International Journal of Statistics and Probability; Vol. 7, No. 2; March 2018
ISSN 1927-7032 E-ISSN 1927-7040
Published by Canadian Center of Science and Education

WSN Node Positioning and Mathematics Modeling Based on Genetic Method

Xiaoyang Liu[1,2], Hengyang Liu[1], Ya Luo[1] & Chao Liu[1]

[1] School of Computer Science and Engineering, Chongqing University of Technology, China

[2] College of Engineering, The University of Alabama, Alabama, USA

Correspondence: Ya Luo, School of Computer Science and Engineering, Chongqing University of Technology, China. E-mail: 158010342@qq.com

Received: December 6, 2017 Accepted: January 4, 2018 Online Published: January 18, 2018

doi:10.5539/ijsp.v7n2p39 URL: https://doi.org/10.5539/ijsp.v7n2p39

Abstract

Node positioning is a basic but important research direction in wireless sensor networks. In practical applications, sensor nodes are mostly randomly deployed, and the distribution is often uneven. There is a low positioning accuracy of nodes in wireless sensor network iterative positioning algorithm. Aiming at the problem of traditional localization algorithm, a new localization algorithm is proposed based on genetic method in this paper. The algorithm uses the genetic model to obtain the node velocity and orientation information, then according to the node's historical trajectory of time series we can get accurate sampling region that can get the high quality sample points which is closer to the unknown node. Simulation results show that the performance of proposed algorithm is superior to the traditional algorithms.

Keywords: wireless sensor network, mathematics model, positioning, genetic method

1. Introduction

Wireless sensor network (WSN) is a wireless networks where sensor nodes are self-organizing. Network nodes have the ability to communicate, calculate, and measure the environment. WSN is a multi-hop network with great application value and prospect in military, industrial, civil and other fields. For most WSN applications, if the data collected and transmitted by the node does not contain a specific location, this information will become meaningless.

The current location algorithms mainly include two categories problems of location algorithms based on ranging and unrelated to ranging. Ranging-based location algorithms include three-edge location algorithm, multi-location algorithm, multi-dimensional scale location algorithm (Multi dimensional scaling MAP, MDS-MAP) and non-line-of-sight positioning algorithms based on disk scatters. The distance-independent positioning algorithms include the centered localization algorithm, distance vector-hop (DV-HOP) Positioning] algorithm, Amorphous positioning algorithm and approximate triangle in-point test (Approximate point-in-triangulation test, APIT) positioning algorithm.

At present, the research on the location of group mobile nodes has caused domestic and foreign research personnel attention, carried out in a large number of group mobile model, group mobile node clustering based on the research of routing protocols, the localization of group mobile nodes is also carried out certain studies. On the basis of estimating the moving characteristics of the group center, each node position can be predicted. Although the algorithm greatly reduces the number of location update messages, there will be data point pairs. The effect of predictions is treated equally, which is the location of a mobile node that is time-referenced. The data is not reasonable. Because the data closer to the predicted point is often more reflective predict the situation of the point. These papers improved it, the use of forgetting factor in the parameter estimation, the new and old data are assigned different weights, and the minimum based on the weighting is proposed multiplication algorithm of positioning method.

In the monitoring area, wireless sensor nodes are often thrown sprinkle the way to the random deployment, the result is the sensor section point distribution which is often uneven density. The previous shift to the beacon node moving path planning algorithm most of the research direction is about on how to ensure more by planning more routes to cover more areas and high positioning rate, so the overall positioning rate can be improved; but positioning time, positioning accuracy and energy cost optimization cannot be simultaneously effective guaranteed. The existing algorithms do not take network nodes density as a reference for positioning. As a result, the nodes are distributed in the same location. That is used for the areas with fewer areas and the areas with densely distributed nodes. It will lead to low positioning accuracy of node distribution in nodes dense regional, regions. References introduced the mobile beacon node assisted positioning mechanism, which is a typical approach to greatly reduce the network implementation deployment cost by using a limited number of mobile beacon nodes.

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 positioning 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.

2. 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 positioning algorithm. The traditional positioning algorithm of SCAN for wireless sensor network can be seen in Figure (1).

