The Research on WSNs Scale-free Topology for Prolonging Network Lifetime

Wenxiao Yin, Benzhen Guo, Hailong Hu, Yanhong Hu, Qiang Li

Abstract—**Network lifetime is an important index to measure the performance of wireless sensor networks (WSNs). Due to the limited energy of nodes in WSNs, prolonging the network lifetime becomes the priority problem in the design of the network. In this paper, we deeply research how to prolong the lifetime of WSNs. Firstly, the node lifetime model in WSNs is studied. Then through using the fitness model for scale-free topology in WSNs, a scale-free topology BNL (Based on the Node Lifetime) for prolonging network lifetime is obtained. Finally, the node degree of the model which obeys the power-law distribution is verified theoretically. The simulation results show that the topological structure based on the evolution of the scale-free network has good fault tolerance characteristics. And it also can balance the network energy consumption and prolong the network lifetime.**

***Index Terms*—wireless sensor networks, scale-free, the network lifetime，the residual energy**

I. INTRODUCTION

Wireless sensor networks which deployed in harsh environments are energy-constrained [1-3]. Nodes in the network are prone to failure due to battery energy depletion and poor environment [4-6]. The scale-free topology with power-law distribution has strong fault tolerance to random failure [7]. A typical scale-free topology structure is shown in Fig. 1. As can be seen from Fig. 1, the connection distribution of a scale-free network is extremely uneven. Many nodes have a small number of connections, and a few nodes have a large number of connections in the network. Therefore, scale-free topology is often used to solve the random failure problem in WSNs [8-10]. However, the WSNs are a special kind of complex network, which have the characteristics of node energy limitation and communication radius limitation. For this reason, the characteristics of WSNs should also be considered when the scale-free topology is applied to WSNs, especially the energy consumption of nodes plays an essential role in the network lifetime. Thus, it is of great significance to construct a lifetime extending topology based on the scale-free network in WSNs.

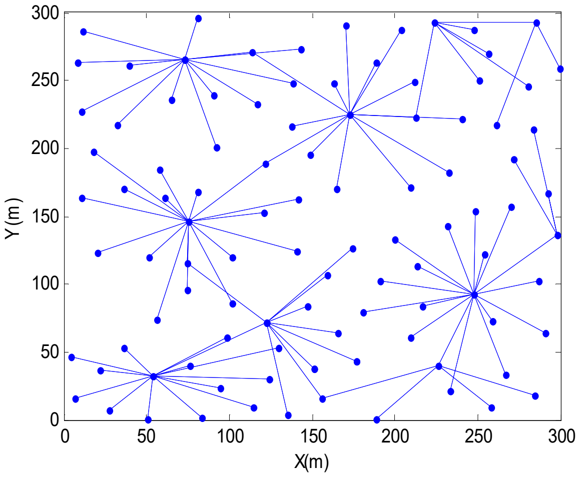

Fig. 1. Scale-free topology

At present, the redundancy mechanism is mostly adopted by researchers for prolonging network lifetime [11][12]. But in this way, it means to increase the unnecessary communication links. This will reduce the network performance and increase the network load. Then Barabasi and Albert [13] studied the topology of the world wide web, the scale-free topology which the degree distribution obeys the power-low distribution is found. At this point, the fault-tolerance feature of scale-free topology has aroused a lot of scholars’ interest. In Ref. [14], Zhu built the energy efficient fault-tolerant topology EAEM (energy-aware evolution model). And it combined the residual energy of nodes with the preferential attachment mechanism of the scale-free network. Finally, they concluded that the scale-free topology has strong fault tolerance for the random failure of nodes. In Ref. [15], the scale-free topology model of inter-cluster optimization is constructed. And the node degree is limited by the residual energy of nodes, which enhances the fault tolerance of topology and prolongs the lifetime of the network. In Ref. [16], the calculation of the node fitness is associated with the value of node energy. Then a WSNs scale-free topology was proposed according to the fitness topology evolution model. In Ref. [17], it considered the residual energy and load of nodes when constructing the scale-free topology, which further improved the invulnerability of WSNs topology and extended the lifetime of the network. However, the models mentioned in the literature [15-17] only considered the influence of residual energy or load on network energy consumption. And these topologies ignored the influence of node lifetime on network topology when constructed the topology, which could limit

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the energy-balancing ability of topology, and then it will have a serious effect on the performance of the network.

