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Research on Localization for Distribution Communication Wireless Sensor Networks Based on DV-Hop

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Abstract: In order to solve the DV-Hop algorithm in 3D environment localization problem, the essay proposed an improved particle swarm optimization algorithm to the three-dimensional environment of unknown node and anchor nodes between the estimated distance and the actual distance of the mean square error is set to the optimal objective function, and then an improved DV-Hop algorithm combining is applied to three-dimensional environment location. Taking the data of distribution network in Huangshan province and topography, geomorphology, communications environment and information management of distribution network in distribution network area of communication engineering as examples, this paper designed an optimized topological structure of smart distribution power grid communication wireless sensor networks and developed routing/terminal/coordinator of wireless sensor networks. Embedded QoS - MAC protocol and QoS guarantee control routing protocol software in the network nodes, the gateway management software with the connection of automatic distribution management system is developed in this paper, which realizing the engineering application of smart distribution power gird communication wireless sensor networks. The experiment results showed that the research on basic theory and the design methods put forward in this paper were suitable for distribution network data specification, which achieves the expected goal of smart distribution power grid communication with high-performed data. *Copyright © 2013 IFSA.*

Keywords: Localization for wireless sensor networks, Dv-hop, Smart distribution power grid.

1. Introduction

The study of wireless sensor network system began in seventies of last century. At that time, the U. S. military has developed "tropical tree" sensor system [1] and applied to the battlefield. The sensors after camouflage with vibration and sound detection device can be used to detect the enemy fleet and send monitoring the news to the command center. After receiving data information, Command center immediately command the air force for bombing so as to blow up a large number of vehicles delivering goods and achieve good effect. Since recent, National natural science foundation of China, National Science Foundation of U. S. and the Eu's seventh period research framework give the key funding to the research on the application of wireless network sensors in electric system. In 2010, Development Framework and Roadmap of Smart Power Grids [2] formulated by National Institute of Standards and Technology clearly listed standard protocol IEEE802.15.4 in wireless sensor networks as one of the recommended communications standards. The application research on wireless sensor networks in smart power grid has wide development prospects. The essence of applying

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wireless sensor networks to smart distribution power grid with high-performed data is multi-objective coordination optimization to solve the problem for a class of uncertain process and data transmission QoS performance index requirements with real-time determination and reliability [2-3].

Scholars study in-depth with localization algorithm, and now there have been many localization systems, including Cricket, AHLos [4] and GPS. Domestic at present basically study node localization under two-dimensional environment, which has also gradually dabbled in three-dimensional field in the last two years. However, basically they put some mature two-dimensional algorithm with simple extension into three-dimensional space, then analyze through relative experiments. For example, in order to solve the application of node localization problem in fault monitoring by using electric utility, Wang Quandi [5] and other people put forward NMDS2MEEF algorithm, which not only reduces the positioning error, but also has little influence of range error and the distribution of nodes. The passage reviews and researches on related literatures, discussing DV-Hop positioning algorithm of theoretical knowledge, also to the existing improved methods to do the experimental analysis. In order to solve the DV-Hop algorithm in 3D environment localization problem, the essay proposed an improved particle swarm optimization algorithm to the three-dimensional environment of unknown node and anchor nodes between the estimated distance and the actual distance of the mean square error is set to the optimal objective function, and then an improved DV-Hop algorithm combining is applied to three-dimensional environment location.

2. Research Design

2.1. Theoretical Basis of DV - Hop Algorithm

DV - Hop Algorithm is a kind of non-ranging localization algorithm based on distance vector routing, which avoids the direct measurement on the distance between nodes [6]. In the process of this algorithm, pending nodes using distance vector routing acquires the minimum hop of the known node, then gets the average distance of each hop. The estimated distance between pending node and the known node is the product of the each hop's average distance and the minimum hop. Last, it calculates spatial coordinates of pending node according to trilateration.

2.2. Basic Calculation Method of Node Localization

1) Trilateration.

