Particle Swarm Based Node Localization in Wireless Sensor Networks

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Abstract- In Wireless Sensor Networks (WSN), node localization is one of the most crucial issues, as many WSN applications depend on the accurate position of the sensor nodes. In last two decades, many range based and range free localization algorithms have been proposed. Relatively range free techniques are more efficient but having poor localization accuracy. Distance Vector Hop (DV-Hop) localization algorithm is most widely used algorithm due to its stability, feasibility and less hardware cost, but it shows poor localization accuracy. To improve its localization accuracy, we proposed a Particle Swarm Optimization (PSO) based improved DV-Hop algorithm viz. PSO-IDV. In the proposed algorithm, average hop size of the anchor is modified by updating a correction factor in it. For further improving the accuracy, we used PSO technique in IDV-Hop. Since localization in WSN is an optimization problem in which with the help of bounded population feasible region, PSO-IDV locates the unknown nodes more accurately and achieves higher convergence rate relatively. Simulation results show that our proposed algorithm is efficient and more accurate in terms of localization accuracy compared to DV-Hop, DV-Hop based on Genetic Algorithm (GADV-Hop) algorithms.

Index Terms — Wireless Sensor Networks, Localization, DV-Hop Algorithm, Particle Swarm Optimization

1. INTRODUCTION

Wireless Sensor Networks (WSN) is an emerging technology and have attracted worldwide interest in research and industries, because of having a large number of applications in various areas such as surveillance, habitat and environmental monitoring, military applications, healthcare, structural monitoring and disaster management [3]. Among all these, many applications depend on the accurate locations of the nodes. Due to this localization has become the crucial issue in wireless sensor networks.

Localization algorithms are basically divided into two categories: range based and range free. The range free schemes use connectivity information and hop values to estimate the location of unknown nodes. Due to some limitations in range based schemes, range free schemes have attracted worldwide researchers' interest because range free schemes are the cost effective alternate solution without any extra hardware. From past some decades, many range free algorithms have been proposed, which will be discussed in the next section.

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Optimization (PSO) based improved Distance Vector (PSO-IDV) hop algorithm which is a range free distributed scheme. PSO [23] is used to improve the localization accuracy of the DV hop algorithm. Simulation results show that our proposed algorithm performs better in terms of accuracy, simplicity and fast convergence than some existing same kind of range free localization algorithms.

The remaining paper is structured as follows: Basic DV-Hop algorithm and some modified DV-Hop algorithms are presented in Section 2. PSO technique is described in Section 3. In Section 4, our proposed algorithm (PSO-IDV) is presented. Then we discussed simulation parameters and experimental results in Section 5. Finally, the whole paper is concluded in Section 6.

2. LITERATURE REVIEW

In literature, a number of range free localization algorithms have been proposed during last two decades such as Centroid [7], Distance Vector Hop (DV-Hop) [6,13], Approximate Point In Triangle (APIT) [9], Convex Position Estimation (CPE) [8], Multidimensional Scaling (MDS) [12] and many more. But among all these range free algorithms, DV-Hop has attracted more concentration of researchers because of its simplification, stability, feasibility and less requirements of hardware. However DV-Hop has poor localization accuracy and needs an improvement in it. Therefore, we will present an improved DV-Hop algorithm based on PSO in coming sections of this paper.

DV-Hop localization algorithm was firstly proposed by Dragons Niculescu et al [13]. Many range free and range based localization algorithms work for those unknown nodes which have atleast three neighbour anchor nodes for position estimation. But DV-Hop algorithm can also work for those unknown nodes which have few or even no anchor at their neighbour. Since in real time scenarios, anchor nodes are deployed in a very small quantity as compared to normal nodes. Although it has poor localization accuracy yet it is most widely used for large scale applications due to its simplicity, stability, feasibility and less requirements of hardware.

Since DV-Hop algorithm is simple to implement and can localize the nodes which have a few or even no neighbour anchors but its localization accuracy needs to be improved. Many improved versions of DV-Hop algorithm have been proposed in the literature, some of them are discussed here.

