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Residual Energy Allocation for Wireless Sensor Network Nodes

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In order to improve the adaptive distribution capability of node residual energy in wireless sensor networks (WSNs), a node residual energy distribution method based on load balancing scheduling and node adaptive deployment is proposed. The method comprises the following steps: construction of an energy load balancing scheduling model of a WSN node, the control of energy balancing of the wireless sensor network node by adopting a spatial link balancing scheduling method, the carrying out of quantitative distribution and characteristic aggregation processing of residual energy output of the wireless sensor network node by adopting a shortest path optimization mechanism, constructing a residual energy load balancing scheduling model of the wireless sensor network node, carrying out energy overhead characteristic analysis by combining node combination rotation scheduling, and carrying out residual energy distribution by using a load balancing scheduling method in an energy coverage area of the WSN node. The simulation results show that the output balance of the residual energy distribution of the wireless sensor network node network using the proposed method is better, the residual energy aggregation performance of the wireless sensor network node is improved, the energy cost of the sensor network is reduced, and the stability and life cycle of the WSN are enhanced.

Keywords: Wireless sensor network; Node; Residual energy; Distribution; Equilibrium

1. INTRODUCTION

A wireless sensor network consists of a large number of small, low-cost sensor nodes. The data transmission process uses the wireless communication self-organizing network, and can be deployed in relatively hostile or remote environments, without requiring human intervention, even from the military deployed in an enemy area where the lives of military personnel and/or civilians are under threat. Moreover, most of the applications based on wireless sensor networks are in strategic positions and are therefore very important. For military or economic purposes, these network applications often become the key targets of a hostile entity. However, due to the strict limitation of the application resources of a wireless sensor network, and the lack of prior knowledge of network node deployment in most cases, during the development of traditional network technology, the initial focus was on ways to achieve stable and reliable communication. With the maturity and development of network technology, network security has gradually become the focus of research attention. Being a new type of network, the developers should, from the outset, consider the security threats that a WSN could face, and determine how to incorporate a security mechanism into the network design to ensure the WSN is safe for communication. The security issue must be considered in the design of the network protocol; if not, and a security mechanism is introduced and implemented later, the cost of doing so will be high. In a wireless sensor network, regardless of its intended application, security protection is essential. Different applications need different levels of security protection: for example, in environmental monitoring and intelligence community, the level of security protection is low, while in military applications, the level of security protection is high.

The use of wireless sensor network technology for data transmission and reception control can improve the stability of these processes. In the node deployment design of sensor networks, energy balance control should be carried out according to the distribution density of nodes, and an energy balance control model of sensor networks should be

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established to reduce the energy cost of sensor networks, thus improving their life cycle.[1] It is essential to study the residual energy distribution method of nodes in wireless sensor networks under density control in order to improve their balance and stability. This residual energy allocation is based on the optimal deployment of network nodes [2]. Combined with the analysis of the characteristics of the residual energy expenditure of a WSN node network, the nodes' automatic deployment model of a WSN is established [3]. According to the energy expenditure of wireless sensor network nodes, cluster head nodes are automatically deployed to improve the adaptive equalization control capability of a WSN. The related residual energy allocation technology has attracted great attention. A node residual energy allocation method based on load balancing scheduling and node adaptive deployment is proposed. A model is constructed for the scheduling of energy load balancing of WSN nodes. The residual energy is distributed to the energy coverage area of these nodes by using the load balancing scheduling method. Finally, simulation experiments are carried out to demonstrate the superior performance of the method in improving the residual energy distribution capability of WSN node network.

2. BASIC DEFINITIONS

2.1 Node Optimization Deployment Model of Sensor

Wireless sensor network nodes have different functions depending on the different application scenarios. Within the same application scenario, WSN nodes have different roles and, therefore, different functions. However, the basic structure of WSN node network in different application scenarios and WSN nodes with different roles within the same application scenario are the same. This basic structure consists of four main parts: energy supply module, sensor module, processor module and wireless communication module. Of these, the processor module can be divided into three parts: processor, memory and high-level application; a sensor module that can be divided into two parts: sensor and a / D converter; and a wireless communication module comprising three parts: media access, physical layer and radio frequency. According to their functions, the nodes that make up the wireless sensor network can be divided into three types: sensor nodes, sink nodes and management nodes. The working process of a WSN system can be divided into sensor data transmission direction and wireless sensor network control direction according to the data flow direction. The sensor data transmission direction works as follow: the scattered sensor nodes in the monitoring area are not only the terminal nodes for collecting sensor information, but also the routing nodes. The information obtained by the terminal sensor nodes is sent to the aggregation node by single-hop or multi-hop mode, and then transmitted to the external network such as a UAV, satellite communication network or Internet. Then, the data information is transmitted to the remote task management node through the external network, so that the received data can be preliminarily processed on the remote task management node. Finally, the remote task management node will present the pre-processed result data to the user. After receiving the data from the remote task management node, the user will use these data for their own processing needs. The WSN control direction works as follows: the user directly connects with the remote task management node, sends the WSN control information to the remote task management node, and then the remote task management node sends the control information to the external network, from which it is sent to the aggregation node by the external network; finally, the aggregation node transmits the control information to the sensor node. The rduino ide development environment is shown in Figure 1.

