Wireless sensor network node localization research based on improved wolves algorithm

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Abstract—DV-Hop is a typical node localization algorithm without ranging of wireless sensor network. Because of the shortcoming that this algorithm's accuracy for node positioning is not high, a sensor node localization algorithm based on improved wolves algorithm is proposed. The algorithm is based on the classic DV-Hop algorithm, converts the wireless sensor node localization problem into a multi-constrained optimization problem, and uses improved wolves algorithm to solve this problem, then obtains the optimal solution of unknown node coordinates. Matlab simulation show that, this algorithm can significantly improve the positioning accuracy of the node than other wireless sensor network node localization algorithm.

Keywords-** **Wireless sensor network; DV-Hop; wolves algorithm

I. INTRODUCTION

WSN (Wireless Sensor Network) was first proposed in the 1990s. As it combines sensor technique with wireless communication, which makes it have great application value. WSN has the sense of self-organization which enables it can work in many poor-living environment and some regions such as deep sea and extremely cold that human beings are unable to reach to collect useful information. Users of the network can analyze the information and obtain useful information, thus using WSN to solve practical problems met in other areas. At present, with the application of WSN in many fields of national life, the role of it is becoming increasingly important, so it is important to do the research on WSN. This paper will attach great importance to the research and improvement of the localization approach in WSN.

Generally speaking, WSN nodes are distributed in the target area randomly, so it is impossible to get the entire sensor coordinates ahead of time. We should adopt certain measures to set the sensor node location. Considering that some factors such as the network costs and life span, the current research are mainly concentrated on the range-free localization approach. The DV-Hop[1] is the popular range-free localization algorithm at present. It requires to fix up GPS system on some nodes which can be the anchor node, while unknown nodes can ensure their coordinates according to the anchor node. As it is no need for us to measure the angle and distance of the sensor node with the use of DV-hop algorithm, the implementation is easy and convenient. But it has the problem of low accuracy of localization, some other algorithms[2-8] has made some improvement on the DV-hop. For example, the literature sixth[6] document proposed improved DV-hop localization algorithm. First of all, it eliminates long-distance beacon node information and updates the distance of minimum hop count and average hop count, then further corrects average hop count distance according to the error between the actual distance of beacon code and estimated distance; The seventh[7] and eighth[8] literature respectively proposed the improved algorithm based on BA (Bat Algorithm) and ABC (Artificial Bee Colony Algorithm)

Compared with other bionic algorithms[9-11], wolves algorithm has higher solving precision and faster convergence rate. This paper proposed an improved localization algorithm based on wolves algorithm to make up the shortcoming of DV-hop, thus enhancing the localization precision of sensor node.

II. INTRODUCTION TO DV-HOP

DV-hop is a range-free localization approach for WSN which was proposed by Niculescu and others in 2003. There are following three stages in its main principles:

1) The calculation of the minimum hop of unknown nodes and anchor codes. Anchor nodes send the message including their own localization information to the neighbor nodes. It contains the hop count which initial value is zero. Unknown nodes record the minimum hop of every anchor node and plus one to the hop count, then forward neighbor nodes.

2) The calculation of the distance of unknown sensor nodes and anchor nodes. Anchor node calculates average Hopsize according to the distances with other anchor nodes and hop counts:

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

In the formula (1), (x_i, y_i) (x_j, y_i) are the coordinates of anchor node i 、 j , h_{ij} is the hop count of anchor node i 、 j .

3) The calculation of unknown sensor node coordinates. Unknown sensor nodes calculate unknown node coordinates according to the recorded every anchor node distances by using the trilateration or MMLE method.

DV-hop has many advantages such as easy implementation, low running cost and low energy-consumption. As extra hardware circuits are not added to

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the wireless sensor nodes, DV-hop can realize simple localization of sensor nodes in the network.

But there are some disadvantages, such as low solving coordinate precision existed in the DV-hop. The main reason is that the size of distance between nodes is not considered into the calculation of sensor node hop count. Besides, the worse connectivity of sensor network also can lead to the low localization precision of sensor nodes.

III. DV-HOP IMPROVEMENT BASED ON IMPROVED WOLVES ALGORITHM

A. Introduction to wolves algorithm

Liu and others proposed wolves algorithm in accordance with the wolves hunting in bionic nature. This algorithms divides artificial wolves into three kinds according to the functions. They are head wolf, detective wolf and power wolf. Head wolf is the leader of wolves; detective wolf's main responsibility is searching for prey; power wolf is in charge of besieging the prey. The rule of head wolf is as follows: In the initial state, the artificial wolf with the optimal adaptive value was the head wolf, which was recorded as Y_{head}. It will not enter the next iteration directly after each iteration until it was replaced by other artificial wolves who were in better position.

Wolves algorithm defines three behaviors as wandering behavior, summoning behavior and siege behavior.