Dengyi et al. [18] proposed an improved DV-Hop algorithm for WSNs. In this, localization accuracy is improved by two methods throughout the whole process. Firstly, normal node refines the average distance per hop by taking mean of anchor node's hop size. Secondly, the anchor nodes also refine the average distance per hop with the angle information between normal and anchor node. Calculating angles between normal and anchor nodes make this algorithm more complicated and energy inefficient.

Chen et al. [17] proposed an improved DV-Hop algorithm based on Particle Swarm Optimization (PSO). There are mainly four steps to describe the algorithm. In step 1, some of the anchor nodes are deployed on the boundary of the sensing field. In step 2, anchor nodes refine their average distance per hop and broadcast this throughout the network. Also normal nodes update the hop size for themselves after receiving the modified average distance per hop of the anchor nodes. In step 3, distance is calculated by normal nodes and position is estimated using 2-D hyperbolic location algorithm [16].

Finally in step 4, PSO is used to improve the accuracy of the algorithm. Anchor nodes placement at the boundary of the sensing field is not a feasible for inaccessible terrain area.

Bo Peng et al. [15] proposed genetic algorithm (GA) based DV-Hop algorithm. The whole algorithm has six steps to perform in which starting three steps are same as for original DV-Hop algorithm and last three steps are for process of genetic algorithm. Though GADV-Hop algorithm improves the localization accuracy up to an extent but by using genetic algorithm, there are some control parameters (crossover, selection and mutation) to be tuned correctly for getting better results.

From the above review, we conclude that localization is the optimization problem and its overall estimation error needs to be minimized. This encourages us to propose PSO-IDV.

3. BRIEF OVERVIEW OF PSO

Eberhart and Kennedy developed the PSO in 1995 [23] based on the analogy of bird flock and fish school where each individual is allowed to learn from the experience of its own and from its neighbors. The PSO technique employs a set of feasible solutions within the search space, called a Swarm of particles with random initial locations. The value of objective function corresponding to each particle location is evaluated.

These particles move in search space obeying rules inspired by bird flocking behavior [10], [11] to find new locations with better fitness. Each particle is allowed to move towards the best position; the particle has come across so far (*pbest*) and the best position encountered by the entire swarm (*gbest*). Somehow, to get the accurate solution, the whole swarm is subdivided into sub-swarms and the particle with the best fitness with in the local swarm is termed as *lbest*.

Consider a search space is *d*-dimensional and ith particle in the swarm can be represented as $Xi = [xi1; xi2; : : : ; xid]$ and its velocity can be represented by another *d*-dimensional vector $Vi = [vi1; vi2; : : : ; vid]$. Let the best position ever visited in the past by the ith particle be denoted by $Pi = [pi1; pi2; : : : ; pid]$. Many a times, the whole swarm is subdivided into smaller groups and each group/sub-swarm has its own local best particle denoted $Pl = [pl1; pl2; : : : ; pld]$, and an overall best particle, denoted as $Pg = [pg1; pg2; : : : ; pgd]$, where subscripts *l* and *g* are particle indices. The particle iterates in every unit time according to (1) and (2):

$$v_{id} = wv_{id} + c_1 r_1 \left(p_{id} - x_{id} \right) + c_2 r_2 \left(p_{gd} - x_{id} \right) + c_3 r_3 \left(p_{ld} - x_{id} \right) \quad (1)$$

$$x_{id} = x_{id} + v_{id} \quad (2)$$

The parameters *w, c1, c2* and *c3* termed as inertia weight, cognitive, social and neighborhood learning parameters, respectively, and have a critical role in the convergence characteristics of PSO. The particles randomize the attraction with uniform random numbers *r1, r2*, and *r3* in the range [0, 1]. The weight factor *w* should be neither too large, (which results in an early convergence), nor too small, (which, on the contrary, slows down the convergence process). A value of *w* = 0:7 and *c1 = c2 = c3* = 1:494 were recommended for fast convergence by Eberhart and Shi after experimental tests in [23].