For the high-frequency circuit part of the PCB, the module Manual of XBee ZB contains specific requirements for the layout of the RF module: the antenna on the module must be as distant as possible from the battery, electrolytic capacitor, copper sheet and other metal materials. In the metal material isolation area, no copper laying and vias are allowed for any structural layer of the PCB. In addition, the XBee ZB module should be as close as possible to the boundary of the PCB. The PCB design and layout are shown in Figure 2.

On the right side of the PCB board is the XBee ZB module, and the dark area is the unpaved copper area, that is, the metal material isolation area of the RF module. The sensor module interface slot is located at the bottom half edge of the PCB, and the sensor module power interface slot is located at the top half edge of the PCB. In the lower middle part of the PCB is MCU controller, in the upper part is the sensor module power switch circuit, and on the left is the power supply module and the USB interface circuit area.

In order to balance the load of nodes and eliminate the energy hole, some research results can be divided into three categories: homogeneous node deployment, heterogeneous node deployment and mobile base station or relay deployment. With the homogeneous node deployment strategy, the reasonable deployment of nodes or the non-uniform deployment of nodes can effectively prevent the energy hole phenomenon.

In order to prevent the occurrence of an energy hole, a uniform distribution strategy of isomorphic nodes is proposed to maximize the network life cycle. Although the energy hole phenomenon cannot be avoided in the free space model, it can be avoided in the two-way model, which provides design guidance for the multi-path design model that has a circular structure. In this paper, the reason for the occurrence of an energy hole is analyzed theoretically, and the unbalanced distribution strategy of nodes in the circular network structure is proposed. The density relationship of nodes in each layer of the network to achieve the sub-optimal energy balance is given and verified. However, if the nodes continue to send data to sink nodes, the energy hole cannot be avoided. This has an important impact on energy consumption, monitoring ability and even the life cycle of the network. Moreover, based on the greedy transfer mechanism of the ant colony algorithm, a node deployment algorithm is proposed, which can quickly achieve full coverage and reduce the deployment cost. Also, ant colony optimization is used to dynamically adjust the sensing and communication radius of nodes to eliminate the energy hole problem and extend the life cycle of the network. The transmitting power of WSN nodes can be divided into

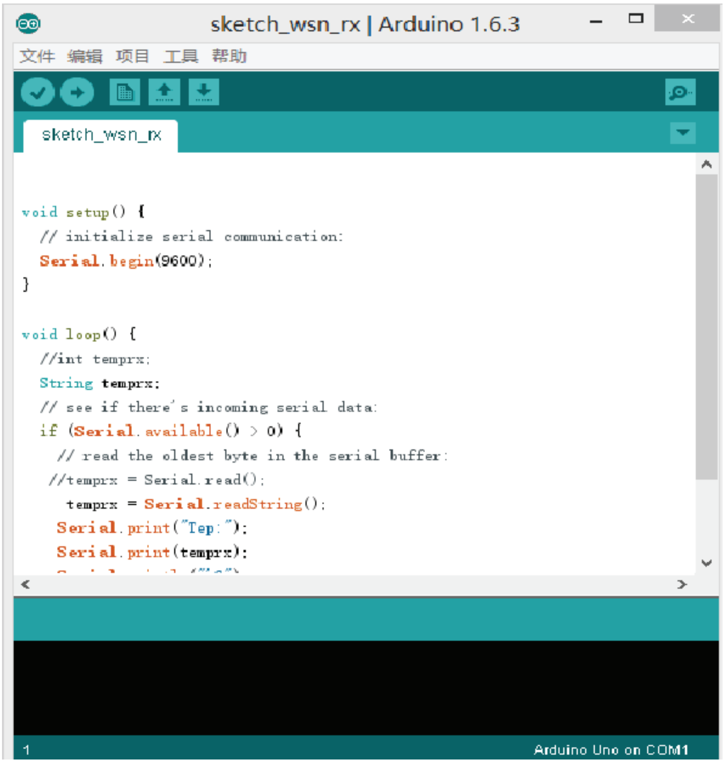


Figure 1 rduino ide development environment.

