An Improved ABC-based Node Localization Algorithm for Wireless Sensor Network

Mudong Li *Wei Xiong*
The Institute of Telecommunication Engineering
The Air Force Engineering University
Xi'an, China
lmd422@163.com xw5893@sina.com

Qing Liang
School of Electronic Engineering
Xi'an University of Posts and Telecommunications
Xi'an, China
liangqing@xupt.edu.cn

Abstract—**Focusing on the problem of the poor locating performance in original DV-Hop algorithm which is one of the range-free algorithms in wireless sensor network (WSN), an intelligent DV-Hop algorithm for locating nodes was proposed in this paper. Fully considering the effect of dynamic topology, the self-adaptive artificial bee colony (SAABC) algorithm was introduced to estimate the unknown nodes location. Simulation results show that the new algorithm has obviously better locating performance precision and precision stability than DV-Hop algorithm without any additional devices and communication overhead. As a result, it is a more promising locating scheme in WSNs with both random distributing nodes and dynamic topology.**

Keywords-Wireless Sensor Networks(WSN); Node localization; DV-Hop; Artificial Bee Colony(ABC) algorithm

I. INTRODUCTION

Wireless sensor network (WSN), consisting of a large number of cheap and miniature sensor nodes, is widely used for monitoring and measuring in complicated environment. The sensor nodes not only can perceive, calculate and gather information from the surrounding, but also can transmit the sensed date to the user [1]. In the application of wireless sensor network, localization is the foundation of all collection information and confirms the position of the incident, which is an important composition of wireless sensor networks. Localization schemes can be divided into range-based schemes and range-free schemes [2]. Unlike the range-based localization algorithm, range-free schemes estimate the location of sensor nodes without measuring distances or angles and do not require any additional hardware for measurement. As a result, this kind of localization algorithm could be a good approach to localize sensor nodes with respect to the constraints of low cost and low energy consumption.

DV-Hop algorithm is one of the most extensive algorithms used in the range-free localization method [3]. Recently, there had been much research about classic DV-Hop algorithm. Approach [4] proposes a strategy to get relatively accurate location from the unknown nodes using the average hopsize and average error for reducing the final localization error. In [5], a new connectivity-based localization method which is on a two-level range of connectivity between each pair of nodes is presented. Approach [6] uses Particle Swarm Algorithm to calculate the location of unknown nodes. Shuffled frog leaping algorithm is adopted to estimate the average hopsize in approach [7].

In this paper, we present an improved algorithm defined as self-adaptive DV-Hop (SADV-Hop) algorithm according to the characteristics of the localization process. Firstly, Artificial Bee Colony (ABC) algorithm is introduced in detail. Then we present an improved ABC named as Self-adaptive ABC (SAABC) algorithm with the expectation to increase the convergence rates and locating precision. Finally, the SAABC algorithm is used at the stage of calculating the coordinates of the unknown nodes. Simulation results show that the performance of proposed algorithm is superior to that of the original DV-Hop algorithm.

The rest of this paper is organized as follows. Section II presents the original ABC algorithm and gives an improved ABC method. In Section III, the SADV-Hop algorithm is proposed. In Section IV, simulation results are shown. Finally, we give the conclusion in Section V.

II. THE IMPROVED ABC ALGORITHM

A. Oringinal ABC Algorithm

Artificial bee colony (ABC) algorithm is a new method based on swarm artificial intelligence algorithm which is proposed by Karaboga [8] in 2005. The ABC system is classified into four types: employed bees, onlooker bees, scout bees and honey sources. Each employed bee is associated with a honey source, in other words, the number of the employed bees is equal to the honey sources.

Firstly, randomly distributed honey sources (solutions) of *SN* are generated over a D-dimensional search space and are evaluated by the fitness function. The employed bees $x_{i,j}$ explore new honey sources $v_{i,j}$ around themselves by

$$v_{i,j} = x_{i,j} + r_{i,j}(x_{i,j} - x_{k,j}) \tag{1}$$

where $i \in \{1,2, \ldots,SN\}$ and $j \in \{1,2, \ldots,D\}$ are randomly chosen indexes; *j* has to be different from *i*; $r_{i,j}$ is a random number in the range [-1,1].

