EESA Algorithm in Wireless Sensor Networks

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Abstract—Since there are many problems of traditional extended clustering algorithm in wireless sensor network like short extended time, over energy consumption, too many deviated position the of cluster head nodes and so on, this paper proposes the EESA algorithm. The algorithm makes many improvements on the way of dividing clusters, strategy of electing the cluster head and construction method of data relay path, the two aspects of inter-cluster energy balance and energy balance among the cluster are taken into account at the same time. Detailed simulation results are taken in this thesis to compare network lifetime, average residual energy, energy consumption standard deviation of cluster head node and changes of average remaining energy between the EESA algorithm and ACT algorithm, EECA algorithm and MR-LEACH algorithm; the simulation results show that: the proposed algorithm reduces the load of hot regional cluster head, balances the energy consumption of the entire network nodes and extends the networks lifetime of wireless sensor.

Index Terms—Distributed Management; Energy Consumption; Cluster Head; Residual Energy

I. INTRODUCTION

In recent years, wireless sensor network is widely used in network manufacturing remote monitoring and other areas, showing a great value has caused many countries military, industry and academia of great concern. Since 2000, the international community has been found in some of the wireless sensor network research reports; Natural Science Foundation of the United States in 2003 developed a wireless sensor network research program in supporting the underlying theory [1-2]; Natural Science Foundation of the United States, driven by the U.S. University of California, Berkeley, Cornell University and other research institutions began a wireless sensor network theory and key technology research. U.S. Department of Defense and the military departments attach great importance to the wireless sensor networks, regarded as an important area of research, and the establishment of a series of military sensor network research projects. From the emergence of wireless sensor networks so far has been developed from the initial node, network protocol design, developed to a smart group research phase and abroad has become a hot new IT technologies, attracting a large number of scholars have launched a wide range of research, and have made some progress (including a large number of nodes in a large number of platforms and communication protocols). However, has not yet formed a complete system of theory and technology to support the development of this emerging field, there are numerous issues to be science and technology breakthroughs, the information field is facing a very challenging task [3].

Wireless sensor networks (WSN) has been widely used in civil and military fields, such as smart home, bio-medical, environmental monitoring, machinery manufacturing and space exploration and so on. In recent years, with the sensor node integration and miniaturization, the node's power limited battery energy is mostly used [4]. As nodes are usually located in uninhabited areas or hazardous environments, it is difficult to carry out energy supplies, while renewable energy technology is not yet mature, so by optimizing energy consumption, maximizing network lifetime of wireless sensor networks becomes primary challenge.

In the application of wireless sensor network, the location information is an indispensable part the node data collection; monitoring information without location information is usually meaningless. Determine the event occurs the location or acquiring data of the node position yes wireless sensor network the most basic one of the functions. In order to providing effective position information, the random layout of the sensor nodes in a network deployment after completion is able to determine their own location. Because node exists to limited resources, randomly deployed, communications vulnerable to environmental disturb or even node failure and other characteristics, wireless sensor network's node localization mechanisms must satisfy the self-organization Xing, robustness, energy efficient, distributed computing and other requirements.

Clustering for wireless sensor networks provides an efficient distributed management framework, and its advantage is easing of management, enhanced network scalability, and easy to implement data aggregation. In combination ambush mode, a network connection between the cluster head backbone of the data within the cluster aggregation processing will relay it to the base station [5-7]. However, from the base station closer to the cluster head node relay task often due to overweight and premature deaths, resulting in the "energy hole" appears. LEACH (low-energy adaptive clustering hierarchy) is the first to propose clustering protocol, using equal probability random cluster head selection round robin fashion. But LEACH does not consider the following questions: 1) All cluster heads are to transfer data directly to the base station, no data transfer phase for good optimization; 2) Cluster heads are chosen randomly, can not guarantee its uniform distribution in the network. Since people in the LEACH protocol based on improved to further reduce energy consumption MR-LEACH...
(Combination ambush routing with low energy adaptive clustering hierarchy) is a typical improved protocol [8-10]. MR-LEACH based on the residual energy of the node to select the cluster head, while using combination ambush relay transmission mode data to the base station. However, the algorithm does not consider the establishment of relay path all cluster heads load balanced, high-rise cluster head based only on the base station broadcast control packets to determine which relay node [11-13]. This causes some nodes premature deaths due to excessive consumption, thereby affecting the network lifetime. C. Sha other design an energy efficient clustering algorithm EECA (energy efficient clustering algorithm), by optimizing the use of cluster head election strategy and build value function to determine the right way to relay path prolong the network lifetime [14-17]. However, this method can not relay path establishment alleviate hot spots cluster head load “energy hole” appears still affect the network lifetime.