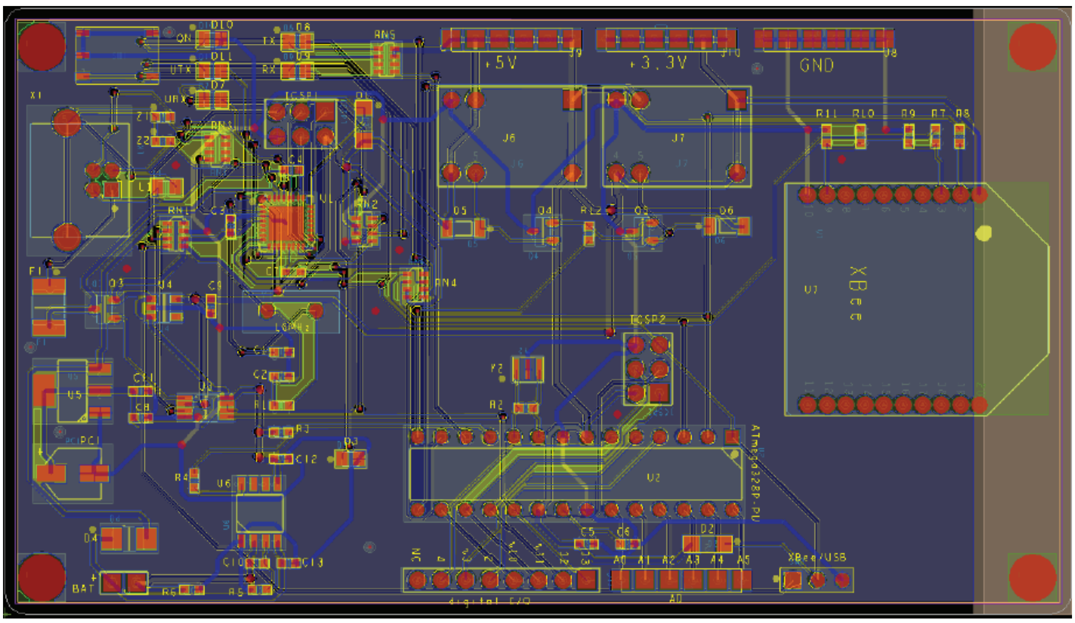


Figure 2 PCB design and layout.

many levels. An effective power control algorithm can make the nodes choose the appropriate transmitting power during the wireless communication process, make reasonable use of limited energy, adjust the data distribution in the network, realize the optimization of network performance, extend the life cycle of the network, and have an impact on the connectivity and topology of the network.

Current power control algorithms can be roughly divided into two types: passive control and active control. The passive mechanism is applied to achieve energy saving by closing the transmission module of those nodes not required for communication. On the other hand, the active control mechanism uses intelligent energy and effective network protocol to reduce energy consumption, which can be implemented in different protocol layers such as the MAC layer, the network layer, and across layers. However, most algorithms balance the energy consumption of nodes in the network by combining active and passive methods. At the same time, according to the different research methods, they can be divided into centralized methods and distributed methods. In order to reduce the energy

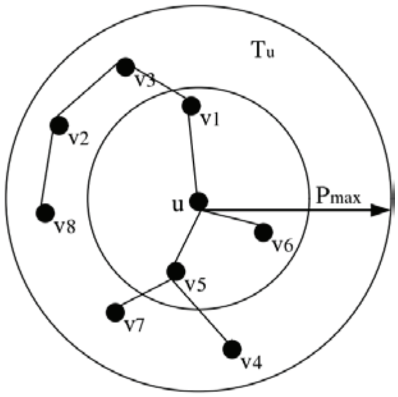


Figure 3 Local topology construction of node u.

consumption of the network, each node first determines the optimal transmission power with the neighbor node, and then obtains the minimum transmission power to ensure the network connectivity. Finally, all nodes in the network will carry out data transmission with the minimal power consumption. In the protocol of COM power, the minimum transmit power to ensure the whole network connection is also used to complete the transmission of all data, and the use of unified transmit power to complete the data transmission is the disadvantage of the above two algorithms. A centralized node emission power control algorithm is proposed for node deployment, which determines the emission power of each node in each ring according to the radius and node density of the monitored area; a distributed node emission power adjustment algorithm is proposed for non-deterministic node deployment, based on the values in the transmission column table, each node in each ring calculates its own energy consumption rate, and the adjacent nodes in the ring cooperate by determining the transmission radius adjustment scheme by quotient. The local topology construction of node u is shown as Figure 3.

In order to realize the residual energy allocation of WSN nodes, the spatial link equalization scheduling method is used to control their energy balance, the optimal deployment model of WSN nodes is constructed, the routing of the sensor network is carried out by cluster hybrid compression method, and the node adaptive allocation structure model of the sensor network is established. For the Sink node i, source and Sink node deployment area interphase interval T_f, the energy bandwidth distribution of the node transmitting L bit data is taken as $T_s = N_f T_f$, considering the degree of the network load equalization, the remaining energy equalization structure of WSN node is constructed at Sink node at Sink node, the node is sent to T_p, the node is distributed within the spatial equalization sensor area, and the energy consumption of cluster is assumed to be a frame data collection bar in the N_c code piece, assuming that the energy consumption in a data collection path is:

$$T_c = ent(T_f / N_c) \tag{1}$$

for convergent nodes, when the transmission bandwidth of reliable neighbor data satisfies $c_j T_c < T_f$, $\forall j \in [0, N_f - 1]$. Suppose that the signal transfer model between routing node A and Sink in a WSN is:

$$s(t) = \sum_i b_j \sum_{j-1}^{N_f - 1} p(t - iT_s - jT_f - c_j T_c) \tag{2}$$

where, b_j is the residual energy loss of the WSN nodes, T_s is the transmission attenuation of the WSN nodes, T_f is the sampling time for the remaining energy of the WSN nodes, and the T_c is the neighbor node sets of sampling interval [4–6]. For all the sensor nodes, the load-balancing scheduling method is adopted to design the wireless topology of the WSN nodes, and the optimization of node deployment is obtained as shown in Figure 4.