Secondly, apply the greedy selection process between $x_{i,j}$ and $v_{i,j}$, and calculate the probability values p_i for the solutions $x_{i,j}$ by fitness values through the equation

$$p_i = \frac{fit_i}{\sum_{i=1}^{SN} fit_i} \tag{2}$$

In order to calculate the fitness values of solutions, the following formula can be used

$$fit_i = \begin{cases} \dfrac{1}{1+fitness(x_i)} & fitness(x_i) \geq 0 \\ 1+|fitness(x_i)| & fitness(x_i) < 0 \end{cases} \tag{3}$$

where $fitness(x_i)$ is the fitness function value of x_i. If a honey source cannot be improved for a predetermined number of cycles referred to *Limit* [9], the honey source is abandoned. The employed bee becomes a scout and a new solution which is produced randomly would replace through

$$x_{i,j} = x_{\min,j} + rand(0,1)(x_{\max,j} - x_{\min,j}) \tag{4}$$

where $x_{\min,j}$ is the lower bound of the parameter j and $x_{\max,j}$ is the upper bound of the parameter j.

Finally, record the best solution and repeat the process until the max C which is the cycle of the algorithm.

B. SAABC Arithmetic

Generally, the ABC algorithm has better performance than Genetic Algorithm in finding the solution of the object function [10]. However, the relation between the employed bees is not fully considered in the original plan of the employed bee's motion. Therefore, it is not strong enough to maximize the searching capacity. Enlightened by the improved approach of PSO in [11], which adds a self-adaptive changing weight factors to adjust a better result, algorithm SAABC introduces a self-adaptive inertial weight w in order to improve the diversity of the honey sources. Assume that the $ObjEmp_i$ is the value of the fitness function for employed bees. And some parameters can be set as: $w_{\max}$= 0.9, $w_{\min}$= 0.1, $Fit_{\min}$= min($ObjEmp_i$), and $Fit_{\max} = \sum_{i=1}^{M} ObjEmp_i \Big/ C/2$.

1) If $ObjEmp_i \leq Fit_{\max}$,

$$w = w_{\min} + \frac{(ObjEmp_i - Fit_{\min}) \cdot (w_{\max} - w_{\min})}{(Fit_{\max} - Fit_{\min})} \tag{5}$$

2) If $ObjEmp_i > Fit_{\max}$,

$$w = w_{\max} \tag{6}$$

So the improved (1) can be written as follows:

$$V_{i,j} = x_{i,j} + w \cdot (x_{i,j} - x_{k,j}) \tag{7}$$

As a result, the SAABC algorithm can not only guide the searching trend of honey sources, but also overcome the shortcoming of strong randomness in original ABC algorithm. The pseudo-code of SAABC algorithm is summarized as follows:

- Initial the population x_i (i=1⋯SN) and other parameters
- Evaluate the population
- Set cycle to 1
- Repeat
  - FOR each employed bee
    - Determine the w by (5) and (6)
    - Produce new solutions $V_{i,j}$ through (7)
    - Calculate the fitness
    - According to the (2) and (3) apply the greedy selection process
  - FOR every onlooker bee
    - Select a solution based on (2) and (3)
    - Generate the new solution by (7)
    - Count the fitness
    - Use the greedy selection process
  - If a honey source cannot be improved for a number of *Limit*, abandon the solution and then replace it with a new location produced by (4)
  - Record the best solution so far
  - Assign cycle = cycle + 1
  - Until cycle = C

III. DV-Hop algorithm Based On SAABC algorithm

A. DV-Hop Algorithm

The traditional DV-Hop algorithm is put forward by Niculescu and Nath in [3], which can be divided into three steps:

Step 1: Each beacon node broadcasts its information, which contains the beacon node's coordinate and a hop-count value that is initialized to zero, throughout the whole network. Beacon nodes compute average distance of every hop themselves by

$$HopSize_i = \frac{\sum_{j=1, j\neq i}^{M} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{\sum_{j=1, j\neq i}^{M} hopS_{ij}} \tag{8}$$

where (x_i , y_i) and (x_j , y_j) are the coordinates of beacon node i and j, $hopS_{ij}$ is the hop-count value between i and j, M presents the number of beacon nodes.

