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Wireless Sensor Network 3-D Positioning Method on Energy Efficiency

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Abstract

Wireless sensor network (WSN) is widely used in industrial control, signal acquisition; intelligent household production and life in various aspects, such as its main communicate through wireless channel. Because of the wireless sensor network (WSN) is widely decorate, its positioning as one of the important applications. The traditional two-dimensional plane positioning has can't meet the demand. Three-dimensional positioning method has become the focus of the study, however, since most sensor nodes in wireless sensor networks are limited energy, aiming at this problem, this paper will consider under the maximum energy efficiency of localization algorithm, under the condition of ensure the positioning precision, minimize the consumption of energy, improving energy efficiency. Simulation analysis show that the proposed algorithm effectively improves the efficiency of energy utilization, and ensure that the three dimensional positioning accuracy and stability.

Keywords: *Wireless sensor network; Node localization; Positioning accuracy; the three dimensional positioning*

1 Introduction

With microelectronics technology and the microelectronic system on board, the signal processing technology and wireless communication technology rapid development and progress, a huge system arises at the historic moment, its numerous, formed a node, which is constructed based on a large number of sensor nodes of wireless sensor network compared with the traditional network, it can be "individual perception", "active" perception by sensor nodes and network integration, implementation of "common sense" or what we need is called "pan in perception [1-3]. Traditional Internet provides the interpersonal information communication platform, but not solve the problem of people and objective physical world information, and good make up for the vacancy of sensor network, its advantages can be used to real-time and continuous monitoring and reporting to the information on the perception of the outside world things. Due to its advantages of rapid exhibition began, anti-destroying ability is strong, high monitoring precision, and large coverage, and can be widely used in military, aerospace, industrial and agricultural, environmental monitoring, *etc*.[4-6], is one of the hotspot in research of

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the communication industry. Wireless sensor network is a blend of a variety of high and new technology, represents the development trend of mobile Internet business, attaches great importance to the home and abroad. At the same time, the components of the wireless sensor network, the generalization for the "Internet of things", to human life and production mode brings revolutionary change. The Internet of things, however, the most basic, also is the most important function is positioning function, it is the foundation of other functions and applications, wireless location technology based on wireless sensor network thus became a focus in the study of academic and industrial applications.

Wireless sensor network with sensor module, wireless communication module, information processing module of sensor nodes, and through the collaboration between each other, can make the real-time monitoring, awareness, and get the information they need to, with micro structure, multiple applications, the characteristics of highly integrated. Wireless sensor network is automatically formed, will be in the form of node to node on the sensory information to the terminal. Therefore, wireless sensor network (WSN) can work in independent environment, can also work with the mobile Internet interconnection to complete the scene information collection.

Wireless sensor network (WSN) is different from the derived from the telecom network and computer network of wireless broadband networks, such as GSM, CDMA, 3 g, 4 g and WLAN wireless broadband networks need human to complete network planning, deployment, configuration and management, *etc.*, and wireless sensor network (WSN) is a fast and flexible self-organizing networks, this remarkable characteristic makes sensor networks need a series of new core technology, including the information fusion technology, distributed data processing technology, the appropriate routing protocol and MAC protocols, synchronization technology, positioning technology and so on. In recent years, many scholars committed to the research of wireless sensor network (WSN) key technology, this article selects the positioning technology of wireless sensor network as the main research direction. Positioning technology provides the node location information, it is an important part of the monitoring object information, and this is because there is no location information data is pointless, the location information of the generation of data routing, information fusion and other follow-up work has an important supporting role. Many applications directly using the sensor network positioning technology, such as regional environmental monitoring, field the positioning of the battlefield. So the development of wireless sensor network location technology of sensor network system has important role in promoting.