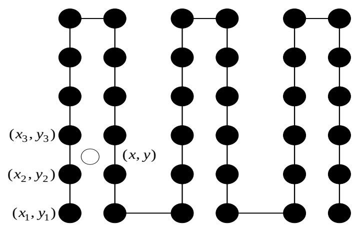

Figure 1. SCAN positioning algorithm

As can be seen from Fig.1.B is the beacon node, the position is (x_1, y_1) ,A is the unknown node, the position is (x, y) ,we suppose $AB = d_1$,so we can get:

$$\left(x_1 - x\right)^2 + \left(y_1 - y\right)^2 = d_1{}^2 \tag{1}$$

$$s.t.\ \ 0 \le x \le l_1, 0 < y \le l_2 \tag{2}$$

The traditional positioning algorithm of CIRCLES for wireless sensor network is shown in Figure(2).

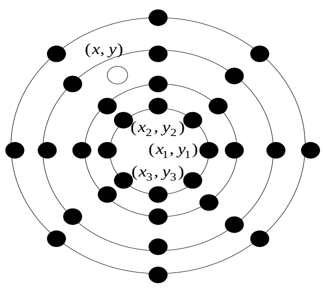

Figure 2. CIRCLES positioning algorithm

The relationship of multilateral positioning of the unknown node is shown in Figure(3).

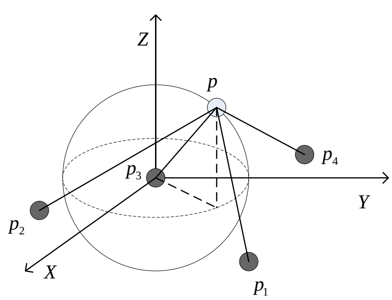

Figure 3. Multilateral positioning of the unknown node

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·

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

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:

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

3. WSN Node Positioning Algorithm

For wireless sensor network node positioning, due to the positioning of the mobile node insert uncertain nodes, so the inserted into the virtual anchor nodes, which helps to limit the positioning error. The node system model is shown in Figure (4).

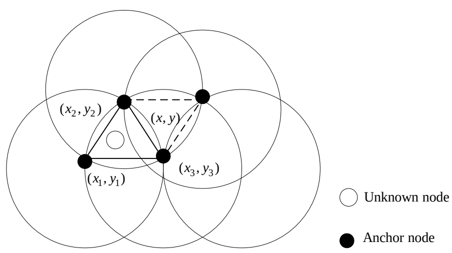

Figure 4. The node system model

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

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

The flow chart of wireless sensor network node positioning is shown in Figure (5).

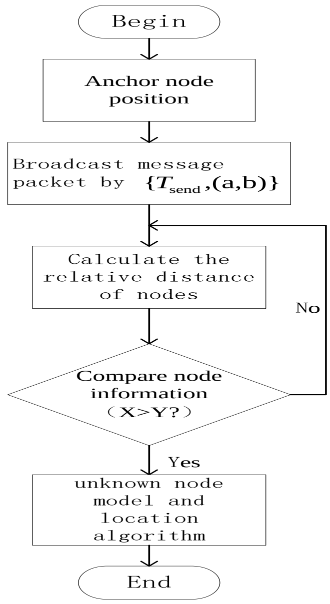

Figure 5. The flow chart of positioning

Where,the anchor node broadcast message is shown in Figure(6). We assume that the received packet position is triangle.

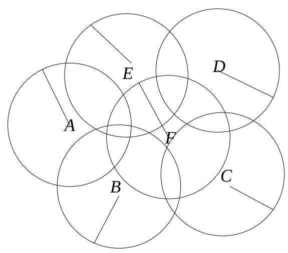

Figure 6. The anchor node of broadcast message

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

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

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

4. 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 Figure (7).

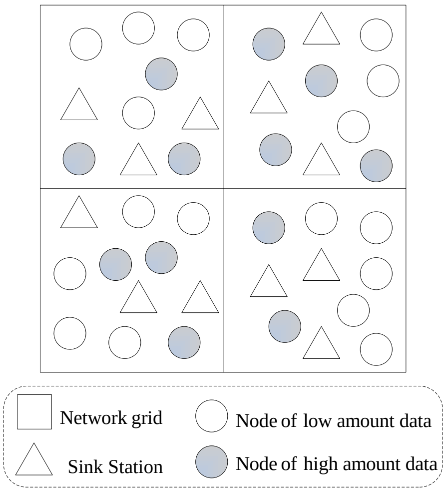

Figure 7. The network model

As can be seen from Fig.1.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

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

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

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

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

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

$$T_i > 0, d_{i\to MS} \geq 0, i = 1, 2, \ldots n \tag{17}$$

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.

