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An improved stable election protocol based on node energy consumption (EC)

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Abstract. Sensors and wireless communication technology are embedded in wireless sensor networks, which are widely used in industrial production and defense, military and other industries. However, the sensor nodes' energy compensation is limited, which affects the service life of wireless sensor networks. Therefore, it is very important to design an improved network routing election protocol based on node energy saving. Based on the SEP protocol introduced by DEEC, a stable clustering election protocol was proposed in this paper to achieve the energy loss of balanced nodes. In addition, Matlab software was used to simulate and analyze the improved election protocol, so as to prove the scientific validity of the protocol.

Key words. Routing protocols, energy consumption; election protocols, wireless sensor networks.

1. Introduction

The twenty-first century is the era of the Internet and the electronic information. With the continuous development of science and technology, people's detection space is more and more broad. Therefore, the detection system cannot be limited to a single operating system. A large number of sensors are required to cooperate, so as to perform more accurate detection tasks [1]. At the same time, the test results are passed to the actual users, so that users can complete the detailed calculation and analysis. With such a strong market demand, wireless sensor networks have become the focus of research of experts and scholars. The modern wireless sensor

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network, which combines sensing technology and wireless communication technology, is the industrial revolution of computer network communication technology since the computer revolution [2]. WSN is a wireless sensor technology with sensing and computing power, which is the world's second largest network structure that keeps pace with the Internet. At the same time, WSN has broad application prospects in the civil, military, agricultural and environmental monitoring. Because WSN is the key factor to transmit information efficiently in wireless networks, the performance of the network itself has a great impact on the overall operation of the network [3]. The traditional network routing protocol nodes are controllable in number. WSN network nodes are huge, and the storage and energy consumption of nodes is very large, which makes that the traditional ADHOC routing algorithm cannot meet the actual application of multi-node and multi-energy WSN. Therefore, according to the characteristics of WSN, it is necessary to develop a routing protocol suitable for WSN [4]. Aiming at the above problems, this paper proposed an improved and stable routing voting protocol based on the characteristics of node energy consumption equalization, so as to achieve the purpose of WSN normal operation.

2. State of the art

Wireless sensing network (WSN) originated from the early warning system of military operations in America. At the beginning of the invention, only a single signal acquisition could be carried out, and the collected signals were only be transmitted between nodes. Later, American military research experts set up a research team for distributed sensing networks, which officially opened the door to WSN's research [5]. In the late 1990s, the research team established a simulated dynamic environment which could adapt to the military battlefield and transmit the actual data of the military battlefield in real time. Wireless sensor networks were moving into people's field of vision. After entering the twenty-first century, industry and academic fields began to be more interested in WSN, and research funding began to be heavily invested in WSN research projects [6]. In 2003, Japan's science and technology enterprises jointly launched the "IPV6 sensor networks" industry plan to accelerate the application of WSN in environmental detection range, so as to establish long-term strategic development goals in environmental testing and national defense military [7]. The distributed sensing networks deploy more sensor terminals in their own system structures. The peripheral nodes need energy supplement to keep the running off. But sometimes the energy cells of these nodes are not able to effectively replenish the power, which causes some of the peripheral nodes to die prematurely during normal operation [8].

In the actual application phase of distributed sensor networks, data transmission is constantly fluctuating and changing, and it is not fixed. The peripheral sensor nodes of WSN are the basic detection unit of distributed sensing network, which are responsible for detecting random detection of objects, and passing the detected data to the users. If in the actual application process, the node's premature death will lead to the detection blind spot. The test data returned will be distorted and the result will be unstable and stable [9]. Domestic and foreign have carried on the

related research work to this kind of question, and proposed many kinds of routing protocols, including LEACH, HEED, DD and other routing protocols. According to the topology ontology structure, the network routing protocols are divided into hierarchical and planar routing protocols [10]. Hierarchical routing protocol is a cluster structure, which has more advantages in application in terms of energy saving and adaptability. LEACH routing protocol is a node energy-saving routing protocol designed based on this idea.

3. Methodology

The design of WSN routing protocol must first consider the efficient supplementary energy of nodes. Although the energy consumption of a single node needs to be monitored and supplemented, the overall energy loss balance is also the focus of consideration. The long distance transmission of WSN needs to consume a great deal of node energy. In order to avoid such a situation, a multi-level jump data transmission is used within a limited range [11]. Because the calculation of nodes is too complex, the computation and storage capacity of sensor nodes is greatly impacted. Therefore, it is more important to design simple and efficient routing protocols to meet the cost of resources. In addition, environment differences also need to design heterogeneous features of nodes. In view of the above design characteristics of WSN wireless network routing, the improved routing protocol has the characteristics of low energy consumption, scalability and heterogeneous features [12].