To solve the above problem, this paper takes the node lifetime as the influence factor of constructing the fitness function by modeling the node lifetime and using the scale-free fitness mechanism evolution strategy. According to the evolution model, the generated topology BNL can effectively balance the node energy consumption and prolong the network lifetime. The rest of this paper is organized as follows. In section 2, we build the lifetime model of nodes. In section 3, we present the evolution model of the fault-tolerate topology and analyze the degree distribution characteristics. In section 4, the simulation results are given. In the end, we summarize this paper in Section 5.

II. NODE LIFETIME MODEL

In this section, the node energy consumption is analyzed firstly. Then the node lifetime model is built.

The node lifetime is limited by the residual energy and the transmitting radius in WSNs. And the failure of nodes has a great impact on the connectivity coverage of the network. According to the first-order RF model [18], the total energy consumption by the communication unit of one node E_{ci} can be expressed as follows:

$$E_{ci} = E_{tx} + E_{rx}\,, \tag{1}$$

where E_{tx} is the energy consumption of the sending unit, E_{rx} is the energy consumption of the receiving unit, and E_{tx} is expressed as follows:

$$E_{tx} = E_{elec}L + \varepsilon_{amp}LR_i^2\,, \tag{2}$$

where E_{elec} is data fusion energy consumption, ε_{amp} is power amplifier energy consumption, R_i is node communication radius, and L is the packet length. And E_{rx} is expressed as follows:

$$E_{rx} = E_{elec}L\ . \tag{3}$$

Then based on Eq. (1)-Eq. (3), the total energy consumption E_{ci} by the communication unit of one node i can be expressed by

$$E_{ci} = E_{tx} + E_{rx} = 2E_{elec}L + \varepsilon_{amp}LR_i^2\,. \tag{4}$$

Let E_i denote the residual energy of the node i, then the node lifetime L_i can be expressed as follows:

$$L_i = \frac{E_i}{E_{ci}} = \frac{E_i}{2E_{elec}L + \varepsilon_{amp}LR_i^2}\,. \tag{5}$$

To sum up, the node lifetime $L(i)$ is obtained based on Eq. (5). According to Eq. (5), the node lifetime is affected by the residual energy of the node and the communication radius of the node. The larger the residual energy of the node and the shorter the communication radius of the node, the longer the lifetime of the node will get. The smaller the residual energy of nodes and the longer the communication radius of the node, the shorter the lifetime of nodes will get. Therefore, it is necessary to consider the residual energy of nodes and the communication radius of the node when constructing the topology, so that the generated topology can balance the network energy consumption and prolong the network lifetime.

III. SCALE-FREE TOPOLOGICAL EVOLUTION MODEL AND DYNAMIC CHARACTERISTICS ANALYSIS

According to the node lifetime model in section 2, this section we propose an improved evolution model according to the preferential attachment mechanism. And based on the evolution model, the BNL topology which can prolong the network lifetime is generated. In this paper, we assume that all sensor nodes in WSNs are deployed randomly, and the nodes are approximately uniformly distributed in the region. The fault-tolerant topology with extended network lifetime is constructed by taking the node lifetime as the fitness function factor when constructing the topology.

A. BNL Topological Evolution Model

Growth and preferential connection are the necessary conditions for scale-free topology formation [19][20]. Due to the limitation of the communication radius of WSNs nodes, it is necessary to use the local world evolution model. The BNL Topological growth process can be expressed as Eq. (6).

$$\Pi(k_i) = \frac{\eta_i k_i}{\sum_{j\in A_i}\eta_j k_j}\,, \tag{6}$$

where $\Pi(k_i)$ is the preferential attachment probability, η_i the fitness function factor, k_i is the node degree. Because the node lifetime is closely related to the lifetime of WSNs, so we construct the BNL topology by taking the node lifetime as the fitness function factor.

$$\eta_i = L_i = \frac{E_i}{2E_{elec}L + \varepsilon_{amp}LR_i^2}\ . \tag{7}$$

Then the BNL topological evolution model is described as follows:

Growth: starting with a small clique of m_0 nodes, and there is one new node joining the network at each successive time step. Every new node connects m edges to the old nodes within their transmission range.