In recent years, domestic and foreign scholars have proposed many positioning mechanism and a scheme of wireless sensor network (WSN), and obtained a large number of research results, but most of these schemes are based on the design and evaluation of deployment of application in two-dimensional environment to consider, and most of the locating scheme is based on four idealized conditions: one is the sensor node communication range is a circular or similar rules; network deployment

environment rules, flat and no obstacle plane or three-dimensional space;3 it is network is homogeneous, that is to say, the network node uniform application environment of the single;4 it is static node is the same. In addition, most of the positioning method of performance analysis and comparing only positioning accuracy, no analysis of network scale, the anchor node density and other performance metrics such as energy consumption, cannot achieve the balance between the indicators, locating method of robustness and life cycle has been destroyed. In practical applications, the sensor node generally need to put in the mountains, underwater, the air, forests and complex environments, such as high-rise buildings. These applications are included in a mountainous battlefield, a floating in the air, air pollution monitoring sensor network a forest monitoring sensor network deployment in the high and low different tree or a structure monitoring network is installed on a bridge, and so on. Under the environment of the real applications, the node layout are allocated by randomly scattered cloth in every position of the detection area, there is no guarantee that the node is uniformly distributed, the wireless signal affected by multipath, shadow, attenuation, *etc*. The influence of various factors, it can't be an isotropic communication range, there are a lot of communication blind zone, also inevitably appear a lot of "hot spot" areas, making the region of the node energy consumption, energy early failure is likely to happen, thus resulting in a lot of "empty" vacuum network area; Such as forest, concave/convex gravamen mountain, a large number of application environments, such as an underwater, underground, there will be some obstacles a serious impact on locating methods, the deployment area won't be the rules of two-dimensional or three-dimensional space; Many application of WSN usually require some or all of the nodes are mobile, rather than a static, such as personnel positioning and tracking, such as car networking is positioned in the applications of node mobility, network topology is dynamic changes in these environments, and to locate a node move real-time, such as energy consumption brings higher request. In the applications of the sensor nodes in the power supply, communication radius, transmission bandwidth, computing and storage capacity, *etc*. [7-12], there will be differences of these conditions is often can't meet in the practical application, is a heterogeneous network. All in all, in these real monitoring area showed the complex network topology characteristics, so for node positioning technology under complicated environment research is imminent.

Most of the locating scheme, especially the 3 d localization algorithm, are mostly based on the idealized model is derived, thus ignore the restrictions of the actual deployment environment, for example, each of the wireless sensor network node energy is limited, so most of the algorithms are pay attention to the performance of positioning accuracy and stability, is positioning accuracy and stability are the direct target localization algorithm parameters; But ignores the non-ideal factors such as the algorithm implementation of energy consumption, and the influence of the positioning performance, obviously its localization algorithm also does not have practical, therefore, in the light of the topological structure of complex cases, adopt

the method of optimization of function optimization, improve the localization accuracy of nodes, reducing the consumption of energy, especially restrictions, the power consumption of each node is the optimization objective function of the characteristics and advantages.

2 Related Research

Position precision is defined as the unknown node Euclidean distance between estimated and actual location, and usually expressed as and communication radius ratio, such as positioning accuracy for the estimation of the r.l represents the unknown node location and distance from the center of the actual and node communication radius ratio 0.1.Usually, the algorithm based on distance than without ranging localization algorithm localization accuracy is higher. Positioning accuracy shows the location of a given location algorithm is out and node matching degree of the real physical location. For a given location as a result, the positioning accuracy and positioning precision of compromise. If you relax the requirements of accuracy, can improve the precision, and vice versa. Therefore, you must put the two indexes in common range, so the location accuracy of instructions are based on the corresponding to assess accuracy, positioning accuracy is also sometimes called the positioning error, both meaning. Error propagation illustrates the positioning error with the increase of measurement error is how to change, intuitively, positioning error is linear measurement error. However, for many positioning system that is not correct, especially for continuous iterative localization algorithm, the trilateral and multilateral measurement, for example, has a larger position error nodes will affect its neighbor node location estimation. In this case, the measurement error is no longer the only factor to the positioning error [12-15].