The classification of routing protocols mainly consists of planar routing protocol and clustering routing protocol. The planar routing protocols are divided into flooding routing protocol, chatting method, SPIN center routing protocol and so on. The late development of directed diffusion routing protocol improves the speed of data transmission, but the data transmission gradient leads to data transmission delay. Directed diffusion transport protocol is a data inquiry type data transmission mode, and it cannot meet the practical application of continuous detection and sensing data [13]. Clustering routing protocol divides the network structure into several cluster regions, and each well divided cluster can be divided into several nodes. Figure 1 shows the basic structure diagram of a clustered routing protocol. As can be seen from Fig. 1, the cluster heads of each cluster are based on the high-level network structure of the original network. The high level network clusters cluster into clusters to push to a higher level network structure. The role of each cluster is not only to fuse and collect node data, but also to transmit data to a higher level cluster head. Therefore, the energy consumption of nodes is relatively large. In order to maximize the lifetime of the network, clustering routing protocols need to improve algorithms and update voting protocols.

Compared with the traditional network protocol, LEACH network transport protocol can reduce the energy consumption of the network and realize the energy balance of the network. In the actual operation process, the data transmission can meet the transfer within the cluster. Because the distance of information transmission is relatively close, only a few cluster heads can transmit data with remote sink nodes in actual operation. For data transmission and information communica-

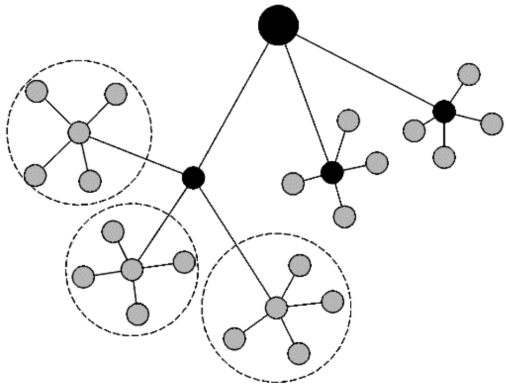

Fig. 1. Basic structure of clustering routing protocol

tion, the shorter the distance, the lower the node energy consumption, the longer the network life. In addition, the LEACH network protocol guarantees that each end node can achieve the same probability as the cluster head. Thus, the energy consumption of the network nodes can be balanced. Combined with data fusion computing, redundant data can be removed, the data of the collected nodes can be efficiently calculated and processed. According to the current usage, the use of the network protocol reduces the energy consumption of the network, and confirms that the LEACH network protocol can increase the service life of the network by at least 10 %.

Figure 2 shows an energy consumption model for LEACH protocols in wireless network applications. As shown in Fig. 2, the nodes of the sensor are evenly distributed in the effective monitoring area, and the nodes do not move randomly when they are used. The energy initial values of the whole network sensor are the same, and the node energy of sink is unrestricted. Sensor nodes do not die randomly during work, and only die out in constant consumption. Wireless communication between sensor nodes and the outside world is unrestricted, and energy consumption is lost in each direction. The system's sensors are controllable in terms of power usage. In the process of transmitting data transmitted by nodes, reasonable radio power can be given according to the actual detection and calculation of distances. Based on the characteristics of the network energy consumption, the energy consumption is mainly the energy consumption of the node when the data is transmitted and transmitted back to the node.

The sensor node is the relay station and amplifier for data transfer. After the data transmission enters the node, it needs to calculate the distance transmitted to the next node, and the reasonable transmission power is then arranged. The data sent consumes a certain amount of energy. The expression of energy consumed during the computation of node sending is calculated as follows [14]

$$E_{\mathrm{Tx}}(L,d) = \begin{cases} LE_{\mathrm{elec}} + Ld^2, & d \le d_0, \\ LE_{\mathrm{elec}} + Ld^4, & d > d_0. \end{cases} \tag{1}$$

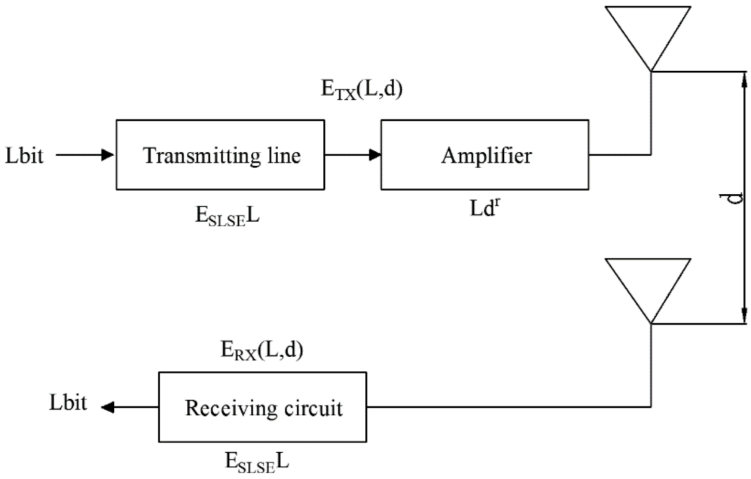

Fig. 2. Energy consumption model of LEACH protocol in wireless network application

