# An adaptive WSN clustering scheme based on neighborhood energy level

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***Abstract*—Hierarchical routing protocol has the advantage of good scalability for WSN network. However classic hierarchical protocol such as LEACH has the energy hole problem. In this paper, a distributed clustering scheme based on neighborhood energy level is proposed to handle this issue. Our scheme dynamically adjust the cluster head selection probability by considering difference between the residual energy of a node and the average energy of its one-hop neighbor nodes. Having finished cluster heads selection, a by-election mechanism of cluster heads is introduced, which aims to find out cluster heads in sparse region and optimize the distribution of cluster heads by compensation. Simulation results show that compared with LEACH protocol, the proposed clustering algorithm is able to extend life cycle of wireless sensor networks and balance energy consumption among sensor nodes.**

***Keywords—adaptive clustering;balanced energy consumption; wsn routing protocol***

## I. Introduction

Wireless sensor network (WSN) has been widely used in environment monitoring and industrial automation [1]. WSN speeds up the development of Internet of Things. WSN consists a large number of sensor nodes deployed in monitored area to collect environment information. These nodes collaborate to forward data packets to a base station by wireless self-organizing communication. As sensor nodes are battery powered, their computation and communication capability are also restricted. It's also hard to replace nodes' batteries manually since nodes are generally deployed in inaccessible area. Therefore, how to prolong life cycle of WSN based on the limited energy budget of sensor nodes is an important problem that need to be solved for wide deployment of WSN.

Routing protocol is an active area of WSN since its performance directly affects the life cycle of wireless sensor networks. As there is no fixed communication infrastructure and communication range of a node is limited, a sensor node has to forward data packets through multi-hop routing and obtain neighborhood topology information in a distributed manner.

WSN routing protocol can be divided into planar routing and hierarchical routing protocols. Hierarchical routing protocol has the advantage of reducing energy consumption of sensor nodes for WSN. LEACH protocol [2] is one of the classic WSN hierarchical routing algorithm. It organizes a WSN into clusters and uses data aggregation to reduce communication distance of sensor nodes. Normal nodes only forward packets to cluster heads, whiles a head node has to receive, aggregate data from member nodes and forward data to a base station. On the other hand, cluster head are rotated between nodes to balance network load. As clustering process of LEACH induces additional overhead, a dynamic/static clustering (DSC) protocol is presented to improve performance of LEACH protocol[3]. DSC keeps cluster structure static for a specified number of rounds to avoid expensive cluster reconstruction. However, they still suffer from the energy hole problem. That is, nodes near a base station are more likely to use up their energy first . Therefore, it is necessary to design an energy-efficient hierarchical WSN routing protocol.

HEED protocol [4] selects cluster heads by interaction and competition between neighboring nodes. Though HEED protocol yields more uniform cluster head distribution and prolongs life cycle of WSN, it need nodes exchange energy information and execute iterative process to complete cluster head election. The overall computation and communication overhead is relatively expensive.

EECS protocol [5] picks candidate cluster heads by a threshold value, then chooses final cluster heads by comparing nodes' energy level. When forming clusters, a node calculates the value of a cost function associated with cluster heads, and decides to join a cluster head with a optimum value. Hence cluster load is improved.

PEGASIS[6] protocol uses a greedy algorithm to organize nodes into a chain, where each node communicates with the adjacent nodes. A unique head is chosen to communicate with a base station each round. PEGASIS reduces energy consumption between nodes; communication. But it places heavy load on nodes near the base station. If a node in the chain run out of its energy, the chain must be reconstructed.

EUCA protocol [7] introduces competition and compares energy between nodes to select cluster heads. But ordinary nodes join cluster by considering factors such as cluster load, energy of cluster heads, distance between cluster heads and a base station to build a virtual backbone structure. As a result, it can prolong network life cycle.

In this paper, we present a distributed clustering scheme based on neighborhood energy level in section 3. It has the following characteristics:(1)An optimized threshold for selecting cluster head, that considers neighborhood density and difference between the residual energy of a node and the average energy of its one-hop neighbor nodes; (2) Candidate cluster heads will check whether they locate in isolated area. If so, they will pick additional cluster heads among neighboring nodes; (3)Cluster heads broadcast HEAD packets to its neighboring nodes, avoiding expensive energy consumption caused by global broadcast. Simulation results in section 4 show that our algorithm balances energy consumption of nodes and extends network life cycle compared with LEACH protocol. Finally, Section 5 concludes the paper and points out further work.

## II. SYSTEM MODEL

### A. Network model

The following conventions are made for network model used in this paper:

(1) The deployed area is of size L * L square meters and $n$ sensor nodes are uniformly distributed. A base station is located in the center of the area. The sensor nodes and base station are stationary.

