - d_2{}^2 \\ \cdots\cdots \\ x_{m-1}{}^2 - x_m{}^2 + y_{m-1}{}^2 - y_m{}^2 + d_m{}^2 - d_{m-1}{}^2 \end{bmatrix} \tag{6}$$

$$X = \begin{bmatrix} x_u \\ y_u \end{bmatrix} \tag{7}$$

The geometric position of unknown node *U* is calculated as

$$X = \left(A^T A\right)^{-1} A^T B \tag{8}$$

3.2 Error Analysis

The error is caused by minimum hops as well as average distance for each hop. Hence, error analysis is done based on these.

- Error caused by minimum hops

From the first step of DV-Hop localization method, it may be observed that no matter how far the actual distance between the two neighbor nodes is, as long as the node receives the information from neighbor nodes, the number of hops is 1. However, the layout of the nodes in real network environment is random, so there will not be huge number of regular nodes, and the path of the twists and turns. The minimum hop count obtained in this case is used in the positioning process and there will be a large error, as shown in Figure 2.

In Figure 2, U is an unknown node, and A1, A2, and A3 denote the beacon nodes. It is assumed that the distance among nodes A1 and U is much smaller than the distance between nodes U and C. However, in traditional DV-Hop positioning process, the hop between A1 and U is 1, and between U and C is also 1. Obviously error of minimum hop is large.

- Error caused by average distance per hop

During step 2 of DV-Hop, beacon node computes the average distance for each hop based on the minimum hops. The unknown node utilizes the average distance per hop of its nearby beacon node timing the hops to estimate the distance among all anchors. In Figure 2, according to DV-Hop method, the average hop distance per hop of A1 is (40 + 40)/(4 + 4) = 10. The unknown node obtains the average hop distance of A1 as well as makes it as its average distance per hop, then estimates its distance to A1, i.e. 10 × 1 = 10. The actual distance among U and A1 is 5, while evaluated distance is 10. Hence, the error among estimated distance and actual distance is relatively large.

This is because of number of bad nodes are present in randomly dispersed sensor network. There is merely node M close to N within one hop, the geographic location of M is well-known. The N just recognizes the M's position in single hop. Hence, N may exist at any

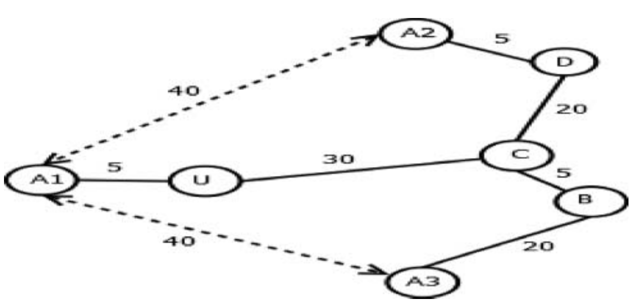

Figure 2: Error analysis

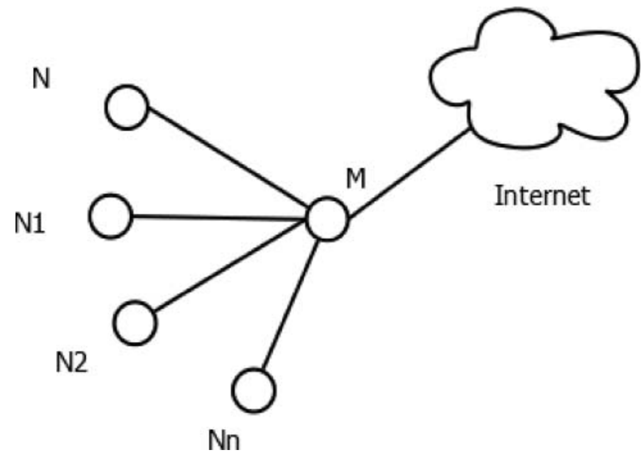

Figure 3: Diagram of bad nodes

place N1, N2, …, Nn, like revealed within Figure 3. It can be known that N's position is not only one of its kind. Otherwise stated, we cannot find out the locality of N, hence it is recognized like a bad node.

4. METHODOLOGY

4.1 Mathematical Formulation of Localization Problem in WSN

It is assumed that m anchor (beacon or known) nodes along with n unknown nodes are in a 2D network. Vector $\theta = [Z_1, Z_2, Z_3, \ldots., Z_{m+n}]$represents the initial coordinates of nodes and$Z_i = [x_i, y_i]^T$. The coordinates of m anchors are (x_1, y_1), (x_2, y_2), (x_3, y_3),…, (x_m, y_m) correspondingly. The soul of localization is to determine the locations of unknown nodes (x_{m+1}, y_{m+1}), (x_{m+2}, y_{m+2}), (x_{m+3}, y_{m+3}),…, (x_{m+n}, y_{m+n}) on the basis of specified coordinates of m anchors along with the distance to the anchors. Hence, the sensor network localization problem may be formulated as

$$(x, y) = f_{i=1,2,\ldots.,m}(x_i, y_i, d_i) \quad (9)$$

where (x, y) and (x_i, y_i) denote the coordinate of unknown node and known node I, respectively. d_i represents the distance among unknown node and known node i.

