An Uneven Clustering Routing Algorithm Based on Energy Load Balancing

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Abstract. In order to improve the network lifetime and energy efficiency, an uneven clustering routing protocol based on energy load balancing (ELBUC) is proposed. In the cluster head selection phase, sensor nodes are selected as candidate cluster heads by turns in ELBUC; in the data transmission phase, it proposes a least energy consumption routing strategy, which comprehensively considers the candidate routing node’s energy and the number of its members, so that the cluster head which has fewer nodes in the cluster become the rely node. Simulation results show that ELBUC protocol not only significantly prolongs the lifetime of the network, but also effectively balance the energy consumption between nodes, and improve the network energy efficiency.

Introduction

Wireless sensor network (WSN) is a wireless ad-hoc network composed of a large number of inexpensive sensor nodes. It has the advantages of real time, low energy consumption, small size, self adaptation and so on. However, the energy supply by the micro battery, so the energy limited has become the biggest limit of Wireless Sensor Networks, in which data transmission is the largest part of the energy consumption. Therefore designing an energy efficient routing protocol can effectively prolong the network lifetime.

In recent years, lots of energy efficient clustering routing protocols have been proposed by scholars. In inter cluster communication phase, either directly or via a multihop path will inevitably produce "hot spots": if using single hop communication, due to long distance transmission, the cluster heads that are far from the Sink node will fail prematurely; when adopting multihop, the cluster heads which are close to Sink will die earlier because of need to assume more forwarding task. In order to solve the problem of "hot spots", Soro [1] put forward the idea of non uniform clustering for the first time, and proposed the unequal clustering size clustering algorithm (UCS). UCS balances the energy dissipation through controlling the size of the cluster, and this scheme can prolong the network lifetime. The energy-efficient uneven clustering [2] (EEUC) elects cluster heads through distributed, nodes generate the final cluster heads considering the competitive radius and residual energy. So that it can have different clusters in size, in which the clusters closer to BS have smaller size, and balances the energy in networks. The energy-balanced unequal clustering protocol [3] (EBUC) also is an energy efficient routing protocol by using the particle swarm optimization (PSO) algorithm, EBUC partitions all nodes into clusters of unequal size. But it will increase the communication
overhead and reduces the scalability of the network. The energy-balancing clustering approach for gradient-based routing [4] (EBCAG) generates the candidate cluster heads via the same threshold, and then creates gradient values according to the hops of candidate cluster heads to sink and figures out the competitive radius via gradient values, in the last selects the final cluster heads. In the inter-cluster communication, EBCAG through multi-hop communication, which can effectively prolong the network lifetime. The energy efficient data collection through hybrid unequal clustering [5] (HUCL) elects the cluster heads considering the remaining energy and membership number of candidate cluster heads and the distance to sink, so that the location of the cluster head is more reasonable. In the inter communication, HUCL divides the network into many layers and then transmits data to the next layer which is closer to BS.

In this paper, a mixed, unequal clustering routing protocol based on energy load balancing is proposed. In the cluster head selection phase, ELBUC is in order to avoid some nodes die earlier by turns to select candidate cluster heads; In the data transmission phase, it proposes a least energy cost routing strategy, which comprehensively considers the candidate node’s energy and the number of its members. Simulation results show that ELBUC protocol not only significantly prolongs the lifetime of the network, but also effectively improve the network energy efficiency.

The remainder of this paper is organized as follows: In Section II we introduce the EEUC algorithm briefly, and points out the shortcomings; In Section III we give a detailed description of the proposed clustering protocol; We present the simulation study of the proposed protocol in Section IV; Finally concludes the paper in Section V.

Problem Description

The EEUC Protocol

EEUC is an unequal clustering algorithm for WSN. It introduces uneven competition radius and then divides the whole networks into clusters with different sizes by which generate that the smaller the radius of the cluster near the base station, the more the number of clusters and make the energy of the cluster head that is close to BS mainly are used for data forwarding. In Reference [2] shows that, Compared with uniform clustering routing algorithm (e.g. LEACH, HEED protocol), EEUC protocol can effectively solve the “hot spots” problem and prolong the network’s survival time.

