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LEACH Routing Protocol Based on Wireless Sensor Networks

Qing Wu[1] and Yixin Yan[2*]

[1, 2]*Harbin University of Science and Technology, Harbin, 150080, P. R. China*
[1]*wuqing129@126.com*, [2]*shiyu_wang@126.com*

Abstract

Wireless sensor network (WSN) is a new research area in modern communications networks. Composed by many stationary or mobile sensor nodes, it constitutes a wireless network through self-organizing and multi-hop way. A sensor network system includes sensor node (end device), sink node (sink) and coordinator node (coordinator). The routing protocol of WSN is to find the optimal route between the source node and destination node. Its primary goal is to improve the quality of network service and achieve a fair and rational use of resources such as network bandwidth for various network nodes and terminals. The work focused on the typical and successful representative in the introduction of hierarchical routing protocol to data fusion technology—LEACH protocol. And the performances of LEACH simulation algorithms were analyzed through MATLAB simulation.

Keywords: *Wireless sensor network, routing protocol, LEACH protocol*

1. Introduction

WSN is a wireless network composed by a set of sensors in a point-to-point way. Constituted by a large number of low-cost micro sensor nodes deployed in the detection area, it's a multi-hop self-organizing network formed by the wireless communication. It's aimed at cooperatively sensing, collecting and processing the information of the perceived objects in the geographic area of the network, then releasing the information to the viewer [1-3]. There are many types of sensors in WSN. They can detect a variety of phenomena in the surroundings such as seism, electromagnetism, temperature, humidity, noise, light intensity, pressure, soil composition, a moving object's size, speed and direction. The wake-up modes of nodes in WSN are as follows: 1) all wake-up mode; 2) random wake-up mode; 3) wake-up mode chosen by prediction mechanism; 4) wake-up mode of duty cycle. Routing protocol searches the optimal route between the source node and destination node to achieve the correct data forwarding on the optimal route [5-7]. Based on hierarchical energy-efficient clustering routing protocol, LEACH was a classic and representative hierarchical routing protocol designed by Heinzelman, *et al.*, from MIT [11]. The basic idea of the algorithm is that the cluster heads are randomly selected in a cyclic manner to evenly distribute the energy load of the network among the sensor nodes. Thus the consumption of network power can be reduced, and the overall survival time of the network can be improved.

2. Basic theory and Technology of WSN

2.1. Architecture of WSN

Architecture of a typical WSN includes sensor node (end device), sink node (sink) and coordinator node (coordinator). They cooperatively sense and collect the characteristic information of the surrounding objects. Afterwards the information is transmitted to a self-organizing network of BS (Base Station) node through a wireless multi-hop communication.

* Corresponding Author

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There are many sensor nodes and few sink nodes in networks. Sink nodes are usually far away from the entire sensor network. The nodes are mostly limited by factors such as energy in WSN [4]. But the energy is not limited within a small covering range and can be assumed as a large one. The sensor nodes, within the covering range, collect data at regular intervals and forward the data to the sink node (base station) via the adjacent nodes. After receiving the information, the sink node sends the information to the coordinator node. Thus the users can configure and manage the sensors via the coordinator node to acquire relevant data. The architecture of a typical WSN was shown in Figure 1.

