Information Systems and Signal Processing Journal (2019) 4: 1-6
Clausius Scientific Press, Canada

DOI: 10.23977/isspj.2019.41001
ISSN 2371-9427

Research on WSN Topology and Protocol for Transmission Lines Monitoring

Wang Baoyi[a,*], Jing Sen[b], Zhang Shaomin[c]

School of Control and Computer Engineering, North China Electric Power University, Baoding, 071003, China

[a]email: wangbaoyiqj@126.com, [b]email: jingsen@163.com, [c]email: zhangshaomin@126.com

Keywords: transmission line monitoring system, wireless sensor network, Long chain avoidance.

Abstract: The battery of the wireless sensor node carries less energy, and its energy-saving requirements are relatively high when the transmission line is deployed. Based on the hierarchical routing protocol, a kind of new communication routing protocol is proposed. Reduce the number of long chains generated by adjacent contacts by introducing distance thresholds. On the selection of the cluster head node, the residual energy of the candidate cluster head node and the distance factor between the node and the base station are fully considered, which improves the data transmission efficiency and node lifetime. Simulation results show that compared with the existing LEACH communication routing protocol, the proposed method reduces the energy consumption of the node and prolongs the survival time of the node, which is suitable for the application of the transmission line monitoring system.

1. Introduction

With the popularity of ultra/UHV transmission lines, the scale of the power grid is expanding, and more and more Transmission lines are laid under complicated geographical conditions. Transmission line distribution has the characteristics of long distance, wide distribution range and difficult maintenance. Compared with the manual inspection, helicopter inspection and machine inspection methods used by the power sector, the wireless sensor network has the advantages of all-weather online, self-organizing network, large-area coverage, adapting to harsh conditions, and low cost. Great application potential is used in transmission line monitoring [1]. In addition, the sensor is used to collect the state information and natural physical information of the transmission line, and the collected data is transmitted to the control center through the linear wireless sensor network composed of the sensor nodes, so that the online real-time monitoring of the high-voltage transmission line can be realized [2].

When the wireless sensor is working, it cannot directly use the electromagnetic induction of the transmission lines to generate electricity. Considering that the power line has requirements for the load, the sensor needs a small volume and weight. Therefore, although the sensor is arranged on the power line, it is still necessary to use a battery to supply power to the monitoring node [3]. Due to the limitation of objective conditions, the battery as energy supply cannot be replaced frequently, so energy saving is the primary consideration for routing algorithm selection [4].

In this paper, the problem of generating long-distance links in wireless sensor networks in transmission line monitoring is proposed. The algorithm of PEEPB (Promote Energy-Efficient Pegasis-Based routing algorithm) is introduced to introduce the method of distance threshold to avoid long-chain generation. For the selection of the cluster head node, an algorithm based on node energy and transmission distance clustering and cluster head rotation is proposed. The appropriate cluster head node is selected to reduce the energy consumption of the node.

2. WSN Topology Design for Transmission Lines

On the transmission line, the sensor nodes are evenly and linearly laid on the high-voltage transmission line. On transmission line monitoring, the main monitoring targets are real-time information such as ambient temperature, ambient humidity, wind direction, rainfall, tension, dip, line temperature, and vibration acceleration. Most of the sensor nodes are arranged on the tower or near the tower [5]. The densely arranged area is within 10m. Only a small number of galloping monitoring nodes are arranged on the transmission line. The whole network presents a large number of local dense areas. A large number of dense layouts appear on the tower, and the monitoring content of the sensor nodes on each tower is roughly the same, which makes the whole network layout regular.

The moving distance caused by the transmission line dancing in the network monitoring node can be neglected compared with its communication distance. Therefore, it is considered that there is no moving problem in the nodes in the network, and the whole network is relatively fixed. The distribution is even, and the distribution distance of the same tower monitoring node is negligible compared with its data transmission distance, so it is considered that the arrangement of the sensor nodes on the same tower is uniform.