EEUC protocol is divided into clustering phase and data transmission phase. In the clustering stage, candidate cluster heads are generated in the whole network, each node generates a random number between 0 and 1; If the value is greater than the threshold value \( T \) (\( T \) is a preset value, \( T = 0.4 \) in EEUC), the node becomes the candidate cluster head, otherwise the node turn into sleep state until the end of the final cluster heads competition. At electing the final cluster heads, candidate cluster heads calculates its competitive radius \( s_j \), \( R_c \) is calculated by

\[
R_c = (1-c_j \frac{d_{max} - d(s_j, BS)}{d_{max} - d_{min}})R_{c0}
\]  
(1)
where \( s_j \) is the candidate cluster head, \( d_{\text{max}} \) and \( d_{\text{min}} \) are the maximum and minimum distance between the sink and nodes, \( c \) is the weighting factor, which can take a value between 0 and 1, \( R_c \) is the maximum competition radius, which is preset during network initialization.

The candidate cluster head generates its set of neighbor cluster heads according to its competitive radius, in which the highest energy node becomes the final cluster head. Ordinary nodes join the nearest cluster from their nearest distance. In the data transmission stage, EEUC protocol divides the data transmission into intra cluster communication and inter-cluster communication. Ordinary nodes deliver data to their cluster head, and the inter cluster communication through multihop routing. In multihop routing, EEUC algorithm selects two node whose energy cost is the smaller in the set of candidate routing nodes, then selects the highest energy node as the relay node, in which energy cost \( s_j \) is

\[
E_{\text{relay}} = d^2(s_i, s_j) + d^2(s_j, \text{BS})
\]  

where \( d^2(s_i, s_j) \) is the square of the distance between the cluster node \( s_i \) and the candidate relay node \( s_j \), \( d^2(s_j, \text{BS}) \) is the square of the distance between the cluster node \( s_j \) and Sink.

**Problem Description**

Compared with other protocols, the EEUC protocol can effectively prolong the network lifetime, however, there are still shortcomings:

1. The EEUC protocol does not take into account the frequency of the node becoming the cluster head in the clustering stage, which will lead to the imbalance of energy consumption among nodes. In each round, all nodes with the same probability \( T \) become candidate cluster heads, which will cause some nodes are frequently elected cluster heads and premature death.

2. In inter cluster multihop routing, the EEUC protocol selects the cluster head which is closer to the sink than itself to build the set of candidate routing nodes. However, it doesn't take into account the distance between its and Sink, which will lead unnecessary energy dissipation. if the following circumstances occur: \( d(s_i, \text{BS}) > TD_{\text{MAX}} \) and \( d(s_i, \text{BS}) < d(s_i, s_j) \), \( s_i \) will sent data to \( s_j \) according to the EEUC algorithm, where \( d(s_i, \text{BS}) \) is the distance between the cluster head \( s_i \) and Sink, \( d(s_i, s_j) \) is the distance between the cluster head \( s_i \) and \( s_j \).
$TD_{MAX}$ is the threshold between multihop and single hop. However, it will generate unnecessary energy dissipation, it is better that $s_i$ delivers data to Sink. As shown in Fig. 1.

(3) In inter cluster multihop routing in EEUC, the set of candidate routing nodes of the cluster head $s_i$, that is $s_i R_{CH}$ is

$$s_i R_{CH} = \{ s_j | d(s_j, BS) < d(s, BS), d(s_i, s_j) \leq k R_c(s_j) \}$$

(3) where $k$ is the smallest positive integer that guarantees $s_i R_{CH}$ is not empty. Eq.3 shows that the EEUC protocol only thinks source nodes as the center to search the next hop forwarding node, and not consider the overall network’s energy cost, it will produce too many transmission times. Reference [6] shows that under the same conditions, the more the number of multihop, the greater the overall energy consumption of the network. So that it can Effectively reduce energy consumption by reducing the number of times of data transmission.

(4) When selecting relay nodes, the EEUC protocol only considers the residual energy of the relay nodes, doesn’t take into account the relay nodes’ own load, which is easy to cause unbalance at energy consumption among cluster heads.

To optimize the problem of above, an uneven clustering routing algorithm based on load balancing is proposed. ELBUC algorithm can improve energy efficiency, and also prolong the network lifetime.

**The ELBUC Protocol**

**Network Model**

Let us consider the scenario that there are $N$ sensor nodes distributed uniformly in a two-dimensional region. Five assumptions are made for the sensor nodes and for the underlying network model.