Preferential connection: the probability which a new node will be connected to the node i depends on the current node degree and the node lifetime. The preferential attachment probability is expressed as:

$$\Pi(k_i) = \frac{L_i k_i}{\sum_{j\in A_i} L_j k_j} = \frac{\dfrac{E_i}{2E_{elec}L + \varepsilon_{amp}LR_i^2}k_i}{\sum_{j\in A_i}\dfrac{E_j}{2E_{elec}L + \varepsilon_{amp}LR_j^2}k_j}\,. \tag{8}$$

Based on Eq. (8), through introducing the node lifetime as the influence factor, the connection probability with short lifetime nodes is reduced and the topology performance is optimized.

B. Analysis of BNL Degree Distribution

In order to utilize the mean-field theory to analyze the performance of the evolving topology, we assume that the node degree k_i is a continuous change parameter with time t. According to the preferential growth process in section 3.1, the growth rate k_i can be described as follows:

$$\frac{\mathrm{d}k_i}{\mathrm{d}t} = m\frac{L(i)k_i}{\sum_{j\in A_i} L(j)k_j} = m\frac{\dfrac{E_i}{2E_{elec}L+\varepsilon_{amp}LR_i^2}k_i}{\sum_{j\in A_i}\dfrac{E_j}{2E_{elec}L+\varepsilon_{amp}LR_j^2}k_j} . \quad (9)$$

Because the node residual energy E_i is a continuous function on a closed interval $[0, \max E]$, R_i is a continuous function on a closed interval $[0, \max R]$, we can obtain

$$0 \le L_i \le \frac{\max E}{2E_{elec}L} . \quad (10)$$

By the intermediate value theorem, we can obtain $L_\xi \in [0, \dfrac{\max E}{2E_{elec}L}]$, thus

$$\sum_{j\in A_i} L_j k_j = L_\xi \sum_{j\in A_i} k_j . \quad (11)$$

Therefore, Eq. (9) can be simplified to

$$\frac{\mathrm{d}k_i}{\mathrm{d}t} = m\frac{L_i k_i}{L_\xi \sum_{j\in A_i} k_j} . \quad (12)$$

Because the nodes in the monitoring area follow a uniform distribution, the probability that the neighbor node set of the new node Q is selected can be expressed by the area ratio $(r_Q^2/2)/r_t^2$. Thus the Eq. (12) can be calculated as follows.

$$\begin{aligned}\frac{\mathrm{d}k_i}{\mathrm{d}t} &= m\frac{r_Q^2/2}{r_t^2}\frac{L_i k_i}{N_t(r_Q^2/2r_t^2)L_\xi <k>_t} \\ &= m\frac{L_i k_i}{N_t L_\xi <k>_t}\end{aligned} , \quad (13)$$

where N_t is the number of network nodes at time t, and $<k>_t$ is the average degree of network nodes at time t. According to the improved preferential attachment, at time t, a topology with $m_0 + t$ nodes and mt edges is generated, i.e. $<k>_t = 2mt/(m_0+t)$ and $N_t = m_0 + t$. Thus the Eq. (13) can be calculated as follows.

$$\frac{dk_i}{dt} = m\frac{L_i k_i}{N_t L_\xi <k>_t} = \frac{L_i k_i}{2L_\xi t} . \quad (14)$$