Step 2: Each beacon node broadcasts its average $HopSize_i$ to the network. The unknown nodes only record the information that is firstly received, and discard the subsequent information. Then the distance between unknown node and beacon node can be estimated by

$$d_{i,n} = HopSize \times hopS_{i,n} \tag{9}$$

Among them, $d_{i,n}$ is the estimation distance and $hopS_{i,n}$ is the minimal hop between beacon i and unknown node n.

Step 3: Unknown nodes compute their location coordinates through trilateration or maximum likelihood estimation according to the estimated distance from Step 2.

B. SADV-Hop Algorithm

In order to reduce the error of the process of localization in DV-Hop algorithm, the SADV-Hop arithmetic which uses the SAABC method is proposed to improve location performance. Assume that d_i is the distance between the beacon nodes and the unknown nodes, (x , y) and (x_i , y_i) are respectively the coordinates of unknown nodes and beacon nodes. Considering the influence of the inaccuracy, environment and communication, the fitness function of SADV-Hop algorithm can be expressed by

$$fitness_i = \sum_{i=1}^{M} \left| \sqrt{(x-x_i)^2 + (y-y_i)^2} - d_i \right| \tag{10}$$

where M is the number of beacon nodes and i is the beacon node index. The algorithm operates as given in Fig.1. At the first step, the network is initialized when sensor nodes are deployed to the area. Then calculate the $HopSize_i$ by (8) and estimate the distance between the beacon nodes and the unknown nodes by (9) through the DV-Hop algorithm. Finally, SAABC arithmetic is applied for computing the coordinates of the unknown nodes, which is the main step of SADV-Hop algorithm.

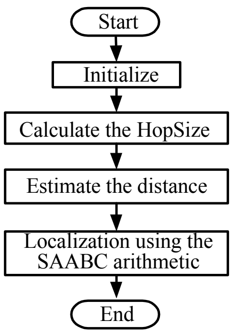

Figure 1. Main steps of the SADV-Hop algorithm

IV. SIMULATION ANALYSIS

To evaluate and analyze the performance of the proposed algorithm, we conduct simulation with Matlab 2010a. Assume that N=100 sensor nodes (including beacons m and unknown nodes) are randomly deployed in a square with length L=100 m. The communication radius R=22 m. Let p_{ture} and p_{est} represent the true and estimated sensor position respectively. The normalized average localization error as follows:

$$error = \sum_{j=1}^{k} \left[\frac{\sum_{i=m+1}^{N} \left(\left| p_{est_i} - p_{true_i} \right| \right)}{(N_c \cdot R)} \right] \Bigg/ k \tag{11}$$

where i is the unknown node index , N_c is the number of the resolved unknown-nodes. Here we also simulate the DV-Hop algorithm using ABC algorithm (remarked as ADV-Hop) for comparison. Considering the energy consumption of wireless sensor network, the parameters of the algorithm are set as: C=20, SN=40, $Limit$=10, $\varepsilon=10^{-5}$. On the other hand, in order to eliminate the accidental error, each experiment is repeated as k=1000 times.

The simulation results are shown from Fig.2 to Fig.5. As we can see from the Fig.2, the normalized average localization error and ratio of beacon nodes show an inverse relationship. The normalized average localization of SADV-Hop algorithm is obviously superior to original DV-Hop algorithm or ADV-Hop algorithm in the same condition. Concretely, the normalized average localization error of SADV-Hop algorithm reduces 35.5% compared with DV-Hop algorithm, and 18.1% compared with ADV-Hop on average.

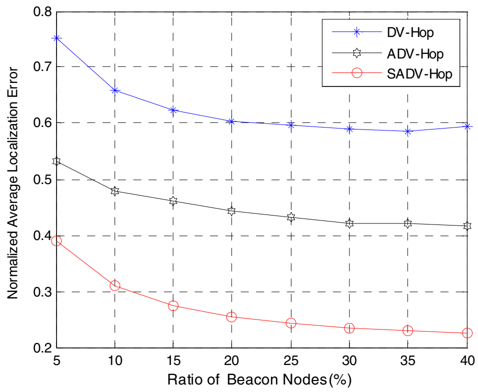

Figure 2. Relationship between beacon ratio and normalized average localization error

