An improved WSN localization algorithm

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Abstract. An improved localization algorithm based on wireless sensor network is proposed to improve the localization accuracy of DV-HOP algorithm in wireless sensor networks. The new algorithm uses three edge distance method to calculate the position relationship between unknown nodes and anchor nodes. MATLAB simulation results show that the new algorithm can effectively improve the positioning accuracy and positioning speed, but the computation overhead is larger, and the energy loss of the node is faster than other conditions.

Introduction

Wireless sensor network is a multi-hop ad hoc network, integrates sensor technology, embedded technology, computer technology, distributed information processing technology and wireless communication technology to collaborate in real-time monitoring, sensing and collecting network distribution area in a variety of environments and supervision of the measured object information, and the data processing, access to detailed and accurate information, and passed to the users who need this information. But whether it is geographical environmental monitoring or traffic monitoring applications and obtain the monitoring information need attached to the corresponding location information, otherwise the data is incomplete, or even lose meaning acquisition. Wireless sensor network sensor node location information acquisition is the basis of a variety of applications, to take a reasonable algorithm to achieve sensor node localization is an important research area of wireless sensor networks.

Introduction of commonly algorithm

A) GPS positioning

GPS positioning is one of the most widely used positioning systems in the world. It has the advantages of high positioning accuracy, wide application range, clock synchronization and so on. The GPS system is made up of 24 satellites, and the accuracy of GPS is adjusted to 20 meters after 2000. GPS system is composed by three parts, one is part of the universal space: 24 satellites in part by the composition of the universe, the earth's surface divided into six orbital planes, each plane four satellites, at any time, ground receiving station to receive signals of 6 satellites; the second part is a ground monitoring: ground control part by the air force base in the U. S. state of Colorado as, in addition, in Maryland and a backup control center; the third is user equipment Part: part of the user is mainly a GPS signal receiving module, usually contain a communication satellite of a specific antenna, a calculation processor and a high precision clock. With the development of electronic technology, the volume of GPS receiver can be very small.

The positioning principle of GPS system is very simple, the distance between the receiving point and the three satellites is measured at first, and then the position is completed by three points. GPS positioning system has obvious defects, namely high in the open area, positioning accuracy, in narrow space positioning accuracy is low, in position to complete the shelter, cannot distinguish between a smaller range of receivers. GPS receivers are usually of high energy consumption, and for the nodes in wireless sensor networks, energy consumption is limited, to each node equipped with a GPS receiver will greatly shorten the lifetime of the network; GPS receiver costs are relatively high, to

each node of the wireless sensor network is equipped with a GPS receiver and need to devote a great deal of the cost, especially for large-scale wireless sensor network is not very suitable.

B) UWB positioning

UWB (Wideband Ultra) has a series of excellent technical characteristics, and it is a very competitive short-range wireless transmission technology. UWB does not use a sinusoidal carrier, but the use of a nanosecond pulse of non-sinusoidal narrow pulse transmission data, so the spectrum of a wide range of. UWB technology is the most basic principle is sending and receiving pulse interval strictly controlled Gaussian single cycle ultrashort pulse, ultrashort single cycle pulse determines the very wide bandwidth of the signal, the receiver directly with a front-end cross correlator the pulse sequence is converted into a baseband signal, eliminating the traditional communications equipment in the mid-level, greatly reduces the equipment complexity. UWB is suitable for high speed and short distance wireless personal communication. UWB can solve the problem of low positioning accuracy, low spectral density, but its communication distance is only a few meters, is the biggest drawback.

C)positioning based on the angle of the signal

Based on signal arrival angle positioning algorithm is a typical range free localization algorithm based on, by some hardware device sensing transmitting node signal direction of arrival, the receiving computing nodes and anchor nodes between relative orientation or angle. Then the triangulation or other ways to calculate the position of the unknown nodes. According to the different known conditions, can be divided into the following two kinds of positioning algorithm.

i) Positioning of known points and angles

As shown in Figure 1, the reference point A1 (x1, y1) and A2 (x2, 22) received signal included angle is α_1, α_2, can be expressed in formula (1).