4.2 PSO Algorithm

The error is caused by minimum hops as well as average distance per hop. The keys of every problem of optimization in PSO are particles inside the search space [29,30]. Every particle has a fitness value that is achieved through objective function as well as the velocity to find out the direction along with distance of the flight. After that, particles follow the recent optimal particles to explore within the solution space. During the initialization procedure of PSO technique, a group of particles is generated randomly, as well as the final optimum solution is achieved through a number of iterations. In each iteration, every particle is capable of updating themselves via two features (to obtain a new location via obtaining a new velocity): particles seek in favor of an optimal solution via themselves that is named "self-awareness", also this procedure generally has a lot to perform through the local search capability; one other aspect named as "swarm intelligence", means toward the optimal solution initiated by entire group. During the velocity updation procedure, it is able to direct the entire group towards the best known spots within the search space. It is predictable about the swarm's travel towards the most excellent solutions underneath the communication and collaboration amid individual and group. Particle's updation activities are expressed as follows:

$$V_{id}(t+1) = V_{id}(t) + C_1 \times \emptyset_1 \times (P_{id} - X_{id}(t)) + C_2 \times \emptyset_2 \times \left(P_{gd} - X_{id}(t)\right) \quad (10)$$

$$X_{id}(t+1) = X_{id}(t) + V_{id}(t+1) \quad (11)$$

where V_{id} denotes the particle's velocity, X_{id} denotes the position of particle. C_1 and C_2 represent the learning coefficient. ϕ_1 and ϕ_2 are the random numbers among 0 and 1. P_{id} is the best solution position individually and P_{gd} is the group best solution position globally.

4.3 An Improved DV-Hop Algorithm using PSO

In DV-Hop method, an error is occurred as the distance is an estimated value. For efficient localization, error must be minimized.

In WSNs, localization technique is able to get the locations of the unknown nodes with optimization scheme from the point of view of global optimization. Several methods derived from optimization scheme have been recommended to solve the WSN localization issue. PSO is a heuristic that may be implemented as a technique of searching the best possible solution. Therefore, we can apply PSO for localization in WSNs. We set up a mathematical model of optimization with use of the distance among the unknown node and anchors, after that apply PSO to provide a solution to the optimization model. Thus, we are able to acquire the location of unknown node.

In the present work, we proposed a new improved DV-Hop algorithm with PSO approach. Assume that $m + n$ nodes are in the WSN, which contains m anchors and n unknown nodes. The coordinate of anchor node is (x_i, y_i), $(i = 1, 2, 3, \ldots, m)$ and the coordinate of unknown node is (x, y).

As said by the second step of DV-Hop, we obtain the distance d_i among an unknown node and anchor node i, $(i = 1, 2, 3, \ldots, m)$. The Euclidean distance among unknown node and anchors can be stated as

$$\begin{cases} \sqrt{(x-x_1)^2 + (y-y_1)^2} = d_1 \\ \sqrt{(x-x_2)^2 + (y-y_2)^2} = d_2 \\ \sqrt{(x-x_3)^2 + (y-y_3)^2} = d_3 \\ \quad \ldots. \\ \sqrt{(x-x_m)^2 + (y-y_m)^2} = d_m \end{cases} \quad (12)$$

The distance is the estimated quantity; thus, error should be there due to difference in true (or actual) value and estimated value of distance. Thus, we presented an improved DV-Hop method with PSO approach. The localization problem can be mathematically formulated as

$$f(x,y) = \mathrm{Min}\left(\sum_{i=1,2,\ldots,m} \left| \sqrt{(x-x_i)^2 + (y-y_i)^2} - d_i \right| \right) \quad (13)$$

In accordance with objective function revealed in Equation (13), we formulate the fitness function like:

$$\mathrm{fitness}(x,y) = \sum_{j=1}^{n} \left(\frac{1}{hop_j} \right)^2 f(x,y) \quad (14)$$

Particle's updations are done with the help of Equations (10) and (11). Equation (14) is the fitness function to estimate the fitness of particles. The total number of iterations is set accordingly. After this process, the best possible solution is considered the same as the final estimated locality of unknown node.

Development steps of improved algorithm

The common steps of improved algorithm are stated as follows:

Step 1: Determine the value of minimum hop from all nodes to every anchor node;
Step 2: Determine average distance per hop of all beacon nodes as per Equation (1);
Step 3: With the help of value of minimum hop count along with hop-size, every unknown node evaluate its distance to anchor as said by Equation (2);

Step 4: Find out the viable zone of every unknown node and make the initial positions and velocities of particles in feasible region;

Step 5: Estimate the fitness of all particles;

Step 6: The updation operations are accomplished to produce the next one. This method is reiterated until stopping criterion is satisfied.