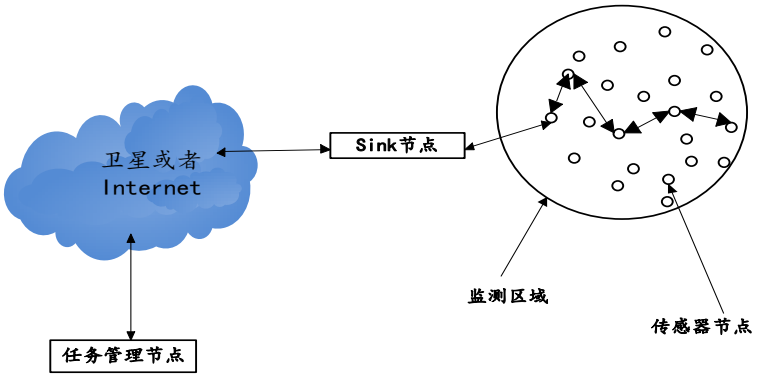


Figure 1. Architecture of a WSN

Figure 1 shows that sensor nodes are basic function units of a WSN. The basic modules of a sensor node include sensor unit, processing unit, communication unit and power supply. Sensor nodes use self-organizing manner for networking and wireless communication technology for data forwarding. All the nodes have two functions—data acquisition and data fusion and forwarding.

Sink node is essential in WSN application environment. As the interface between WSN and the coordinator node, it connects the sensor network with the external networks such as the Internet. The conversion of communication protocol can be realized between the protocol stacks. Meanwhile, the detection task of the coordinator node is released, forwarding the collected data to the external networks. Sink node has strong functions—adequate energy, large storage capacity and high computing power. And good extensionality and flexibility are also required.

2.2. Protocol Stack Architecture

There is a large difference between the software and hardware of a computer terminal in the network. The entire network is required to comply with a strict communication stipulation—network protocol in order to achieve an accurate data exchange. And WSN is inevitable to observe such stipulation for the realization of a normal communication. The biggest difference between the hierarchical model of protocol stack architecture and OSI protocol is the three accessorial platforms: energy management platform, mobile management platform and task management platform. Consequently, a WSN consists of eight parts—physical layer, data link layer, network layer, transport layer, application layer, energy management platform, mobility management platform and task management platform.

Physical layer: Media specifications for data transmission and the base layer that needs to be observed by terminal equipment in communication.

Data link layer: The encapsulation of data into frame and the detection of frame data.

Network layer: Data fusion and "routing algorithm" core of network layer.

Transport layer: Data transmission control.

Application layer: Provide environment for users to develop application software related to wireless sensor network.

Three platforms: Energy management platform is responsible for controlling the use of energy; mobility management platform manages the relevant information of node mobility, establishing and maintaining the routing information of nodes; task management platform manages the monitor tasks received by sensor nodes.

Three platforms are not systematized but reflected in network layer, data link layer and physical layer while more embodied in the transport layer and application layer. The transmission security of data remains an important issue for high layers.

3. Routing Protocol of WSN

WSN network layer mainly sends packet from the source node to the adjacent nodes or directly to the destination node via networks, achieving data fusion. It is responsible for route discovery, route maintenance and route selection, so an efficient communication can be performed between the sensor nodes [9]. The execution efficiency of routing algorithm directly affects the ratio of sensor nodes controlling the receiving and transmission of data and effectively collecting data. Routing protocol achieves the data forwarding of the network layer by searching the optimal route between the source node and the destination node and transmitting the packet on this route. However, WSN is very different from other existing traditional networks such as point-to-point network and wireless local area network. Their routing protocols were designed to improve the quality of network service and achieve the fair and reasonable use of resources such as network bandwidth among various network nodes and terminals to the greatest degree. Thus these protocols search the optimal communication path between the source node and the destination node regardless of energy consumption during the communication. However, both the energy shortage of sensor nodes and the transmission of the data collected by nodes in the network layer require a large amount of energy in WSN. Therefore, WSN routing protocol pursues the efficient use of energy rather than the optimal communication path. It extends the life cycle of the entire network as much as possible. Hence, the routing algorithm is the core of the entire network. WSN routing protocol can be divided into plane routing and hierarchical routing according to the final network topology.

3.1. Classification of Routing Protocol

There's no central control node throughout the network. The sensor nodes are equal, sharing the task of data acquisition and forwarding. Consequently, the energy is evenly consumed in each node. However, the routing protocol has a significant shortcoming—each sensor node maintains a large number of routing information. The information occupies partial storage capacity of the nodes, while the maintaining also consumes some energy. Nevertheless, if the sensor nodes are far away from the sink node, multi-hop communication can be adopted for data transmission to save energy. And direct single-hop communication can be used for a short distance. The topology of plane routing protocol is shown in Figure 2.