Anchor nodes is essential to the global coordinate system and a reference system. Fault nodes in addition to know in advance that its position is no difference with other ordinary nodes, fault node location information can be hard-coded into, or through some additional hardware such as a GPS receiver. Fault node layout has a significant influence on the positioning performance of the existing algorithms can be found, if the pin placed around the sensor network node can obtain higher positioning accuracy, additional anchor node is placed in the center of the network can also improve the positioning accuracy, therefore, is necessary for the system designer before the deployment of sensor networks, plan the position of the anchor nodes. Obviously wrong node density, the higher the corresponding location accuracy will be, but too much of anchor nodes will increase the cost of a sensor network localization algorithm needs to make a trade-off between the positioning performance and cost. The practical application of wireless sensor network environment tend to be bad, when the influence of the sensor network layout after the good external environment, there may be some nodes failure, run out of battery capacity, the signal of the multipath effect, communication blind spots, changes in the environment impact range and so on a series of problems, generally will affect the node localization, to replace the one problem node generally difficult to achieve,

which requires the positioning system and the localization algorithm modules have higher robustness and fault tolerance, can use their own some of the software and hardware resources for correcting errors or restructuring or adjust itself to the best state to adapt to the current environment to reduce the positioning error. From the positioning performance index analysis, high performance of localization algorithm has higher precision, lower nodes density, low cost, high robustness. The various performance indicators according to the practical application of concrete to make a certain balance design the most appropriate localization algorithm [16-17].

Locating method based on distance measurement by measuring the signal propagation time, signal propagation time difference between nodes, signal arrival Angle, signal intensity, receiving interference intensity and the packet reception rate and the information such as link quality indicators to calculate the distance between nodes, and then USES trilateration method and triangulation method or maximum likelihood estimation to estimate the node coordinates. Typical locating method based on distance measurement are: RSSI, ToA, TDoA and AoA.

RSSI method is based on RF connectivity and positioning parameters of the received signal strength, the node hardware requirements is low, advantage is defiance of the distance, mature technology, low cost, small energy consumption, positioning scope is bigger. Infrared and ultrasonic positioning parameter error is small, can reach level of 10 centimeters, but need to be in the terminal integration of special ultrasonic sensor module or ultrasonic array, lead to bigger volume and power of terminal. Other ultrasonic transmission distance is short, it and infrared can only line-of-sight transmission, are susceptible to interference from the outside environment. Method by measuring the signal propagation time to estimate the distance of the node, the node will bring a very precise clock, reception of signal transmission time to start node needs to know. TDOA measurements with TOA measurement method is a little similar, using rf signal propagation time, can use two kinds of different propagation speed signals, with arrival time difference to measure the distance between the nodes, the signal is converted into a distance, speed and time is suitable for dense deployment and network node carry line-of-sight devices. Because usually ultrasonic signal propagation distance for 20 to 30 feet and obvious, the technology is mainly limited to the distance of the ultrasonic signal. The two high precision positioning method (cm-level accuracy), but need additional hardware support, the hardware requirements

3 The Model of Wireless Location

If random distribution in 3 d space with a sensor node is responsible for receiving known location target source emission signal, the i th are the coordinates of the sensing nodes (x_i, y_i, z_i), assumptions to determine the position of the unknown target source for (x, y, z).The unknown target signal source and each square of the distance perception nodes can be expressed as

$$r_i^2 = (x_i - x)^2 + (y_i - y)^2 + (z_i - z)^2 \quad (1)$$

Simple as

$$r_i^2 = x_i^2 + y_i^2 + z_i^2 - 2x_i x - 2y_i y - 2z_i z$$

$$+ x^2 + y^2 + z^2, i = 1, 2, \cdots M \quad (2)$$

In wireless location, once get the TDOA measurements can build TDOA location equations. But hyperbolic equations based on TDOA location is a nonlinear equation, to seek the solution is not an easy thing, different method and constitutes the positioning accuracy of localization algorithm, mainly to 2 d Chan algorithm is extended to 3 d space. Chan algorithm is a kind of analytic expression of recursive equations solution, the algorithm is a relatively small amount of calculation, under the environment of noise obeys the Gaussian distribution, high positioning accuracy. If random distribution in 3 d space with a sensor node is responsible for receiving known location target source emission signal, the first are the coordinates of the sensing nodes, assumptions to determine the position of the unknown target source for (x, y, z).The unknown target signal source and each square of the distance perception nodes can be expressed as