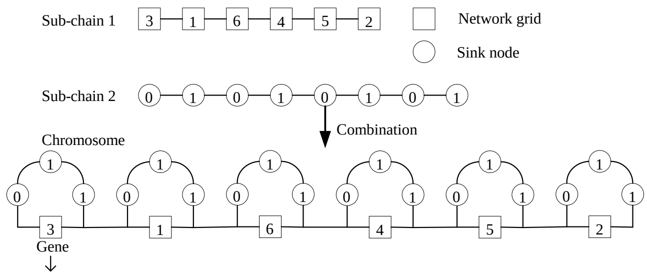

Figure 8. The relationship between the sub-chain and the chromosome

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 $0 \sim 1$.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 Figure (9).

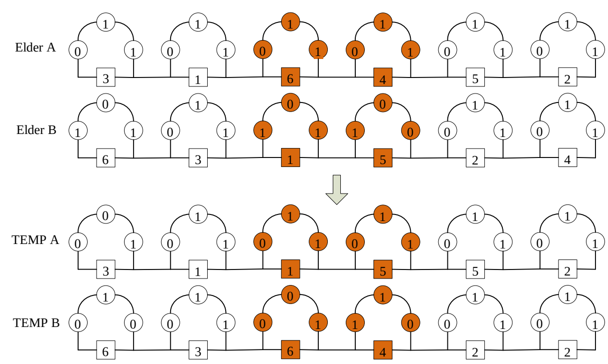

Figure 9. The exchange of parental matching regions

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, as can be seen from Figure(10).

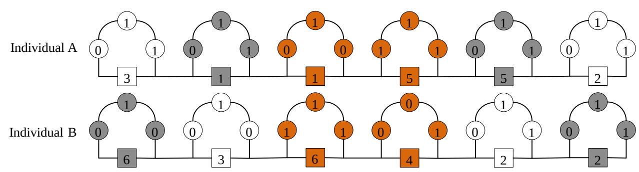

Figure 10. The substitution map of matching relationship

Step 5: Mutation

Generate a random number between $0 \sim 1$.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. As can be seen from Figure (11).

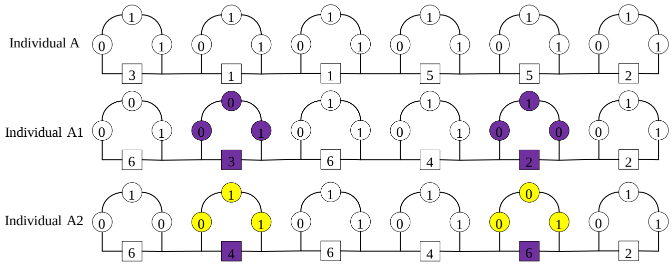

Figure 11. Mutation operation

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:

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

Subject to:

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

5. Simulation Analysis

5.1 Main Parameters Setting

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

Tabel 1. Main simulation parameters setting

Parameter	Value
WSN monitoring area	$150\text{m}\times150\text{m}$
The number of grid	16
The number of sensor nodes	150
Node communication radius	50m
Node sensor the data volume	$0\sim7500\text{bit}$
Formula (1) parameter	60 nJ/bit
Formula (1) parameter	$25\ \text{PJ}/\left(\text{bit}\cdot\text{m}^2\right)$
Node initial energy	$0.15\,\text{J}$
Data transmission rate	2 kbit/s
Crossover probability	0.4

5.2 Simulation Results Analysis

Considering the 150 nodes to be mounted on the random uniform topology. The relation between node radius and positioning error is shown in Figure(12).