Fig. 1 shows the schematic of the method. $A(x_1, \mathrm{y}_1)$, $B(x_2, \mathrm{y}_2)$, $C(x_3, \mathrm{y}_3)$ are supposing to be determined and the distance from pending D to each point can be expressed as d_1, d_2, d_3 .Position coordinates of D point can be expressed by (x, y), which can get the following:

$$\begin{cases} \sqrt{(x-x_1)^2+(y-y_1)^2}=d_1 \\ \sqrt{(x-x_2)^2+(y-y_2)^2}=d_2 \\ \sqrt{(x-x_3)^2+(y-y_3)^2}=d_3 \end{cases}, \quad (1)$$

Equation (1) can be written as $A_t x = b$, and then calculates position coordinates of D point as

$$\hat{x}=(\hat{x},\hat{y})= \\ =\begin{bmatrix} 2(x_1-x_3)2(y_1-y_3) \\ 2(x_2-x_3)2(y_2-y_3) \end{bmatrix}^{-1} \begin{bmatrix} x_1^2-x_3^2+y_1^2-y_3^2+d_3^2-d_1^2 \\ x_2^2-x_3^2+y_2^2-y_3^2+d_3^2-d_2^2 \end{bmatrix} \quad (2)$$

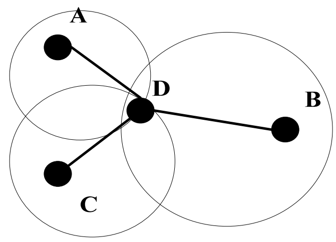

Fig. 1. Trilateration.

2) Triangulation.

Triangulation is shown in Fig. 2. The principle of triangulation is as follows 7]. The coordinate of A, B and C respectively is $(x_a, y_a),(x_b, y_b),(x_c, y_c)$. The angels of node D corresponding to A, B and C are $\angle ADB, \angle ADC, \angle BDC$ respectively. The position coordinates of D is (x, y) and analyzes the relationship between A point, B point and their angels. It the segmental arc AC is in ΔABC, then there is only one circle that satisfies the conditions. Center coordinates are supposed to be expressed by $O_i(x_{oi}, y_{oi})$ and radius is r, then $a=\angle AO_iC=(2\pi-2\angle ADC)$ and gets the following equation:

$$\begin{cases} \sqrt{(x_{o1}-x_a)^2+(y_{o1}-y_a)^2}=r_1 \\ \sqrt{(x_{o1}-x_c)^2+(y_{o1}-y_c)^2}=r_1 \\ \sqrt{(x_a-x_c)^2+(y_a-y_c)}=2r_1^2-2r_1^2\cos\alpha \end{cases}, \quad (3)$$

Using the same method to determine the corresponding center of a circle $O_2(x_{o2}, y_{o2})$ and radius r_2, as well as $O_3\left(x_{o3}, y_{o3}\right)$ and r_3. Last, it determines the coordinate of D point by $D(x, y), O_1\left(x_{o1}, y_{o1}\right), O_2\left(x_{o2}, y_{o2}\right)$ and $O_3\left(x_{o3}, y_{o3}\right)$ through using triangulation.

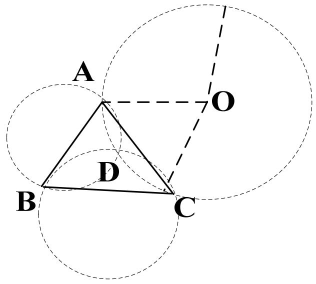

Fig. 2. Triangulation.

3) Maximum likelihood method.

Fig. 3 shows the schematic of the method. Suppose there are nth points, which can be written like $\left(x_1, \mathrm{y}_1\right), \left(x_2, \mathrm{y}_2\right), \left(x_3, \mathrm{y}_3\right), \ldots \left(x_n, \mathrm{y}_n\right)$. $d_1, d_2, d_3 \ldots d_n$ are the distances from points to point D. The coordinate of D point is supposed as (x, y), then exist the following equation:

$$\begin{cases} \sqrt{\left(x-x_1\right)^2+\left(y-y_1\right)^2}=d_1 \\ \sqrt{\left(x-x_2\right)^2+\left(y-y_2\right)^2}=d_2 \\ \vdots \\ \sqrt{\left(x-x_n\right)^2+\left(y-y_n\right)^2}=d_n \end{cases}, \tag{4}$$