$$r_{i,1} = cd_{i,1} = r_i - r_1 \quad (3)$$

Because of the hyperbolic equation (3) is nonlinear in nature. To solve the nonlinear equations must first carries on the linearization. For the traditional algorithm for nonlinear equations linearization, the introduction of auxiliary variables, namely the first hypothesis for the target coordinates has nothing to do with auxiliary variable, using the weighted least square method to get the initial solution. In order to further improve the accuracy of positioning, then get the estimated position coordinates and auxiliary variables such as constraint conditions in a known the WLS estimate, the improved location estimation.

In order to calculate and describe the convenient, first of all make the position vector:

$$z_a = \left[z_p^T, r_1 \right]^T \quad (4)$$

Where $z_p = [x, y, z]^T$

To do the type (3) transform and square, namely

$$r_i^2 = (r_{i,1} + r_1)^2 \quad (5)$$

To get the following equation

$$\begin{aligned} r_{i,1}^2 + 2r_{i,1}r_1 = & -2(x_i - x_1)x - 2(y_i - y_1)y \\ & - 2(z_i - z_1)z + x_i^2 + y_i^2 + z_i^2 \\ & + x^2 + y^2 + z^2 \end{aligned} \quad (6)$$

You can get the positioning error, as shown in type (7)

$$w = m - nz_a \tag{7}$$

Where

$$m = \frac{1}{2}\begin{bmatrix} r_{2,1}^2 - \left(x_2^2 + y_2^2 + z_2^2\right) + \left(x_1^2 + y_1^2 + z_1^2\right) \\ r_{3,1}^2 - \left(x_3^2 + y_3^2 + z_3^2\right) + \left(x_1^2 + y_1^2 + z_1^2\right) \\ r_{M,1}^2 - \left(x_M^2 + y_M^2 + z_M^2\right) + \left(x_1^2 + y_1^2 + z_1^2\right) \end{bmatrix} \tag{8}$$

$$n = \begin{bmatrix} x_2 - x_1 & y_2 - y_1 & z_2 - z_1 & r_{2,1} \\ x_3 - x_1 & y_3 - y_1 & z_3 - z_1 & r_{3,1} \\ \vdots & \vdots & \vdots & \vdots \\ x_M - x_1 & y_M - y_1 & z_M - z_1 & r_{M,1} \end{bmatrix} \tag{9}$$

4 Particle Swarm Localization Algorithm of Energy Efficiency

Originated in particle swarm optimization algorithm and simulate the behavior of the birds foraging activities, so as to put forward a kind of biological modeling global stochastic optimal heuristic search algorithm. The group from the collection of particles, the algorithm is similar to other biological modeling algorithms (genetic algorithm), is the competition between the individual and the cooperation, to search optimal solution in the multidimensional space. But it's different from evolutionary algorithms such as genetic algorithm, crossover and mutation operations such as no need for an individual to, but the individual in the population as there is no volume of M dimensional space! No quality of particles, each particle moves in a certain speed, and to the individual historical best position and the global best position, so as to realize the evolution of the solution. Particle swarm optimization algorithm and genetic algorithm, simulated annealing algorithm, compared to other similar biological heuristic algorithm has some advantages such as simple algorithm and easy to realize, few parameters and high accuracy, good global searching performance, the advantages of fast convergence rate, in the scientific research and engineering practice have been widely an extensive attention and been applied in large-scale wireless sensor networks.

Assumption in M dimensional search space, the size of the group s, group of particle i position X_{im} and speed of attribute V_{im}, location attribute the solution space of the problem $lbest_{im}$, and the speed attribute $qbest_{im}$ is updated solution space vector.