According to the node distribution of the WSN node network shown in Figure 1, the input node state position is SN, sink, and when the distance $d(vi, vj)$ between the two nodes [7], The nodes' uneven energy consumption limits the service time of the network. For the cluster routing protocol, which communicates directly between cluster head node and base station, the energy consumption increases with an increase in the distance between cluster head and base station. These cluster head nodes run out of energy prematurely, which means that the network has isolated nodes or isolated areas, so that it can no longer provide services to meet the needs. In order to solve this problem, this paper proposes a new non-uniform clustering method to balance the energy consumption of nodes. By analyzing the energy consumption difference caused by the different distances between the node and the base station, the optimal cluster radius of different nodes is further obtained. According to the results, the number of cluster heads increases with the increase of the distance from the base station. The cooperative model of the reliable neighbor data of the sensor network is described in the following formula:

$$\alpha^i_{\text{desira}} = \alpha_3 \cdot \frac{\text{Dis}_{\text{pre}} - \text{Dis}_j}{3R} + \alpha_4 \frac{\min\left[AP_i, AP_j\right]}{AP_{\text{init}}} \tag{3}$$

$$\alpha^i_{\text{desira}} = \alpha_3 \cdot \frac{\text{Dis}_{\text{pre}} - \text{Dis}_i}{3R} + \alpha_4 \frac{AP_i}{AP_{\text{init}}} \tag{4}$$

wherein

$$\begin{cases} \alpha_3 + \alpha_4 = 1, \alpha_3, \alpha_4 \in 0, 1 \\ \alpha_4 = \frac{\max_j(\min[AP_i, AP_j]) - \min_j(\min[AP_i, AP_j])}{AP_{\text{init}}} \\ \alpha_4 = \frac{\max_i(AP_i) - \min_i(AP_i)}{AP_{\text{init}}}, \text{formula(3)} \end{cases} \tag{5}$$

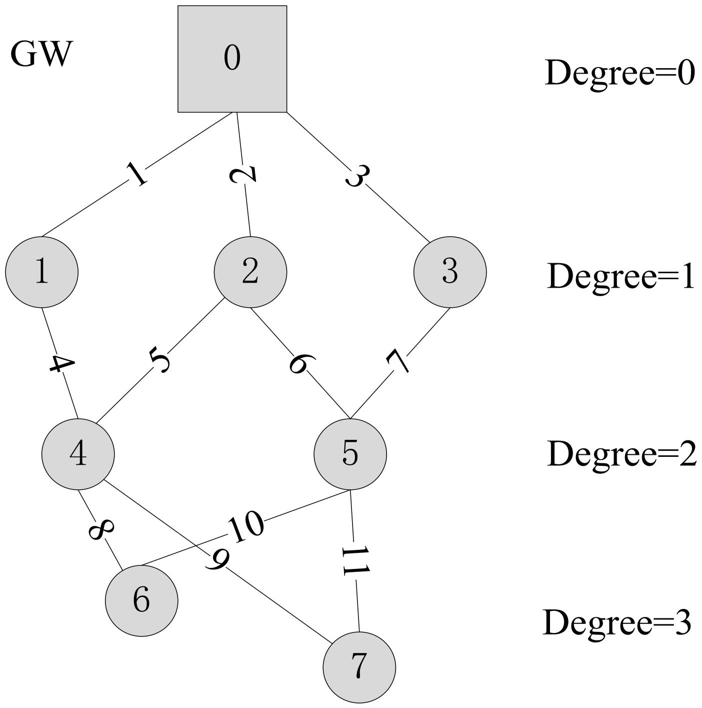


Figure 4 Node optimal deployment model for wireless sensor networks.

In the energy overhead region of the sink node, the automatic partitioning method of the sensor deployment area is used for adaptive optimization, and the shortest path method is used to optimize the node deployment of the sensor [8]. The optimal detection model of the node location is described as:

$$\alpha_{\text{desira}}^{i} = \alpha_1 . \frac{\text{Density}_i}{\sum_i \text{Denstity}_i} + \alpha_2 \frac{AP_i}{AP_{\text{init}}} \tag{6}$$

wherein

$$\begin{cases} \alpha_1 + \alpha_2 = 1, \alpha_1, \alpha_2 \in 0, 1 \\ \alpha_2 = \frac{\max_i(AP_i) - \min_i(AP_i)}{AP_{\text{init}}} \end{cases} \tag{7}$$

In summary, the optimal deployment of the sensor nodes is realized. According to the node deployment model, the residual energy allocation and adaptive control of the WSN node network are carried out [9].