Assuming that $f(T_i, T_\xi) = \dfrac{T_i}{T_\xi}$, Eq. (14) can be simplified as

$$\frac{dk_i}{dt} = f(T_i, T_\xi)\frac{k_i}{2t} . \quad (15)$$

The above differential equation can be obtained by using the method of separating variables, thus

$$k_i(t) = Ct^{f(L_i, L_\xi)/2} . \quad (16)$$

And then, combined with the initial conditions $k_i(t_i) = m$, we get

$$k_i(t) = m(\frac{t}{t_i})^{f(L_i, L_\xi)/2} , \quad (17)$$

then the probability $p(k_i(t) < k)$ can be expressed as follows:

$$p(k_i(t) < k) = p(t_i > t(\frac{m}{k})^{2/f(L_i, L_\xi)}) . \quad (18)$$

Considering that in the evolution process of the BNL topology, only one new node is added to the network for each time step, so it follows a uniform distribution. And its probability density function is $p(t_i) = 1/(m_0 + t)$. Thus, we can get the degree distribution of BNL topology as follows.

$$\begin{aligned}\frac{\partial p(k_i(t) < k)}{\partial k} &= \frac{\partial(1 - p(t_i \le t(\frac{m}{k})^{2/f(L_i, L_\xi)}))}{\partial k} \\ &= \frac{2}{f(L_i, L_\xi)} m^{2/f(L_i, L_\xi)} k^{-(1+2/f(L_i, L_\xi))}\end{aligned} . \quad (19)$$

According to Eq. (19), the degree distribution of the BNL obeys the power-law distribution, and the power exponent is $\lambda = 1 + 2/f(L_i, L_\xi)$ and $\lambda > 1$. Because $f(L_i, L_\xi)$ is affected by the node lifetime, which leads to that the new node prefers to connect to the node with a long lifetime. All in all, the BNL fault-tolerant topology can tolerate random failure and prolong the network lifetime by using the fitness model.

IV. SIMULATION RESULTS

In this section, to ensure the practical significance of our topology, extensive simulation tests were carried out by using the MATLAB tool. The performance of the proposed BNL is compared with the energy conservation representativeness topology FTEL and EAEM. In the simulation experiment, the three topologies all adopt the same initial network size and assume that the nodes have the same initial energy. All the following simulation results are the average of 100 repeated tests. The simulation parameters are shown in Table 1.

TABLE I
THE EXPERIMENTAL PARAMETERS

Parameter name	Value
Node number N	100
Monitoring circle domain radius r	400
Node maximum transmission radius $r_{\max}$	100
Nodes initial energy E_0	1
Data fusion energy consumption E_{elec}	50
Amplifier power consumption ε_{amp}	100
Packet length L	100

A. *BNL Degree Distribution*

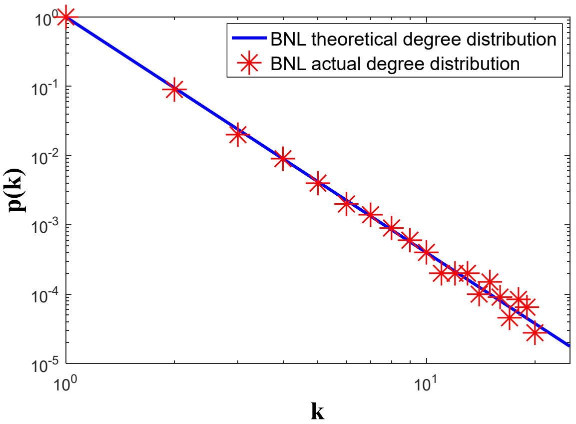
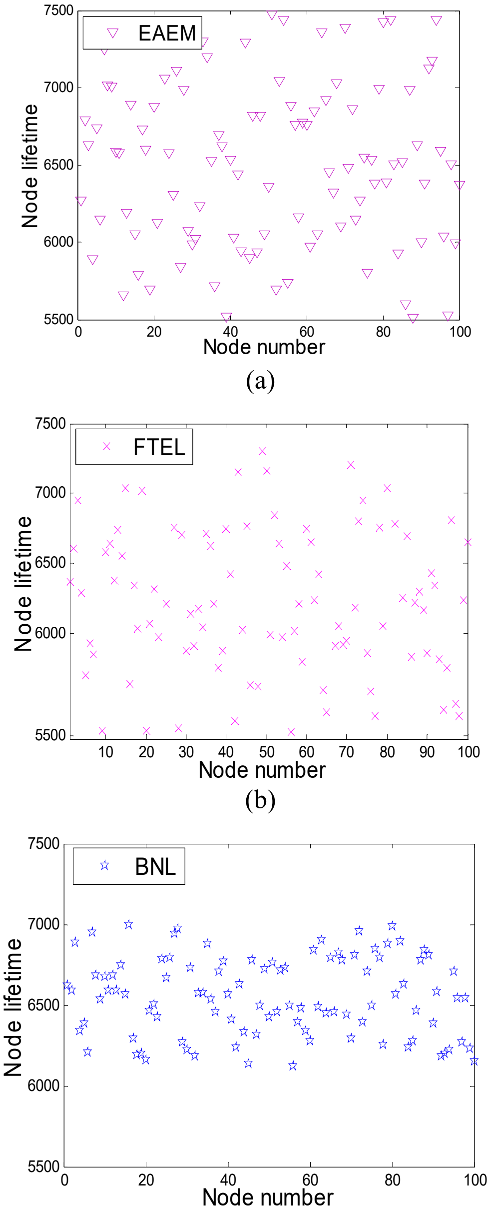