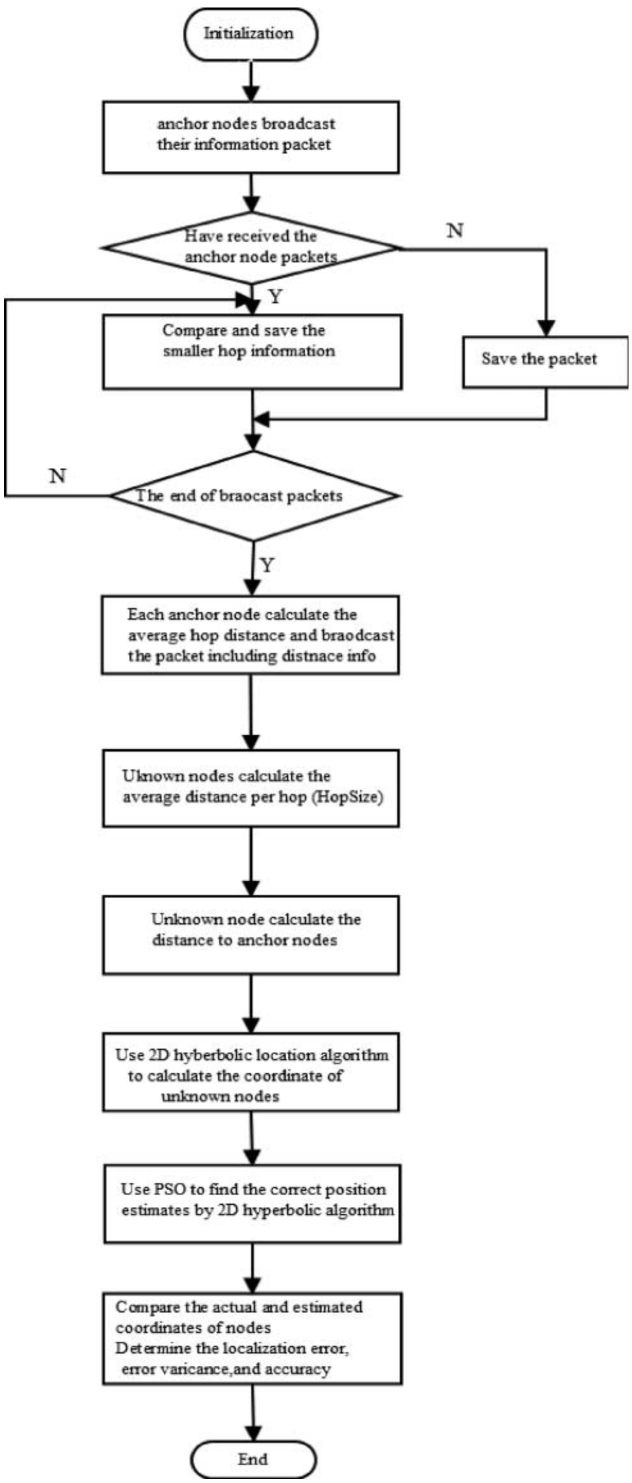

Figure 4: Flow chart of proposed algorithm

The flow chart of proposed improved localization method is revealed in Figure 4.

5. RESULTS AND ANALYSIS

By modifying DV-Hop algorithm with PSO, positioning error can be minimized through various steps. In this part of paper, we present the results of implemented algorithm and investigation of these for localization parameters. To validate the performance of proposed method in comparison to other methods, namely DV-hop, improved DV-Hop, etc. simulations are performed on MATLAB 2015a.

The experimented region is an open area with a set size of 100 m × 100 m in all trials and 100 nodes are installed at random in 2D network area. As revealed in Figure 5, red pentacles stand for anchors and black dots correspond to unknown node. Every node has an identical communication radius that is equal to 30 m.

The PSO parameters exploited in simulation are revealed in Table 1.