2.2 Energy Balance Control

The basis of wireless data communication is the identification and matching of communication data. The structure of the communication data is the data format agreement that must be followed between communication objects in wireless data communication to ensure effective and reliable communication between parties. In a WSN, the information transmitted between nodes can be identified only by coding and packaging according to the set structure, and information exchange can be realized between nodes. All the communication data in the ZigBee communication protocol stack is organized in frame format, and the relevant data that needs to be transmitted wirelessly is packaged and sent in the agreed frame format. When the application layer is ready to send information, it will first send a request to the APS, and then the network layer, MAC layer and physical layer under it will add corresponding frame headers to the information, so as to frame the information with a standard format.

The energy balance control of the WSN nodes is carried out by adopting a spatial link balance scheduling method [10, 11], the residual energy output of the nodes is quantified and distributed and the characteristics are aggregated by adopting a shortest path optimization mechanism. The energy cost distribution interval of the nodes is represented by a weight coefficient [12]. Under a fixed network topology, the node link matrix $S_{N\times L}$, and the load of the WSN sensors within a designated area n_i is as follows:

$$\text{candidate} = \{n_j | d(n_i, n_j) < d_0 \cup d_j < d_i, n_j \in CH\} \tag{8}$$

The characteristics of the information collected by the WSN nodes are reconstructed, and the energy transceiving conversion control method is adopted to obtain the power consumption of the mobile nodes as follows:

$$\begin{aligned} E &= E_{Tx}(l, d(n_i, n_j)) + E_{Rx}(l) + E_{Tx}(l, d_j) \\ &= l(E_{elec} + \varepsilon_{fs} d^2(n_i, n_j)) + lE_{elec} + l(E_{elec} + \varepsilon_{fs} d_j^2) \\ &= 3lE_{elec} + l\varepsilon_{fs}(d^2(n_i, n_j) + d_j^2) \end{aligned} \tag{9}$$

Assuming that there are n nodes in a data collection path, the distance between the empty node and Sink is calculated, and the sensor network topology is established [13]. For the central node, i.e. the cluster head, the test objective function T(n) of energy overhead is:

$$T(n) = \begin{cases} \frac{P}{1 - Pr \bmod (1/P)} \cdot \left\{ c \left[\frac{E_{\text{res}}}{E_{\text{init}}} + \left(r_u \operatorname{div} \frac{1}{p} \right) \left(1 - \frac{E_{\text{res}}}{E_{\text{init}}} \right) \right] \right. \\ \left. \quad + (1 - c) \frac{d_{\text{ans}} - d_i}{d_{\text{mas}} - d_{\min}} \right\} \text{n}\epsilon\text{G} \\ \quad 0 \qquad \text{else} \end{cases} \tag{10}$$

The formula above indicates that when the energy prefabrication r_u of the node of the WSN is 0, and the interval between the sending node and the receiving node of the sensor network is clustered to d0, the number of transmission hops in the cluster is lower than that of the cluster head, and the sub-matrix $B_{N\times 1}$ of energy cost equalization modulation is obtained. The calculation formula is:

$$\begin{aligned} r(t) &= \sum_i \sum_{j-0}^{N_f-1} \sum_{l-0}^{L-1} b_i \alpha_i p(t - iT_s - jT_f - cT_c - \tau_i) + \omega(t) \\ &= \sum_i \sum_{j-0}^{N_f-1} b_i p_h(t - iT_s - jT_f - cT_c - \tau_0) + \omega(t) \end{aligned} \tag{11}$$

There is a central node Chi in each class, and the link matrix $S_{N\times L}$ is obtained by using a spatial equalization scheduling method. Under the full-network energy equalization control structure, the number of transmission hops in the WSN node cluster is:

$$\begin{aligned} r(t) &= \sum_i \sum_{j-0}^{N_f-1} \sum_{l-0}^{L-1} b_i \alpha_i p(t - iT_s - jT_f - cT_c - \tau_i) + \omega(t) \\ &= \sum_i \sum_{j-0}^{N_f-1} b_i p_h(t - iT_s - jT_f - cT_c - \tau_0) + \omega(t) \end{aligned} \tag{12}$$

wherein

$$p_h(t) = \sum_{l-0}^{L-1} \alpha_1 P(t - \tau_{l,0}) \tag{13}$$

In addition, $\omega(t)$ is the measured value of each cluster and $p_h(t)$ is the balanced measured value of the WSN node in the center of the cluster head. Based on the above analysis, a residual energy balance control model of the node-based WSN is constructed, and adaptive scheduling is carried out according to the energy aggregation characteristics to improve the residual energy distribution capability of the WSN node network [14].