Fig. 2. BNL degree distribution

Fig. 2 shows the BNL degree distribution. As shown in Fig. 2, the degree distribution of the BNL obeys the power-law distribution. And it has the characteristics of a low probability of high degree node and high probability of low degree node. Thus, the topology has a good fault tolerance characteristic, and it is suitable for WSNs unattended environment.

B. The Energy Balance Capacity Analysis

The energy balance capacity is an important part of a topology structure performance. After 1500 rounds of topology operation, the energy balance capacity of nodes in the network is analyzed by using the lifetime of all nodes in the current network. The lifetime of all nodes in the network is similar, namely, the energy consumption of the network is relatively balanced.



(a)

(b)

(c)

Fig. 3. Node lifetime comparison

Figure 3 shows the comparison of node lifetime after 1500 rounds of topology operation in the EAEM topology, the FTEL topology, and the BNL topology. As shown in Fig. 3, the BNL model has the most balanced node lifetime. The nodes of the other two models have a short lifetime, which is most likely to fail due to energy exhaustion. The node lifetime of BNL topology is maintained between 6100 and 7000 rounds. This is because the BNL topology takes the node lifetime as the fitness when constructing the topology so that the network energy consumption is finally balanced.

C. The Network Lifetime Contrast

The network lifetime is usually regarded as the time when the first nodes in the network fail. In Fig. 4, we show the network lifetime of the EAEM topology, the FTEL topology and the BNL topology. As shown in Fig. 4, the network lifetime of BNL topology is maintained about 6300 rounds. But the network lifetime of FTEL topology is maintained about 5500 rounds and the network lifetime of EAEM topology is maintained about 5100 rounds. The network lifetime of the BNL topology is longer than the EAEM topology and the FTEL topology, which shows that the BNL topology can effectively prolong the network lifetime.

