NONLINEAR MODELING AND ANALYSIS OF WSN NODE LOCALIZATION METHOD

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ABSTRACT

In this paper, node localization algorithms in wireless sensor networks are researched, the traditional algorithms are studied, and some meaningful results are obtained. For the localization algorithm and route planning of WSN exists a big localization error in wireless communication. WSN communication system is researched. According to the anchor nodes and unknown nodes, a new localization algorithm and route planning method of WSN are proposed in this paper. At the same time, a new genetic algorithm of route planning of WSN is proposed. The performance of the node density and localization error is simulated and analyzed. The simulation results show that the performance of proposed WSN localization algorithm and route planning method are better than the traditional algorithms.

KEYWORDS

wireless sensor network;anchor node; localization algorithm; route planning

1. INTRODUCTION

So far, in the process of studying and developing of wireless sensor networks(WSN), security has been concentrated less. As a new network,the wireless sensor network is a multi-discipline, highlyintersecting researched hot field, which is of both military and business values.Topology control is one of the most fundamental problems in wireless sensor networks.[1-2]. WSN,which are the newest technology of information collecting and processing, have a wide range of application including military and business. But the node localization information has a key role in the application of wireless sensor network.Research of the wireless sensor network gradually gets the focus from the industrial and academe[3-4]. It has a great application future in the military and civil area. Reducing power consumption to extend network lifetime is one of the most important challenges in designing wireless sensor networks. In order to improve the positioning accuracy of wireless sensor networks, references [5-7] proposed a localization algorithm DAC-ND based on aggregation, collinearity and connectivity of anchors. The relationship between the positioning accuracy and the distribution of anchors were studied. The experimental shows that the anchor nodes in collinear or concentration distribution can lead to poor positionig accuracy for WSN localization algorithms based on distance measurement. References [8-15] prolonged network lifetime, good scalability and proper load balancing are important requirements for many sensor

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network applications. Clustering sensor nodes is an effective technique for achieving these goals. Clustering Algorithm based on Node Correlation (CANC) is proposed.CANC utilizes received signal strength, residual energy and connectivity to choose cluster-heads. It takes the node correlation into account to determine cluster members. Analysis and simulation results show preliminarily that, the new CANC algorithm can make cluster-heads well distributed and achieve good performance in terms of system lifetime, scalability and LBF (load balancing factor). Classi`c clustering algorithms in wireless sensor networks are studied ,which are fixed operation periods and too much information exchanged in cluster-heads selection. Then an Energy-Efficient Clustering Algorithm (EECA) is proposed, whose kernels are adaptive operation period model and a new cluster-heads selection method[16-18]. Simulation results show that the proposed protocol can adjust operation period adaptively and reduce the information exchanging in choosing cluster-heads, is more energy-efficient and suitable for wireless sensor network. A new localization algorithm and route planning for use in wireless sensor network are studied in References[19-20].References[21-22]presents the analytic and simulation results of the performance of UWB relative localization estimation in wireless sensor networks. References [23-24]propose resolving schemes of data collection in wireless sensor networks of both plane model and linear and nonlinear mathematics model,and proposed a new node route planning method.

The main contributions of this paper are listed as follows.(1) A new WSN node localization algorithm is proposed to reduce the localization error and and the number of anchor nodes.(2) A new genetic algorithm of route planning of WSN is proposed Some novel synchronization results are proposed.These results are more practical.(3) The novel route planning method is proposed for prolonging network lifetime and obtaining shortest path in WSN.

The rest of this paper is organized as follows. In Section 2,the wireless sensor network system model node route planning is researched. In Section 3,the localization algorithm and route planning is built up for the wireless sensor network communication system. In Section 4,simulation results are presented.Finally,conclusions are drawn in Section 5.

II. TRADITIONAL WSN NODE ROUTE PLANNING

Wireless sensor network network includes an anchor nodes and unknown nodes. It can be implemented with a laser or microwave communication between them.It is a challenging problem about the localization algorithm. The traditional localization algorithm of SCAN[25-26] for wireless sensor network can be described as follows:

The beacon node's position can be noted as (x_1, y_1) ,A is the unknown node, the position is (x, y) ,We suppose $AB = d_1$,so we can get:

$$(x_1 - x)^2 + (y_1 - y)^2 = d_1^2 \tag{1}$$
$$s.t.\ 0 \le x \le l_1, 0 < y \le l_2 \tag{2}$$

The traditional localization algorithm of CIRCLES[27-28] for wireless sensor network [20-21] is noted as follows.The relationship of multilateral localization of the unknown node is shown in Fig.1.

