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Research on Dynamic Clustering Routing Considering Node Load for Wireless Sensor Networks*

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ABSTRACT

Aiming at the problem that node load is rarely considered in existing clustering routing algorithm for Wireless Sensor Networks (WSNs), a dynamic clustering routing algorithm for WSN is presented in this paper called DCRCL (Dynamic Clustering Routing Considering Load). This algorithm is comprised of three phases including cluster head (CH) selection, cluster setup and inter-cluster routing. First, the CHs are selected based on residual energy and node load. Then the non-CH nodes choose a cluster by comparing the cost function of its neighbor CHs. At last, each CH communicates with base station by using multi-hop communication. The simulation results show that comparing with the existing one, the techniques life cycle and date volume of the network are increased by 30.7 percent and 29.8 percent respectively by using the proposed algorithm DCRCL.

Keywords: Wireless Sensor Network; Dynamic Routing; Clustering Algorithm; Node Load

1. Introduction

As Wireless Sensor Network (WSN) is a kind of energy constrained multi-hop self-organizing networks, how to save energy and maximize life cycle is the core problem of WSN [1-3]. In cluster based WSN, the network is divided into distinct clusters with a single leader called cluster head (CH). CHs are either selected among normal senor nodes or in some case some high energy nodes called gateways which are deployed as CHs [4]. CHs transmit all the local data from normal nodes to base station (BS), so that normal nodes use less energy while CHs consume more. To prevent the death of CHs from extra load, the CH rotation mechanism is used to equilibrium energy consumption of the network by changing CHs dynamically in existing algorithm called LEACH [5]. However, the main disadvantage of LEACH is that a sensor node with very low energy may be selected as a CH and the CHs send the packet to BS directly in single hop communication. Thus, this method increases the energy consumption of the CHs and reduces the network life cycle.

A large number of algorithms have been developed to improve LEACH namely PEGASIS [6], HEED [7] etc. Compared to LEACH, PEGASIS improves network lifetime, but its data delay is significantly high and it is unsuitable for large-sized networks. The HEED periodically selects CHs based on the node's residual energy and proximity measure of the neighbor nodes or node degree. In MRPUC [8], the authors design multi-hop routing and unequal clustering algorithm using residual energies of all sensor nodes and distance between sensor nodes to the BS to extend network lifetime. Although these algorithms can improve the network life cycle, the load problem is not considered. As a result all the data will be transmitted to the BS, the nearer from the node to the BS, the higher load it will have. Higher load means forwarding data more frequently, and consuming more energy. What's more, unbalanced load also leads to unbalanced energy consumption and the decrease of network life cycle.

In this paper, we propose a dynamic clustering routing algorithm which considers the load problem. This algorithm contains three phases namely CH selection, cluster setup and inter-cluster routing. In Section 2, these phases are introduced in detail. Simulation results are given in Section 3 followed by the conclusion in Section 4.

2. DCRCL Algorithm Description

2.1. Cluster Head Selection

The general factors considered in CH selection are node residual energy, distance from CH to BS, distribution of CHs, communication cost within the cluster and so on. In DCRCL, the threshold function is optimized by consi-

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dering residual energy and node load.

In CH selection phase, every sensor node is given a random number from 0 to 1. The node will be candidate CH if the random number is less than the threshold. The optimized threshold function is shown as follow:

$$T(n)=\begin{cases}\dfrac{p}{1-p[r \bmod (1/p)]}\times[\lambda_1\dfrac{E_{res}}{E_{ini}}+\lambda_2(1-\dfrac{\eta}{k})], n\in G\\ 0\end{cases} \quad (1)$$

Where, p is the probability of a node chosen to be CH, r is the present round, G is a gather of nodes which were not chosen to be CH in the past $1/p$ round. E_{res} and E_{ini} mean the residual energy and initial energy of nodes, η is load factor and k is normalization coefficient, λ_1 and λ_2 are weight coefficients.

The optimized function retains the advantage in LEACH that CHs are rotated by increasing the probability of being candidate CH for unselected nodes. At the same time, it balances energy and load to make the nodes with higher residual energy and lower load easier to be candidate CH.

In the multi-hop network with a single BS, the load of CH contains not only the communication with nodes inside, also the channel utilize when CH transmit data from other CHs to BS [9,10]. The load considered in this paper is the latter.

As shown in **Figure 1**, the load of node A is the data comes from the nodes in dash area, indicated by η. In other words

$$\eta = n\times q\times pk\_size \quad (2)$$

Where, n is the node number in dash area, q is the probability that a node transmit data in every moment, pk_size is the size of every packet which is a same value for every node in the network. Suppose that nodes are distributed uniform in the network, so

$$n=\frac{S_0}{S}\times N$$

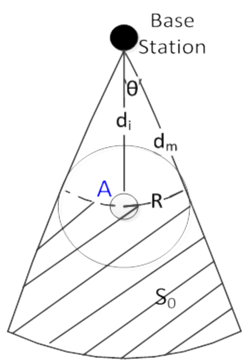


Figure 1. Node Load Model.