W.K. Lai proposed an ACT (Arranging cluster sizes and transmission ranges for wireless sensor networks) protocol, the cluster head by calculating the amount of energy consumed to determine the cluster radius, then the ideal location for election cluster head node [17-19]. Meanwhile, according to the principle of the relay load equal allocation construct data aggregation tree. However, the following deficiencies exist ACT: 1) With time, the cluster head node will gradually deviate from the ideal position, can not continue to maintain the optimality; 2) From the base station closer to the cluster head still bear heavier loads, the "energy hole" the problem is not solved.

In this paper, the inherent characteristics of the wireless sensor networks have the advantages and disadvantages of the above algorithm, an improved energy efficient data aggregation algorithm EESA (Energy-efficient separating algorithm). This paper divided in cluster mode, the cluster head election strategy and data relay path construction method has been improved, taking into account inter-cluster energy consumption and the cluster head node is too large too wireless sensor networks to extend a short time, energy consumption standard deviation and average remaining energy changes in other aspects of the simulation were compared in detail experiments using network simulator Omnet + + proceed. MAC layer assumes the ideal and the communication link is correct. Experiments carried out in the steady state. The simulation results show that: EESA algorithm can effectively avoid the energy hole problem and reduce the energy consumption of the entire sensor network, thereby prolonging the network lifetime.

II. ENERGY MODEL

Consider an area of L × W rectangular sensor network (L and W denote the length and width of the sensing region), N evenly distributed sensor nodes in the area.

A. Hypothesis

(a) Base station and the location of sensor nodes are fixed. All nodes are uniformly distributed density ρ in this region, and through the exchange of information to identify itself and a base station location.

(b) Each node has a unique identifier (ID). The same initial energy of all nodes and transmission are energy controllable. The highest energy level state, the node may communicate directly with the base station.

(c) Links are symmetrical. If the transmission power is known, the node according to the received signals strength to estimate the distance to another node.

(d) All nodes with the same fixed rate sensing and continuously send data to the user, which is equal to the length of each data packet.

B. Energy Model

Energy consumption is calculated using the classical model. A 1-bit message transmission the energy consumption of the distance d:

\[ E_d(r,s) = \begin{cases} 1 \times E_{\text{dev}} + 1 \times E_{\text{fc}} \times d^2, & d < d_0 \\ 1 \times E_{\text{dev}} + 1 \times E_{\text{amp}} \times d^2, & d \geq d_0 \end{cases} \]

where in, \( E_{\text{dev}} \) means to transmit or receive data bit energy consumption; \( f_r \) and \( f_s \) denote the sender and the receiver determined by the distance between the amplification different 1-bit data of the energy consumption. If the distance is less than a threshold value \( d_0 \), using free-space model (\( f_r \)); Otherwise, the multipath model (mp).

Receiving the message the energy consumption:

\[ E_r(l) = 1 \times E_{\text{dev}} \]

Polymerizing the energy consumed messages:

\[ E_p(r,l) = 1 \times E_{\text{agg}} \]

where in, \( E_{\text{agg}} \) polymerized for 1-bit data represents the energy consumed. EMAX represents a threshold residual energy. If a node residual energy is less than this value, it
will give up running cluster head node. According to
equation (1) - (3) can be obtained EMAX values:
\[ E_{\text{max}} = (\beta \times \gamma E_{\text{elec}} + (\lambda - 1) E_{\text{agg}} + (1 - \theta)(\lambda + 1)(E_{\text{elec}} + \varepsilon_p d^2)) \]
where in said number of times to obtain data for each
round; \( \theta \) indicates the aggregation data compression ratio;
d represents the current processing node and its next hop
distance between nodes; \( \lambda \) represents the number of
neighbors of a node.

