
A Load Balance Routing Algorithm Based on Uneven Clustering

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Abstract

Aiming at the problem of uneven load in clustering Wireless Sensor Network (WSN), a kind of load balance routing algorithm based on uneven clustering is proposed to do uneven clustering and calculate optimal number of clustering. This algorithm prevents the number of common node under some certain cluster head from being too large which leads load to be overweight to death through even node clustering. It constructs evaluation function which can better reflect residual energy distribution of nodes and at the same time constructs routing evaluation function between cluster heads which uses MATLAB to do simulation on the performance of this algorithm. Simulation result shows that the routing established by this algorithm effectively improves network's energy balance and lengthens the life cycle of network.

Keywords: *Wireless Sensor Network (WSN), Clustering Algorithm Load balance Uneven*

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1. Introduction

In WSN nodes which consume large number of energy will be quickly ineffective leading network topology to change when node load is uneven. This not only narrows the network monitoring scope but also makes some data fail to reach sink node which greatly influences the life time of the whole network. Therefore an important problem must be considered in the design of WSN routing protocol which is finding a good strategy to guarantee the balance of node energy consumption.

In recent years some algorithms propose some new route strengthening mechanisms aiming at Directed Diffusion Protocol. While they present disadvantages. For example, Literature [1] proposes that strengthening route is determined when establishing gradient which only takes node energy of the next hop and its hop count distance to sink node into account. However, strengthening route mainly thinks about residual energy of node and the minimum hop count value from node to sink node. Therefore this route is just a local optimum one. Literature [2] proposes to set an energy threshold value when choosing strengthening route in which nodes whose residual energy is lower than threshold value cannot transmit data. However, this algorithm does not introduce how to determine the energy threshold value. Literature [3] considers the residual energy of all nodes along the whole route in which the minimum node residual energy serves as the route's energy and the route with maximum energy and minimum length becomes strengthening route. It is obviously seen that just using the minimum node residual energy to be the route's energy is not enough. LEACH Algorithm in Literature [4-5] does not take uneven distribution of cluster head into consideration in which too big transmitting distance between cluster head and sink will lead cluster head node to consume energy so quickly that network life time greatly runs down. HEED Algorithm in Literature [6] effectively avoids uneven distribution of cluster head while unbalancing load of cluster head node also exists. EEUC in Literature [7] never discusses about competition radius and demands node's position given which is too idealized. In terms of the prevalent problem of load node's uneven energy consumption in clustering routing protocol under WSN environment, this paper puts forward a kind of load balance routing algorithm based on uneven clustering.

2. Routing Algorithm Based on Uneven Clustering

This paper randomly deploys nodes in a rectangular region A with fixed boundary length. Simulation environment possesses the following features:

- (1) All sensor nodes keep isomorphic and each node is marked with a sole ID. Sink node is set in the middle of square region and never moves after position being fixed.
- (2) Sink node can receive each node's position and ID information. Each node can also receive its distance to sink node and calculate its approximate distance to the node transmitting data according to RSSI (Received Signal Strength Indication) strength.
- (3) In certain region nodes can arbitrarily adjust transmitting power of signal.
- (4) Nodes regularly collect data from monitoring region and transmit them to cluster head. Cluster head does fusion processing on the received data and then sends to sink node.

2.1. Calculating the Best Number of Network Clustering by Uneven Clustering Mechanism

This paper combines with classical clustering algorithms LEACH and HEED in which uneven clustering mechanism [8-9] is first used to calculate the best number of network clustering. Here size of each cluster namely the number of common nodes should be adjusted according to a certain rule. After candidate cluster heads appear, they will compete to become to final cluster head in order to establish reasonable and multi-organized topological structure and save energy.

The number of common nodes close to sink is small. Instead the number of common nodes far to sink is large. This effectively reduces communication frequency between cluster head and sink. It also decreases energy consumption. Suppose that the maximum value of competition radius of candidate cluster head R is R_{max} , its minimum value is R_c and competition radius from common node to sink node is $(1+c)*R_c$. Value interval of c is [0, 1] to control the value range of parameter. Candidate cluster head S_i determines its competition radius S_i .