$$\begin{cases} x = -\dfrac{(y_2 - x_2 \mathrm{tg}\alpha_2) - (y_1 - x_1 \mathrm{tg}\alpha_1)}{\mathrm{tg}\alpha_2 - \mathrm{tg}\alpha_1} \\ y = -\dfrac{(x_2 - y_2 \mathrm{ctg}\alpha_2) - (x_1 - y_1 \mathrm{ctg}\alpha_1)}{\mathrm{ctg}\alpha_2 - \mathrm{ctg}\alpha_1} \end{cases} \quad (1)$$

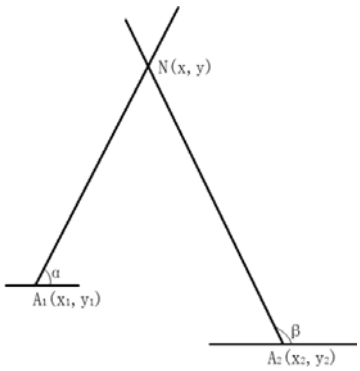

Fig.1 Positioning of two points and angles

ii) Positioning of three points and three angles

As shown in Figure 2, A1, A2 and N determine circle $C_1(x_{c_1}, y_{c_1})$, arc A_1A_2 corresponding central angle $\theta = (2\pi - 2\alpha)$, according to formula (2) can solve the center$(x_{c_1}, y_{c_1})$and radius r_{c_1}, thus by A_1, A_2 and n three points determine a inscribed circle $O_1(x_{c_1}, y_{c_1}, r_{c_1})$. Similarly, A_1, A_3 and n three points determine a inscribed circle $O_2(x_{c_2}, y_{c_2}, r_{c_2})$,$A_2$, A_3 and n three points determine a inscribed circle $O_3(x_{c_3}, y_{c_3}, r_{c_3})$. According to the circle O_1, O_2, O_3 can determine the point D (x_d, yd).

$$\begin{cases} (x_1 - x_{c_1})^2 + (y_1 - y_{c_1})^2 = r_{c_1}^2 \\ (x_2 - x_{c_1})^2 + (y_2 - y_{c_1})^2 = r_{c_1}^2 \\ (x_3 - x_c)^2 + (y_3 - y_c)^2 = 2r_{c_1}^2(1 - \cos\theta) \end{cases} \quad (2)$$

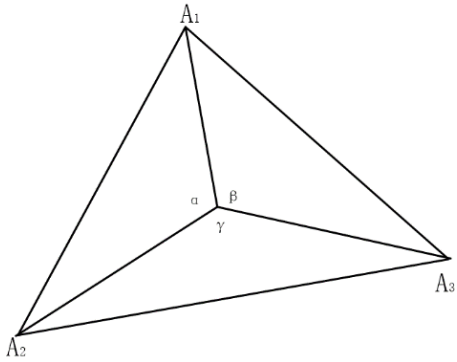

Fig.2 Positioning of three points and three angles

D)positioning based distance

The basic idea of distance based location method is to measure the distance between the nodes, and calculate the position of the nodes by using the geometric method.

The schematic diagram of the three side positioning method is shown in Figure3. The coordinates of N_1, N_2 and N_3 of the 3 nodes are known as (x_1, y_1), (x_2, y_2) and (x_3, y_3). The distance of each node from the node to be located i is r_1, r_2 and r_3. The formula (3) is obtained by the knowledge of geometry.

$$\begin{cases} (x - x_1)^2 + (y - y_1)^2 = r_1^{\ 2} \\ (x - x_2)^2 + (y - y_2)^2 = r_2^{\ 2} \\ (x - x_3)^2 + (y - y_3)^2 = r_3^{\ 2} \end{cases} \qquad (3)$$

By the formula (3) we can know the coordinate position of the node i as shown in the formula (4).