Each equation in column minus the last equation, it can get the following:

$$\begin{cases} x_1^2-x_n^2-2\left(x_1-x_n\right)x+y_1^2-y_n^2-2\left(y_1-y_n\right)y= \\ \quad =d_1^2-d_n^2 \\ x_{n-1}^2-x_n^2-2\left(x_{n-1}-x_n\right)x+y_{n-1}^2-y_n^2-2\left(y_{n-1}-y_n\right)y= \\ =d_{n-1}^2-d_n^2 \end{cases} \tag{5}$$

The above equation can be expressed like $AX=b$, in which

$$A=\begin{bmatrix} 2\left(x_1-x_n\right)2\left(y_1-y_n\right) \\ 2\left(x_{n-1}-x_n\right)2\left(y_{n-1}-y_n\right) \end{bmatrix}$$
$$b=\begin{bmatrix} x_1^2-x_n^2+y_1^2-y_n^2+d_n^2-d_1^2 \\ x_{n-1}^2-x_n^2+y_{n-1}^2-y_n^2+d_n^2-d_{n-1}^2 \end{bmatrix}, \tag{6}$$
$$X=\begin{bmatrix} x \\ y \end{bmatrix}$$

According to maximum likelihood method, the position of D can be calculated, which can be expressed by using the following equation:

$$\hat{x}=\left(A^T A\right)^{-1} A^T b, \tag{7}$$

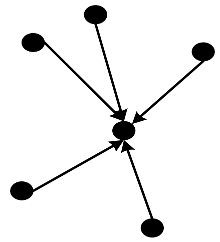

Fig. 3. Maximum likelihood method.

4) Hyperbola location method.

As shown in Fig. 4, we suppose coordinate of anchor node as (x, y), in which $i=A, B, C, D$. The position of pending node S can be described as (x, y). Supposing the distance from A to other node is d_{JA}, we can get the following equation:

$$\sqrt{\left(x-x_J\right)^2+\left(y-y_J\right)^2}-\sqrt{\left(x-x_A\right)^2+\left(y-y_A\right)^2}= \\ =d_{JA}, \mathrm{j}=B, C, D \tag{8}$$

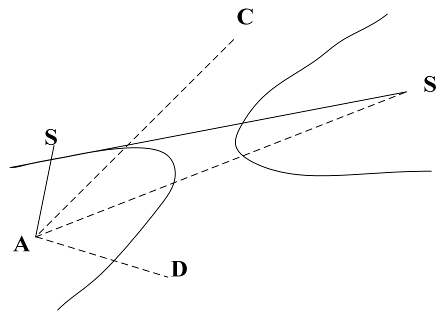

Fig. 4. Hyperbola location method.

The position of S point can be evaluated by using least square method, and then locates it according to the hyperbolic method. In generally, it must have at least four nodes.

3. Empirical Analysis

3.1. Acquisition of Estimated Value of the Pending Nodes and the Known Nodes

According to the received position information and corresponding minimum hop of other anchor nodes, one anchor node can estimate the average distance or average hop distance between them. The average distance can be calculated by the following equation:

$$hopesze_i = \frac{\sum_{j \neq i} \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2}}{\sum_{j \neq i} hop_{ij}}, \quad (9)$$

where j is the other nodes. $\sum$ represents the position coordinate of i node and j node. hop_{ij} is the hop distance of node i and node j. We generally adopt flooding algorithm in order to avoid repeatedly receiving the average hop distance sent by the same anchor node. In large-scale networks, this problem can be solved by setting TTL in average hop distance.