3. OPTIMIZATION OF NODE RESIDUAL ENERGY ALLOCATION METHOD IN WIRELESS SENSOR NETWORKS

3.1 Quantization Distribution and Feature Aggregation of Residual Energy Output in WSN Nodes

In order to construct an energy load balancing scheduling model of the WSN nodes and adopt the spatial link balancing scheduling method to carry out the energy balancing control of the WSN nodes, the optimal design of the residual energy distribution method of the WSN nodes is carried out, and the residual energy distribution method of the WSN nodes based on the load balancing scheduling and the node adaptive deployment is proposed. The energy balance control of the WSN nodes is carried out by adopting a spatial link balance scheduling method, the quantitative distribution of the residual energy output of the WSN nodes and the aggregation of characteristics are done by means of a shortest path optimization mechanism, the data packet transmission distance is fixed, and the energy space balance distribution matrix of the sensor is defined:

$$P = E[d_k X_k] = E \begin{bmatrix} d_k x_{0k} \\ d_k x_{1k} \\ \vdots \\ d_k x_{Lk} \end{bmatrix} \tag{14}$$

Energy cost characteristics are analyzed in combination with node rotation scheduling, and the shortest routing cost of multi-hop among clusters is obtained:

$$P_{\text{AOMDV}} = (1 - P_d)^2 \left\{ 1 - \left[1 - (1 - P_e)^n (1 - P_d)^{n-1} \right]^m \right\} \tag{15}$$

The shortest path optimization method is adopted to detect the routes of the WSN nodes, and the mean square error is obtained, which is expressed as:

$$MSE = \xi = E\varepsilon_k^2 = Ed_k^2 - 2W^T P + W^T RW \tag{16}$$

The probability density function of cluster head distance is calculated, and the node closest to the geometric center is selected as the energy consumption node. The energy residual density obtained should meet the following requirements:

$$\max_{p_i \epsilon P_i} u_i(p_i, p_{-i}) = \ln(1 + \gamma_i), \quad i \in N \tag{17}$$

The optimal energy-saving control is carried out under the condition of maximizing the output power, and the routing transfer probability of the sensing network is:

$$h(t) = \sum_{l-0}^{L-1} \alpha_l \delta(t - \tau_{l,0}) \tag{18}$$

Under the constraint of the maximum robust coefficient, the route-sensing radii of WSN nodes can be expressed as:

$$NIntra_i(n) = NIntra_i(n) + 1, \quad \text{if} \quad j \in N_i \cap t_{ij} < T_h \tag{19}$$

Energy costs can be determined by combining a spatial region distributed reconstruction method, and the distribution feature set of cluster head nodes is $NInter_i(n)$, which is expressed as:

$$\mathit{NInter}_i(n) = \mathit{NInter}_i(n) + 1, \text{ if } j \notin N_i \cup t_y \geq T_h. \tag{20}$$

If the energy output probability density of a WSN node is expressed by $CIntera_{\lambda(n)}$ and the maximum threshold value of the node is expressed by $CIntra_{\lambda(n)}$, then

$$\begin{aligned} \mathit{CIntra}_i(n) &= \frac{\mathit{NIntra}_i(n)}{T}, \\ \mathit{CInter}_i(n) &= \frac{\mathit{NInter}_i(n)}{T}. \end{aligned} \tag{21}$$

Under the optimal equilibrium scheduling model, the maximum energy cost of the sensor network is obtained with:

$$U_i(n) = \alpha \mathit{CIntra}_i(n) + (1-\alpha)\mathit{CInter}_i(n), \quad \alpha \in (0, 1) \tag{22}$$

Using the load balancing test method, the output power factor of the sensor network is obtained with $P^* = [p_{\max}, p_{\max}, \ldots, p_{\max}]^{\mathrm{T}}$. For the cluster head ID, E_{res}, δ and its distance from Sink are fixed, the output energy is adaptively evaluated as:

$$E_{Rx}(l) = l E_{elec} \tag{23}$$

where, d is the Sink node distribution distance of the WSN nodes; E_{elec} is the residual energy of the cluster head; R is the transmission scheduling round of the wireless sensor network. To sum up, the equivalent energy balance control method is adopted to carry out the quantitative distribution and feature aggregation of the residual energy output of WSN nodes, and the hole-prevention algorithm is optimized according to the evaluation results [15, 16].

3.2 Density Control and Residual Energy Distribution

Building a node network residual energy load balancing scheduling model of the wireless sensor network, and carrying out energy cost characteristic analysis by combining node combined rotation scheduling, and obtaining the energy cost of the WSN nodes is done as follows:

$$\begin{aligned} E_{init} &= E_R + E_T + E_F \\ &= \sum_{r=1}^{L_i} \sum_{n_j \in S_i^r} E_{Rx}(l) + \sum_{r=1}^{L_i} \sum_{n_g \in N_i^r} E_{Tx}(l, d_{(n_i,n_g)}) + \sum_{r=1}^{L_i} l_r E_{DF} \\ &= \sum_{r=1}^{\mathrm{L_i}} \left\{ \sum_{n_j \in S_i^r} E_{Rx}(l) + \sum_{n_g \in N_i^r} E_{Tx}(l, d_{(n_i,n_g)}) + l_r E_{DF} \right\} \end{aligned} \tag{24}$$