III. EESA ALGORITHM

Various extension cycle operations by wireless sensor
network life cycle saving algorithm are essentially
minimize system energy loss, while the energy
consumption evenly distributed to each node. In
clustering wireless sensor networks, energy imbalance is
mainly reflected in two aspects: First, the use of
combination ambush transmission mode, different cluster
head to the base station due to the different distances
ranging from energy consumption, namely the
inter-cluster energy imbalance; Second, the cluster head
because of the need to complete more than the cluster
members work and consume more energy, that energy is
not balanced cluster problem. But it is just an ordinary
cluster head sensor nodes, limited energy, the cluster
head will inevitably lead to premature deaths network
time shortened. Therefore, to reduce the energy
consumption of the cluster head node, ensure that the
entire network node energy balance is the key to extend
the network lifetime. Therefore, this paper made some
improvements mainly from the energy balance of
departure.

A. Improved Clustering Methods

The basic division of cluster clustering algorithm does
not consider the energy consumption can be divided into
homogeneous and heterogeneous clustering into two
categories. EESA energy consumption from the
perspective of the clustering method has been improved.

\[ \begin{align*}
\text{The base station} & \\
\text{The first layer} & \\
\text{The second layer} & \\
\text{Y layer} & \\
\end{align*} \]

Y assumes an experimental network has clusters of
various sizes layer (1) and the members of each cluster to
the cluster head node transfer 1 bit of data. To facilitate
the calculation, we will be in two different levels of the
transmission distance between clusters as the sum of their
radii (except for the first layer). That is, Y to Y-1 layer
transmission distance layer (\( r_y + r_{y-1} \)), Y-1 Y-2 layer to
the distance of the transmission layer (\( r_y - 1 + r_{y-2} \)), etc.
(Figure 2). Since the outermost layer (first layer Y) relay
cluster head node is not only responsible for handling this
task cluster node transmits data, it is total energy
consumption can be expressed as:
\[ \pi_{r_y,1}^2 r E_{\text{elec}} + \pi_{r_y,1}^2 r E_{\text{agg}} + (1 - \phi) \pi_{r_y,1}^2 r E_{\text{elec}} + \varepsilon_p (t_y + f_{y-1})^2 \]

The first represents the cluster head node to receive the
members of the cluster node to send energy consumption
data; second represents the energy consumption for data
aggregation; third portion represents the processed data
transmitted from the Y layer to the first layer, Y-1 energy
cost. Since the first Y-1 layer only to consider
the cluster head node within the cluster node transmits the
data, but also on the trunk of the Y layer data processing,
their total energy consumption can be expressed as:
\[ \pi_{r_y,2}^2 r E_{\text{elec}} + \pi_{r_y,2}^2 r E_{\text{agg}} + (1 - \phi) \pi_{r_y,2}^2 r E_{\text{agg}} + (1 - \phi)^2 \]

Similarly, the first Y-2 layer to simultaneously cluster
head node of the cluster and the relay Y-1 of the first
layer of the data processing, the total energy consumption
can be expressed as:
\[ \pi_{r_y,3}^2 r E_{\text{elec}} + \pi_{r_y,3}^2 r E_{\text{agg}} + (1 - \phi) \pi_{r_y,3}^2 r E_{\text{agg}} + (1 - \phi)^2 \]

In this way, the cluster head node of each layer of the
total energy consumption can be calculated by the
following formula:
\[ \begin{align*}
\pi_{r_y,1}^2 r E_{\text{elec}} + \pi_{r_y,1}^2 r E_{\text{agg}} + (1 - \phi) \pi_{r_y,1}^2 r E_{\text{elec}} + \varepsilon_p (t_y + f_{y-1})^2 & \\
\pi_{r_y,2}^2 r E_{\text{elec}} + \pi_{r_y,2}^2 r E_{\text{agg}} + (1 - \phi) \pi_{r_y,2}^2 r E_{\text{agg}} + (1 - \phi)^2 & \\
\pi_{r_y,3}^2 r E_{\text{elec}} + \pi_{r_y,3}^2 r E_{\text{agg}} + (1 - \phi) \pi_{r_y,3}^2 r E_{\text{agg}} + (1 - \phi)^2 & \\
\vdots & \\
\end{align*} \]