(1) The sensor nodes and the Base Station are all stationary after deployment and the BS is deployed at a fixed location outside the sensing field.

(2) Sensor nodes are homogeneous and have same initial energy.

(3) Sensor nodes have power control capabilities to vary their transmitted power.

(4) Sensor nodes knows its own geographical information.

(5) Data fusion is used to reduce the total data message.

The radio model used in ELBUC is same as in [7]. The energy consumed to transmit $k$ bit data a distance $d$ is

$$E_{tx}(k,d) = k E_{tx\_elec} + k E_{amp} d^\beta$$

(4)

where $E_{tx\_elec}$ is the energy dissipated per bit to run the transmitter circuit, $E_{amp}$ is the energy dissipated per bit to run the transmit amplifier, $\beta$ is path loss and a constant. The energy cost of the receiver is given by:

$$E_{rx}(k,d) = k E_{rx\_elec}$$

(5)

where $E_{rx\_elec}$ is the energy dissipated per bit to run the receiver circuit and the energy consumption of fusing $k$ bit data is $E_{ag}(k) = k E_{ag}$. 

Cluster Head Selection Phase

In this phase, the ELBUC protocol selects candidate cluster nodes by turns, and then selects the final cluster heads based on the residual energy of candidate nodes. Set the number of sensors is $N$, the size of sensing area is $S$, from [5], there is at least one minimum competitive radius in the network, and there is only one final cluster head in the minimum competition radius. The minimum competitive radius is $R_{c_{\text{min}}} = (1 - c) \times R_{c_{0}}$, so that the number of final cluster nodes generated in each rounds is $S / (\pi R_{c_{\text{min}}}^2)$, and the maximum ratio of expected cluster heads to all nodes is

$$p_{\text{max}} = \frac{S / (\pi R_{c_{\text{min}}}^2)}{N}$$ \tag{6}$$

According to Eq.6 it can ensure that most of sensor nodes are selected as the final cluster heads per $1 / p_{\text{max}}$ rounds. so we can set the threshold $T(s_i)$ to decide node $s_i, 1 \cdots N$ to become the candidate cluster node or not. $T(s_i)$ is

$$T(s_i) = \begin{cases} 
1, & s_i \in G; (N - \sum_{i=0}^{(r-1)\mod(r_m)} m_i) > N \times P \\
0, & s_i \notin G \\
1 - \sum_{i=0}^{(r-1)\mod(r_m)} \frac{m_i}{N}, & s_i \in G; (N - \sum_{i=0}^{(r-1)\mod(r_m)} m_i) \leq N \times P 
\end{cases}$$ \tag{7}$$

where $p$ is the ratio of expected cluster heads to all nodes, $r_m = 1 / p_{\text{max}}$ is the maximum of cycle period of rounds, $m_i$ is the number of cluster heads at $(r - 1) \mod(r_m)$ round, let $m_0 = 0$, $r$ is the current round, $r \geq 1$, $G$ is set of nodes which didn’t $s_i$ become the final cluster head before $(r - 1) \mod(r_m)$, $s_i$ is sensor node. Eq.7 points out that once the sensor node is elected as the cluster head before $(r - 1) \mod(r_m)$, it will no longer participate in the selection of candidate cluster heads; Until $(r - 1) \mod(r_m) = 0$, all nodes will regain the opportunity to compete to being a candidate cluster. So that It can ensure that almost all nodes are elected as cluster head at the same frequency per $1 / p_{\text{max}}$, and avoid sensor nodes frequently elected as cluster head and premature death.

The ELBUC protocol adopts mixed election strategy: At the initial stage of each round, BS broadcasts a message which contains $T(s_i)$, TDMA and so on. And then the node which isn’t the final cluster head participates in the selection of cluster heads spontaneously. Finally cluster heads inform a message to BS, which contains the number of sensor nodes in the networks and the number of selected as cluster heads in current round through global broadcast. The details of cluster head elections are as follows.
(1) The sensor node that wasn’t selected as the cluster head before \((r-1) \mod (r_{m})\) receives the message form BS, and generates a random number \(u\) between 0 and 1; Otherwise the node go into sleep state and keep sleeping until the cluster head selection phase ends.

(2) If \(u < T(s_{i})\), the node becomes the tentative cluster head; Otherwise the node go into sleep state. And then each tentative cluster head broadcasts a COMPETE_HEAD_MSG which contains its ID, residual energy and competitive radius \(R_{c}\). The broadcast radius of every control message is \(R_{c0}\) in this phase.