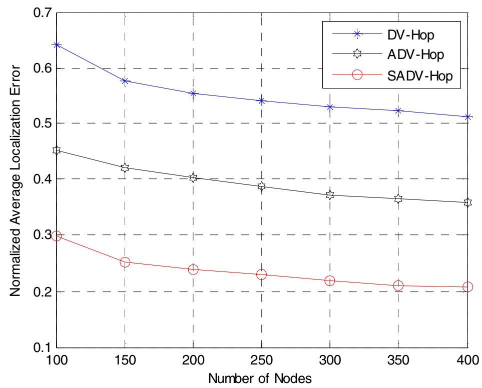

Figure 3. Relationship between nodes number and normalized average localization error

Seen from Fig.3, with the increase of nodes number, the mean square localization error of the three algorithms reduces and tends to slow down. The error of SADV-Hop algorithm is obviously less than that of DV-Hop and ADV-Hop. With the changes of numbers from 100 to 400, the normalized average localization error of SADV-Hop algorithm reduces 31.75% and 15.74% respectively compared with the DV-Hop algorithm and ADV-Hop algorithm on average.

At the same time, in order to further analyze and compare the performance of the three algorithms, we contrast to probability density of localization error based on k=1000 times simulation experiments. Assume that 100 sensor nodes (including 10 beacons) are randomly deployed in a square with the length L=100 m. The communication radius remains constant. The simulation results are shown in Fig. 4 and Fig. 5.

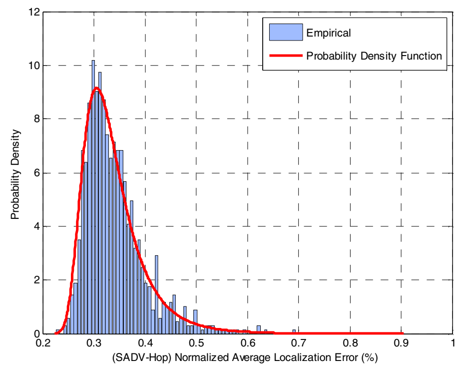

Figure 4. Probability density of SADV-Hop

AS we can see from Fig. 4, the values of normalized average localization error for SADV-Hop algorithm have a steady concentrated distribution between 25% and 40%, and a very weak distribution from about 60% to 90%. The minimum value and maximum value within results are respectively 22.3% and 90.4%, and the mean error is 33.8%.

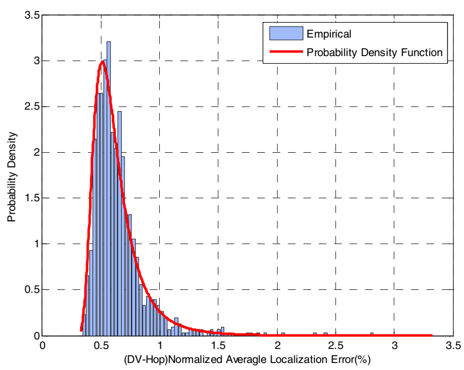

Figure 5. Probability density of DV-Hop

In Fig. 5, the results mainly distribute around 60% in a small range, and there is a relatively weak distribution from 80% to 330%. Meanwhile the minimum normalized average localization error is 32.44% and the maximum value is the 332.31%. The average error of statistical results from Fig. 5 is 63.79%.

In a word, SADV-Hop algorithm has obviously superior performance than DV-Hop algorithm in respects of positioning precision and stability. It’s a feasible approach to use the SAABC algorithm at the process of localization in the DV-Hop algorithm. In addition, SADV-Hop algorithm availably increases the searching precision and global searching ability compared with ADV-Hop, and the computation consumption is kept in lesser levels.

V. CONCLUSIONS

ABC algorithm is a new and unique swarm intelligent algorithm with the merits of few control parameters, simple operation and easy to implement. Aiming at the shortage of poor searching precision and worse global searching ability, this paper proposes an algorithm named SAABC which synthetically considers the problem of energy cost in wireless sensor network and improves the global searching precision and stability. Moreover according to the DV-Hop algorithm, the SADV-Hop algorithm is put forward and solves the problem of large location error of DV-Hop effectively. The simulation results show that the performance of SADV-Hop algorithm is significantly improved compared with the original DV-Hop algorithm and ADV-Hop algorithm in the aspects of location precise and stabilization. At the same time, communication and calculation expenses increase slightly.

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