Where, N is total node number, S_0 is the coverage of the dash area and S is total coverage of the network.

On the base of the distance from A to BS namely d_i, communication radius R and network range d_m, we can get

$$S_0=2\theta\times\pi\times(d_m^{\,2}-d_i^{\,2}) \quad (3)$$

$$S=\pi d_m^{\,2} \quad (4)$$

$$\theta=\arcsin\frac{R}{d_i} \quad (5)$$

So

$$\eta=2Nq\times\frac{\arcsin R/d_i\times\left(d_m^{\,2}-d_i^{\,2}\right)}{d_m^{\,2}}\times pk\_size \quad (6)$$

It is observed that node load is related to communication radius and the distance from node to BS.

2.2. Cluster Setup

In the cluster setup phase of DCRCL, CH competitive mechanism is introduced to avoid the unbalanced distribution of CHs in LEACH. After being a candidate CH, a node competes with other candidates in its communication range R, the one who has most residual energy is the winner. R is given as follow

$$R=\left(1+\alpha_1\frac{d_i}{d_m}+\alpha_2\frac{E_{res}}{E_{ini}}\right)\times R_{min} \quad (7)$$

where, d_i, d_m, E_{res}, E_{ini} are defined above. R_{min} is the minimum competition radius, α_1 and α_2 are weight coefficients and $\alpha_1+\alpha_2=1$.

Equation (7) shows that competition radius of CH and nodes in the cluster will decrease when the CH is nearer to BS and owns less residual energy. Considering that further CHs need close ones to transmit their data, the close CHs will have enough energy and free load to ensure the stability of the network in this way.

By Equation (7), it is known that $R\propto d_i$.

So θ can be approximated to a fixed value. Fused with Equation (5), we can see that

$$k=2Nq\theta\times pk\_size$$

Then, the selected CHs broadcast cluster request signal to the nodes in their communication range. Normal nodes choose which cluster to join in by using energy cost function shown as follow

$$f(i,j)=\beta_1\frac{d_{(i,j)}}{E_i}+\beta_2\frac{d_j}{E_j} \quad (8)$$

where, $d(i,j)$ is the distance from node i to CH_j, dj is the distance from CH_j to BS, E_i and E_j mean the residual energy of node i and CH_j. β_1 and β_2 are weight coefficients and $\beta_1+\beta_2=1$.

As the Equation (8) shows, normal nodes prefer to cooperate with the CH which is closer to BS and owns more residual energy. The choose process is shown in **Figure 2**.

2.3. Inter-Cluster Routing

The model that data is transmitted directly from CHs to BS, as known in LEACH, usually results in short life cycles of CHs and the network. In the proposed algorithm DCRCL, an energy balanced multi-hop communication model is established to use network energy more efficiently. The attribute equilibrium function for inter-cluster routing contains several factors namely residual energy, CH load and inside node number. The specific equation is as follows

$$D_{EBi} = \omega_1 N_{Ei} + \omega_2 N_{Li} + \omega_3 N_{Ci}$$

where, N_{Ei}, N_{Li}, N_{Ci} are uniformed CH residual energy, CH load and inside node number. ω_1, ω_2 and ω_3 are weight coefficients and $\omega_1 + \omega_2 + \omega_3 = 1$.

CHs send routing request signal RREQ to the neighbor CH which has higher attribute equilibrium value than the average of all neighbors by computing the equilibrium function. At the same time, the link information in RREQ is updated. The information will be used by the destination node to choose a best link and send routing reply signal RREP, as shown in **Figure 3**.

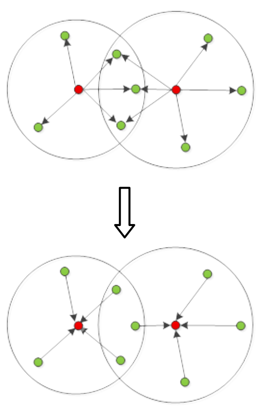


Figure 2. Cluster Setup Process.

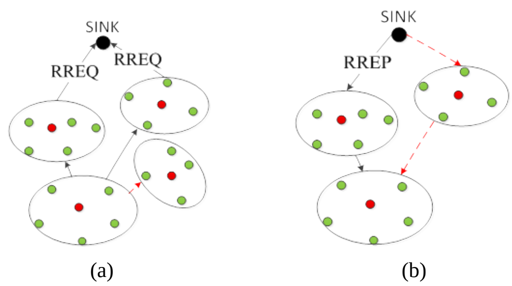


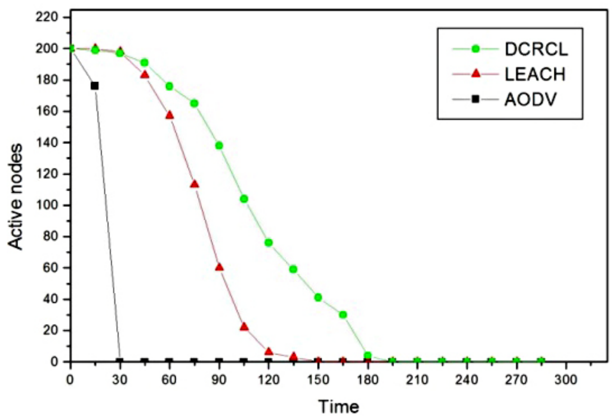
Figure 3. (a) Routing Request; (b) Routing Reply. Inter-cluster Routing Process.