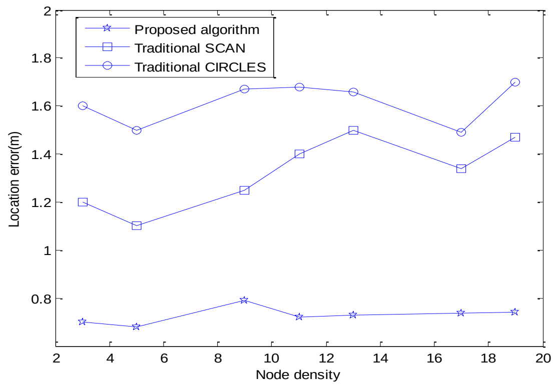

Figure 12. Relation between node density and positioning error

As shown from Figure(12).The positioning error performance of proposed wireless sensor network node positioning algorithm is better than traditional SCAN and CIRCLES.The relation between node density and positioning proportion is shown in Figure(13).

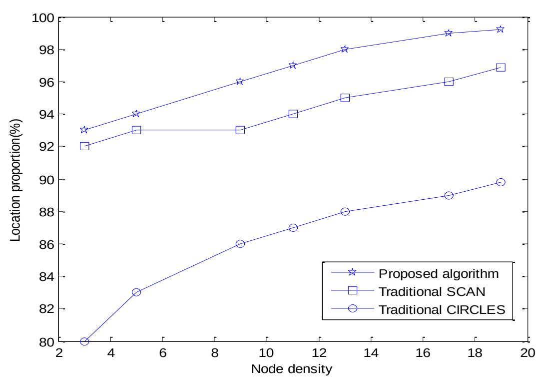

Figure 13. Relation between node density and positioning proportion

As can be seen from Fig.13.The positioning proportion performance of proposed wireless sensor network node positioning algorithm is better than traditional SCAN and CIRCLES methods.The relation of movement speed of nodes and positioning error is shown in Figure(14).

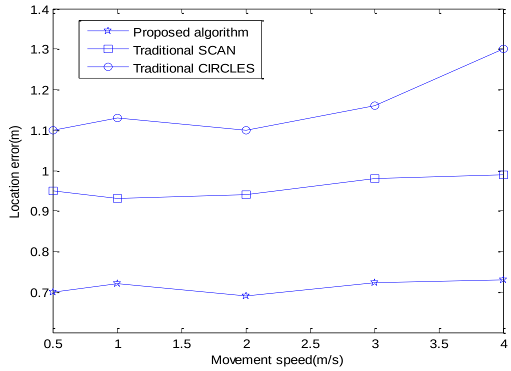

Figure 14. Relation of movement speed and positioning error

As can be seen from Fig.14.With the increase of movement speed of nodes, the shows different changing tendency along with different positioning error. In all, the proposed algorithm is better than the traditional SCAN and CIRCLES methods. Positioning time under different movement speed is shown in Figure(15).

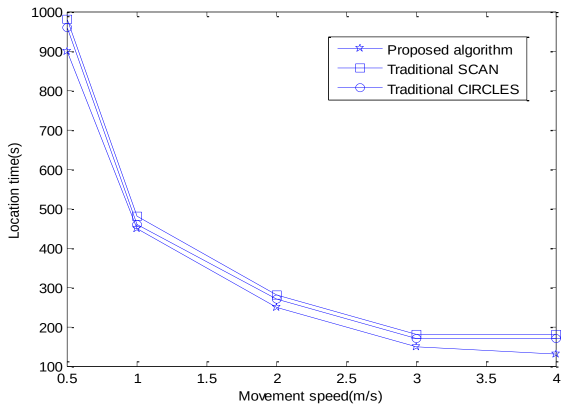

Figure 15. Node density and positioning error

As can be seen from Figure(15),the positioning time is different when the movement speed is different. With the increase of movement speed, the positioning time is becoming less.

When the number of nodes n is equal 50.The relation between average positioning error and ranging radius is shown in Figure(16).

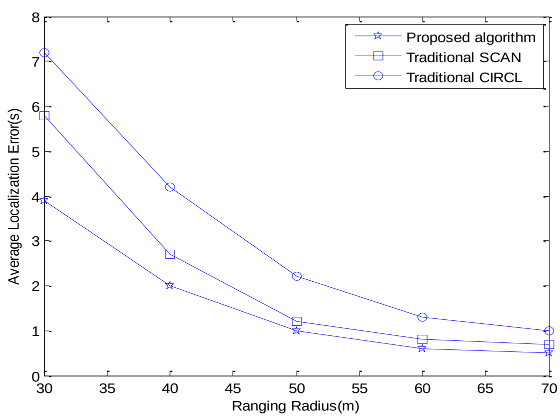

Figure 16. The average positioning error under different ranging radius

In Figure(16).The ranging radius is increased from 30 to 70. The average positioning error of the algorithms with the increase of ranging radius is becoming less.Compared with traditional methods(SCAN and CIRCL), the proposed node positioning algorithm was 21.5 % and 11.6% decreased, respectively.