The fluctuation of cluster head node is L_f. The density control method is used to analyze the energy aggregation characteristics. The lifetime of WSN is L_l, and then there are:

$$L_f = \min\{L_i\}, \qquad L_l = \min\{L_i\} \tag{25}$$

Under the optimal energy balance control, the cavity feature set covered by the WSN area is obtained as follows:

$$V_{res}(r) = \frac{\sum_{i=1}^{N} \{E_{res}^r(n_i) - E_a^r\}^2}{N} \tag{26}$$

where $E_{res}^r(n_i)$ is the transmission characteristic distribution set representing the energy cost detection area in the R-th round is obtained as follows under the control of the whole network energy balance:

$$u_i(p_i^*, p_{-i}) > u_i(p_i, p_{-i}), \quad \forall p_{-i}, \quad \forall i \in N \tag{27}$$

In the initial network topology, the optimal energy control solution set of adjacent grid feature points is:

$$\varepsilon_i(p_{-i}) = \{\arg \max_{p_i \in P_i} u_i(p_i, p_{-i}), p_{-i} \in P_{-i}\} \tag{28}$$

Among them, the spatial distribution set of residual energy distribution is $\varepsilon_i(p_{-i}) = \varepsilon_i(p)$, and the maximum energy expenditure characteristic quantity is $E(P) = [\varepsilon_i(P_{-1}), \varepsilon_i(p_{-2}), \ldots, \varepsilon_n(P_{-n})]^{\mathrm{T}}$, which shows that the residual energy distribution algorithm designed in this paper has uniform convergence. To sum up, the analysis of energy expenditure is carried out in combination with the scheduling of node rotation, and the residual energy distribution is carried out in the energy coverage area of WSN nodes by using the load balancing scheduling method to improve the network's capability to control the balancing of energy.

4. SIMULATION EXPERIMENT AND RESULT ANALYSIS

Experiments were carried out to determine the performance of the improved model in realizing energy load balancing scheduling and residual energy distribution of WSN nodes. MATLAB is used for algorithm design in the experiment, and the sensor network node deployment design is carried out on OMNet++ platform. The simulation parameter settings are shown in Table 1.

According to the above simulation parameter settings, the residual energy distribution simulation of WSN nodes is carried out, the shortest path optimization mechanism is adopted to carry out the quantitative distribution and feature aggregation processing of the residual energy output of WSN nodes. The residual energy load balancing scheduling model of the WSN nodes is constructed to obtain the output energy efficiency overhead of the WSN under different densities as shown in Figure 5.

Analysis of Figure 5 shows that the adaptive control capability of the residual energy distribution of the WSN nodes using this method is better, and the network is more efficient. In order to compare performance, different methods are used to test network energy efficiency and transmission delay. The results of these comparisons are shown in Figure 6.

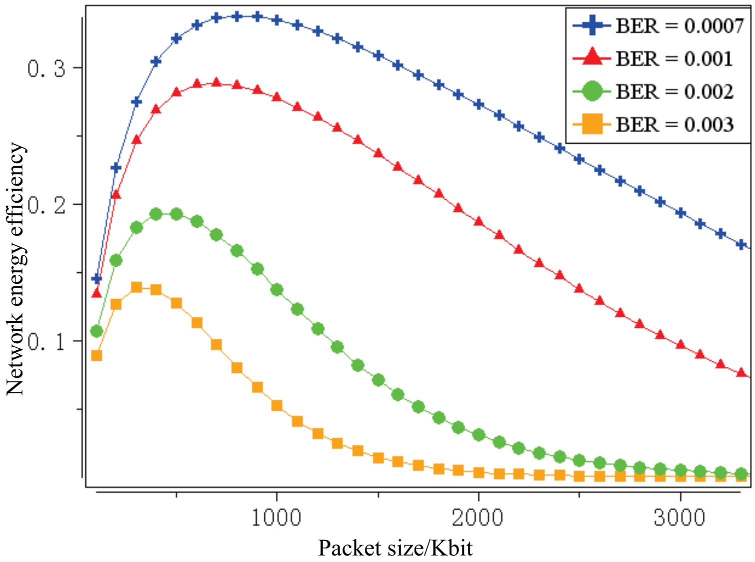
Figure 6 shows that the energy efficiency and transmission delay of residual energy distribution of WSN nodes using this method are higher.