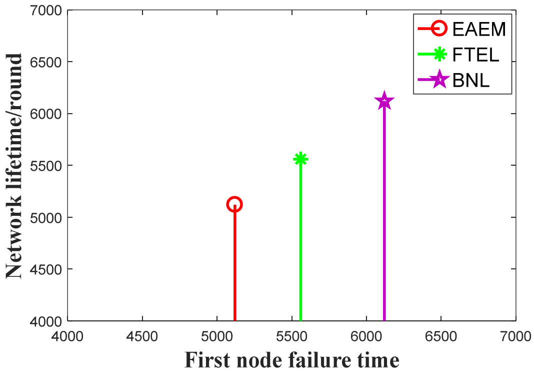


Fig. 4. The network lifetime contrast

D. The Relationship Between Node Degree and Lifetime

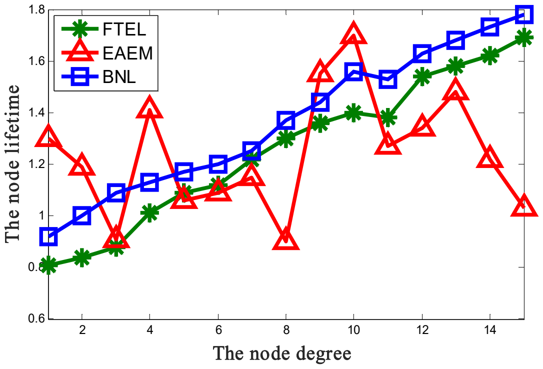


Fig. 5. The topology fault tolerance contrast

In this part, the average node lifetime for the BNL topology is compared to the EAEM and the FTEL after 2000 rounds of topology operation. As shown in Fig. 6, the node degree in accordance with the abscissa, the ordinate node lifetime for growth curve for result analysis. And the node lifetime is the average lifetime of the node with degree k. As can be seen from Figure 6, both the BNL and the FTEL have the characteristic of a higher node lifetime with a higher degree, which is conducive to WSNs energy balance, and the EAEM doesn't have this property. Also, it is obvious that the BNL has a longer node lifetime than FTEL at the same node degree. This is mainly because the BNL topology takes the node lifetime as the fitness when constructing the topology so that the network energy consumption is finally balanced.

E. The Topology Fault Tolerance Contrast

Random failure and selective failure are often used to measure the topology fault tolerance. In the experiments, random failure is regarded as the process that the nodes are removed randomly in the network, and selective failure is regarded as the process that the nodes are removed selectively according to the node degree descending. To measure topology fault tolerance, FTEL, EAEM and BNL were compared in simulation experiments.

Fig. 5 shows the random failure tolerance of the three topologies when the same nodes are removed randomly in the network. From Fig. 5, we can find that when the same number of random failure nodes are removed, the network scale of the BNL topology is larger than the other two topologies. For example, when 16 nodes are removed randomly, the BNL topology has about 70 remaining nodes in the network, but the FTEL topology has about 63 remaining nodes and the EAEM topology has about 57 remaining nodes in the network. It indicates that the BNL topology still has good fault tolerance ability for random failure.

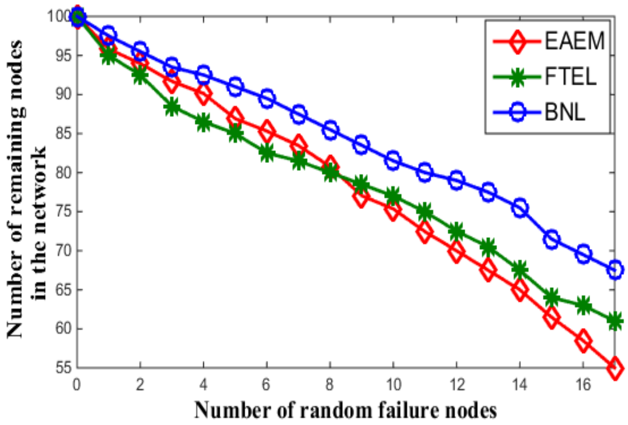


Fig. 5. The topology fault tolerance contrast

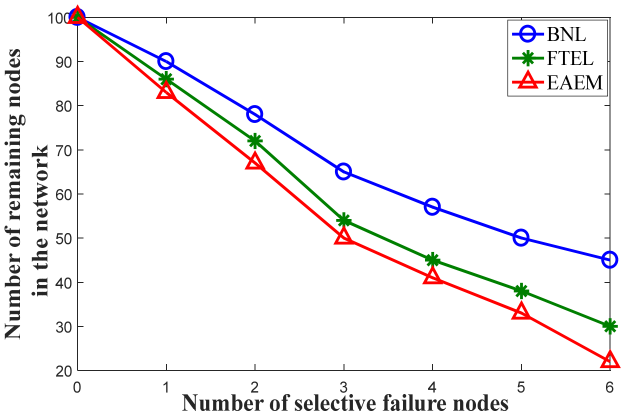


Fig. 6. The topology selective failure tolerance contrast.