1) Wandering behavior: Detective wolf goes forward tentatively and records the odor

concentration of the prey. According to the difference of the odor concentration, the detective wolf chooses the direction which order concentration is greater than its own position and has the greatest odor concentration. If the odor concentration is greater than the head wolf at the moment, the position of head wolf will be replaced by the detective wolf. The new formula of the position of detective wolf is :

$$x_{id}^{p} = x_{id} + \sin(2\pi \times p / h) \times step_{a}^{d} \tag{2}$$

h is the sum of direction, is the selected direction.

2) Summoning behavior: Head wolf starts to beckons for power wolf to make it advance towards the prey. Power wolf advances to head wolf at a larger attack step. The displacement formula of power wolf is:

$$x_{id}^{k+1} = x_{id}^{k} + step_{b}^{d} \times (g_{d}^{k} - x_{id}^{k}) / \left| g_{d}^{k} - x_{id}^{k} \right| \tag{3}$$

g_{d}^{k} is the D-dimensional position of head wolf in the -generations wolves.

If the power wolf i perceives that the prey concentration is greater than head wolf, it will take the place of head wolf, then beckons for other power wolves. When the distance between the power wolf i and head wolf is smaller than d_{near}, power wolf will carry out the siege behavior. Suppose wait optimization variables' value ranges is $[d_{\min}, d_{\max}]$, the calculation formula of d_{near} is:

$$d_{near} = \frac{1}{D \times \omega} \times \sum_{d=1}^{D} \left| d_{\max} - d_{\min} \right| \tag{4}$$

D is Wait optimization variables, ω is distance decision factor。

3) Siege behavior: When power wolf walks near the prey, it will unite detective wolf to besiege the prey, thus catch it. The displacement formula of power wolf and detective wolf is:

$$x_{id}^{k+1} = x_{id}^{k} + \lambda \times step_{c}^{d} \times \left| x_{hd}^{k} - x_{id}^{k} \right| \tag{5}$$

λ is the random number uniformly distributed in $[-1,1]$

If the prey concentration which artificial wolf i perceives is greater than the original position, the place of artificial wolf will be renewed, otherwise the position remains unchanged.

In the above three simulation behaviors, $step_a$、$step_b$、$step_c$ is the step length of three behaviors separately, the following conditions should be met:

$$step_{a}^{d} = 0.5 step_{b}^{d} = 2 step_{c}^{d} = \frac{\left| d_{\max} - d_{\min} \right|}{S} \tag{6}$$

S is step length factor.

At the same time, the population renewal mechanism which is called "strong survived" also exists in the wolves algorithm. After catch the prey, the algorithm will eliminate the weakest artificial wolf that perceives prey odor, then generate the new artificial wolf to replace it randomly. Suppose the number of eliminated artificial wolves is Q, Q is random number which range is $[n/2 \times \beta, n/\beta]$, β is scaling factor.

B. Localization algorithm for WSN nodes improvement

According to the above introduction, we can learn that detective wolf plays a very important role in wolves algorithm, which decides the speed and precision of global optimization. In the early iteration, the speed should be accelerated, while the precision should be enhanced in the later iteration. This paper improves the wandering behavior of the wolves algorithm. The improved displacement formula of detective wolf is:

$$x_{id}^{p} = \begin{cases} x_{id} + \sin(2\pi \times p / h) \times step_{a}^{d} \times (e^{-t}) & t < T_Y \\ x_{id} + \sin(2\pi \times p / h^2) \times step_{a}^{d} \times (e^{-t}) & t > T_Y \end{cases} \tag{7}$$

T_Y is the iterative threshold.

During the actual running process of DV-Hop, both external factors and internal measurement factors will lead to the errors in the final result, so for the unknown sensor node $C(x, y)$, its position coordinates have the following constrains:

$$\begin{cases} d_1^2 - \varepsilon_1^2 \le (x - x_1)^2 + (y - y_1)^2 \le d_1^2 + \varepsilon_1^2 \\ d_2^2 - \varepsilon_2^2 \le (x - x_2)^2 + (y - y_2)^2 \le d_2^2 + \varepsilon_2^2 \\ \vdots \\ d_n^2 - \varepsilon_n^2 \le (x - x_n)^2 + (y - y_n)^2 \le d_n^2 + \varepsilon_n^2 \end{cases} \tag{8}$$

d_1 , d_2 ... d_n is the actual measuring distance, ε_1 , ε_2 ... ε_n is the calculation error.

Calculate (x, y) to make fitness function $f(x, y)$ has minimum value, thecalculation formula of $f(x, y)$ is:

$$f(x,y)=\sum_{i=1}^{m}(\sqrt{(x-x_i)^2+(y-y_i)}^2-d_i) \quad (9)$$

So the detailed algorithm steps of node localization are:

Step1 Calculate the distance between unknown node $C(x, y)$ and other anchor nodes.