Each candidate solution by optimizing the function to determine whether the optimal. The particle swarm optimization method to approximate the objective function is minimum, search the global optimal solution in the M dimensional space. Set the number of iterations to k, then the speed and the location of the particle I

updated according to the following two formulas, until we find the global optimal solution or the maximum number of iterations.

For the purpose of this article, the proposed objective function as shown in type (10)

$$\begin{aligned} &\min \boldsymbol{w} \\ &\text{s.t. } E_i < e_{\max} \\ &\quad \left\| nz_a \right\| \geq r \end{aligned} \tag{10}$$

From the point of optimization of function, E_i the energy consumed for each node, and $e_{\max}$ for each node localization can dominate the biggest power at a time. So this condition to ensure the wireless sensor network in the positioning of application for a long time, but not because energy consumption is too large and cause the entire network paralysis. And the second condition on behalf of the received signal has a certain strength, so as to guarantee the final nodes to receive accurate signal in fusion, in a sense, that is both security sensor nodes to send power need not too big, resulting in waste of energy; Also can't make send power is too small, unable to receive the signal.

According to the optimized function, and the particle swarm algorithm, can get the following steps:

Step1 network establishment Network initialization, a ID, assigned to each sensor node and beacon node and the unknown node are marked. Then, beacon node to a jump in the scope of unknown node to send a message, a message content including your ID and the three-dimensional coordinate values. Unknown node will receive a recorded message.

Step2 can locate the unknown node selection According to the received message, select a jump within the scope of the number of beacon nodes for at least four of those who can locate the unknown node distance, on the other hand, has won the position estimate unknown node can be as a beacon nodes, fixing the other unknown nodes.

Step3 determination of ranging error Can locate the unknown node measurement with its neighbors (jump range) the distance between the beacon nodes, a record for distance measurement, the distance measurement error of measurement value exists. Among them, the line-of-sight error can use small zero mean and variance of additive gaussian noise simulation; Non line-of-sight error can be used is mean and variance of additive gaussian noise simulation, the non-line-of-sight error is determined by the non-line-of-sight propagation, which is verified through the regional test.

Step4 the application of particle swarm optimization method In the three dimensional search space, using the particle swarm optimization method, through the loop iteration, seeking to make formula (10) define the objective function of the smallest particle's position, as the optimal solution of x.

Step5 the judgment of exit criteria According to the setting calculation accuracy and to identify the largest number of iterations, if meet one of the conditions, then exit the loop and the global best position of the group as the optimal solution; Otherwise, return to step (2).

For particle swarm optimization (PSO) algorithm, can get the following process:

（1）Initialize the w， c_1， c_2

Initialize the maximum number of iterations K，

（2）Initialize the $X_{\max}$， $X_{\min}$ 和$V_{\min}$、$V_{\max}$；

（3）for $i = 1 : s$

for $m = 1 : M$

Randomly selected： $X_{\min} \le X_{im} \le X_{\max}$

Randomly selected V_{im}： $V_{\min} \le V_{im} \le V_{\max}$

end

end

（4） $k = 1$

While（$k < K$）and（$\boldsymbol{w}(qbest) < w_t$）

for $i = 1 : s$

calculate $\boldsymbol{w}(x)$

if $\boldsymbol{w}(qbest) < w_t$

for $m = 1 : M$

$qbest_{im} = x_{im}$

end

end

（5）for $i = 1 : s$

for $m = 1 : M$

$V_{im}(k+1) = wV_{im}(k) + c_1 r_1(\mathrm{k}) + \mathrm{c}_2 r_2(\mathrm{k})$

$X_{im}(k+1) = X_{im}(k) + V_{im}(\mathrm{k})$

end

5. Simulation Results

Matlab simulation in this paper, the size of three-dimensional space, in this space, set up wireless sensor for 100, and these nodes to uniform distribution, so that the distance of each sensor for 20 m; Nodes in the simulation experiment, it was assumed that has obtained the distance between the measured values, and adopts zero mean and variance of 4 gaussian random noise simulation range measurement error; Using the mean, variance of 5 to 16 gaussian random noise simulation non-line-of-sight error of measurement.