PSO based localization method has very low memory requirements because it has to store only a limited number of variables such as *pbest, gbest, lbest* and current particle position at any stage of the search process. The proposed PSO method uses a particle population size of *k* = 20. Hence, memory requirement of PSO based localization technique is very low compared to memory available in current sensor nodes, e.g., MICA2 Mote has a programming flash memory of 128 bytes.

4. PSO BASED IDV-HOP ALGORITHM

We present our proposed algorithm i.e. PSO based IDV- Hop. It is well known that DV-Hop algorithm is based on Distance Vector (DV) routing. Distance between the nodes is estimated by the hop count value multiplied by the hop size of the anchor. But there is large amount of error between the calculated and actual value when the hop count value is greater than equal to two hops. Original DV-Hop algorithm does not consider the deviation created by anchors. The improved algorithm implements the revised hop size in the network to calculate the distance between normal node and anchor node and uses PSO to estimate correct location of the nodes.

In our algorithm, starting two steps are same as original DV-Hop algorithm. In step 3 of our algorithm, calculated distance is modified. Consider *Dij* is the distance between two anchors *i* and *j*, calculated according to equation (3), as follows:

$$Dij = HopSizei \times hopij \;, \text{ where } i \neq j \quad (3)$$

The actual distance between two anchor nodes can be calculated by their coordinates, as follows:

$$D'_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \;, \text{ where } i \neq j \quad (4)$$

where*(xi,yi)* and *(xj,yj)* are the coordinates of anchors i and j respectively. Now from equation (3) and (4), error between the estimated distance and actual distance;d^e_{ij} can be calculated by the following relationship.

$$d^e_{ij} = \left| D_{ij} - D'_{ij} \right| \quad (5)$$

Now this distance error value is used to modify the average distance per hop value of the anchor node by adding the correction factor ψ to the previous hop size value of the particular anchor. This correction factor is used to refine the average distance per hop deviation of the anchor node. ψi is the correction factor of an anchor i and can be calculated using formula (5).

$$\psi_i = \frac{\sum_{i \neq j} d^e_{ij}}{\sum_{i \neq j} h_{ij}} \quad (6)$$

Now finally the specific distance between unknown node and anchor node can be calculated according to Eq. (7).

$$d'ij = (HopSizei + \psi i) \times hopij \;, \text{ where } i \neq j \quad (7)$$

Still the modified distance value calculated from (7) is not so much accurate because it is an estimated value, there must be error. Therefore, further we use a very efficient optimization technique i.e. PSO to minimize the error of localization in WSN. So the localization problem can be formulated in terms of objective function as:

$$f(x_u, y_u) = \text{Min} \left(\sum_{\substack{i=1,2....k \\ u=k+1......n}} \left| \sqrt{(x_u - x_i)^2 + (y_u - y_i)^2} - d_{iu} \right| \right) \quad (8)$$

where *(xi,yi)* is the coordinates of anchor nodes, *i=1,2...k*. *(xu,yu)* is the estimated coordinates of unknown nodes, *u=k+1,k+2....n* and *diu* is the distance between anchor nodes and unknown nodes, calculated according to formula (6). There are total *N* sensor nodes in the network i.e. *N= k+n*.

There are six steps of our proposed algorithm as shown in Fig.1.