The entire monitoring system consists of a three-layer network. The first layer is composed of sensor nodes, which are responsible for collecting the wire dancing, micro-meteorology, line damage and other related data of the transmission line, and then uploading to the sink node. The second layer is composed of a sink node and a base station. On the one hand, the sink node realizes data transmission through the wireless link, and is transmitted from the ordinary sink node to the cluster head aggregation node [6]. On the other hand, the cluster head node performs data fusion after receiving the data. The third layer is composed of a base station and a substation, and transmits long-distance data to the control center through an existing power private network or a public network [7]. The research content of this paper is mainly to verify and verify the network routing of the second layer sensor nodes.

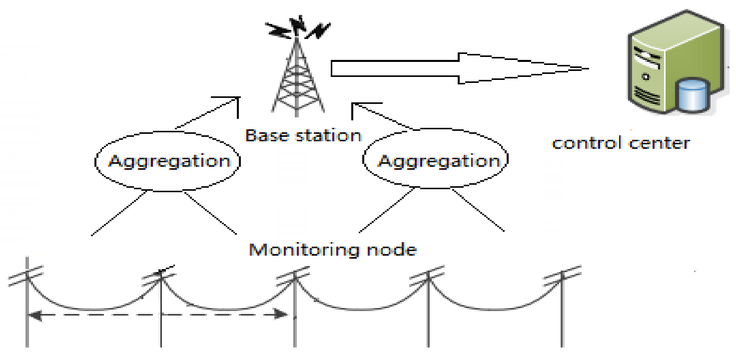

Figure 1: Structure of WSN applied in transmission line

3. Energy-efficient Routing Protocol Designed for Transmission Line Monitoring Data Transmission

3.1. Problem Statement

The distance of the transmission line is positively correlated with the value of the transmission voltage. The 220kv transmission line generally has several tens of kilometers, the UHV transmission line is usually several hundred to thousands of kilometers, and the distance between the adjacent towers (range) is 100~200m [8]. Therefore, the topology of the transmission line monitoring system is a long-distance link. If the direct communication method is adopted, the energy of the node far from the base station will be exhausted in advance; and the multi-hop relay transmission mode is used to select the appropriate chain. Long, avoiding the production of long chains is our first focus.

3.2. Wireless Transmission Energy Consumption Model

In this paper, the node energy consumption of the transmission and reception link in the transmission line monitoring system is based on the classical radio energy consumption mode [9]. When the transmission data frame length is m, and the distance is d, the energy consumption is:

$$E_{tr}(m,d)=\begin{cases} m*E_{elec}+d*e_{fs}*d^2(d<d_0) \\ m*E_{elec}+d*e_{mp}*d^4(d\geq d_0) \end{cases} \tag{1}$$

The length of the entire data packet is 46B, where E_{elec} represents the energy consumed by transmit and receive circuits to process the unit bit data; represents the free space model used when $d<d_0$. Transmit and receive circuits consume unit bits per unit area. ε_{mp} represents the multipath transmission model used when $d>d_0$. The energy consumed by transmitting unit bit data in the square area of the unit area of the transmitting and receiving circuits is proportional to d^4.It can be seen from E_{tr} that the energy consumption of the node is mainly related to the transmission distance. The sensor node far away from the base station consumes more energy during the data transmission process. How to minimize the distance between the sensor node and the base station and select the cluster for data forwarding? The first node is the focus of attention.

3.3. Solution

The long transmission distance consumes the energy of the sensor node prematurely. So how to effectively avoid the long-distance transmission of the sensor network is the focus of attention. The distribution distance of the transmission tower is between 100 and 200 m, and the arrangement of the sensors is similar in each tower. Therefore, the transmission line can be abstracted into one line segment, and the sensor node is regarded as an equidistant node in the line segment.