where \( r_1, r_2, ..., r_y \), respectively from the first layer, the
second layer, the Y-radius of the cluster layer; \( r \)
represents the first layer to the base station transmission
distance (see Equation (12)); \( E_{\text{elec}}(1 \leq i \leq y) \) represents
the \( i \) layer cluster head node energy consumption.

As each layer is assumed cluster head energy
consumption are almost equal, we can use the following
formula to calculate the radius of each layer of the cluster:

\[ E_i \cong E_j \cong E_y \]

\[ t_i + t_x + \ldots + t_y = \frac{\mu}{2} \]  \quad (9)

According to equation (8) - (9), the calculated radius of all clusters, the cluster division is completed.

Figure 2. Calculating the radius of FIG Group 2

B. Improved Cluster Head Election Strategy

In order to reduce the load on the cluster head, unlike the previous single cluster head election strategy, EESA elections simultaneously two different nodes - processing nodes and forwarding node as the cluster head node (Figure 3). By separating the task, the task of a single cluster head node is assigned to two finish to reduce cluster head nodes and the cluster members within the energy poor. After the election, combined with the 3.1 calculated cluster radius, the completion of the formation of clusters.

Figure 3. Family head node election

1) Handling and Forwarding Node Election

In the beginning of each round, each node in the communication within a radius of broadcast basic message \( E - M_{xy} \) (IDs, \( e_x, L (x, y) \)). \( E_{rs} \) and L \( (x, y) \) denote the residual energy of the node \( s \) and location. All at the broadcast source within a radius of nodes are considered neighbors, and after receiving the broadcast message updates its neighbor table. Each of the remaining energy is greater than EMAX nodes have the opportunity to participate in the election and become the candidate nodes, assuming that the proportion of the candidate node \( p_r \). Case in layer \( j \) (\( 1 \leq j \leq Y \)), cluster head election process is as follows:

Each candidate node \( s \) will be based on the updated information table to calculate the communication of all neighbors within a radius of the average residual energy \( E_{rs} \):

\[ E_{rs} = \sum_{i=1}^{\chi} \frac{E_{rs}}{\gamma} \]  \quad (10)

\( S \) and its neighbors average communication distance between nodes can be expressed as:

\[ t_s = \sum_{r=1, r_{\text{rsn}}}^{\chi} \frac{t_s}{\lambda} \]  \quad (11)

\( D_{sm} \) to represent a node distance between \( s \) and \( m \), then:

\[ D_{sm} = \sqrt{(x_s - x_m)^2 + (t_s - t_m)^2} \]  \quad (12)

Taking into account the residual energy and distances were applied each candidate node equations (13) and (14) to calculate the processing nodes and forwarding node competitive index value:

\[ PR_s = \sigma \frac{E_{rs}}{E_{rs}} + \lambda \frac{1}{t_s} \]  \quad (13)

\[ PR_s = \lambda \frac{E_{rs}}{E_{rs}} + \lambda \frac{t_x + t_y}{r(t, m^w)} \]  \quad (14)

where \( \mu \) and the value are determined by the distribution of nodes within a cluster and the residual energy situation decision, \( d (s, BS) \) indicates that the node \( s \) and the distance between the base station. Then, the candidate node in the communication message broadcasting competition radius:

\[ \text{Com}_r \text{Pr}_o (ID_s, E_{rs}, CLP_s, CLF_s) \]

Broadcast is completed, all of the candidate nodes are converted to receive state and waiting time \( T \). Set the minimum length of \( T \) to ensure that all nodes can be received from the neighbor nodes competing messages. After each candidate node it and the receives index value comparison competition. CLP node with the largest value will be successfully elected to processing nodes, and the maximum value of the CLF has been elected as a forwarding node. If two or CLF CLP equal the highest index value, with the larger residual energy of nodes elected. If a candidate node CLP and CLF also have the highest index value, which will act as both the processing nodes and forwarding nodes both roles.