(2) All sensor nodes are homogeneous with the same capability. Each node has a unique identifier ID. Initially all nodes choose the same transmission power level and the corresponding transmission range is assumed to be a circle with radius R( the disk communication model,[8]).

(3) Sensor nodes can adjust their transmission power adaptively and judge distance between nodes by strength of received signal.

### B. Energy Model

We adopt the same radio energy model [] to estimate energy consumption when a source node transmits $l$ bits to a node over a distance $d$:

$$E_{TX}(l,d) = l \cdot E_{elec} + l \cdot \varepsilon_{fs} \cdot d^2, d \le d_0 \quad (1)$$

$$E_{TX}(l,d) = l \cdot E_{elec} + l \cdot \varepsilon_{fs} \cdot d^4, d > d_0 \quad (2)$$

where $E_{elec}$ is the power loss per bit caused by transmitter circuitry. The energy per bit over distance $d$ required by amplifier under the free space model(resp., multi-path fading model) causes $d^2$ path loss and the (resp., $d^4$ path loss).

Energy consumption for receiving $l$ bits is:

$$E_{RX}(l) = l \cdot E_{elec} \quad (3)$$

## III. Our CLUSTERING PROTOCOL

As the threshold value specified by LEACH protocol does not consider energy level of nodes, it may yield unbalanced energy consumption between cluster head nodes . As LEACH protocol suffers from energy hole problem and yields uneven distribution of cluster heads, this paper puts forward a distributed clustering protocol based on energy of neighborhood (DCNE) algorithm to handle the above issues. Details of our protocol are discussed as follows.

At first, all nodes communicated with neighboring nodes within its communication range to build a neighboring list to record ID of neighbor nodes and their energy level.

Similar to LEACH protocol, the execution of our protocol is also divided by cycles containing several rounds. Each round consists of a cluster forming phase and a steady data transfer phase. The cluster forming phase is divided into the cluster head selection phase and compensation phase.

### A. Cluster Head Seletion Phase

At the start of the $k$th round in a cycle, neighboring nodes should exchange information about their energy level. Then a threshold value is computed as follows:

$$T^{(k)} = \frac{a}{n_i^k + 1} + \frac{E_{res}^{i,k} - E_{ave}^{i,k}}{E_{ave}^{i,k}}, i \in G \quad (4)$$

$G$ is a set containing live nodes that have not been head nodes during the execution of current cycle. $n_i^k$ is the number of nodes within node $i$'s communication range. The parameter a can be used to control the expected number of cluster head nodes around node $i$. $E_{res}^{i,k}$ denotes node $i$'s remaining energy level. We use $n_i(j)$ to represent the $j$th neighbor of node $i$. $E_{ave}^{i,k}$ denotes the average energy level of its one-hop neighbor nodes, which can be computed by:

$$E_{ave}^{i,k} = \frac{E_{res}^{i,k}}{n_i^k + 1} + \sum_{j=1}^{n_i^k} \frac{E_{res}^{n_i(j),k}}{n_i^k + 1} \quad (5)$$

Node $i$ would generate a uniform random number $U$ . If $U < T^{(k)}$ , node $i$ declares itself as a head node by broadcast HEAD control packets among its neighbors.

The idea behind equation (4) is that we scale up or down the threshold value by difference between the residual energy of a node and the average energy of its one-hop neighbor nodes on the basis that each node within its communication range has the same chance to become a cluster head node. As a result, nodes with high residual energy in dense region are more likely to become cluster head nodes.

Let the random variable $X_i(k)$ denote the number of cluster head nodes around a live node $i$. We establish the following theorem about the expected number of cluster head nodes around a live node $i$ .

**Theorem 1**. Under the assumption that energy consumption of neighboring nodes is an identically distributed random variable, our cluster formation phase yields $E(X_i(k)) \ge a$ .

Proof of Theorem 1 will appears in the full version of this paper.

### B. Compensation Phase

As nodes becomes cluster head nodes in a randomized way, cluster head selection phase cannot guarantee an even cluster structure. Cluster head nodes executes a by-election process during compensation phase to balance cluster head nodes distribution.

At the end of cluster head selection phase, each cluster head node scales up its transmission power level to detect whether there are cluster head nodes within the doubled communication range 2*R* by broadcasting a DETCET packet and setting a timer. Any cluster head node located in this area should respond with a ACK packet.

If a cluster head node does not receive any response when a timer expires, it concludes that it is located in an isolated area. To handle this issue, the isolated cluster head node would pick a one-hop neighbor node with maximum energy level as a new cluster head node.