We use localization error of each unknown node. The localization error of unknown node i is described through the following equation:

$$\text{Error}_i = \sqrt{(x_i^{\text{est}} - x_i^{\text{act}})^2 + (y_i^{\text{est}} - y_i^{\text{act}})^2} \tag{15}$$

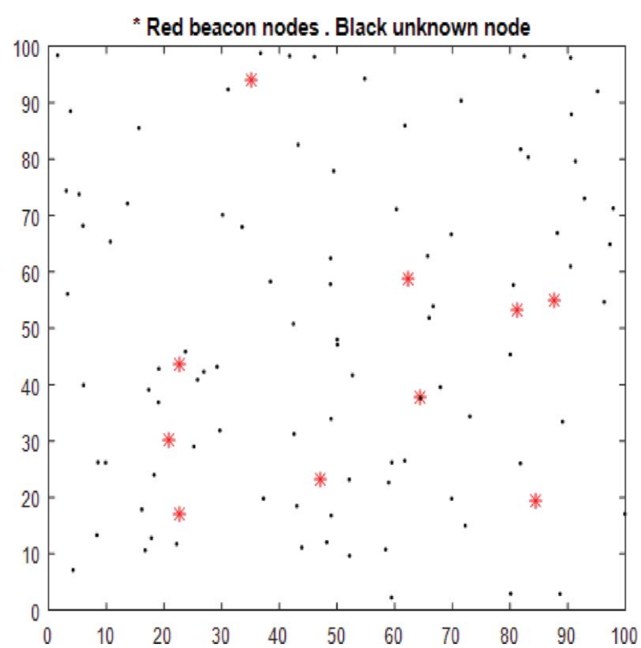

Figure 5: Nodes distribution

Table 1: PSO parameters

Parameter	Value
$C_1 = C_2$	2.05
ω	0.9
Number of particles	30
V_{max}	10
Number of iterations	100

where (x_i^{est}, y_i^{est}) and (x_i^{act}, y_i^{act}) denote the estimated and actual position of unknown node i.

The most important measure of localization problem is localization error. Average localization error is described as the proportion among whole error and quantity of unknown nodes. It can be computed as

$$\text{Localization Error(LE)} = \frac{\sum_{i=1}^{n} \text{Error}_i}{n \times R} \tag{16}$$

We analyze the impact of total number of nodes, anchor nodes, and communication range on the localization results. The stability and accuracy of localization are analyzed by localization parameters and these performance parameters are calculated by the following formula:

$$\text{Localization Error Variance} = \frac{\sum_{i=1}^{n} (\text{LE}_i - \overline{\text{LE}})^2}{n - 1} \tag{17}$$

Localization Accuracy

$$= \frac{\sum_{i=1}^{n} \sqrt{(x_i^{est} - x_i^{act})^2 + (y_i^{est} - y_i^{act})^2}}{n \times R^2} \tag{18}$$

$$\text{Coverage} = \frac{\bigcup_{i=1}^{n} R^2(x_i, y_i)}{\text{Area}} \tag{19}$$

where $R(x_i, y_i)$ is the radius of sensor centered at (x_i, y_i), n denotes the quantity of unknown nodes, and $\overline{\text{LE}}$ is mean of localization error. Area is the deployment area, i.e. area of experimental region. Where, n is given as

$$n = \text{total number of nodes} - \text{number of anchor nodes} \tag{20}$$

5.1 Analysis of Results

From Equations (16) and (20), it is clear that number of nodes, number of anchor nodes, and node's communication radius all influence the localization error. Therefore, we evaluate our results against the parameters given as

(1) Total number of nodes
(2) Proportion of anchors
(3) Node's communication radius

Keeping the area of 100 m × 100 m, the analysis of algorithm in terms of localization error, error variance, accuracy, and coverage has been performed

5.2 Total Number of Nodes

In Figure 6, it can be examined that when overall quantity of nodes rises inside the area, the error in localization of DV-Hop, improved DV-Hop, as well as proposed algorithm reduces. That is for the reason that as the node density enhances, the quantity of unknown node increases. Thus, average quantity of neighbors for every node enhances, and therefore, the network turns out to be a well-connected one. The influence of total amount of nodes on localization error, error variance, accuracy, and coverage is shown in Figures 6–9, respectively.

- Localization Error

The result of the above-developed algorithm has been evaluated with DV-Hop and improved DV-Hop in terms of localization error by changeable number of nodes (50–300). It has been observed that when the quantity of nodes increases, localization error of IDV-Hop suddenly falls when total nodes are in the range