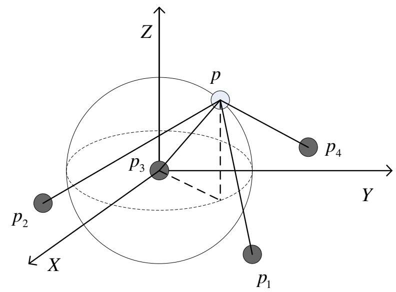

Fig.1. Multilateral localization of the unknown node

There are two beacon nodes in the wireless sensor network system. The position of beacon node C (x_2, y_2, z_2), $AC = d_2$, the mathematics model can be denoted as[28-29].

$$\begin{cases}(x_1-x)^2+(y_1-y)^2+(z_1-z)^2=d_1^2\\(x_2-x)^2+(y_2-y)^2+(z_2-z)^2=d_2^2\\y=0\ or\ y=l_1\ or\ z=l_2\\s.t.\ 0\le y\le l_1, 0<z\le l_2\end{cases} \tag{3}$$

There are three beacon nodes in the wireless sensor network system, the mathematics model can be expressed as

$$\begin{cases}(x_1-x)^2+(y_1-y)^2+(z_1-z)^2=d_1\\(x_2-x)^2+(y_2-y)^2+(z_2-z)^2=d_2^2\\(x_3-x)^2+(y_3-y)^2+(z_3-z)^2=d_3^2\\y=0\ or\ y=l_1\ or\ z=l_2\\s.t.\ 0\le y\le l_1, 0<z\le l_2\end{cases} \tag{4}$$

The distance of anchor nodes can be calculated as follows:

$$d_{kj}=\begin{cases}[\sum_{i=1}^{l_k}(s_{ki}-x_{ji})^{\alpha}]^{1/\alpha} & k=1\\[\sum_{i=1}^{l_k}(s_{ki}-x_{j(i+l_{k-1})})^{\alpha}]^{1/\alpha} & k>1\end{cases}\quad k=1,2,\ldots,M; j=1,2. \tag{5}$$

III. WSN NODE LOCALIZATION ALGORITHM

For wireless sensor network node localization, due to the Localization of the mobile node insert uncertain nodes, so the inserted into the virtual anchor nodes, which helps to limit the localization error. The node system model is shown in Fig.2.

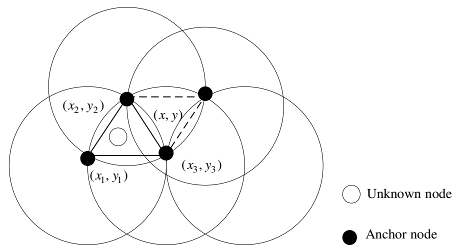

Fig.2. The node system model

The node movement route plan are obtained.So we can get:

$$\begin{cases} x = x_0 + r \times t \times \cos(2\pi t + \varphi) \\ y = y_0 + r \times t \times \sin(2\pi t + \varphi) \end{cases} \tag{6}$$

Similarly,in the triangle ,we can get:

$$\cos\theta = \frac{(d_2^2/4) + d_1^2 - d_0^2}{d_1 d_2} \tag{7}$$

Combined with formula (6) and (7),d_0 can be expressed as:

$$d_0 = \frac{\sqrt{2d_1^2 + 2d_3^2 - d_2^2}}{2} \tag{8}$$

The total path length can be expressed as

$$D = \sum_{t=1}^{20} \sqrt{r^2 + 4r^2\pi^2 t^2 + 4r^2 t \sin(4\pi t) + 4r^2 t \cos(4\pi t)} \tag{9}$$

Node relative positioning and the radial error can be expressed respectively:

$$error_{avg} = \frac{\sum_{i=1}^{n} \sqrt{\left(x_i - x_i^{'}\right)^2 + \left(y_i - y_i^{'}\right)^2 + \left(z_i - z_i^{'}\right)^2}}{n \times R} \times 100\% \tag{10}$$

$$error_x = \frac{\sum_{i=1}^{n} abs(x_i - x_i^{'})}{n \times R} \times 100\% \tag{11}$$

IV. WSN NODE ROUTE PLANNING

In WSN, the uneven distribution of nodes and the different amount of perception data will lead to the imbalance of energy consumption and hotspot problem.To solve this key problem of WSN,a route planning algorithm of mobile WSN sink node is proposed to prolong network lifetime and travel shorter route in wireless sensor networks. By defining the grids in the network area, several candidate sites of mobile sink are distributed in each grid, and then sink node select a site for sojourning and collecting data of nodes in each grid. Based on the relationship between network lifetime and the selection of sink sites, the network model is proposed in Fig.3.