Formula 1 shows the value of R.

$$R = (1+c) \frac{d(S_i, BS) - d_{min}}{d_{max} - d_{min}} * R_c \quad (1)$$

In the formula, $d(S_i, BS)$ stands for the distance between Node S_i and sink. d_{max} is the maximum distance from node to sink and d_{min} is the minimum. After candidate cluster heads are elected, Multi-Competition Iterative Algorithm is applied to choose the final cluster head who will broadcast the competition information. Radius is R. Suppose that S_i, S_j are elected to be candidate cluster heads at the same time, candidate cluster heads will form a collection in the area whose original point is S_j and radius is R. Here the candidate cluster head with the highest evaluation function will be elected to become the final cluster head and its cluster head number K_{final} will be counted. The number of nodes in each cluster should cater for $N_{out} = N / K_{final}$.

2.2. Adjusting the Number of Nodes in Cluster

Literature 8 proposes that practical communication radius of nodes can be delimited based on nodes' density so that sizes of network clustering are different leading load to be even. However, the revised communication radius makes nodes beyond the radius find suitable cluster head again and this node's communication distance increases at the same time which leads the node to consume too much energy and prematurely die because it has been far from cluster head. Algorithm of this paper regulates the practical clustering result according to the

best number of cluster so that numbers of node in each cluster are balanced and their energy consumptions are even to lengthen life cycle of the whole network.

2.3. Electing Iterative Process of Cluster Head

Design the Evaluation Function of Clustering Node:

A node should not only consider node's energy but also reflect energy distribution of its neighbor nodes when establishing route. Node which is far from the very node needs more energy. Node close to it needs less. An evaluation function will be constructed according to this feature shown in Formula 2:

$$f(k) = \delta e_k + \frac{\lambda}{n-1} \sum_{i=1, i \neq k}^n \frac{e_i r_i}{r_i + 1} \quad (2)$$

Here $\delta + \lambda = 1$ ($\delta \in [0,1]; \lambda \in [0,1]$), e_k is the residual energy of node, r_i is the distance from the i th node to Node k , e_i is the residual energy of Node i , δ is the energy influencing factor of the current node and λ is the energy influencing factor of neighbor node. This regulation can balance the contribution proportion of the whole network's node energy to communication radius.

Node distribution of wireless sensor network in practical network is uneven. Evaluation function considers the node's energy and also the distribution and energy condition of its neighbor nodes which can balance the network energy distribution and prevent dark spot in network from prematurely appearing.

Establishing Process of Cluster:

(1) Initialization phase

During the establishing phase of network, specific transmission power of sink broadcasts a signal to the whole network. After receiving the signal, each node will calculate its approximate distance to sink based on RSSI strength. During this phase nodes in network are preliminarily divided in which node operating cluster head chooses algorithm to form temporary cluster and cluster head. Each node calculates its communication radius R according to Formula 1 and regulates its transmitting power based on the communication radius by which it broadcasts data package to neighbors. Nodes in the cluster exchange position information and energy information through this data package. Neighbor nodes renew their neighbor lists after receiving the package.

(2) Election Phase of Cluster Head

After candidate cluster heads are determined, status information of cluster nodes will be collected among which are their positional information, energy information and determining the final cluster head based on evaluation function. Formula 3 is used to determine threshold value.

$$T(n) = \begin{cases} \frac{P}{1 - p[r \bmod (1/p)]} * f(k) & n \in G \\ 0 & \text{others} \end{cases} \quad (3)$$

New cluster head is determined by Formula 3 in which cluster head sends information to cluster nodes so that the optimized cluster head collects and fuses nodes' information. As the formation of optimized cluster comprehensively considers the status information of neighbor nodes, energy consumption of nodes is balanced thus effectively prevents dead node from frequently appearing.

2.4. Data Communication Process

Route Evaluation Function among Cluster Heads:

As communication energy consumption of cluster head and sink node exponentially increases with distance increasing, transmission from cluster head to sink node adopts combination of single hop and multi-hop to transmit data. Evaluation function of route is shown in Formula 4:

$$g(ch) = \beta \frac{E_{res}}{E_{avg}} + (1 - \beta) \frac{D(S_{ch}, BS)}{d_{max}} \quad (4)$$

E_{res} and E_{avg} are respectively residual energy and average energy of cluster head node. $D(S_{ch}, BS)$ is distance from cluster head to sink node. d_{max} is the maximum distance from node to sink node. $\beta \in [0,1]$.