2) Cluster Formation

According to result of the comparison processing nodes run successfully in its communication radius node broadcasts the campaign success message \( S_{rs} - p_{rs} \) (IDs, \( E_{rs}, L(x, y) \)), the remaining nodes then waits to receive the message. Once a candidate node receives one or more
of the campaign a success message, it will give up to continue to compete and send join messages $\text{Join}_P_n$ (IDs, $E_{rs}, L \ (x, y)$) to the maximum received signal strength broadcast nodes. Because only responsible for forwarding node forwards the processed data, so no election broadcast to its entire neighbor success message. It will only win the election messages to join the cluster data packet message, and sends it to the same cluster of processing nodes (forwarding node and the processing node if the same node, this step is omitted). Therefore, compared with the existing algorithms, this paper proposes a new algorithm does not increase the load more messages. Thereafter, the processing node for all cluster members assigned TDMA slots.

3) Data Aggregation Tree Construction

In the data aggregation tree construction process, EESA select from the current forwarding node nearest two lower processing nodes as a candidate relay node and the residual energy of candidate nodes and forwarding this data needs to compare the energy consumption, according to the comparison results to determine relay node. With the first layer and the second layer $q \ p (1 \leq p < q \leq y)$ as an example, assume that a cluster layer $q \ u$, it is forwarded to the p-layer node selected as a relay node of a processing node. Assume that v and p layers cluster $u \ w$ is from two recent clusters. According to equation (1), $CLPu$ packet can be calculated are sent to it and $CLPw CLPv$ consumed energy difference:

$$\Delta E = E_P - E_w$$

(16)

The formula represents clusters $u \ k, u$ amount of data sent. Also, calculate the remaining nodes CLPV and CLPW energy difference:

$$\Delta E = E_v - E_w$$

(15)

The simulation results by the network emulator $O_{new}$ experimentally derived. MAC layer assumes the ideal and the communication link is correct. Experiments carried out in the steady state, simulation parameters as shown in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node Number</td>
<td>99</td>
</tr>
<tr>
<td>Network Range (Square Meter)</td>
<td>41.52</td>
</tr>
<tr>
<td>Initial Energy Of Nodes (Joule)</td>
<td>2.2</td>
</tr>
<tr>
<td>The Candidate Notes Proportion p</td>
<td>0.32</td>
</tr>
<tr>
<td>$E_{num} (10^4 \text{Joule} / \text{Bit})$</td>
<td>51</td>
</tr>
<tr>
<td>$\epsilon_n (10^4 \text{Joule} / \text{Bit} / \text{Square Meter})$</td>
<td>10</td>
</tr>
<tr>
<td>$d_n / \text{Meter}$</td>
<td>102</td>
</tr>
<tr>
<td>$E_{sys} (10^4 \text{Joule} / \text{Bit} / \text{Meter} / \text{sign})$</td>
<td>6</td>
</tr>
<tr>
<td>Data gram Length (Bit)</td>
<td>502</td>
</tr>
</tbody>
</table>

B. Experimental Results and Analysis

1) Network Life

Several different algorithms applied network life curves shown in Figure 5. As can be seen from the figure, the use of network EESA has the longest life. MR-LEACH based only on the residual energy of the node to select cluster head, EEECA cluster head at the same time in the choice of the reference node residual energy and communication distance and other factors. However, since no combination ambush communication between the two modes of energy consumption imbalance cluster head to make improvements, some cluster head node premature death led to the shortening of the life of the network. ACT according to energy consumption for each cluster head to be adjusted for the size of the cluster, but there are also energy whole problem. Meanwhile, as time progresses, the resulting cluster head node election will gradually deviates from the ideal position so that the cluster head and the cluster members difference between a rapid increase in energy consumption. The EEECA calculating the energy consumption among clusters determines the cluster, while using mission critical node separation method to reduce energy consumption, thereby
prolonging the network lifetime. Thus, EESA algorithm can balance between the energy consumption of the node, to improve the lifetime of sensor networks is important.