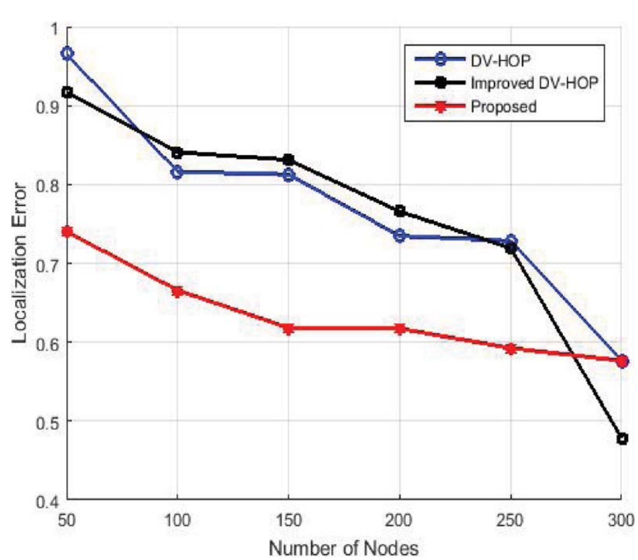

Figure 6: Localization error with varying number of nodes

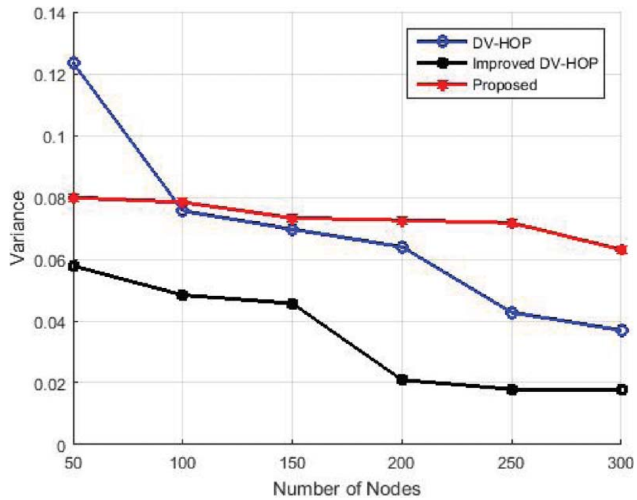

Figure 7: Localization error variance with varying number of nodes

250–300. This is because of positioning problem of IDV-Hop for dense network.

- *Localization Error Variance*

The result of the above-developed algorithm has been evaluated with DV-Hop as well as improved DV-Hop in terms of localization error variance by varying number of nodes (50–300). It has been observed that when the quantity of nodes is less, localization error variance of DV-Hop suddenly falls when total nodes are in the range 50–100. This is because of error problem of IDV-Hop for sparse network.

- Localization *Accuracy*

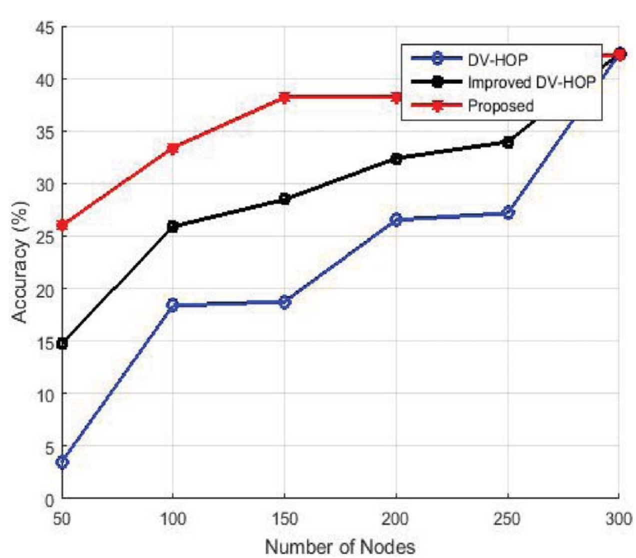

Figure 8: Localization accuracy with varying number of nodes

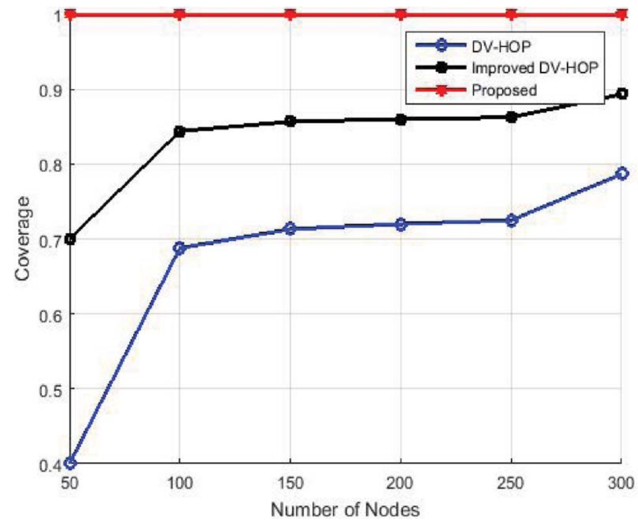

Figure 9: Coverage with varying number of nodes

The result of the above-developed algorithm has been evaluated with DV-Hop as well as improved DV-Hop in terms of localization accuracy by changeable number of nodes (50–300). It has been observed that when the quantity of nodes rises, localization accuracy of algorithm improves. This is because of the quantity of neighbors for every node enhances in dense network therefore the network turn out to be well connected.