Step2 Initialize wolves algorithm parameters, including detective wolf numbers TF 、 power wolf numbers MF 、wandering step length $step_a$ 、wandering step length $step_b$ 、siege step length $step_c$ 、searching precision η 、 maximum number of iterations $T_{\max}$ 、 wandering numbers $YZ_{\max}$ 、renewal scale factor β and so on.

Step3 Initialize the position of wolves randomly, and choose the best artificial wolf as head wolf according to fitness function.

Step4 Detective wolf starts to carry out wandering behavior until the prey odor concentration Y_i that detective wolf i perceives is greater than that Y_{head} which head wolf perceives or reaches the maximum wandering number $YZ_{\max}$.

Step5 Head wolf starts to beckons for power wolf to make it advance towards the prey. If the power wolf i perceives that the prey concentration Y_i is greater than Y_{head} , it will take the place of head wolf, then beckons for other power wolves, otherwise it will not keep advancing towards the direction of head wolf until $d_{tm} < d_{near}$.

Step6 Power wolf unites detective in carrying out siege behavior.

Step7 Replace some artificial wolf according to the “strong survived” mechanism.

Step8 Judge whether the position of head wolf (x, y) meets demand precision or reaches the maximum number of iterations $T_{\max}$. If it is, the output (x, y) is the unknown node coordinate, otherwise continue the Step4.

IV. EXPERIMENT AND ANALYSIS

A. Simulation environment

Using Matlab 2010b as the simulation tool, this experiment set the sensor nodes numbers as 100, square of 100×100 *as the deployment area. All the senor nodes are placed in a random way, and the position of anchor node is known. Evaluation criteria of localization results uses the equation mentioned in the literature [12]:*

$$error=\frac{1}{M}\sum_{i=1}^{M}\sqrt{\left(x_i-\hat{x}_i\right)^2+\left(y_i-\hat{y}_i\right)^2}\times100\% \quad (10)$$

(x_i, y_i) 、 $(\hat{x}_i, \hat{y}_i)$ is the actual position and estimated position of unknown node.

B. Simulation results

This experiment compared algorithm mentioned in the paper with BADV-Hop proposed in literature[7] and ABCDV-Hop in literature[8]. The comparison covered some aspects including different anchor node numbers and communication radius.

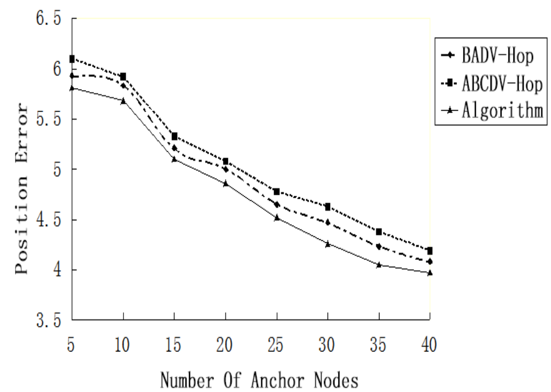

Figure 1. Algorithm comparison based on different number of anchor nodes

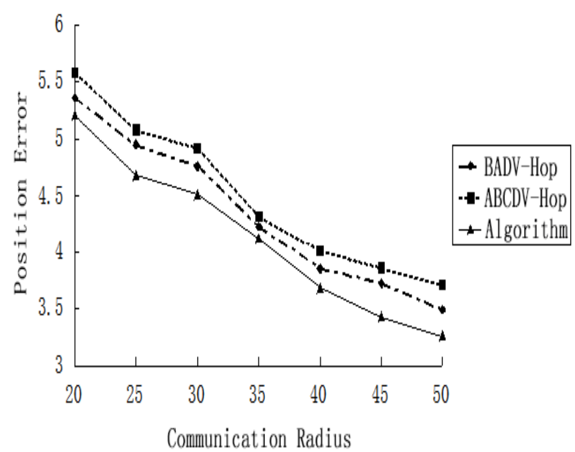

Figure 2. Algorithm comparison based on different communication radius

Fig 1 and Fig 2 are running comparison diagram of the three kinds of algorithms based on different numbers of anchor nodes and communication radius. We can learn that with the increase of numbers of anchor nodes and communication radius, solving precision of three kind of algorithms became higher gradually, while in the same condition, DV-hop improvement based on improved wolves algorithm had a remarkable enhancement in comparison with BADV-Hop and ABCDV-Hop.

V. CONCLUSION

Node localization is one of the key technologies of WSN. Because of the low accuracy of node positioning of the classical DV-Hop, this paper put forward a sensor node localization algorithm based on wolves algorithm. Compared with other bionic algorithms, wolves algorithm has higher solving precision and faster convergence rate. Simulation result shows that the algorithm proposed in the paper enhances the localization precision of sensor node remarkably.

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