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 2(x_1 - x_3)2(y_1 - y_3) \\ 2(x_2 - x_3)2(y_2 - y_3) \end{bmatrix}^{-1} \begin{bmatrix} x_1^{\ 2} - x_3^{\ 2} + y_1^{\ 2} - y_3^{\ 2} - r_1^{\ 2} + r_3^{\ 2} \\ x_2^{\ 2} - x_3^{\ 2} + y_2^{\ 2} - y_3^{\ 2} - r_2^{\ 2} + r_3^{\ 2} \end{bmatrix} \qquad (4)$$

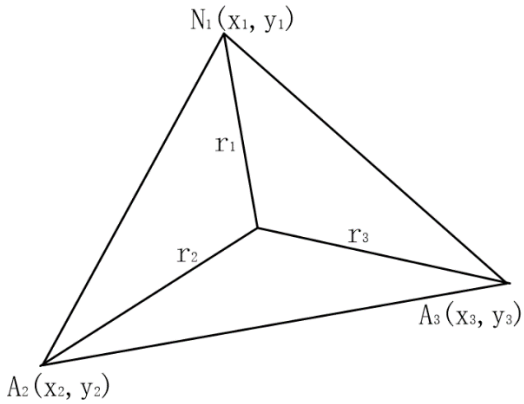

Fig.3 Distance localization algorithm

E) Positioning based on signal feature

Signal feature based positioning algorithm is mainly used in the transmission of radio frequency signals will be decreased with the increase of distance. The mathematical model of the attenuation of the signal in the channel is in accordance with the formula (5). Under the premise of the known transmit power, the receiving node measures the received power, calculates the propagation loss, and transforms the loss into the distance using the signal propagation model. The advantages of positioning based on the signal characteristics are low cost, each wireless sensor node has a communication module, access to RSSI value is very easy, no additional hardware.

$$P(d) = P(d_0) - 10n\lg(\frac{d}{d_0}) - x_\sigma \qquad (5)$$

Where D is the distance between two nodes, d_0 is the reference distance constant and N is the channel attenuation index, usually under the condition of $n \in [2, 4]$, P is the power, x_σ is zero mean,

σ is variance of Gaussian random noise variables. By measuring the signal power of the receiving point, the distance between the transmitter and the receiver can be obtained. But in the actual work process, there are many kinds of signal interference, the environment has a great impact on the power of the signal, so the application of this method has greater limitations.

An improved localization algorithm

A) DV-Hop algorithm

Distance vector hop DV-Hop localization mechanism is similar to the distance vector routing mechanism in traditional networks. Its positioning process is as follows:

i） The position of each node and the calculation of minimum hop beacon nodes number

The beacon node broadcasts its own location information to the neighbor nodes, which contains the hop count field, and is initialized to 0. The accept node record has the minimum hop count to each beacon node, and ignore the large hop count packets from the same beacon node. Then the jump value is added 1, and forwarded to the neighbor node. By this method, all nodes in the network can record the minimum hop count of the beacon node.

ii） Calculate the actual hop distance between unknown nodes and beacon nodes

Each beacon node uses the formula (6) to estimate the actual distance of each hop according to the position information and the hop number of the other beacon nodes recorded in the first stage.

$$S = \frac{\sum_{j \aleph i} \sqrt{(x_i + x_j)^2 + (y_i - y_j)^2}}{\sum_{j \neq i} h_j} \qquad (6)$$

Among them,（x_i,y_i）and（x_j,y_j）is the beacon node i, j coordinates, H_j is the beacon node i and j between the jump number .

Next, the beacon node will calculate the average distance of each hop with the packet broadcast to the network with the survival cycle field. The unknown node only records the first average distance received and forwarded to the neighbor nodes. This strategy ensures that the vast majority of nodes receive the average distance of each hop from the nearest beacon node. After receiving the average hop distance of the unknown node, the hop distance of each beacon node is calculated according to the number of hops recorded.

iii） Calculation of its position by using the three side measurement or the maximum likelihood estimation method

In the second stage, the unknown node is used to record the distance between each beacon node, and to calculate its own coordinates by using the three side measurement method or the maximum likelihood estimation method. The distance vector algorithm uses the average distance to calculate the actual distance, and the hardware requirement of the node is low, and the realization is simple. The disadvantage is that there is a certain error by using the distance to replace the straight line.