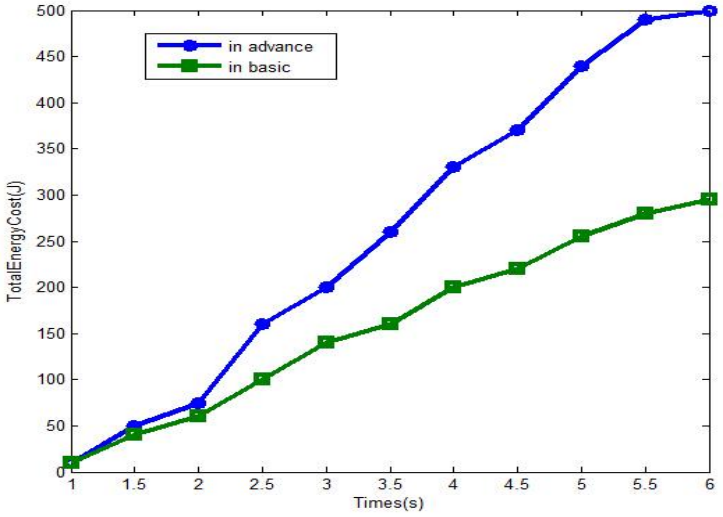

Figure 1. Times V.S. Total Energy Cost

Figure 1 shows the traditional respectively three-dimensional positioning method and the proposed particle swarm method in this paper, with "in advance" and "basic" in. Can get from the picture, with the increase of positioning time, after 2 seconds, the energy consumption of the joule number there will be a big difference. As you can see, the algorithm proposed in this paper the maximum in 6 s place, but will not increase, while the traditional three-dimensional localization algorithm with linear time increasing, thus it can be seen that the proposed scheme in each node of the energy saving advantage.

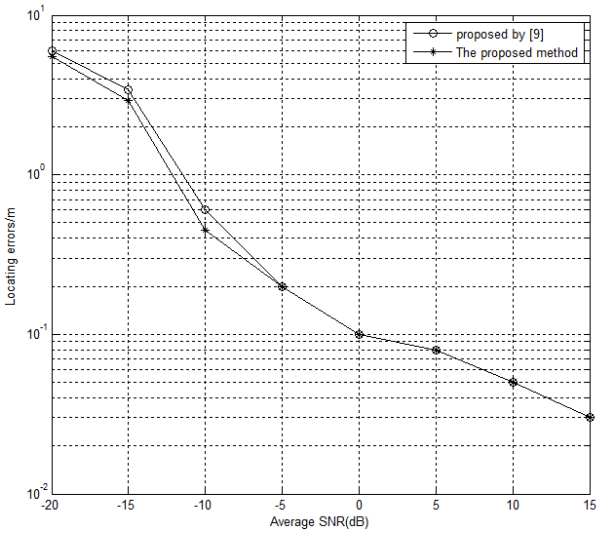

Figure 2. SNR V.S. MSE (dB)

See from figure 2, although the particle swarm optimization algorithm, the improved in terms of energy utilization, however, its positioning accuracy did not decline, but under the condition of low signal-to-noise ratio increased, especially -

20 dB to - 10 dB, the positioning error rate is lower than the literature [9] of the proposed algorithm. When large signal noise ratio (SNR), two schemes of positioning precision flat, but this plan still have a little advantage.

6 Conclusions

In this article, through the analysis of three dimensional positioning system, find the defects of the now design positioning algorithm that does not consider the actual needs, in order to improve the positioning accuracy, and in order to save energy of each node, improve the utilization efficiency of node, in this paper, application of particle swarm algorithm to optimize the objective function, thus increasing the application of the algorithm in the actual scene, the simulation results show that the algorithm precision had certain increase, and in terms of energy use efficiency has improved significantly.

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