2) Average Remaining Energy

Figure 6 shows the four algorithms average remaining energy of the nodes. Obviously, EESA algorithm is better control of energy consumption of nodes. MR-LEACH, EECA and ACT have adopted a combination ambush communication model, the residual energy difference lies in their cluster head election and data aggregation tree was constructed in different ways. In each one cluster head election, MR-LEACH directly specify the maximum residual energy of cluster head node by the base station to determine the next hop for each cluster head node. EECA cluster head in the election at the same time taking into account the remaining energy and communication distance on two factors, and by constructing an association formed by these two factors, the weights for each cluster head function to select the optimal relay node. ACT according to each cluster head to calculate the amount of energy cluster radius, then the election closest to the ideal location node as the cluster head. Meanwhile, according to the principle of the relay load it has the equal allocation to construct data aggregation tree. Thus, MR-LEACH due to the lack of full consideration of factors which led to excessive energy consumption; EECA no right to make any improvements hot issues, energy hole still exists; while the ACT will be running late because the selected cluster head nodes far from an ideal location resulting increase in energy consumption. EESA improved from three hot issues: First, according to the cluster head to calculate the total energy equal to the radius of the cluster, reaching the inter-cluster energy balance; Second, while elections two nodes are used to complete the work of a single cluster head, By separating the task slowed key nodes within the cluster energy consumption; Third, by calculating the difference ΔE-ΔET to construct data aggregation tree, to achieve a balance of total energy consumption across the network. Therefore, EESA has the highest energy utility and maximum residual energy.

3) The Cluster Head Node Energy Consumption Standard Deviation

Shown in Figure 7, the cluster head election and bear the load of different cluster head node energy consumption standard deviation is also showing irregular shocks. In the cluster head election process, MR-LEACH only consider the node residual energy, EECA algorithm design also refer to the node's residual energy and communication distance of these two factors. In the combination ambush communication mode, each cluster head due to load a different type of energy consumed. Therefore, MR-LEACH and EECA algorithm curve fluctuations, the cluster head node energy consumption are not balanced. ACT cluster head according to the energy consumption to calculate the cluster radius, to a certain extent, reduce the hot issue. Meanwhile, post-maintenance using cross-layer data transfer mode also allows different levels of cluster head is located has the similar energy consumption. Therefore, ACT algorithms curve is relatively stable. As can be seen from the figure, EESA has the most stable curve algorithm. This is because the EESA using load balancing cluster head idea to reduce hot spots, while the task of separating the cluster head reduces the energy consumption of key nodes within the cluster, avoiding the energy difference between the larger nodes.

4) Average Remaining Energy Changes

Figure 8 shows the average of the remaining nodes in the network the energy curve. In this paper, the average residual energy of nodes to measure the change in the equilibrium level of consumption of several algorithms. The smaller the average remaining energy changes that the more balanced energy consumption. As can be seen from Figure 8, with the other three algorithms, EESA average remaining energy change is small, that is to get more balanced energy consumption. This is because, when using EECA, ACT, and MR-LEACH three algorithms, the “energy hole” problem evident from the
base station closer to the cluster head node often due to overloading of death before the other nodes, resulting in the average residual energy curve shocks. The EESA from both inter-cluster and cluster perspective consider the energy balance, effectively easing the “energy whole” effect and the average change in the minimum residual energy.

![Graph of energy changes](image)

Figure 8. Average remaining energy changes

V. CONCLUSION

Reduce energy consumption of wireless sensor networks is a fundamental problem. In this paper, clustering in wireless sensor network energy consumption imbalance problem, we propose a new and improved algorithm EESA. The algorithm respectively between the clusters and the cluster from the perspective of energy balance considerations, the basic methods and clustering in cluster head election strategy was improved. Energy consumption according to the network topology and the way to solve the clustered combination ambush mode cluster head due to the load caused by the different amount of energy consumption of different problems to achieve a balanced energy consumption among clusters. Meanwhile, the task separation method effectively reduces the energy consumption of key nodes within the cluster, making all nodes in the network tends to balance energy consumption. Simulation results show that the algorithm can effectively improve the energy efficiency of WSN and extend the network lifetime.

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