B) Improved algorithm

Localization algorithm in wireless sensor networks, the number of nodes in the positioning of the number of nodes, the location of the higher precision of the location of the node, but the above algorithm, this view is not enough. This method can reduce the positioning accuracy by introducing the bad beacon node. In hop distance localization algorithm based on need a higher proportion of beacon nodes, in order to obtain a higher positioning accuracy, but if the ratio of beacon nodes is too high, will greatly increase the cost of wireless sensor networks. Based on the above ideas, an improved algorithm is proposed, which is mainly divided into 4 steps:

i) threshold value setting: set an empirical parameter n, if the beacon node is less than N, the other nodes are not required to participate in the localization;

ii) to find the position of the node distance from the beacon nodes and the minimum number of hops and distance;

iii) select beacon node localization: determine the location of nodes around less than n of the beacon a few points, if the number of nodes more than 3, from the choice of 3, and in accordance with the three side of the measurement method for positioning;

In the DV-HOP algorithm, through analysis of node between the distance metric can be found using the distance does not reflect the anchor node for the positions of unknown nodes, the size of the impact, thus affecting the positioning accuracy. Therefore, we can introduce the concept of weighted coefficient, the basic idea is: in the DV-HOP algorithm, the size of the anchor node can be reflected by the weight factor of the size of the influence of the unknown node position. When determining the position of the node, the node should be given a more accurate weight coefficient of the anchor node. The weight coefficient not only reflects the influence degree of different anchor nodes to the position coordinate information of unknown nodes, but also reflects the intrinsic relationship between them. When the weighted coefficient is less than a certain threshold value, the anchor node will be ignored because of the large error. Can make use of the number of hops to reflect the size of the weighted coefficient, hop number between unknown node distance of anchor nodes, the error is bigger and bigger, the weighted coefficient of anchor nodes along with the increase of the number of jump decreases. In the improved algorithm, the average hop distance between the nodes around the unknown nodes should be considered, and the number of hops between the anchor nodes and the unknown nodes should be considered. At the same time, it should consider the influence of the environment on the average distance of each hop so as to achieve the purpose of reducing the error.

C) Simulation of improved algorithm

In order to verify the validity and feasibility of the algorithm, this paper simulated the algorithm and DV-HOP algorithm, and compared the results with the results. The simulation tool uses MATLAB R2009b, which is randomly distributed in 100 m * 100 m region. One part is the anchor node, which carries the GPS equipment, can know its own coordinates, and the other unknown nodes need to be calculated through the calculation. All nodes have the unique ID number of the whole network and relatively static. Node communication radius of 15 meters set. The performance of two algorithms in the case of low connectivity and high connectivity is shown in Figure 4.

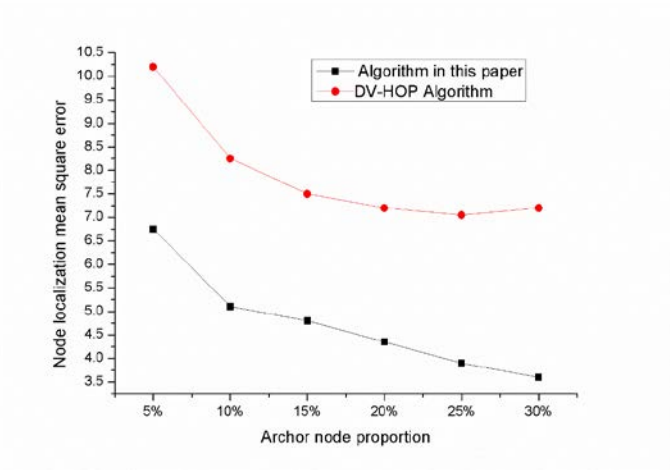

Fig.4 Comparison of two algorithms

Conclusions

In view of the localization accuracy of DV-HOP localization algorithm is not high, this paper proposes an improved algorithm, which is based on the two aspects of distance estimation and positioning calculation. First of all, put forward new unknown node and anchor node distance calculation, based on the triangle formed between unknown nodes and anchor nodes, the jump distance and the number of known between anchor nodes, to estimate the unknown nodes and anchor nodes distance; secondly, it puts forward the concept of anchor nodes trust and according to anchor nodes average hop distance values for trust calculation. Finally, the nodes coordinate calculated. From the simulation results, we can see that the improved algorithm has obvious advantages

compared with the DV-HOP algorithm in both the localization accuracy and the stability of the node localization.

In the further work, the key to improve the positioning accuracy of the problem, at the same time reduce the amount of communication and computing nodes, improve the use of node energy time, making the application of wireless sensor network.

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