When distance from cluster head to sink node is bigger than R_{th} , cluster head can directly communicate with sink node namely single hop. If distance from cluster head to sink node is smaller than threshold value R_{th} , it is ideal to use multi-hop way to transmit data.

Data Communication Process among Cluster Heads:

Multi-hop routing project among multi points is a new researching direction [10] in which communication among clusters adopts combination mechanism of single hop and multi-hop.

Cluster head node calculates its own $g(ch)$ of evaluation function and then broadcasts note list to its neighbor cluster head node which includes two parameters: node ID and evaluation function. Each cluster head node compares its own evaluation function value with the received one in which the bigger one becomes the father node and the node whose evaluation function $g(ch)$ value is the maximum is chosen to be the root node of multi-hop route. Therefore the cluster head node with enough energy and close to sink node will prior be the root node. Cluster head collects and fuses data along this route until transmitting it to sink node.

3. Simulation Result and Analysis

This paper simulates the performance of this algorithm using MATLAB whose configuration of specific network scene and main nodes' parameters goes as follows: scene region is 100×100m, node position is [50,50], node initial energy 1J, total number of node is 100 and threshold value d_0 is 87m.

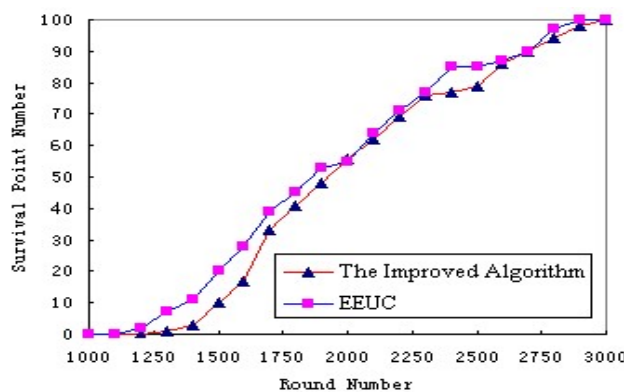


Figure 1. Comparison with Life Cycle of EEUC Network

Figure 1 is the comparison figure with life cycle of typical EEUC network. It is seen from Figure 1 that the time of node being out of work in the improved protocol is later than that of EEUC and also the improved one's gentle degree of curve is better than that of EEUC which can reflect the speed of energy dissipation. As this protocol considers the influence of node's residual energy, node's attribution is readjusted among nodes with the same distance according to clustering size. During transmitting process, lower energy-consumption node is prior considered to become the next transmitting node which effectively balances network energy consumption and lengthens network life cycle.

The number of data package received by base station is shown in Figure 2. It is seen from Figure 2 that utilization rate of the improved protocol is higher than EEUC. The number of data package received by sink node is larger meaning that it can practically transmit more data for observers.

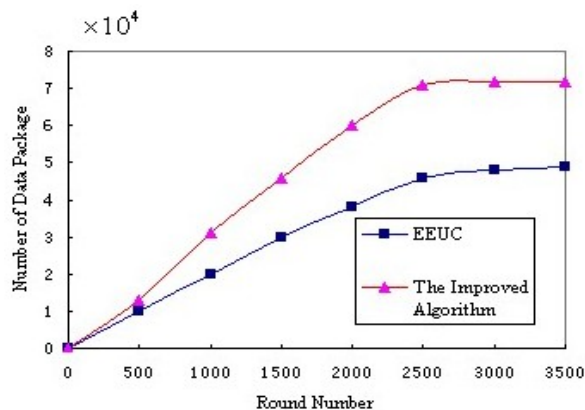


Figure 2. Comparison Figure of Data Package Number Received by Base Station

4. Conclusion

Experiment result shows that the whole performance of improved protocol is better than that of EEUC which can be analyzed from two aspects:

- (1) Energy consumption during clustering process is lower than that of EEUC which reduces network load.
- (2) During routing process, the improved one comprehensively considers energy distribution of neighbor nodes and decreases data transmission in network which leads nodes with high energy to do more transmitting tasks and effectively saves energy of network as a whole.

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