(3) The tentative cluster head \(s_{j}\) constructs the set of adjacent tentative cluster heads after receiving the control messages, \(s_{j}, S_{CH}\) is calculated using

\[
s_{j}, S_{CH} = \{ s_{k} \mid s_{k} \in \text{tentative CHs}, d(s_{j}, s_{k}) \leq \max(R_{c}(s_{j}), R_{c}(s_{k}))\}
\]

(4) Tentative cluster heads compare with their adjacent tentative cluster heads in terms of residual energy. Once \(s_{j}\) finds that its residual energy is more than all nodes in its set \(s_{j}, S_{CH}\), it will win the competition and broadcast a FINAL_HEAD_MSG to inform its adjacent tentative cluster heads.

(5) If the residual energy of the tentative cluster head \(s_{j}\) isn’t the largest in its set \(s_{j}, S_{CH}\), it needs to wait for other tentative cluster heads whose residual energy is larger than \(s_{j}\) to make decisions: if the tentative cluster head \(s_{j}\) receives a FINAL_HEAD_MSG from an adjacent tentative cluster head in \(s_{j}, S_{CH}\), it will give up the competition and inform all its adjacent tentative cluster heads by broadcasting a Quit_Election_MSG; If \(s_{j}\) receives a Quit_Election_MSG from an adjacent tentative cluster head in \(s_{j}, S_{CH}\), it will remove this adjacent tentative cluster head from \(s_{j}, S_{CH}\) and then return to 4. This procedure will continue until all cluster heads have been selected.

**Cluster Formation Phase**

In cluster formation phase, all sleeping nodes wake up and each cluster head inform a message named CH_FINAL_MSG to all sensors through global broadcasting, then each non-cluster head node chooses its own cluster head base on the least communication cost, which can be obtained from the largest received signal strength, and sends a JoinCluster_msg to inform its cluster head. Finally, each cluster head inform a message to all nodes and BS, which contains TDMA schedule, the number of sensor nodes of network and cluster heads in current round.

**Data Transmission Phase**

The ELBUC protocol divides the data transmission phase into the intra cluster data transmission phase and the inter cluster data transmission phase. In the intra cluster data transmission, a non cluster head node deliver data to its cluster head at a specific time slot. The cluster head aggregates these data gathered from its members into a single length-fixed packet.

In the inter-cluster data transmission phase, Cluster heads sends the packet to the BS via multihop communication. The ELBUC protocol adopts a least energy consumption routing algorithm. as follows is the reasoning process.
Reference [8] shows that in case of the distance between the cluster head \( s \) and BS is \( D \), data deliver to BS trough \( k \) hops, when the distance of one hop \( d_{\text{hop}} \) is same, the total energy consumption of communication \( E_{\text{total}} \) is minimum. The function about \( E_{\text{total}} \) and \( E_{\text{total}} \) can be given by

\[
E_{\text{total}} = \frac{(k-1)lE_{\text{rx_elec}} + kl(E_{\text{tx_elec}} + E_{\text{amp}} \frac{D}{k})^\beta}{k}
\]

\[
= (\text{ceil}(\frac{D}{d_{\text{hop}}}) - 1)lE_{\text{rx_elec}} + \text{ceil}(\frac{D}{d_{\text{hop}}})(l(E_{\text{tx_elec}} + E_{\text{amp}}d_{\text{hop}}^\beta))
\]

where \( l \) is the packet size, and then we can use this formula to get the derivation of \( d_{\text{hop}} \).

\[
\frac{\partial E_{\text{total}}}{\partial d_{\text{hop}}} = D(l(\beta - 1)E_{\text{amp}}d_{\text{hop}}^{\beta - 2} - \text{ceil}(\frac{D}{d_{\text{hop}}})(l(E_{\text{tx_elec}} + E_{\text{rx_elec}}))
\]

Let \( \frac{\partial E_{\text{total}}}{\partial d_{\text{hop}}} = 0 \), by applying Eq.11, \( d_{\text{best hop}} \) is calculated,

\[
d_{\text{best hop}} = \frac{\beta l(E_{\text{tx_elec}} + E_{\text{rx_elec}})}{(\beta - 1)E_{\text{amp}}}
\]

(11)

From Eq.11, we can find that under the condition of the communication cost is minimum, it can get an optimal one hop distance \( d_{\text{best hop}} \), and the value of \( d_{\text{best hop}} \) has nothing to do with \( D \), only and related with the physical characteristic parameters of transceiver circuit and amplifier circuit. So that once the node position is determined, the optimal hop count of the node can be determined, \( k_{\text{best}} = \text{ceil}(D/d_{\text{best hop}}) \). And so on, there are multiple node data transmission in the networks, if adopting the optimal one hop \( d_{\text{best hop}} \) forwarding, the communication cost \( E_{\text{total}} \) is the lowest.