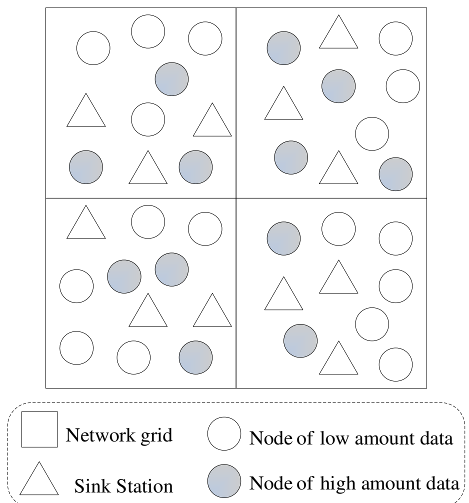

Fig.3. The network model

As can be seen from Fig.4.The monitoring area is divided into multiple same grid size. The length of grid is L ($L<R$, R is the communication radius of WSN). Wireless sensor nodes (n) are distributed randomly in the monitoring area. V_{grid} denotes the grid set. V_{node} is the sensor node set. According to the actual circumstance of the network. Sink station nodes (m) are distributed in each grid. $|V_{site}| = m \times G$ and $|V_{sel-site}| = G$.

The sensor nodes to send data to a node of one hop routing is considered. The energy consumption of node i send 1 bit data to the sink node is as follows:

$$E_i = \begin{cases} f \times \left(E_{else} + \varepsilon_{fs} d_{i \to MS}^2\right), & d_{i \to ms} < d_0 \\ f \times \left(E_{else} + \varepsilon_{mp} d_{i \to MS}^4\right), & d_{i \to ms} \geq d_0 \end{cases} \tag{12}$$

Where, f is the sensor node data transmission rate.

The network life cycle T_{net} can be defined by Network began to run into any one node energy exhausted by the time. survival time of network node i can be expressed as

$$T_i = \left\{ \frac{S_e^i}{E_i t_i} \middle| t_i = \frac{S_{data}^i}{f}, i = 1, 2, \ldots, n \right\} \quad (13)$$

Where, S_e^i is residual energy of node i . S_{data}^i is the sense data volume of node i . t_i is the consuming time by accessing sink nodes.

Based on the above analysis. Purpose is to maximize the network life cycle, and to minimize sink moving path length.

The optimization model can be formulated as

$$\max \left(\min_{i \in V_{node}} T_i \right) / d_{TSP} \quad (14)$$

$$s.t.\ T_i t_i \times \left(E_{else} + \varepsilon_{fs} d_{i \to MS}^2 \right) \le S_e^i \quad \forall i \quad (15)$$

$$f t_i = S_{data}^i \quad \forall i \quad (16)$$

$$T_i > 0, d_{i \to MS} \ge 0, i = 1, 2, \ldots n \quad (17)$$

Where, formula (14) is the ratio of $\min_{i \in V_{node}} T_i$ (maximize the network lifetime) and d_{TSP} (The only site selection in each grid node traversal path length in their wake).Constraint formula (15) ensures that each sensor node in the network life cycle energy consumption is less than the initial energy of data transmission. Constraint formula (16) ensure that each sensor node in the mobile sink to access data transmission time is equal to the volume of the data of perception. Constraint formula (17) ensures the network life cycle and the distance of the sensor nodes to the mobile sink node is not negative.

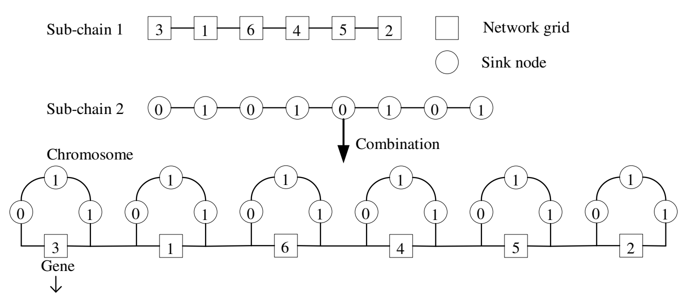

Fig.4. The relationship between the sub-chain and the chromosome

The optimization model can be solved by the following steps:

Step 1: Initialization

Initializes a double-stranded chromosomes,the number of chromosomes is C .The number of iterations g is equal to 0.Chromosome operands $c = 0$, $a_1 = a_2$.