6. 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,positioning 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 positioning algorithm and route planning method are simulated. The performance of the proposed positioning algorithm and route planning method is better than the traditional methods.

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

In the future,we intend to study the spatial positioning 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.

Acknowledgement

The paper was supported by Science and Technology Research Program of Chongqing Municipal Education Commission(KJ1600923,KJ17092060), Young Fund Project of Humanities and Social Sciences Research of Ministry of Education of China (16YJC860010), National Social Science Fund of China West Project(17XXW004), Social Science of Humanity of Chongqing Municipal Education Commission(17SKG144), Natural Science Foundation of China (61571069, 61501065, 61502064, 61503052, 91438104).The author Xiaoyang Liu thanks for the financial support from CSC(China Scholarship Council)(No.201608505142).

References

Amar, K., Kumar, N., & Prasanta, K. J. (2017). Energy efficient path selection for mobile sink and data gathering in wireless sensor networks. AEU-International *Journal of Electronics and Communications, 73*(2), 110-118. http://dx.doi.org/10.1016/j.aeue.2016.12.005

Dang, T. H., Le, H. S., & Trong, L. V. (2017). Novel fuzzy clustering scheme for 3D wireless sensor networks. *Applied Soft Computing, 54*(1), 141-149. http://dx.doi.org/10.1016/j.asoc.2017.01.021

Guangqiang, C., Bingyan. C., Pengfei, L., Peng, B., & Chunqun, J. (2015). Study of aerodynamic configuration design and wind tunnel test for solar powered buoyancy-lifting vehicle in the near-space. *Procedia Engineering, 99*(3):67-72. http://dx.doi.org/10.1016/j.proeng.2014.12.509

Guanhua, W., Shanfeng, Z., & Kaishun, W. (2015). TiM: fine-grained rate adaptation in wLANs. *IEEE Transactions on Mobile Computing, 15*(3), 748-761. http://dx.doi.org/10.1109/TMC.2015.2421938

Jian, A., Ling, Q., Xiaolin, G., & Zhenlong, P. (2017). Joint design of hierarchical topology control and routing design for heterogeneous wireless sensor networks. *Computer Standards & Interfaces, 51*(2), 63-70. http://dx.doi.org/10.1016/j.csi.2016.11.002

Jie, H., LieLiang, Y., & Lajos, H. (2015). Distributed Multistage cooperative-social-multicast-aided content dissemination in random mobile networks. *IEEE Transactions on Vehicular Technology, 64*(7), 3075-3089. http://dx.doi.org/10.1109/TVT.2014.2354295

Muhammad, A., Ehsan, U. M., Mustafa, R., & Xiaopeng, H. (2016). Adaptive energy-efficient clustering path planning routing protocols for heterogeneous wireless sensor networks. *Sustainable Computing: Informatics and Systems, 12*(5), 57-71. http://dx.doi.org/10.1016/j.suscom.2016.09.001

Rachid, B., Mohamed, A. H., Narimane, C., & Mourad, C. (2017). PEAS with Location Information for coverage in Wireless Sensor Networks. *Journal of Innovation in Digital Ecosystems, 3*(2), 163-171. http://dx.doi.org/10.1016/j.jides.2016.11.002

Reem, E. M., Ahmed, I. S., Maher, A., & Ahmed, S. S. (2017). Energy-efficient routing protocols for solving energy hole problem in wireless sensor networks. *Computer Networks, 114*(3), 51-66. http://dx.doi.org/10.1016/j.comnet.2016.12.011

Xenakis, A., Foukalas, F., & Stamoulis, G. (2016). Cross-layer energy-aware topology control through Simulated Annealing for WSNs. *Computers & Electrical Engineering, 56*(1), 576-590. http://dx.doi.org/10.1016/j.compeleceng.2016.02.015