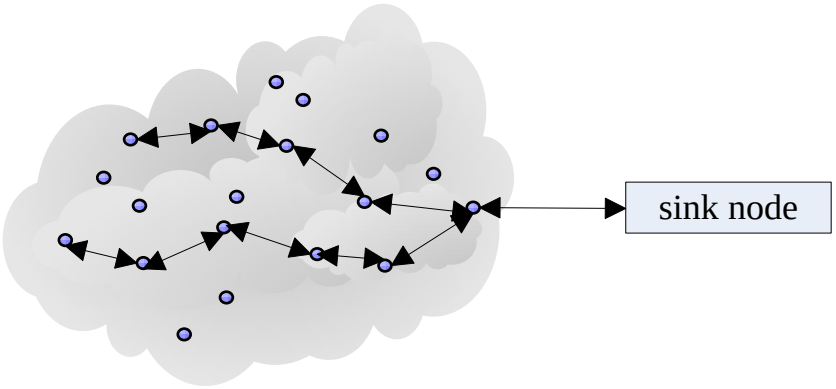
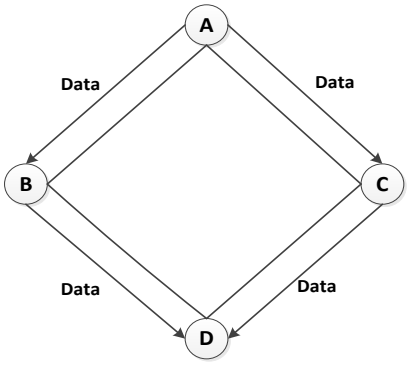


Figure 2. Topology of Plane Routing Protocol

The typical plane routing algorithms are Flooding, Gossiping, SPIN, DD, Rumor, *etc.*, among which flooding algorithm is an early routing technology. If sending data to node D, A will send a packet to all the neighbor nodes by broadcasting. After receiving the packet, each node, except for node A, will continue to send the packet to all the neighbor nodes by broadcasting until D receives the data. Although simply achieved, it is apt to cause information implosion and overlap.

Information implosion: the nodes simultaneously receive multiple copies of the same data. Figure 3 shows that node B and C receive and broadcast the information broadcasted by node A. Thus node D simultaneously receives the packet from B and C, leading to an unnecessary waste of energy and the reduction of network lifetime. Information overlap: the information received by node W and Q will be transmitted to H with an overlap, so H will receive two x, shown in Figure 4.



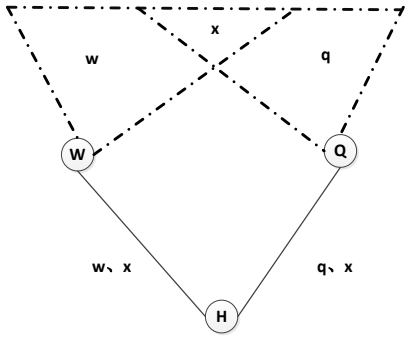


Figure 3. Information Implosion **Figure 4. Information Overlap**

Gossiping algorithm is formed to overcome two problems. A node randomly selects a neighbor one for transmission after receiving a packet.

Based on Flooding, SPIN makes an improvement—whether the node receives a packet is determined by negotiation. Energy conservation and the data transmission over different channels are nevertheless ignored.

Rumor algorithm uses the thought that two curves have great probability of intersection in Euclidean plane. When detecting an event, a node adds the event to a self-preservation table

to form an event table. Afterwards, a packet of broker message generates. The broker message spreads along the random path, so does the inquiry message sent by the sink node. When the broker message and inquiry message intersect, a full path from the sink node to event area is formed. But the plane routing has poor extensibility.