Step 2: Chromosome assessment

Calculate all the fitness of chromosomes, those have biggest fitness will be selected to the next generation of populations.

Step 3: Selection

According to the roulette strategy, select two chromosomes which need to cross.

Step 4: Cross

Generate a random number between 0□1.If it is greater than the value of a_1.Crossover operation was carried out on the selected two chromosomes. Crossover operation is used by using partial matches the crossover. First randomly generated two intersections, definition of these two areas as the matching area. And the exchange of two elder matching area.As can be seen from Fig.9.

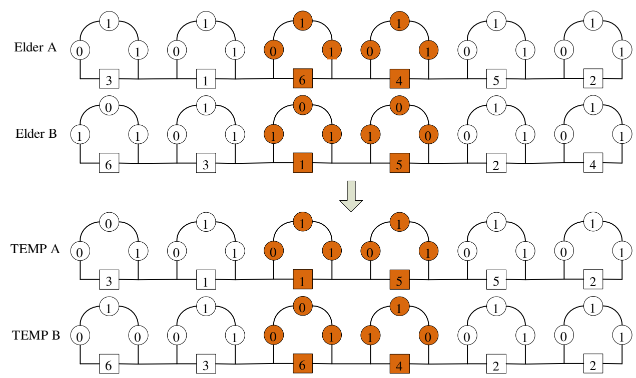

Fig. 5. The exchange of parental matching regions

The TEMP A,TEMP B of matching area in digital duplication. According to match the location of the area one by one to replace.Matching relationship is $\{3 \leftrightarrow 2, 1 \leftrightarrow 4\}$.Generation individual A and B.

Step 5: Mutation

Generate a random number between 0□1.If it is greater than the value of a_1.Crossover operation was carried out on the selected two chromosomes.Randomly generated two variants. Exchange of chromosome two variants of genes, Variation of pair to sub-chain 2(sink station chain) a corresponding value for a variable.

Step 6: Return (End)

$c = c+1$,if $c < C-1$, skip to step 3.Otherwise $g = g+1$ and $m = 0$.If $g < g_{\max}$, return to step 2. Otherwise, double chain of genetic algorithm is termination. Obtain largest fitness of chromosomes. The chromosome decoding available mobile sink node traverses the entire optimal path grid to collect data.

The congestion prediction of WSN is defined as:

$$fc_j = \frac{1}{2} \cdot \alpha_j + \frac{1}{2} \beta_j \tag{18}$$

Where, α_j is cache utilization of the node j , β_j is the congestion factor of the node j . $\beta_j = l_j / L$. L indicates the total number of links in the current network.

Node forwarding goodness is defined as:

$$fs_j = \frac{\left(1 - fc_j\right)^2}{1 - e^{-\varepsilon_j}} \tag{19}$$

Where, ε_j denotes the minimum number of hops from the node to the target node.

In order to evaluate the quality of the path calculated by the multipath routing algorithm, the path fitness function from the source node s to the destination node d is defined based on the parameters defined as follows:

$$fitness_{s,d}(i) = \sum_{j=1}^{n} \left(\mu_{ij} \cdot fc_{ij}\right) / \varepsilon \tag{20}$$

Subject to:

$$\begin{cases} \{s, i1, i2, \ldots ij \ldots, d\} \in path(s \to d, i) \\ \mu_{ij} = 0,1 (j = 1, 2, \ldots, n) \end{cases} \tag{21}$$

V. SIMULATION ANALYSIS

A. Main parameters setting

Main simulation parameters setting of WSN node localization and route planning are shown in Table 1.

Table 1. Main simulation parameters setting

Parameter	Value
WSN monitoring area	150m×150m
The number of grid	16
The number of sensor nodes	150
Node communication radius	50m
Node sensor the data volume	0 □ 7500 bit
Formula (1) parameter	60 nJ/bit
Formula (1) parameter	25 PJ/(bit·m^2)
Node initial energy	0.15 J
Data transmission rate	2 kbit/s
Crossover probability	0.4

B.Simulation results analysis

To verify the convergence of the proposed algorithm, the largest fitness value and the average fitness is simulated and calculated. Its convergence speed, the optimization results are shown in Fig.6.