When the inter-cluster routing is established, CHs record the link and compute the optimized transmission power according to the distance to next hop. The link will be used abidingly until next CH selection phase comes.

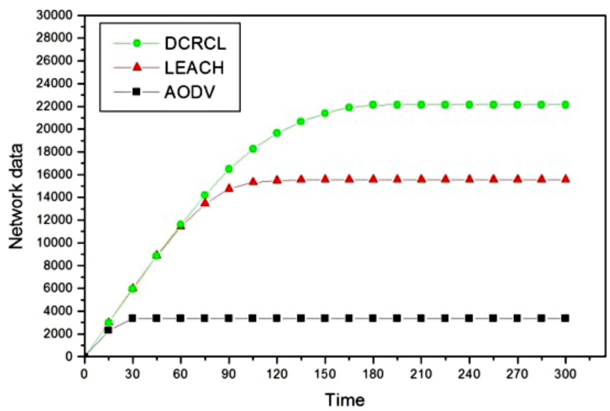
3. Experimental Results

Extensive experiments are performed for the proposed algorithm on MATLAB7.0 with the following experimental set up. All sensor nodes are distributed random in a 200 m × 200 m area, all nodes are immobile with the same initial energy 0.1J. Nodes in cluster use TDMA mechanism on MAC layer and the communication mode is two-way. Time cycle of simulation is 300 rounds. For the sake of comparison, we also run the LEACH and AODV.

In **Figure 4**, the node number is 200 and the size of packet is 500 bit. We sampled the results every 15 rounds. As shown in **Figure 4(a)** that in the case of DCRCL, all nodes are inactive after 200 rounds, the network life cycle is increased by 566.7 percent and 33.3 percent compared with 30 rounds of AODV and 150 rounds of LEACH. **Figure 4(b)** shows that the data received by BS in DCRCL is 42.8 percent more than LEACH.



(a)



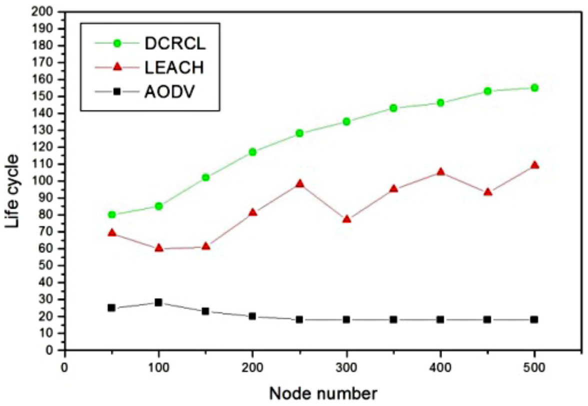
(b)

Figure 4. (a) Active Nodes; (b) Data Received by BS.

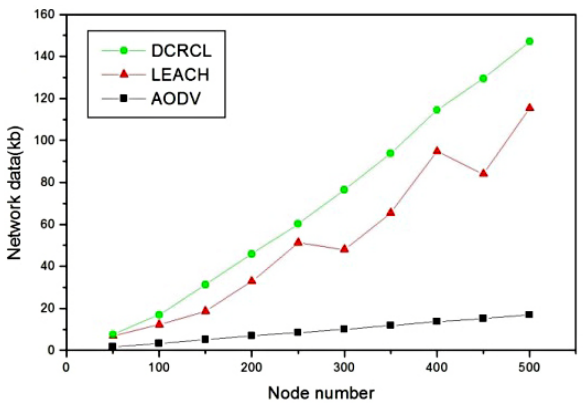
Considering the generalization, more experiments are performed by using different number of nodes from 50 to 500. It is shown in **Figure5** that the proposed algorithm in this paper also performed well for large scale networks. **Figure 5(a)** shows that average life cycle of DCRCL is 30.7 percent higher than LEACH and the curve is smoother than LEACH which means our method works more steadily. In **Figure 5(b)**, the average data received by BS in DCRCL is 29.8 percent higher than LEACH, and get to the highest 47.6 percent when the node number is 450.

4. Conclusion

In this paper, a dynamic clustering routing algorithm considering node load for wireless sensor networks is presented. In which, CHs are selected by considering residual energy and node load, a cost function based on energy and distance is used to set up the cluster and CHs use multi-hop inter-cluster routing model which is established by the attribute equilibrium function. The experiment results show that the proposed algorithm is more efficient with respect to network life cycle and network data than LEACH and AODV.



(a)



(b)

Figure 5. (a) Life cycle; (b) Date Received by BS. Comparison between DCRCL, LEACH and AODV for different node number.

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