5. CONCLUSIONS

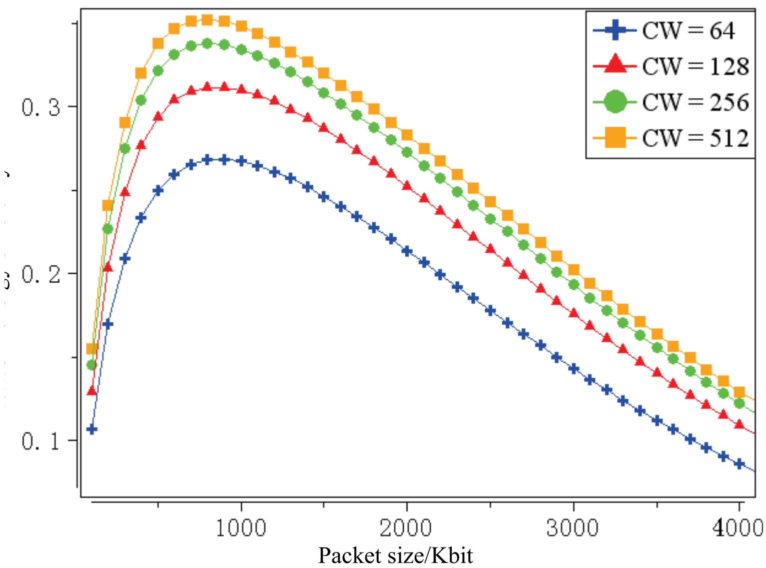
The energy balance control model is established for the sensor network to reduce its energy cost and extend its life cycle. A node residual energy allocation method is proposed based on load balance scheduling and node adaptive deployment. An energy load balancing scheduling model of WSN nodes is constructed, a spatial link balancing scheduling method is adopted to carry out energy balancing control of WSN nodes, a shortest path optimization mechanism is adopted to carry out quantitative distribution and characteristic aggregation processing of residual energy output of WSN nodes, adaptive scheduling is carried out according to energy aggregation characteristics, energy overhead characteristic analysis is carried out in combination with node combination rotation scheduling.Research shows that this method is more efficient and reduces delay in distributing the residual energy of

Table 1 Simulation Scenes and Parameters.

Simulation scenarios and parameters	Value	Simulation scenarios and parameters	Value
Coverage of sensor network	800×800	Total number of nodes N	2000
Node density	18	Node initial energy	12 KJ
Gateway location	(0,0)	Packet size	2.8 pJ/(bit·m^4
E_{DF}	1.8	d_0	2.6



(a) BER of different densities

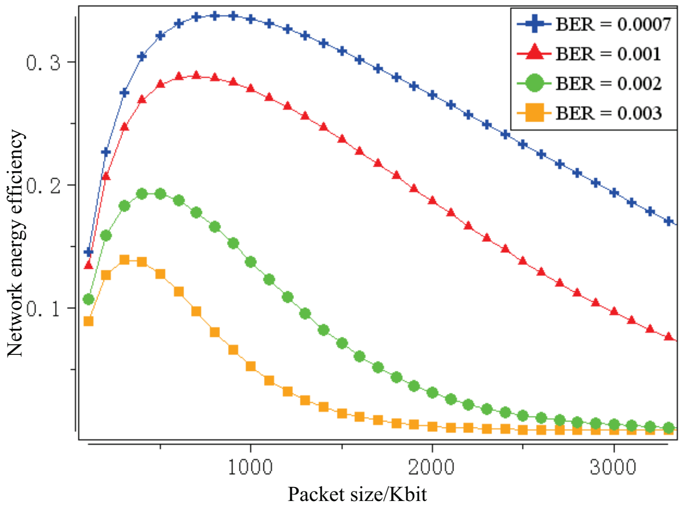


(b) Competition window changes

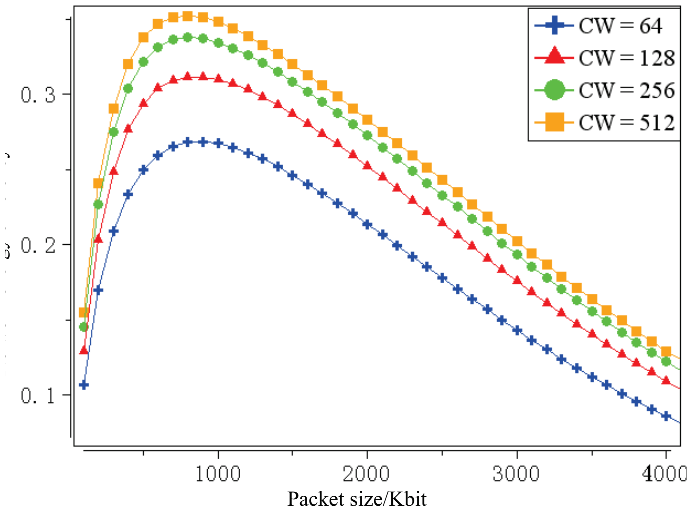
Figure 5 Energy overhead of the sensor network under different parameter variations.

nodes in wireless sensor networks, thus improving the output stability of the network.

Energy supply is a major problem for wireless sensor networks, and one in urgent need of a solution. With the development of technology, the energy supplement technology for sensor network nodes provides an open-source solution to the energy problem. Obtaining energy from the environment is considered to be a good solution for sensor networks. With the development of technology in various related fields, it is likely that energy will no longer be a



(a) BER of different densities



(b) Competition window changes

Figure 6 Comparison of residual energy distribution efficiency of WSN nodes.

restriction for WSN. However, with the continuous expansion of their application scope, WSNs collect data related to physical events of interest to users, and obtain information about the physical world information through various sensing devices. These can transmit information comprising a range of elements including audio, video, and light intensity. Because the sensor nodes transmit large volumes of information, their security is a core issue. If there are malicious attacks such as information exposure and tampering, they will undoubtedly cause losses. Therefore, in the future, researchers will focus on WSN security, which will be the next research direction, extending the work presented in this paper.

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