The minimum energy consumption path of a cluster head deliver data to BS as shown in Fig.2. node A, B and BS forms the optimal transmission path. However, owing to the randomness of cluster head election and the location of cluster head is uncertain, the ideal path does not necessarily exist in practical applications. But we can build the multihop routing according to the optimal path.

The detailed procedure of the inter-cluster multihop routing is as follow.

(1) Set threshold \( d_{\text{best hop}} \). Once \( d(s_i, BS) \leq d_{\text{best hop}} \), the cluster head deliver data to BS; Otherwise the cluster head deliver data to BS via multihop communication.

(2) The cluster \( s_i \) constructs the set of candidate relay nodes \( s_i \cdot R_{CH} \). \( s_i \cdot R_{CH} \) can be given by

\[
s_i \cdot R_{CH} = \{ s_j | s_j \in CHs, d(s_j, BS) < d(s_j, BS), d(s_j, s_{io}) < d_{\text{best hop}} \}
\]

(12)

where \( s_{io} \) is the ideal location of the next hop of the cluster node \( s_i \), the point B as shown in Fig.2, because the coordinate of \( s_i \) and BS and \( d_{\text{best hop}} \) are known, the \( s_{io} \) also can be given. According to Eq.12 can ensure that the cost is minimum.
(3) Then we define a weight of each candidate relay node, \( W_j(s_j) \). Only considering the communication cost of the whole network, ignoring the residual energy and the internal load of relay nodes, it will cause energy consumption among clusters imbalanced. So we consider the residual energy and the internal load of relay nodes as shown in Fig.3. The \( W_j(s_j) \) is defined as:

\[
W_j(s_j) = \frac{E_{res}(s_j)}{E_{average}(s_j,R_{CH})} \cdot \frac{n_{average}(s_j,R_{CH})}{n(s_j)}
\]

where \( E_{res}(s_j) \) is the residual energy of the candidate relay node \( s_j \), \( E_{average}(s_j,R_{CH}) \) is the average energy in \( s_j,R_{CH} \), \( n_{average}(s_j,R_{CH}) \) is the average number in \( s_j,R_{CH} \), \( n(s_j) \) is the number of \( s_j \). According to Eq.13, the cluster head \( s_i \) selects two nodes whose value of \( d(s_j,s_{io}) \) is smaller than others in \( s_i,R_{CH} \). Finally the node \( W_j(s_j) \) which is minimum become the relay node of \( s_j \).

![Figure 2. The Optimal Energy Consumption Path.](image)

![Figure 3. The Unbalanced Energy Consumption Topology.](image)

(4) Then we find out the distance between \( s_i \) and BS, \( d(s_i,BS) \). Once \( d(s_i,BS) > d_{best\ hop} \), \( d(s_i,s_j) \geq d(s_i,BS) \), \( s_i \) delivers data to BS; Otherwise \( s_i \) delivers data to the relay node \( s_j \).

(5) Return to 1 until all data are sent to BS.

**Protocol Analysis**

The message complexity of ELBUC is discussed in this part.

Let \( N \) be the number of sensor nodes in the network, from Eq.7 we can get that the number of tentative cluster head nodes for a round is \( T(s_i) \times N \). At the beginning of the cluster head selection phase, \( T(s_i) \times N \) tentative cluster heads are produced and each of them broadcasts a COMPETE_HEAD_MSG, and then each of them makes a decision by broadcasting a FINAL_HEAD_MSG to act as a final cluster head, or a Quit_Election_MSG to act as an ordinary node. Suppose \( m \) final cluster heads are selected, the final cluster heads send out \( m \) CH_FINAL_MSG, and then \( N-m \) ordinary nodes transmit \( N-m \) JoinClustermsgs. the message complexity is \( N \times T(s_i) + N \times T(s_i) + m + (N-m) = (2T(s_i)+1)N \), that is \( o(N) \).
Simulations and Analysis

The simulation tool is MATLAB. And parameters, including network lifetime, cluster head distribution, the energy of communication, Error-free communication links and ideal MAC were assumed for the simulation. Data fusion occurs only in cluster head. 100 nodes are distributed in a rectangular area of 200*200, the initial energy of nodes is 0.5J, the location of BS is (100, 250). The detail simulation parameters as shown in Table 1.