Fig. 6 shows the changes number of remaining nodes in the network under the different number of selective failure nodes (1, 2, 3, 4, 5, 6) for the BNL, FTEL and the EAEM topology. As shown in Fig. 6, when the same number of nodes are removed selectively, the network scale of the BNL topology is larger than in the EAEM and FTEL topology. For example, when 6 nodes are removed selectively, the BNL topology has 45 remaining nodes in the network, but the FTEL topology has 30 remaining nodes and the EAEM topology has 21 remaining nodes in the network. This phenomenon indicates that the BNL topology can complete the monitoring task better than the EAEM and FTEL topology under selective failure. Hence the BNL topology has a stronger ability to tolerate selective failure nodes than the EAEM and FTEL topology.

F. The Structure of BNL

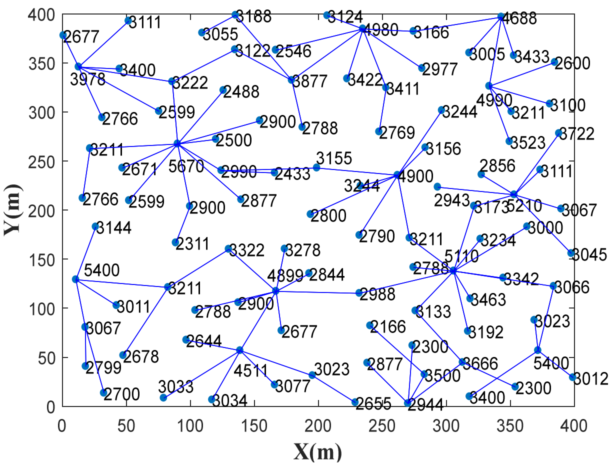


Fig. 7. The structure of BNL.

Fig. 7 presents the structure of BNL after 2000 rounds of topology operation. The number near the node represents the remaining lifetime of the node. As shown in Fig. 7, nodes with longer remaining lifetimes have more connections and undertake more data forwarding tasks. This is because the BNL topology takes the node lifetime as the influence factor when constructing the topology. And this approach has made the longer lifetime nodes have a larger connection probability as shown in Fig. 7. Also, the topology lifetime is extended by the BNL topology. Moreover, the structure of BNL has the scale-free characteristics that many nodes have a small number of connections and a few nodes have many connections in the network. Therefore, the BNL topology has a good fault tolerance when it faces random failure.

V. CONCLUSIONS

In this paper, we deeply study the application of the scale-free network in WSNs. A new fault tolerant topology BNL for prolonging the network lifetime has been proposed. The proposed topology includes a new influence factor which is better than the existing one in terms of energy efficiency and lifetime of the network. It takes the node lifetime as the influence factor when constructing the topology so that the high-energy nodes and the nodes with short communication distance have a larger connection probability. Also, the goal of a balanced network energy consumption is achieved. The experiment results show that the topology generated by this mechanism conforms to the basic characteristics of scale-free networks, and the node degree distribution obeys the power-law distribution. Thus, the BNL topology has a strong fault-tolerant ability, which lays a good foundation for the design of fault-tolerant topology in WSNs.

REFERENCES

[1] Salman, Ayman Dawood, Osamah Ibrahim Khalaf, and Ghaida Muttashar Abdulsahib, "An adaptive intelligent alarm system for wireless sensor network," in Indonesian Journal of Electrical Engineering and Computer Science, vol. 15, no. 1, pp. 142-147, 2019.

[2] Alassery, Fawaz, "Convergence between Virtual MIMO and Node Deployment Strategy for High Performance Multi-hop Wireless Sensor Networks," IAENG International Journal of Computer Science, vol. 46, no. 2, pp. 349-357, 2019.

[3] B.Y. Abbas, A.Q. Din, A.A.A. Alshreef, Y.E.A. Al-Salhi, “Security issues and challenges in Wireless Sensor Networks: A survey,” IAENG International Journal of Computer Science, vol. 44, no. 2, pp. 135-149, 2017.

[4] Sarkar, Amit, and T. Senthil Murugan, "Cluster head selection for energy efficient and delay-less routing in wireless sensor network," in Wireless Networks, vol. 25, no. 1, pp. 303-320, 2019.

[5] Razzaq, Ammara, Ahmed M. Khedr, and Zaher Al Aghbari, "Distributed Fault Tolerant Target Tracking Protocol for New Face-based Wireless Sensor Networks," IAENG International Journal of Computer Science. vol. 47, no. 2, pp. 250-261, 2020.