- Coverage

The result of the above-developed algorithm has been compared with DV-Hop as well as improved DV-Hop in terms of coverage by changeable number of nodes (50–300). It has been observed that when the quantity of nodes rises, coverage of DV-Hop and IDV-Hop algorithms improves. This is because of average quantity of neighbors for every node enhances in dense network therefore the network turn out to be well connected

5.3 Ratio of Anchor Nodes

We kept constant the total quantity of nodes and communication radius. In such situations, we noticed that when the percentage of anchors rises inside the area, error in localization of DV-Hop, improved DV-Hop, as well as proposed algorithm decreases. As the amount of anchors in the system boost for a set quantity of entire nodes, then numbers of hops among anchor and unknown nodes lessen as well as the unknown node gets info from added anchors. As a result, the evaluated distance amid unknown and anchor node is more close to real distance. Thus, localization error of algorithms decreases in the midst of increasing fraction of anchor nodes. The effect of anchor variation on error, error

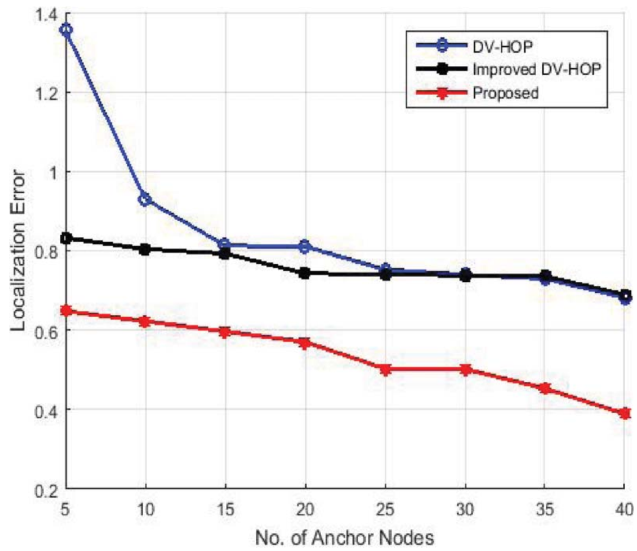

Figure 10: Localization error with varying number of anchor nodes

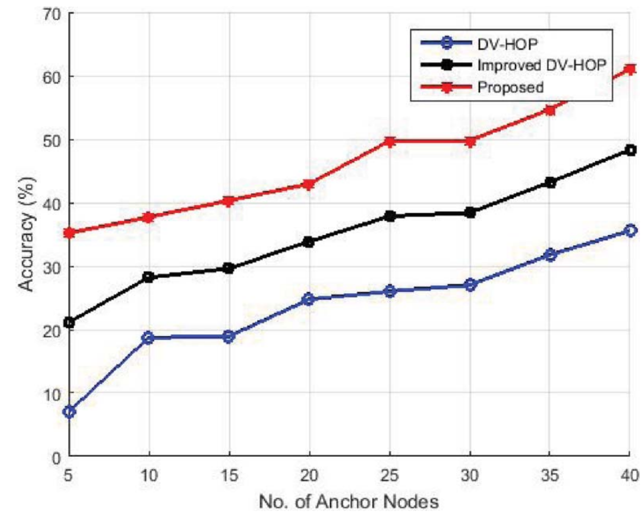

Figure 12: Localization accuracy with varying number of anchor nodes

variance, accuracy, and coverage of localization is demonstrated in Figures 10–13, respectively.

- Localization *Error*

The result of the above-developed algorithm has been compared with DV-Hop as well as improved DV-Hop in terms of localization error by changeable number of anchor nodes (5–40). It has been observed that when the quantity of anchors rises, localization error of IDV-Hop suddenly falls when anchor nodes are in the range 5–10. This is because of the anchor ratio, as the ratio of anchors increases the number of hops among anchors and unknown node lessens.

- Localization *Error Variance*

The result of the above-developed algorithm has been evaluated with DV-Hop as well as improved DV-Hop in terms of localization error variance by varying number of anchors (5–40). It has been observed that when the quantity of anchors rises, localization error variance of DV-Hop suddenly falls when anchor nodes are in the range 5–10. This is because of the anchor ratio, as the anchors ratio increases, the number of hops among anchors and unknown node lessens.

- Localization *Accuracy*

The result of the above-developed algorithm has been compared with DV-Hop as well as improved DV-Hop in terms of localization accuracy by changeable number of anchor nodes (5–40). It has been observed that when