3.2. TTL of Packet Radio

In the first study of packet radio, we don't give a definite value to limit the grouped TTL N, making the most of nodes receive the information at least from three beacon node. After a period of development, someone suggest that the upper limit of TTL should be set as the number of beacon nodes. However, this method can not reduce traffic of nodes to a great degree. If there are anchorth beacon nodes distribute in the monitoring area of $area \times area$ randomly, then there are m[th] beacon nodes distribute in $\pi\left(NR\right)^2$, getting the following equation of N:

$$N = \frac{1}{R}\sqrt{\frac{area^2 \times m}{Anchor \times \pi}}, \quad (10)$$

where N is the possible value of minimum hop distance of the upper limit on TTL of packet radio. R represents the covering radius of each node. Area is the length of monitoring area of sensor networks. M is the number of beacon nodes needed for each pending node. Anchor is the sum of beacon nodes. The experimental results show that the limited hop distance got from the above equation is always small and the choosing standard of TTL of packet radio should be optimized continuously.

Therefore, the improved method based on joint probability density is put forward in this paper. Random variable X can be supposed as the number of nodes, $x \in \left[0, Anchor\right]$. Anchor represents the number of nodes. Random variable Y is the area of the region, $y \in \left[0, L \times L\right]$. L is the length of this area. Hence, their joint probability density is shown in the following equations:

$$f\left(x\right) = \begin{cases} 1/Anchor & 0 \le x \le Anchor \\ 0 & \text{other} \end{cases}, \quad (11)$$

$$f\left(x\right) = \begin{cases} 1/L^2 & 0 \le y \le L^2 \\ 0 & \text{other} \end{cases}, \quad (12)$$

Because X and Y are independent of each other, so according to the above equation the joint probability density function is shown as the following equation:

$$f\left(x, y\right) = \begin{cases} \frac{1}{Anchor \times L^2} & 0 \le x \le Anchor, 0 \le y \le L^2 \\ 0 & \text{other} \end{cases}, \quad (13)$$

If there are m[th] nodes in the range of N hop in which nodes are more than 95 %, we can get the following equation:

$$P\left(x \ge m, y \le \pi\left(NR\right)^2\right) \ge 0.95, \quad (14)$$

After simplification, it becomes

$$N \ge \frac{L}{R}\sqrt{\frac{0.95 Anchor}{\left(Anchor - m\right)\pi}}, \quad (15)$$

By simulating different network connectivity, choosing $R = 0.8R$ and gradually adjusting the parameters, finally we get N of TTL is

$$N = \begin{cases} \frac{L}{0.8R}\sqrt{\frac{0.95 Anchor}{\left(Anchor - m\right)\pi}} & \frac{L}{R}\sqrt{\frac{0.95 Anchor}{\left(Anchor - m\right)\pi}} \le \frac{L}{0.7R} \\ \frac{L}{0.7R} & \frac{L}{R}\sqrt{\frac{0.95 Anchor}{\left(Anchor - m\right)\pi}} \ge \frac{L}{0.7R} \end{cases}, \quad (16)$$

3.3. Add Useful Package for Data Packet

Due to the limited bandwidth of wireless channel, flooding protocol may cause a large number of data packets transmitting within the space at the same time, which causes the data collision, mutual interference between information. Meanwhile, there may be other network transmission of packets in the space caused by interference, or the noise caused by environment or the results caused by multipath attenuation phenomenon. Interference can be divided into the following three conditions: another effective package arrives when nodes are receiving a valid package; Node is receiving a valid packet when a noise package arrives; Node is receiving a noise package when a valid packet arrives.

Information collision interference can cause the error information when the nods are receiving data. Interference accumulates when there is multiple packages interference. When the rate of packet error reaches a certain degree, nodes could not be correctly decoded or correcting mistakes so they destroy data packets directly, which the effective data is missing. In order to effectively avoid data loss, this paper proposes to add a useful package for data packet. After nodes receiving data packet, due to large error rate during the analysis phase and under the condition of being mistaken the effective packet for invalid package or interfered package, it will read useful package. It this package is regarded as useful package, then the node sends a request to sending node, asking to send the data packet again.