[6] Srivastava, Vikas, Sachin Tripathi, and Karan Singh, "Energy efficient optimized rate based congestion control routing in wireless sensor network," in Journal of Ambient Intelligence and Humanized Computing, vol. 11, no. 3, pp. 1325-1338, 2020.

[7] T. Qiu, J. Liu, W. Si and D. O. Wu, "Robustness Optimization Scheme With Multi-Population Co-Evolution for Scale-Free Wireless Sensor Networks," in IEEE/ACM Transactions on Networking, vol. 27, no. 3, pp. 1028-1042, 2019.

[8] Haoran Liu, Rongrong Yin, Bin Liu, Yaqian Li, “A scale-free topology model with fault-tolerance and intrusion-tolerance in wireless sensor networks,” in Computers & Electrical Engineering, vol. 56, no. 1, pp. 533-543, 2016.

[9] Keshri, Neha, Anurag Gupta, and Bimal Kumar Mishra, "Impact of reduced scale free network on wireless sensor network," in Physica A: Statistical Mechanics and its Applications, vol. 463, no. 1, pp. 236-245, 2016.

[10] Z. Ye, T. Wen, Z. Liu, X. Song and C. Fu, "Fault-tolerant scheme for cascading failure of scale-free wireless sensor networks," 2016 IEEE International Conference on Information and Automation (ICIA), Ningbo, pp. 2006-2011, 2016.

[11] Zebbane, Bahia, Manel Chenait, and Nadjib Badache, "A distributed lightweight redundancy aware topology control protocol for wireless sensor networks," in Wireless Networks, vol. 23, no. 6, pp. 1779-1792, 2017.

[12] S. Hu and G. Li, "Fault-Tolerant Clustering Topology Evolution Mechanism of Wireless Sensor Networks," in IEEE Access, vol. 6, pp. 28085-28096, 2018.

[13] Ferreira, Ricardo M., Rita MC de Almeida, and Leonardo G. Brunnet, "Analytic solutions for links and triangles distributions in finite Barabási–Albert networks," in Physica A: Statistical Mechanics and its Applications, vol. 466, pp. 105-110, 2017.

[14] Hailin Zhu, Hong Luo, Haipeng Peng, Lixiang Li, Qun Luo, “Complex networks-based energy-efficient evolution model for wireless sensor networks,” in Chaos, Solitons & Fractals, vol. 41, no. 4, pp. 1828-1835, 2009.

[15] Ya-Qi Wang, Xiao-Yuan Yang, “Study on a model of topology evolution of wireless sensor networks among cluster heads and its immunization,” in Acta Physica Sinica, vol. 61, no. 9, pp. 090202-1-10, 2012.

[16] Gengzhong Zheng, Qiumei Liu, "Scale-free topology evolution for wireless sensor networks," in Computers & Electrical Engineering, vol. 39, no. 6, pp. 1779-1788, 2013.

[17] Hao-Ran Liu, Wen-Xiao Yin, Tao Han, Ming-Ru Dong, “Wireless sensor network fault tolerant topology for lifetime optimization,” in Acta Physica Sinica, vol. 64, no. 4, pp. 040509-1-8, 2014.

[18] Liu Bin, Dong Ming-Ru, Liu Hao-Ran, Yin Rong-Rong, Han Li, “A scale-free fault tolerant topology model in wireless sensor network for toleration of comprehensive fault,” in Acta Physica Sinica, vol. 63, no. 17, pp. 170506-1-8, 2014.

[19] D. G. Zhang, W. B. Dai, Q. X. Niu, "Local-world weighted topology evolving model for wireless sensor networks," in Acta Electronica Sinica, vol. 40, no. 5, pp. 1000-1004, 2012.

[20] Hao-Ran Liu, Wen-Xiao Yin, Ming-Ru Dong, Bin Liu, “Study on the scale-free topology model with strong intrusion-tolerance ability in wireless sensor networks,” in Acta Physica Sinica, vol. 63, no. 9, pp. 090503-1-8, 2014.