At the end of cluster forming phase, each cluster head node would broadcast JOIN message among its neighboring nodes. Each normal node then decides to join clusters by distance to a cluster head node.

Finally, each cluster head node creates a TDMA schedule for cluster member nodes to avoid intra-cluster interference.

## IV. SIMULATION

We simulate the proposed DCNE protocol under MATLAB development platform. The performance of our DCNE protocol is compared with LEACH protocol in terms of network lifetime and the energy consumption per round. We run the simulation 15 times to take the average value.

### *A. Simulation setup*

The simulation sets network size to be 100x100 square meters with 100 nodes randomly deployed . A base station locates at the position (50,50). The value setting of simulation parameters are listed in Table 1. Transmission range is set to be 20m that is feasible for Mica2 node [9].

TABLE I. SIMULATION PARAMETERS AND VALUES

| Parameter | *Value* |
|---|---|
| Network size ($m^2$) | 100x100 |
| Number of nodes | 100 |
| Base Station position | (50,50) |
| Data packet size | 4000bits |
| Control packet size | 64bits |
| Energy consumption in free space | 10pJ/bit/ $m^2$ |
| $E_{elec}$ | 50nJ/bit |
| Initial node energy | 0.5J |
| Transimission range(m) | 20 |

Figure 1 demonstrates that DCNE protocol improves network lifetime over LEACH protocol. The round until the first dead node in LEACH protocol is 1021,while this value in DCNE protocol is 1222. The round until the last dead node in LEACH protocol is 1561,while this value in DCNE protocol is 1939. Hence DCNE protocol can effectively extend network life cycle .

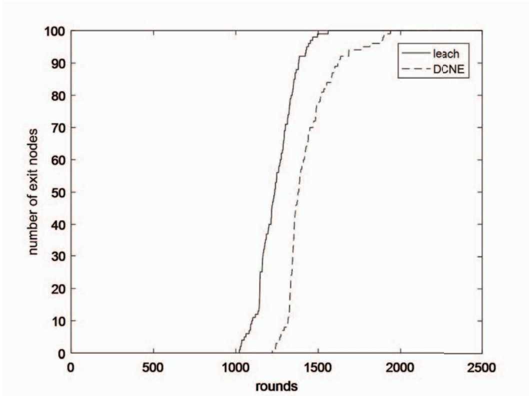

Figure 1 life cycle of network

Figure 2 evaluates the energy consumption per round. The difference between maximum and minimum energy dissipated per round when using DCNE protocol is 0.0601J,while this value in LEACH protocol is 0.2467J. Hence DCNE protocol can effectively balance node energy consumption .

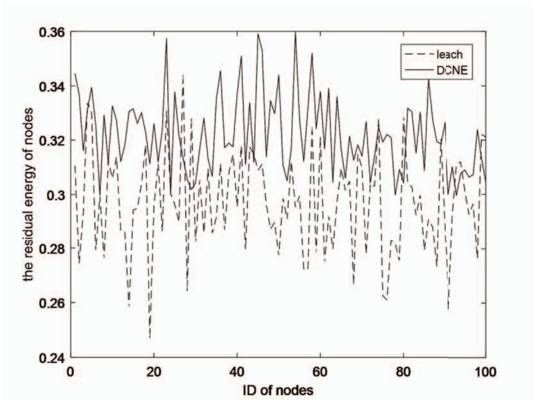

Figure 2 residual energy of nodes in one round

DCNE protocol is proposed in this paper for WSN clustering protocol. DCNE protocol scale up/down the cluster head selection probability by considering neighborhood density as well as difference between the residual energy of a node and the average energy of its one-hop neighbor nodes. Compensation mechanism for cluster head nodes is also introduced to yield more balanced cluster structure.

A lot of simulation experiments is conducted to compare performance between DCNE protocol and LEACH protocol in terms of network lifetime and the energy consumption per round. Simulation results shows DCNE protocol improves over LEACH protocol.

## VI. CONCLUSION

DCNE protocol is proposed in this paper for WSN clustering protocol. DCNE protocol scale up/down the cluster head selection probability by considering neighborhood density as well as difference between the residual energy of a node and the average energy of its one-hop neighbor nodes. Compensation mechanism for cluster head nodes is also introduced to yield more balanced cluster structure.

A lot of simulation experiments is conducted to compare performance between DCNE protocol and LEACH protocol in terms of network lifetime and the energy consumption per round. Simulation results shows DCNE protocol improves over LEACH protocol. Our future work will consider WSN clustering protocol over unreliable environment.

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