3.4. Distance Calculation Phase of Corrected Overlapping Degree

3.4.1. Selective Modification of the Shortest Path Table

This paper only chooses some representative nodes and corrects their minimum hop in the shortest path table, which considers the following two reasons:

1) The minimum hop from adjacent node to the same node is used in corrected equation, which shows that if network connectivity is equal to 10 and node can receive information from m[th] anchor nodes, then this node at least communicate with 9 adjacent nodes. If the value of m is big, then the data need to be sent in several times. If there are 200 nodes and pending nodes, then the addition of network communication burden at least increased to 1800 groups when executing a complete correcting task of the minimum hop for all the nodes in the network [8].

2) Through simulation experiment, we find the calculated minimum hop of the most nodes is not big and hop correcting for all the unknown nodes does n't significantly reduce localization error. By testing different network connectivity, the relationship between average hop distance and communication radius is shown in Table 1.

Table 1. The relationship between average hop distance and communication radius.

Connectivity	30.5	25.3	21.3	18.74	15.5	14.4	13.2	12.1
Hopsize/R	0.766	0.771	0.761	0.747	0.725	0.735	0.739	0.698
Connectivity	11.3	10.9	10.1	9.07	8.57	8.0	7.34	6.12
Hopsize/R	0.682	0.708	0.699	0.696	0.685	0.660	0.666	0.585

The following is the correcting idea of minimun hop. If the minimun hop is bigger than 5, then first calculates the farthest distance from the corresponding node to monitoring area and next compares the distance with minimun hop in the table. If the distance is smaller than minimun hop, then the minimum hop is

$$fix\_hops_i = \frac{\sum hop_j + hop_i}{neighbors} - 0.5, \qquad (17)$$

3.4.2. Hop Distance Estimation of a Hop Node

According to the area of the two circular intersections and the ratio of the two circular intersections, we can calculate the center distance of two circles and get the algorithm to calculate the distance between nodes according to the overlapping degree of the adjacent nodes, which is shown in Fig. 5.

Supposing the radius of the circle is r, then according to geometry the area of the overlapping part is

$$S_{overlocp} = \left(S_{\sec torABC} - S_{\Delta ACD}\right) = 2\left(\overbrace{2\arcsin\sqrt{1-\left(\frac{AB}{2r}\right)^2}\times\frac{\pi r^2}{360}}^{part} - \sqrt{r^2+\left(\frac{AB}{2}\right)^2}\times\frac{AB}{2}\right), \qquad (18)$$

$$overlap = \frac{S_{overlap}}{S_A + S_B - S_{overlap}}, \qquad (19)$$

According to the above equation, we can analyze the relationship between the overlapping degree and the length of AB. Because nodes are uniformly scattered within the circle, so the number of nodes in an area is equal to size of the area. Therefore, we can use the number of the nodes in an area to represent the size of the area. The radius represents the covering radius of the node, and area overlapping can be used to represent overlapping degree of covering area between adjacent nodes. The center of a circle represents the localization of nod.

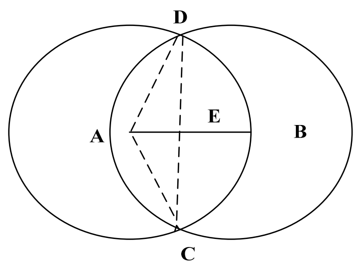

Fig. 5. Hop Distance Estimation of a Hop Node.

4. Conclusion and Discussion

This paper mainly studies the basic knowledge of DV-Hop and does some experiments at the same time. The experimental result is shown in the followings:

1) The overlapping area of overlap with neighboring nodes to replace according to the adjacent node communication radius within the overlap area and node distance mathematical

relationship. Seek the distance between nodes. To fix a hop hop distance error and replace the communication overhead.

2) After locatin the unknown node temporarily escalate as anchors and involved in adverse node positioning. Position and then recovery for unknown nodes. Trying to reduce the amount of calculation, without increasing energy consumption situations to deal with bad node as the problem, reducing the overall positioning error.

3) To study of particle swarm optimization algorithm, and its improving. It puts forward the adaptive weighted and the survival of the fittest thoughts into the particle swarm algorithm. Improves the convergence speed, which overcomes the defects of easy to fall into local optimum, easier to find the global optimal solution.

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