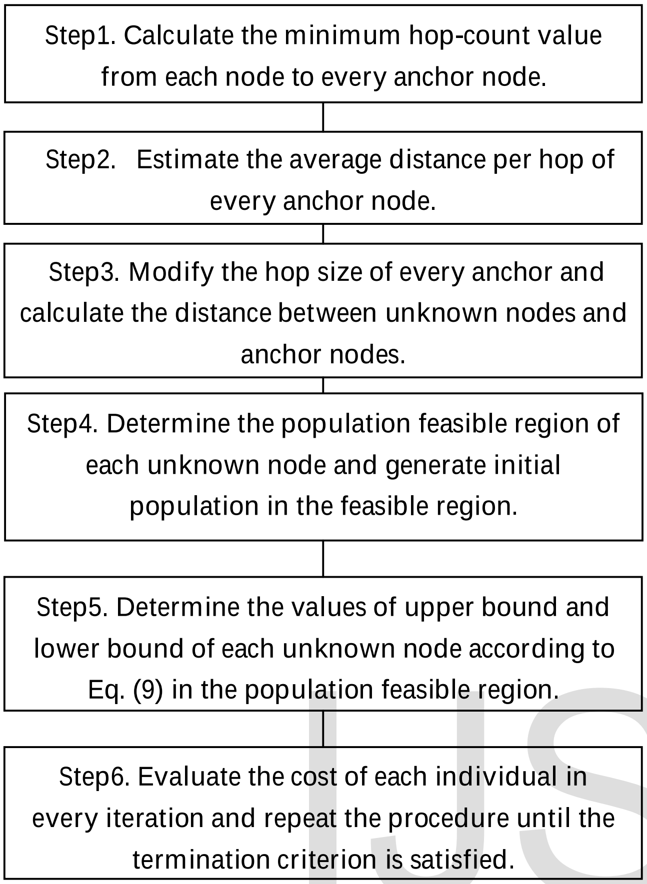

Fig.1 Steps of IDV-Hop using PSO

In section V, we will present the simulation parameters, experimental results and comparisons of our algorithm to some existing algorithms.

5. RESULTS AND DISCUSSION

In this section, we present the simulation of our proposed algorithm i.e. PSO based IDV Hop algorithm in MATLAB 7.10 to evaluate the performance in terms of localization errors with different parameters and also make comparisons with some other existing algorithms viz. DV-Hop [13], GADV-Hop [15] under same scenario.

In our simulations, 100 sensor nodes (anchor nodes (k) and unknown nodes (n)) are evenly distributed randomly in two dimensional fixed square area of 100×100 m2 as shown in Fig. 2, where red pentacles represent the anchor nodes and black dots represent unknown nodes. Each node has equal communication radius which is set to 25*m*. Simulation parameters are shown in Table I.

Table1. Simulation Parameters

Parameters	Value
Total Number of nodes	100
Area	100×100 m^2
Communication Range	25 *m*
Number of anchor nodes	20%
Population	50
Generations	500

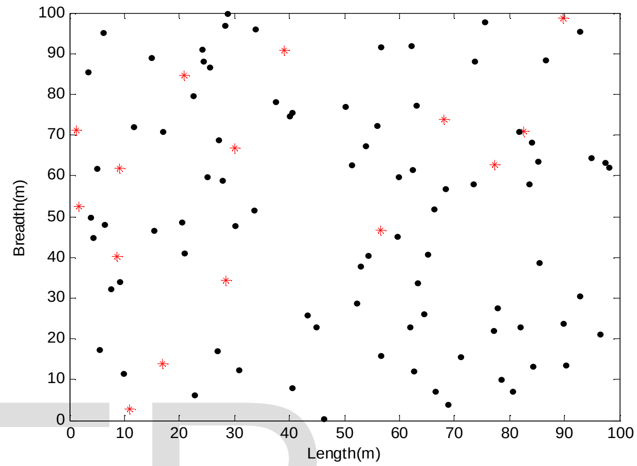

Fig.2 Nodes Distribution

To compare the performance of our algorithm with other existing algorithms, we calculate the localization error of each unknown node, mathematically which can be expressed by the following equation:

$$\text{Localization Error} = \sqrt{(x_u - x_a)^2 + (y_u - y_a)^2} \quad (10)$$

where *(xu,yu)* is the estimated coordinate and *(xa,ya)* is the actual coordinate of unknown node.

The estimated localization error shows the measure of accuracy of algorithm. Accuracy is better when the estimation error is smaller.