Table 1. Simulation Parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data packet size</td>
<td>4000 bytes</td>
<td>$E_{sig}$</td>
<td>5nJ/ (bit • signal)</td>
</tr>
<tr>
<td>Control packet size</td>
<td>100 bytes</td>
<td>$R_{c0}$</td>
<td>90m</td>
</tr>
<tr>
<td>$E_{rx} = E_{tx}$</td>
<td>50nJ/ bit</td>
<td>$\beta$</td>
<td>2</td>
</tr>
<tr>
<td>$E_{amp}$</td>
<td>10pJ/ (bit • m^2)</td>
<td>$c$</td>
<td>0.5</td>
</tr>
</tbody>
</table>

The Election of Ratio of Cluster Heads $p$

From section III we can know that the message complexity of ELBUC protocol depends on $p$. First, we analyzes the relationship between $p$ and the network lifetime. Fig.4 shows that the network lifetime is the maximum in the case of the ratio $p = 0.4$. In addition, we analyzes the relationship between $p$ and the number of cluster number. Fig.5 shows that the number of cluster heads in the first 15 rounds with different value of the ratio $p$, in which the simulation value is got its mean from 500 simulation experiments. Fig.5 shows that the smaller the value $p$, the greater of change of the number of cluster heads between round and round, that will cause energy consumption among nodes uneven. And the number of cluster heads each round will tend to be stable in the case of $p \geq 0.4$.

The simulation results show that ELBUC protocol can generate a stable number of cluster heads each round, and the network lifetime is the longest in the case of the ratio $p = 0.4$.
Network Energy Efficiency

Fig.6 depicts that the network survival time of EEUC protocol and ELBUC protocol with change of time (rounds). From Fig.6 shows that the time of first dead node of EEUC and ELBUC protocol are 541 and 685; the time of half dead nodes of EEUC and ELBUC protocol are 827 and 875; the time which all nodes is dead of EEUC and ELBUC protocol are 901 and 957. No matter from which angle analysis, the network survival time of ELBUC protocol is longer than the EEUC. The simulation results show that ELBUC protocol can effectively prolong the network lifetime.

Reference [9] defines the energy efficiency which is the ratio of the first node's death time and the total time which all nodes to death, and the greater the ratio, the more balanced the energy consumption of nodes, the higher the energy efficiency of the network. According to Fig.6, the energy efficiency of EEUC protocol and ELBUC protocol are 59.8% and 71.6%. The results show that ELBUC protocol not only significantly prolongs the lifetime of the network, but also can effectively balance the energy consumption among nodes, and the energy efficiency of the network is higher than EEUC.

![Figure 6. The Network Survive time in Various Protocols.](image1)

![Figure 7. The Network Survive time in Various Protocols.](image2)

Extended Performance of Network

At last, this paper analyzes the network survival time with the change of the number of nodes. Fig.7 depicts that the first dead node time with the change of the number of nodes. It shows that the network lifetime increased with the increase of the number of nodes of the EEUC protocol and ELBUC protocol, in addition, at the same number of nodes, the network lifetime of the ELBUC protocol is longer than the EEUC.

The simulation results show that the network lifetime of ELBUC protocol increases with the increase of the number of nodes in the network, which is suitable for large scale network model.
Summary

In this paper, in order to improve the network lifetime and energy efficiency, we propose an uneven clustering routing protocol based on energy load balancing (ELBUC) for WSN. In the cluster head selection stage, ELBUC is in order to avoid some nodes die earlier by turns to select candidate cluster heads; in the data transmission phase, it proposes a minimum energy consumption routing strategy. Simulation results show that the ELBUC protocol can not only significantly prolong the network lifetime, but also can effectively balance the energy consumption among nodes. In addition, the scalable performance is better, which is suitable for large scale network model.

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