Symbol E_{elec} in the formula represents the node energy value consumed by the wireless network when transmitting one section of data, and d represents the effective distance between the previous node's transmission and the location of the latter node. According to the law of conservation of energy in the transmission process, the nodes that receive data also need to consume part of their energy. The energy value consumed by the node that receives one section of data is calculated as

$$E_{\text{RX}}(L) = LE_{\text{elec}}\,. \tag{2}$$

The clustering process for wireless network transmission needs to be made by an election protocol. Each node can determine which node as the cluster head, which mainly depends on the distributed network WSN in cluster head probability, and whether a node become cluster head in the transmission of data in the previous stage. The threshold formula for a node to become a cluster head is [15]

$$T(n) = \begin{cases} \dfrac{p}{1-p\left(r \mod \frac{1}{p}\right)} \text{ if } n \in G, \\ 0 \text{ if } n \notin G. \end{cases} \tag{3}$$

In formula (3), p represents the proportion of nodes that become cluster heads at each node, which is the basic probability value that we often call cluster heads, r is the data transmission cycle in wireless networks and G represents the overall integration of nodes into cluster heads.

In the current cycle, the node that becomes the cluster head is announced to all nodes in the message inside the node, which expresses the ID information of the node. Cluster heads adopt protocol broadcast, and each cluster capital sends energy consumption information broadcast. The nodes of non-cluster heads decide which

cluster header to join according to the incoming message. Typically, non-cluster heads choose the nearest cluster head, which reduces the energy consumed by signal transmission.

Compared with the establishment stage of the cluster, the stable transmission nodes consume much longer time, and the energy consumption of each node is also the largest. After the cluster is determined, the gap table can be confirmed, and data transmission is officially initiated. The gap table divides the transmission phase into frames at each time frame. Each frame is divided into a plurality of gaps according to the node condition in the cluster. The nodes in the cluster randomly assign a reasonable gap and send the received information to the cluster head within the gap. Fig.3 shows the detailed operation of the agreement. The protocol assumes that the nodes in the cluster keep the data transmission and ensure that each node does not conflict with the competition.

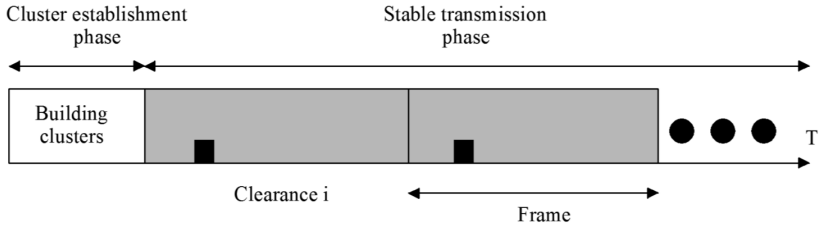

Fig. 3. Specific operation flow of network transport protocol

According to the requirements of the above process, when the node becomes a cluster head, it must always be ready to receive data from other nodes in the cluster. After the data is collected, the data is fused and the redundant data is removed by itself. First, the converged data is passed to the sink node. At the same time, the cluster head is far away from the sink position at this stage. Therefore, the process consumes the most energy, and the specific output transmission process is shown in Fig. 4. In the stable transmission phase, the LEACH protocol adopts periodic cluster head election, which makes the distributed network transmission structure with more balanced energy consuming.

In order to propose an improved stable election protocol, the cluster head election method is used to compute the residual node energy with the expression as follows

$$p(s_i) = \frac{np_{\text{opt}}(1+a_i)}{n+\sum_{i=1}^{n} a_i} \frac{E_i(r)}{\overline{E}(r)} . \tag{4}$$

In the formula, $p(s_i)$ represents the cluster head probability of a single node, a_i denotes the multiples of the node s_i above a certain base energy, and p_{opt} is the cluster head probability, which can be solved by the ratio of the optimal cluster head number to the total number of nodes n in the network. Symbol $E(r)$ represents the residual energy of the node in the rth cycle, and $\overline{E}(r)$ represents the average residual energy value of all nodes in the entire network in the rth cycle.