Hierarchical routing protocol (clustering routing protocol) is usually used in a large-scale network. LEACH (Low Energy Adaptive Clustering Hierarchy) is a relatively mature and commonly used routing algorithm completed by the self-organizing property of nodes. All the sensor nodes in WSN are divided into several clusters, and each cluster is made up of a cluster head node and some cluster members. Cluster head is responsible for collecting data of each cluster member, fusing the data and conducts single-hop communication with the sink node. Cluster head node consumes large energy to prevent the death of nodes due to energy depletion. Cluster head needs to be updated periodically to ensure that the energy consumption of the whole network is evenly assigned to the nodes throughout the network. Clustering routing protocol reduces the frequency of message routing through multi-hop communication of cluster nodes and data fusion. Thereby the energy consumption of sensor nodes can be lowered. Clustering routing protocol is suitable for large-scale WSN with good extendibility. It includes LEACH protocol, TEEN protocol, PEGASIS protocol and EEUC protocol, where the mature and popular LEACH protocol is the current study focus.

3.2. LEACH Routing Protocol

LEACH is short for low energy adaptive clustering hierarchy. Using cluster-based structure, the protocol localizes data communication within each cluster to reduce the long-distance wireless communication; what's more, data compression and fusion are used to compress multiple packets, reducing the amount of data transmission; above all, cluster head node is randomly selected in a cyclic manner. The energy load of the whole network is evenly distributed to each sensor node, balancing energy consumption and extending the network lifetime. The topology of LEACH protocol is shown in Figure 5.

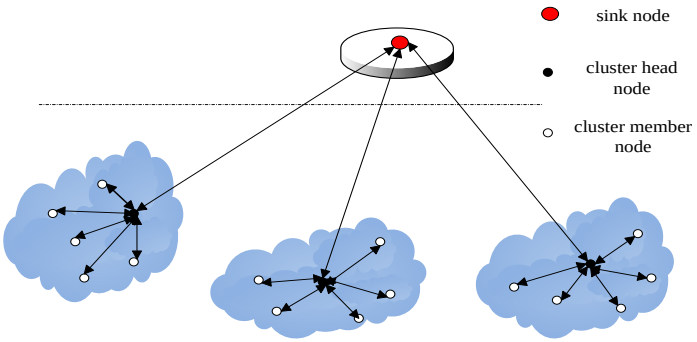


Figure 5. Topology of LEACH Protocol

LEACH implementation is a cyclical process where each cycle is divided into the formation and stable transmission of clusters. The time of the stable transmission should be larger than that of the formation for reducing the energy consumed by the formation of clusters.

Formation: First, a cluster head is randomly elected in the network. The information of one node becoming a cluster head will be broadcasted throughout the area. When receiving the broadcast message, the other nodes choose the cluster to join according to the strength of the signal of cluster head. Consequently, a cluster is formed. Stable phase: The cluster nodes

transmit the collected information to the cluster head after stability. The cluster head is in charge of receiving and fusing the data, then sending the data to the sink node. A new round of cluster head election will be launched throughout the network after a period of the stable phase.

4. Simulation Analysis of LEACH Protocol

4.1. Establishment of Simulation Environment

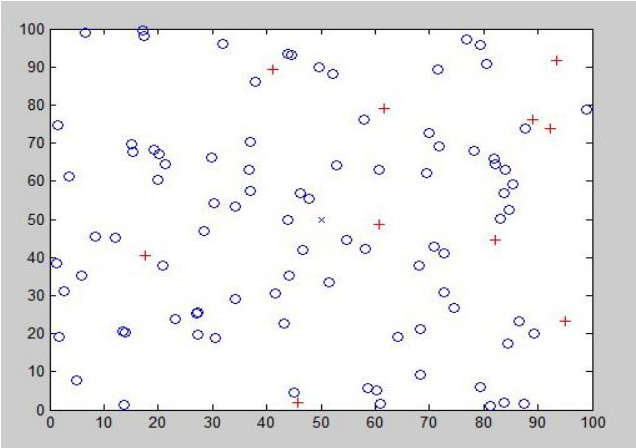


Figure 6. 100 Randomly Distributed Nodes (Normal Node, Cluster Head Node, Sink Node)