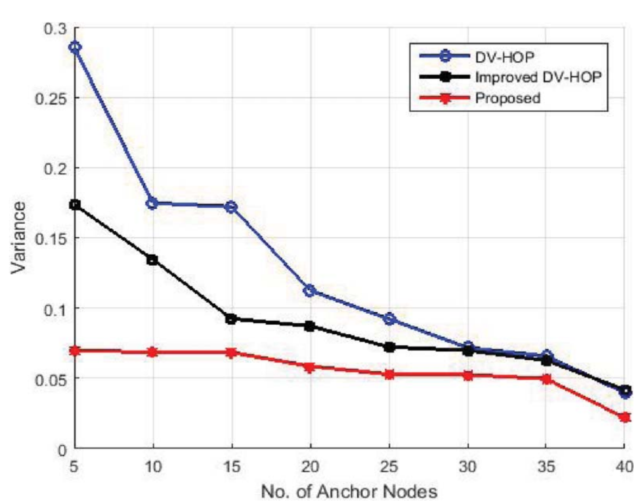

Figure 11: Localization error variance with varying number of anchor nodes

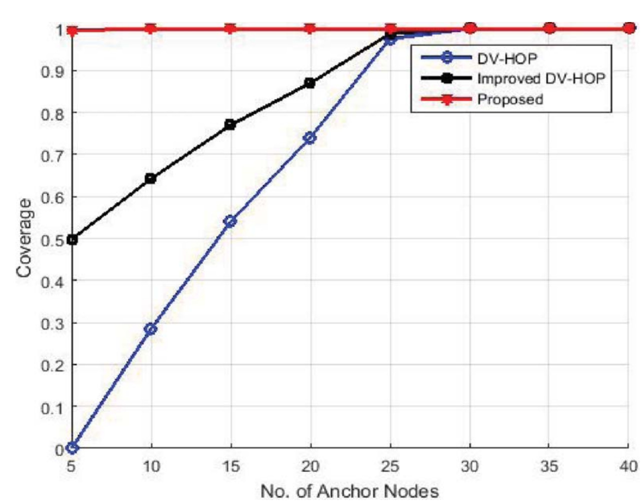

Figure 13: Coverage with varying number of anchor nodes

the quantity of anchors rises, localization accuracy of algorithm improves. This is because of average quantity of neighbors for every node enhances in dense network therefore the network turn out to be well connected.

- Coverage

The result of the above-developed algorithm has been evaluated with DV-Hop as well as improved DV-Hop in terms of coverage by changeable number of anchor nodes (5–40). It has been observed that when the quantity of nodes rises, coverage of DV-Hop and IDV-Hop algorithms improves.

5.4 Communication Radius of Sensor Nodes

The whole quantity of sensor nodes kept consistent and the amount of anchors is 10% of the entire nodes. In these scenarios, we examined that when the nodes' communication radius enhances, error in localization of DV-Hop, improved DV-Hop, and proposed algorithm decreases. As communication radius enhances for a set amount of unknown and beacon nodes, network becomes well connected. The influence of communication radius variation on localization error, error variance, accuracy, coverage is demonstrated in Figures 14–17, respectively.

- Localization *Error*

The result of the above-developed algorithm has been evaluated with DV-Hop as well as improved DV-Hop in terms of localization error by varying communication radius (10–30 m). It has been observed that when the communication increases, error of DV-Hop and

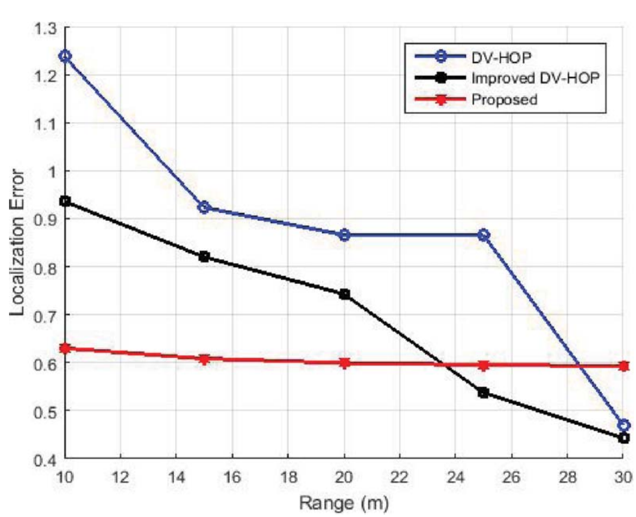

Figure 14: Localization error with varying communication radius

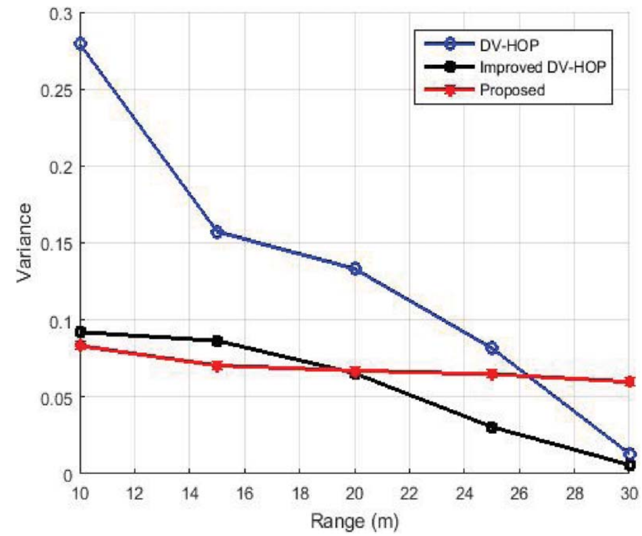

Figure 15: Localization error variance with varying communication radius

IDV-Hop suddenly falls when radius is in the range 25–30 m. This is because of the communication radius, as the communication radius increases the number of neighbors' increases means number of hops amongst nodes are less thus DV-Hop and Improved DV-Hop shown better results.