To compare the performance of our algorithm with existing techniques, we calculate mean error of each algorithm with different parameters under same scenario. Mean error can be calculated as the ratio of total localization error to the number of unknown nodes (n) and can be expressed as follows:

$$\text{Mean Error} = \frac{\sum_{a,u=1}^{n} \sqrt{(x_u - x_a)^2 + (y_u - y_a)^2}}{n} \quad (11)$$

Fig.4 shows the estimated localization mean error of these algorithms with different number of anchor nodes deployed. It can be seen from the results that our algorithm performs better than existing three algorithms of [13], [15] and [17]. It is observed from the Fig.3 that when the number of anchor nodes increases, mean localization error of four algorithms decreases.

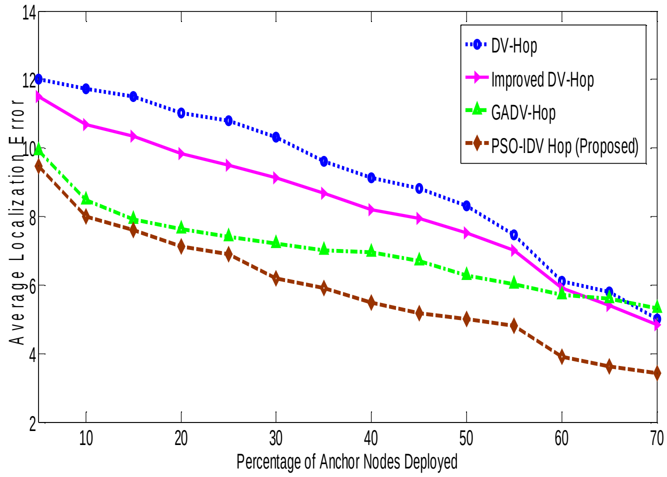

Fig.3 Mean localization error with different number of anchor nodes.

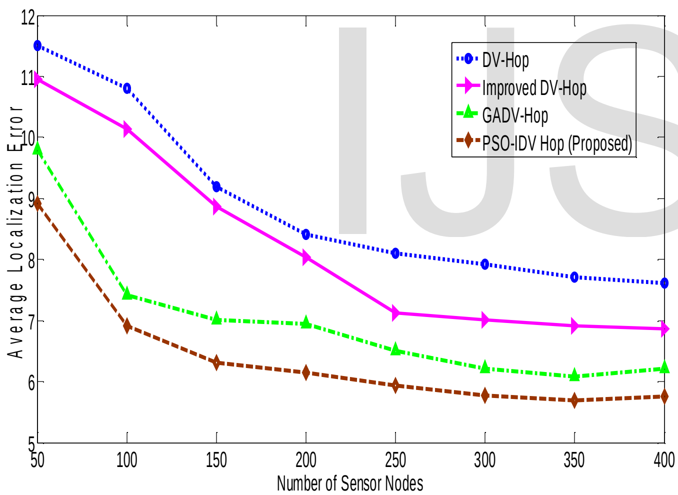

Fig.4 Mean Localization error with different number of sensor nodes

The result data of each algorithm is taken as the average of 100 independent simulation experiments.
Fig.4 shows the mean localization error with different number of sensor nodes. Sensor nodes are tuned from 50 to 400 with 20% anchors nodes and communication range is set to 25 m. It is observed from the figure that mean localization error decreases as number of sensor nodes increases. It is due to the reasons that as the number of sensor nodes increases, minimum hop count value also increases and average hop size of the anchors become more accurate and hence improve the localization accuracy.

It can be seen from the simulation results of Figs. 3 and 4, our proposed algorithm viz. IDV-Hop using PSO outperforms the existing algorithms.

5. CONCLUSIONS AND FUTURE WORK

Localization is a critical issue in WSNs, since many applications depend on the accurate localization of the nodes. To improve the localization accuracy of the range free algorithms, we proposed PSO-IDV Hop technique for WSNs. In the proposed algorithm, average hop size of an anchor is modified using correction factor and distance between the unknown nodes and anchors is calculated based on modified hop size. For further improvement in localization accuracy, we use an efficient optimization technique viz. PSO in this paper. Our proposed algorithm bounds the feasible region of initial population. Simulation results show that our proposed algorithm has better accuracy than DV-Hop, GADV-Hop and DV-Hop using PSO algorithms.

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