The threshold expression for which the node becomes the cluster head is

$$T(s_i) = \begin{cases} \frac{p(s_i)}{1-p(s_i)(r \mod \frac{1}{p(s_i)})} \ fi, s_i \in G, \\ \\ 0 \text{ otherwise.} \end{cases} \tag{5}$$

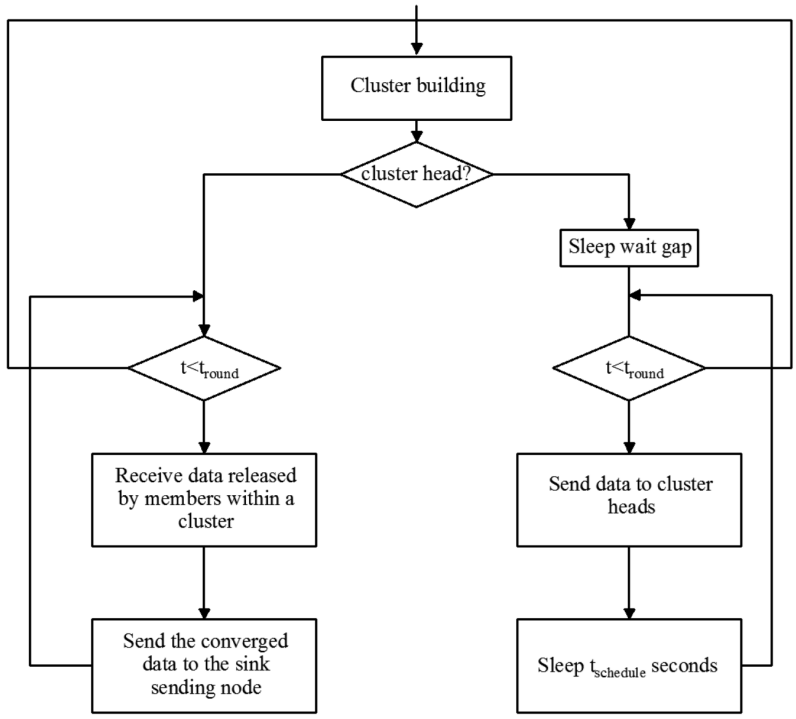

Fig. 4. The receiving and sending process of node energy

In the above formula, $T(s_i)$ represents the threshold of each node, and r is the cycle of node calculation. It is assumed that the energy consumption of each node in the energy cycle of each node is the same. Symbol E_{tot} is the initial total energy of the network and R is the total number of the network. Then, the average energy consumption $\overline{E}(r)$ of the round nodes is the average energy consumption of the network

$$\overline{E}(r) = \frac{1}{n} E_{\text{tot}}(1 - \frac{r}{R}) \tag{6}$$

According to the energy loss calculation method of average node, the election mechanism of cluster head in traditional DEEC protocol is improved. In order to select the cluster head intelligently for the remaining nodes, the energy of other nodes should be estimated. Elections can't be held beyond the threshold. Since the energy consumption in the process of the cluster head's receiving data, fusing data and sending data, the nodes with high residual energy should be elected as

cluster heads during the next round of election. In this study, the design of dynamic threshold interval is proposed. The reason for this design is that the nodes with higher residual energy value become larger, so that the energy consumption of each node is uniform, and the network transmission lifetime is extended.

4. Result analysis and discussion

Figure 5 shows a curve relation between the number of messages and the time in the process of data transmission in the sink node of a multistage network protocol, which shows the changes of protocol nodes' receiving and transmitting information over time. When receiving and transmitting messages with the same amount of energy consumed, DEEC-TA nodes receive more information. This shows that the protocol has more information throughput, and it can transmit more efficient data under the same energy consumption. In addition, it is found that the ability of sink to transmit data between DEEC and the improved DEEC protocol is relatively large. This is because the traditional DEEC protocol predicts the running cycle, which makes the average energy value of nodes too large, the election number of cluster heads in the whole operation cycle relatively small, and the total number of sink too small to explain. The optimized DEEC protocol can optimize the threshold interval. According to the nodes of different energy values, different threshold intervals are designed. In this way, the cluster heads formed in each cycle of the network are more reasonable, and the data received and sent by sink is more uniform.