- Localization *Error Variance*

The result of the above-developed algorithm has been evaluated with DV-Hop and improved DV-Hop in terms of localization error variance by varying communication radius (10–30 m). It has been observed that when the communication radius increases, localization error variance of DV-Hop suddenly falls when radius is

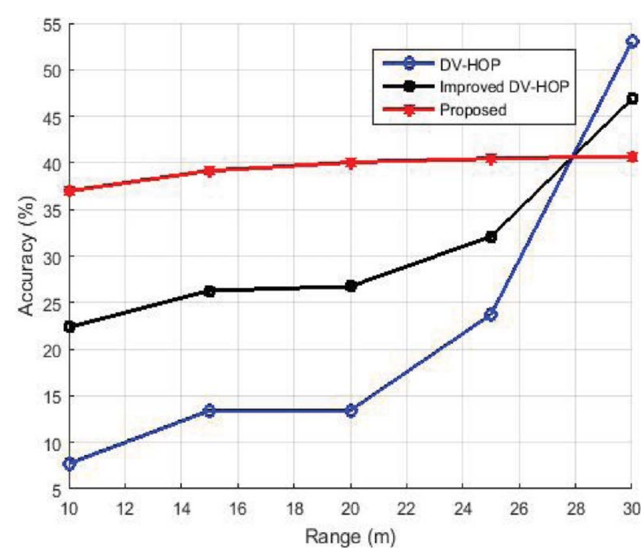

Figure 16: Localization accuracy with varying communication radius

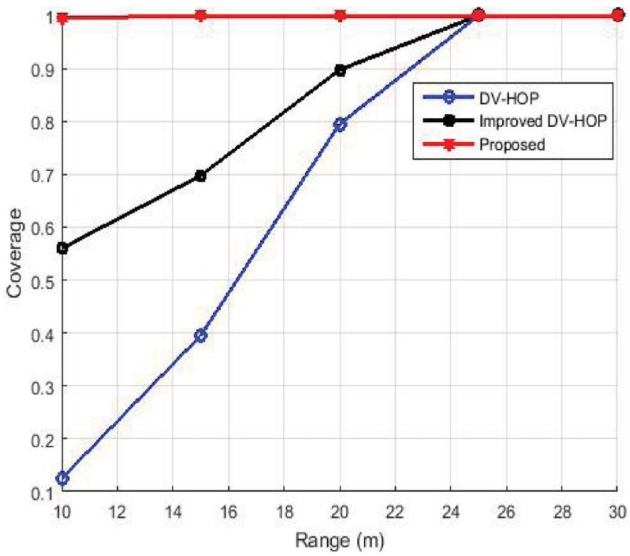

Figure 17: Coverage with varying communication radius

in the range 10–15 m. This is because of the node's range, as the communication range increases the network becomes well connected.

- Localization *Accuracy*

The result of the above-developed algorithm has been evaluated with DV-Hop and improved DV-Hop in terms of localization accuracy by varying communication radius (10–30 m). It has been observed that when the communication radius increases, localization accuracy of algorithm improves. This is because of average quantity of neighbors for every node enhances in dense network therefore the network turn out to be well connected.

- Coverage

The result of the above-developed algorithm has been evaluated with DV-Hop and improved DV-Hop in terms of coverage by varying communication radius (10–30 m). It has been observed that when the communication increases, coverage of DV-Hop and IDV-Hop algorithms improves.

6. CONCLUSION

In the present work, we have developed and implemented a new improved DV-Hop algorithm for localization based on PSO. In the development process, we have calculated hop count value, average hop size, compute the position and perform error analysis and further modify and develop a mathematical model for implementation of meta-heuristic (PSO) approach. Finally, an improved DV-Hop algorithm using PSO has been developed and implemented, which decreases the localization error with no increase in added hardware as well as cost of computation. The developed method utilizes anchor's hop size through which the unknown node determines its distance. Moreover, the locations of unknown nodes are improved with PSO approach. The analysis of developed algorithm has been carried out in terms of localization error, error variance, accuracy, and coverage with varying amount of nodes, ratio of anchor nodes, and communication radius. From the results it has been observed that our algorithm provides less localization error as compared to DV-Hop as well as Improved DV-Hop algorithms.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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