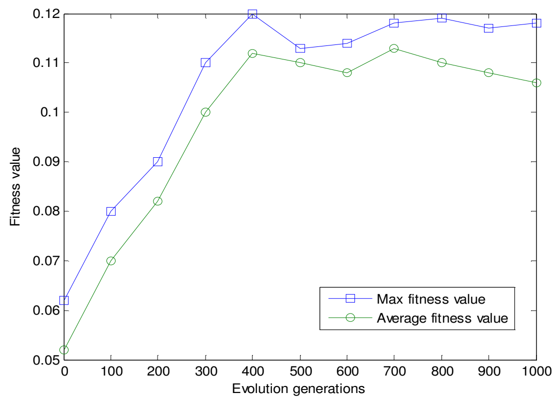

Fig.6. The convergence of proposed algorithm

As can be seen from Fig.8,the proposed algorithm has good convergence by comparing the optimal solution and the average solution.

In order to compare network life cycle performance of the proposed algorithm and the traditional algorithms(MS-LEACH-RN algorithm and LEACH algorithm).Sensor nodes(50,100,150,100,250,300) are distributed randomly in the area of WSN.

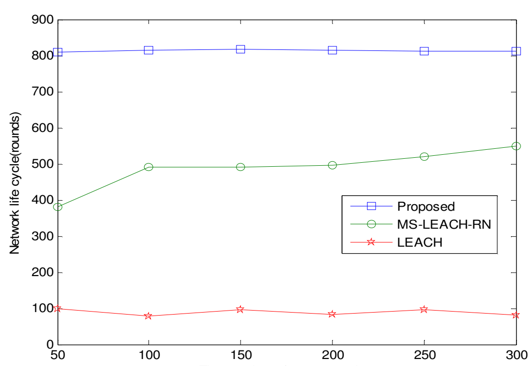

Fig.7. Network lifetime

As shown in Fig.7, the proposed algorithm of the network life cycle is 1~2 times the traditional algorithm of MS-LEACH-RN, it is 8 times of the LEACH algorithm. It is proved that the proposed algorithm can extend the network survival time considering the 150 nodes to be mounted on the random uniform topology. The relation between node radius and localization error is shown in Fig.8.

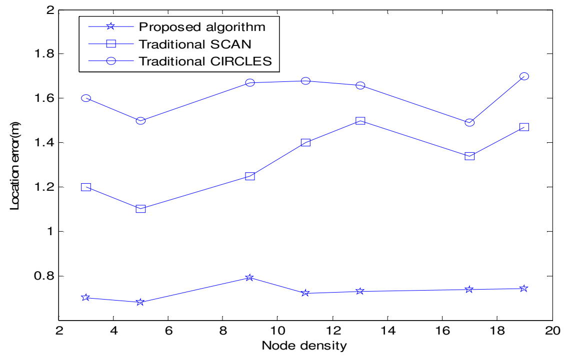

Fig.8. Relation between node density and localization error

As can be seen from Fig.8.It shows different changing tendency along with different localization error.In all,the proposed algorithm is better than the traditional SCAN and CIRCLES methods.

When the number of nodes *n* is equal 50.The relation between average localization error and ranging radius is shown in Fig.9.

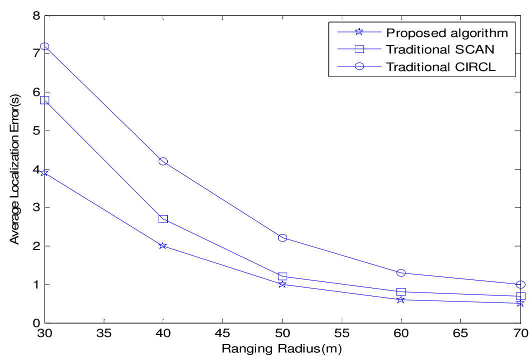

Fig.9. The average localization error under different ranging radius

In Fig.9.The ranging radius is increased from 30 to 70.The average localization error of the algorithms with the increase of ranging radius is becoming less.Compared with traditional methods(SCAN and CIRCL), the proposed node localization algorithm was 21.5 % and 11.6% decreased, respectively.

VI. SUMMARY

Based on the analysis of the wireless sensor network,some conclusions are obtained.First of all, the wireless sensor network communication system is set up.Then,localization algorithm and node route planning of wireless sensor network are proposed. Some mathematics model is built according to the wireless sensor network communication system, a new genetic algorithm of route planning of WSN is proposed.Last,WSN node localization algorithm and route planning method are simulated. The performance of the proposed localization algorithm and route planning method is better than the traditional methods.

Though this work is targeted at the node localization of WSN, the methods presented here could be applied for other applications such as the localization of nodes through Internet of Things (IOT) and Internet of Vehicles (IOV).

In the future,we intend to study the spatial localization of nodes in WSN, which is an active area of research,with many applications in sensing from distributed systems,such as micro aerial vehicles, smart dust sensors, and mobile robotics.

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