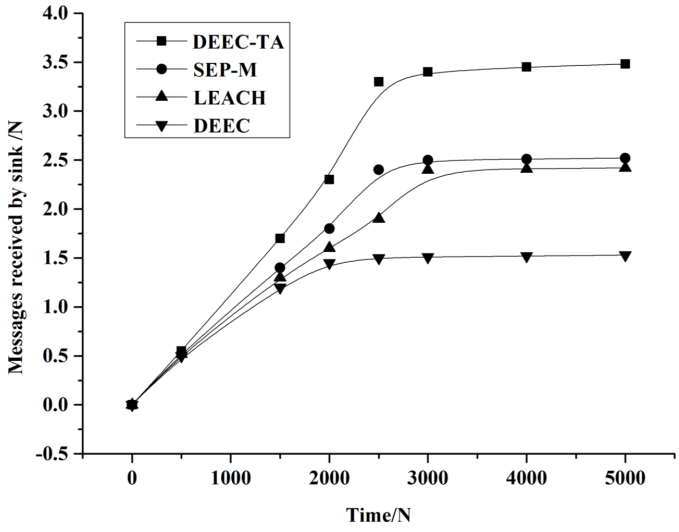

Fig. 5. Node data transmission message and time relation curve

Figure 6 shows the relation between the energy loss and the time of the nodes in the multistage heterogeneous wireless network transmission. As we can see from Fig. 6, when the wireless network is running, the total energy consumption of each

protocol is increasing. Before 1200 weeks, the total energy consumption of the network transmission protocol selected in this paper has no significant difference in the actual operation process. After the curve equal ratio method is adopted, the total energy consumption of the improved DEEC network transmission protocol proposed in this paper is minimal. When the cycle time is more than 1200 weeks, the total energy consumption of LEACH is the least, the total energy consumption of DEEC is the most, and the total energy consumption of SEP-M is centered. At this time, the running time of LEACH and SEP-M has exceeded the stable stage of normal operation, and the survival of nodes has been reduced, so that the total energy consumption has been reduced. Therefore, when the cycle is greater than 1200 weeks, the DEEC and the modified DEEC protocol do not have the research value of comparative analysis. To sum up, in the stable data transmission phase, the improved DEEC protocol has the least total energy consumption. According to the simulation of the improved protocol simulation results, compared with other protocols, the improved network transfer protocol can better balance the energy consumption of the network nodes, enhance the data throughput of the network and stabilize the data transmission cycle.

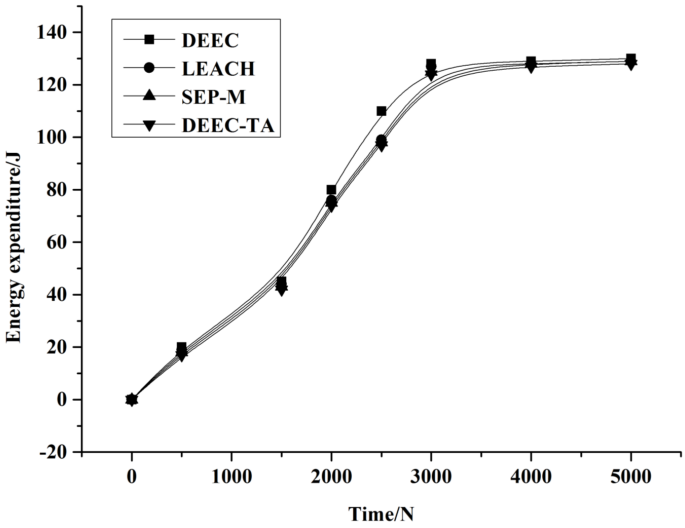

Fig. 6. Relationship between energy loss and time of nodes in multistage heterogeneous wireless network transmission

5. Conclusion

WSN is a comprehensive subject technology, involving interdisciplinary fields of many subjects, which is widely used in information collection, defense, and military and natural environment detection. Based on the lowest comprehensive energy consumption of wireless network node and the minimum maximum data throughput as the research object, the research of WSN routing protocol was carried out, and

the heterogeneous cluster election protocol of wireless network was improved in this paper. The key technologies of WSN wireless network structure were summarized and analyzed. On the basis of discussing the characteristics of routing technology in wireless networks, the traditional DEEC protocol defects were improved and an improved DEEC algorithm was proposed. The objective of the improvement is to minimize the energy consumption of nodes and to change the election of cluster heads into more reasonable agreements. The improved protocol and its calculation method of extremum interval can set the dynamic extreme range of the cluster head election, which can greatly improve the probability of high energy nodes being elected as cluster heads, and reduce the probability of low energy for nodes to be elected as cluster heads. In addition, the energy consumption is more balanced throughout the network operation. In this study, it was assumed that the transmission positions of sensor nodes and sink remained unchanged, whereas nodes had moving characteristics in practical applications. Therefore, the research of wireless network routing protocol also needs to incorporate the node's mobile features into the research factors, which needs to be considered.

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