MATLAB were used for the simulation of WSN, establishing the simulation environment. Figure 7 shows 100 randomly distributed nodes in a region of 100╳100, where the sink node (the blue fork) is located at (50, 50); the blue circles are the normal output nodes with the initial energy of 0.5J, while the red crosses are the cluster head nodes with the initial energy of 0.5╳ (1 + a) ╳ J.

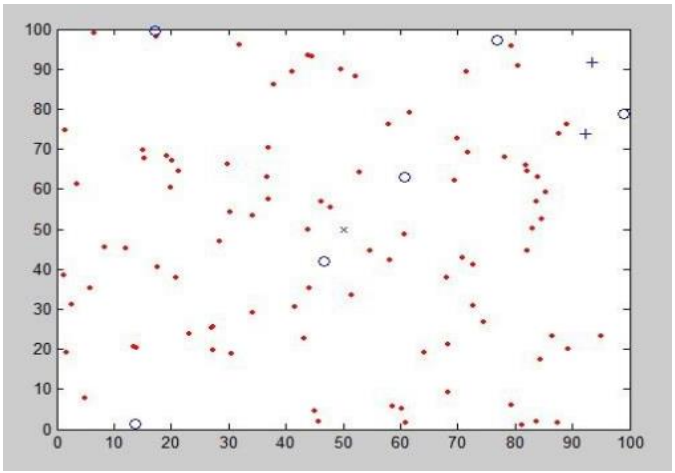


Figure 7. 100 Randomly Distributed Nodes

The energy of a node would decrease due to data transmission, receiving and fusion during the simulation. A node would die and can't send or receive data when the energy was depleted. The cluster head node transmits information to the sink node.

4.2. Simulation Analysis of Node Energy

The curve of Figure 8 represents the life cycle of nodes in LEACH protocol. The survival rate of nodes decreased after a certain period, and the first dead node appeared in 1000s [8, 10]. As the gradual reduction of the number of survival nodes, the network energy decreased until exhausted.

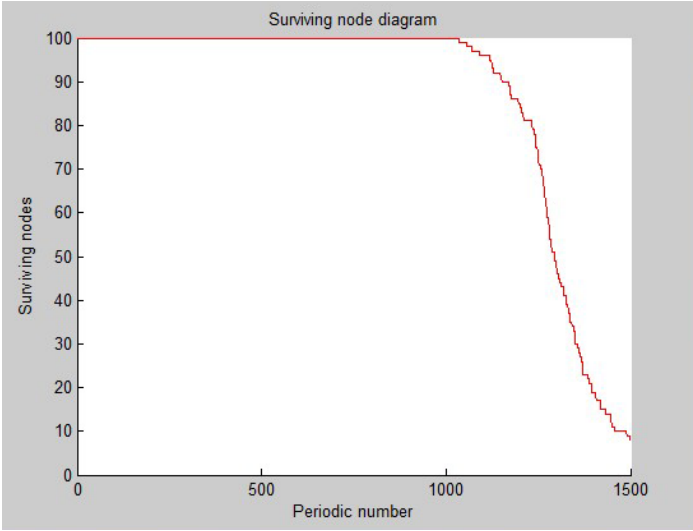


Figure 8. Survival Nodes

Energy is an indicator most concerned by WSN. As the gradual reduction of the number of survival nodes, the network energy decreased until exhausted.