The PEEPB algorithm reduces the number of long chains generated by introducing a $d_{threshold}$. The algorithm starts to establish clusters from the farthest point from the base station. It is assumed that i nodes have been added to the cluster, and the link length between node v and node v+1 is represented by d_v。

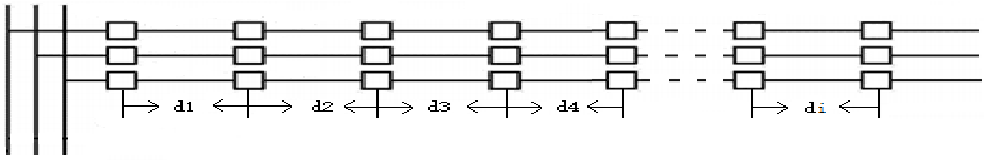

Figure 2: Partial chain consisting of nodes in a cluster

If the link length between two adjacent nodes is greater than or equal to $d_{threshold}$, we call the link between the two adjacent nodes a long chain. The following method is used to define the threshold, as shown in the equation:

$$d_{threshold}=\alpha\left[\sum_{v=1}^{i-1} d_v/(i-1)\right] \quad (2)$$

In all nodes to be added to the chain, it is assumed that node i+1 is closest to node i. Before node i+1 joins the chain, the distance is compared between itself and node i. If $d_i \le d_{threshold}$, indicating that the link between node i+1 and node i is not a long chain. Node i+1 joins the long chain by directly connecting with node i; if $d_i > d_{threshold}$, it means that the link between node i+1 and node i is a long chain. At this time, node i+1 cannot be connected with node i, and node i+1 will find the nearest distance from itself on the chain.

After the end of the chain construction, the entire wireless sensor network enters the working state, and all cluster nodes begin to collect periodic data in the network [10].The entire acquisition process is performed. The cluster head node collects data of all sensor nodes in the cluster, and performs local processing such as data fusion to reduce the number of access points of the device, prolong the life of the sensor node, and reduce network collision. The cluster head node then forwards the data to the aggregation center and performs a residual energy information broadcast to push other cluster members to collect the cluster head energy to drive the coarse first rotation program.

3.4. Data Collection Phase

After the cluster head node is selected, the entire wireless sensor network enters the working state, and all cluster nodes begin to collect periodic data in the network. The entire acquisition process is performed. The cluster head node collects data of all sensor nodes in the cluster, and performs local processing such as data fusion to reduce the number of access points of the device, prolong the life of the sensor node, and reduce network collision. The cluster head node then forwards the data to the aggregation center and performs a residual energy information broadcast to push other cluster members to collect the cluster head energy to drive the coarse first rotation program.

The energy balance optimization algorithm based on node energy and distance between nodes proposed in this paper makes each node consume similar energy levels and prolongs the life of the network. After the selected cluster head energy reaches a certain threshold, a new round of cluster head selection process is started, and a more suitable cluster head node is selected in time. The simulation results show that the PEEPB algorithm can more effectively balance the energy load and select a more suitable cluster head node, thus extending the life cycle of the whole network.

4. Analysis of Experimental Results

4.1. Experimental Scene Settings

In this paper, MATLAB is used as the simulation platform to analyze the method of building the chain through the threshold and the selection mechanism of the cluster head node in the chain through the simulation environment. In order to evaluate the performance of the proposed PEEPB algorithm, the MATLAB simulation is applied to the wireless sensor network on the transmission line. On the actual transmission line, the main sensor nodes are arranged on the transmission pole tower.

In a chain region of length 5000 m, a set of sensor nodes are arranged every 50 m. A group of sensor nodes consists of five sensor nodes that monitor ambient temperature, ambient humidity, transmission line pull, transmission line temperature, and transmission line vibration acceleration. The communication distance of all nodes is 50m. The sampling temperature of the ambient temperature sensor node is 4 bytes, and the sampling data of the environmental humidity sensor node is 2 bytes. The sampling data of the transmission line tension sensor node, the transmission line temperature sensor node, and the vibration acceleration node are the same, all of which are 3 bytes. Assuming that the initial energy of the node battery is 2J, the length of data transmitted by a group of nodes in one cycle is 15 bytes. When each node transmits or receives data, the energy required by the transmitting circuit is E_t=50nJ/bit, the energy consumed by the power amplifier is that E_f =100pJ/ (bit·d^2), and the amplification factor of the signal amplifier is E_{mp}=0.0013pJ/bit/d^4, the signal transmission distance d_0=50m, the threshold for triggering the rotation of the cluster head node is 0.12J.

4.2. Result Analysis

Figure 3 shows the comparison of the number of nodes remaining in each round of the routing algorithm. It can be seen from the curve trend in the figure that when the wireless sensor network uses the PEEPB algorithm, the death rate of the node is smaller than the death rate of the LEACH protocol, and the network lifetime is also extended to some extent. The results demonstrate the superiority of the PEEPB algorithm in reducing energy consumption. After the end of the 150th round, the number of nodes surviving the PEEPB algorithm accounted for 81% of the total, which is higher than 31% of the LEACH algorithm. It can be seen that the PEEPB algorithm has a significant improvement effect on reducing node energy consumption and extending node lifetime.

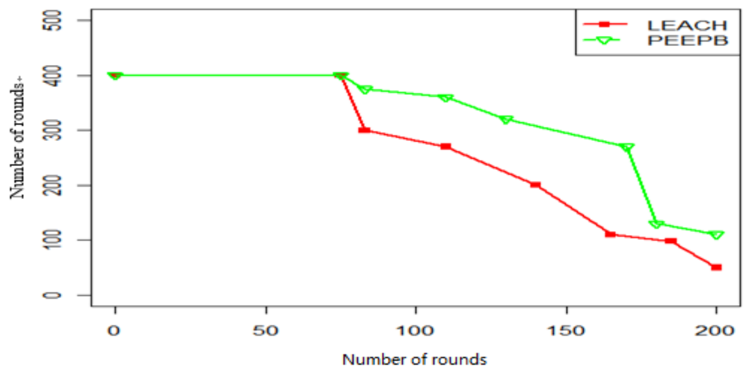

Figure 3: Number of surviving nodes

5. Conclusions

According to the topology structure of the wireless sensor network with long chain distribution in the transmission line, the PEEPB algorithm introduces a threshold in the chain construction process to avoid long links between nodes and reduce the number of hops during data transmission. In the clustering algorithm, the node rotation is used to select the cluster head to avoid the cluster head node quickly exhausting energy due to excessive load, and achieve the purpose of equalizing the energy consumption of the nodes in the cluster. The existing clustering algorithm does not fully consider the residual energy of the candidate nodes when the cluster head node rotates, and its random selectivity cannot guarantee load balancing.

References

[1] Liu Yongguang. Design and Implementation of Transmission Tower Health Monitoring System Based on Multi-sensor Data Fusion [D]. Taiyuan University of Technology, 2016.

[2] Deng D, Yuan H, Cui Y, et al. Energy Management of WSN-based Charge Measurement System of Ultra High-voltage Direct-current Transmission Line [J]. Wireless Networks, 2016:1-15.

[3] Li P, Jiang W, Xu H, et al. Energy Optimization Algorithm of Wireless Sensor Networks Based on LEACH-B[C]// International Conference on P2P, Parallel, Grid, Cloud and Internet Computing. Springer, Cham, 2016:391-404.

[4] Zhang Wenkui. Research on Wireless Sensor Networks and Related Technologies in Smart Grid Applications [D]. Huazhong University of Science and Technology, 2012.

[5] Liu Weiqiang,Jiang Hua,Wang Xin.Research and Improvement of PEGASIS Protocol in Wireless Sensor Networks[J].Journal of Transduction Technology,2013,26(12):1764-1769.

[6] Yu Yongchang, Wei Gang. An Improved Algorithm Based on PEGASIS Protocol in Wireless Sensor Networks [J]. Chinese Journal of Electronics, 2008(07): 1309-1313.

[7] Sun Xiaoya, Li Yongqian, Li Tian. Application of Wireless Sensor Network in Power System [J]. Sensors and Microsystems, 2012, 31(06): 5-7+11.

[8] Feng Sen. Research on Routing Optimization Protocol for Wireless sensor Networks for Intelligent Power Distribution [D]. North China Electric Power University, 2015.

[9] Li Zhaoxiang. Research on Algorithm of Data Fusion in Wireless Sensor Networks [D]. Wuhan University of Technology, 2011.

[10] SUN Lingyi, HUANG Xianxiang, CAI Wei, XIA Meini. Data Fusion Algorithm for Wireless Sensor Networks Based on Neural Network [J]. Journal of Transduction Technology, 2011, 24(01): 122-127.