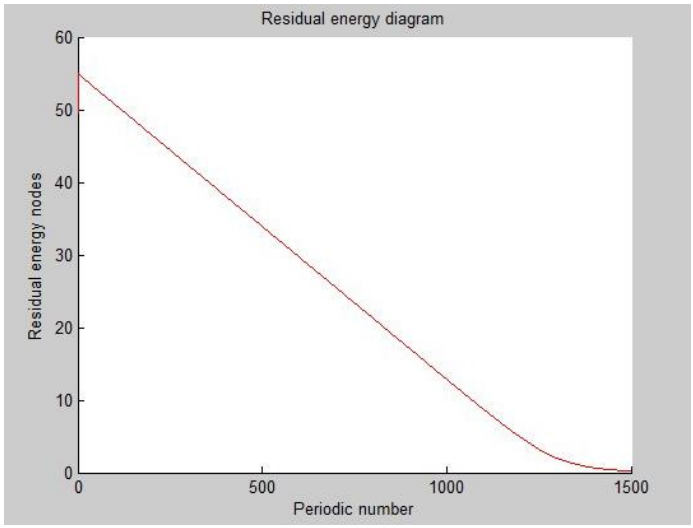


Figure 9. Residual Energy

5. Conclusions

WSN routing protocol is the current research focus. LEACH algorithm in hierarchical routing protocol proposed in the work adopts the algorithm of cluster head election. The function and death of the nodes throughout the network can be understood by waiting for the cluster head election. The network energy consumption is greatly reduced, and the life cycle of WSN is improved through cluster head election. LEACH algorithm can be clearly comprehended via MATLAB simulation.

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References

[1] Q. Yingying, Y. Jiguo and W. Nannan, "Distributed Energy-efficient Clustering Algorithm of Wireless Sensor Network", Computer Engineering**,** vol. 3, **(2011),** pp. 35-45.
[2] Z. Dongfeng, D. Hongwei, L. Yuanzhuang and Z. Yifan, Wireless Sensor Network Experimental Course, Yunnan University Press**,** vol. 3, **(2011),** pp. 147-49.
[3] S. Fengjun, "Communications Algorithms of Wireless Sensor Network", Publishing House of Electronics Industry**,** vol. 3, (**2011),** pp. 3-5.
[4] Z. Aliouat and M. Aliouat, "Efficient Management Of Energy Budget for PEGASIS Routing Protocol, Sciences of Electronics, Technologies of Information and Telecommunications (SETIT)", 6th International Conference on IEEE, **(2012),** pp. 516-521.
[5] B. Qing, Z. Yan and Z. Yanjuan, "Research on Clustering Routing Algorithms in Wireless Sensor Networks", In Proceedings of International Conference on Intelligent Computation Technology and Automation (ICICTA), IEEE, **(2010),** pp.1110-1113.
[6] K. Akkaya and M. Younis, "A Survey on Routing Protocols for Wireless Sensor Networks", Elsevier Ad Hoc Network Journal, vol. 3, **(2005),** pp. 325-349.
[7] J. Q. Feng and D. Manivannan, "Routing Protocols for Sensor Networks, Consumer Communications and Networking Conference", CCNC2004, IEEE, **(2004)**, pp. 55-60.
[8] A. Sinha and A. Chandrakasan, "Energy Aware Software, VLSI Design", Thirteenth International Conference on, IEEE, **(2012),** pp. 50-55.
[9] W. Heinzelman, J. Kulik and H. Balakrishnan, "Adaptive Protocols for Information Dissemination in Wireless Sensor Networks", MobiCom '99 Proceedings of the 5th annual ACM/IEEE international conference on Mobile computing and networking, **(1999)**, pp. 174-185.
[10] A. Sinha and A. Chandrakasan, "An dynamic power management in wireles sensor Networks, Design & Test of Computers", IEEE, vol. 18, issue 2, **(2001)**, pp. 62-74.
[11] W. R. Heinzelman, A. Chandrakasan and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks, System Sciences", Proceedings of the 33rd Annual Hawaii International Conference on, **(2000),** pp. 2-7.
[12] W. Shengbing, "Modulation classification of radio signals", Southeast University, **(2006)**, pp. 20-35.

