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An Energy-Aware Clustering Algorithm in Wireless Sensor Networks

Abstract. *Due to the limitation of energy resources, energy efficiency is a key issue in wireless sensor networks (WSNs). Clustering is proved to be a good way to realize hierarchical topology control, which can improve the scalability and prolong the lifetime of wireless sensor networks. In this paper, a new scheme called Energy-Aware Clustering Algorithm (EACA) is presented .Based on the LEACH, EACA take into consideration node's current energy and degree in clustering process, and the energy-Aware cluster head rotation method can achieve the balance of energy consumption among nodes within a cluster. Simulation experiments show that EACA balances the energy consumption well among the cluster heads and prolongs the network lifetime.*

Streszczenie: *Z powodu ograniczeń zasobów energii, wydajność energetyczna jest kluczowym problemem w bezprzewodowych sieciach czujnikowych. Klastrowanie realizowane w topologii hierarchicznej może poprawić skalowalność i przedłużyć czas życia sieci. W opracowaniu przedstawiono nowy schemat algorytmu klastrowania uwzględniający energię (EACA). Oparty o protokół LEACH, algorytm EACA w procesie klastrowania bierze pod uwagę bieżącą energię a powstający w procesie rotacji klaster główny zapewnia zrównoważenie energii między jego węzłami. Badania symulacyjne wykazują, że algorytm EACA równoważy pobór energii wewnątrz klastra głównego i przedłuża czas życia sieci.* ***Uwzględniający energię algorytm klastrowania w bezprzewodowych sieciach czujnikowych***

Keywords: wireless sensor networks, LEACH, weight, cluster heads
Słowa kluczowe: Bezprzewodowe sieci czujnikowe, LEACH, Waga, Klaster główny

Introduction

Wireless sensor networks(WSNs) is an emerging technology, which has a wide spread of potential applications, including environment monitoring, smart spaces, medicine- systems and robotic exploration etc [1-5]. In a traditional sensing system, a limited number of wireless sensor nodes are usually remotely located from the area of interest, wireless sensor networks have limited energy resources, So WSNs operations must be energy efficient in order to maximize the network lifetime. However, designing an efficient routing protocol for WSNs is a great challenge due to the limitations in the resources of the WSNs such as the limitation of the power source, computation capability and memory size [1-6].

The data transference in WSN is managed by routing protocol. There are several routing protocols in WSNs. gained through analyzing different moment of interferograms, therefore the mass diffusion coefficients was gained by conversion.

Furthermore, there are many objectives for these routing protocols. Some of these protocols are concerned with the quality of service in transferring the data among the nodes. Some are concerned with energy efficiency because of the limited energy power of the wireless sensor nodes. Clustering is an effective scheme in increasing the capability and lifetime of WSNs, and an important way for topology control. In clustering networks, nodes are divided into several clusters, in each cluster, one of the sensor nodes is elected as the cluster head (CH), and the rest are the cluster members (CM). Each CM collects data from the environment periodically and then sends the data to the CH. When the data from all the cluster members is received, the CH aggregates the data and sends it to the base station. Therefore, this CH performs more operations than any other regular node in the cluster, which will lead CH to consume more energy than the CM [1-6].

In order to overcome the energy limitation and imbalance consumption energy among sensor nodes, An Energy-Aware Clustering Algorithm (EACA) is presented in this paper. Based on the LEACH, EACA take into consideration node's current energy and degree in clustering process, the rest of the paper is organized as follows. Section 2 covers the related works in this area. Section 3 exhibits the network model and presents the EACA in detail. In Section 4, we detail our simulation efforts and the analysis of results obtained. Finally, Section 5 concludes the paper.

Relate works

To route data efficiently in WSNs, various routing protocols have been proposed. The CH selection and clustering are very important procedure In cluster-based WSNs. Low energy adaptive clustering hierarchy LEACH is a hierarchy architecture which randomly assigns the CH periodically, and alternates the qualification between all nodes in the networks, each node independently elects itself as a CH with a probability In the set up state, In CH selection, the node decides by randomly generate a number between 0 and 1, a node whose random number is less than the threshold is selected as CH. The threshold *T(n)* for the r-th round is defined as follows[2]:

$$T(n) = \begin{cases} \dfrac{p}{1 - p * [r \bmod (1/p)]} & n = G \\ 0 & ; \ other \ ; \end{cases} \tag{1}$$

where *p* express the expectation of the probability to be selected as CH, *G* is the nodes set including those nodes not yet been selected a CH in recent.

The LEACH considers nothing about energy factors, so that some nodes with low residual energy may be exhausted very fast. Some protocols based on LEACH advance the performance by improving the clustering approach, deterministic cluster-head selection（DCHS）improved *T (n)* calculation as following [2].

$$T(n)_{new} = \frac{P}{1 - P(r \bmod (1/P))} \times \frac{E_{current}}{E_{\max}} \tag{2}$$

where $E_{current}$ is the node's current energy value; E_{max} is the node's initial energy value. The value of $\frac{E_{current}}{E_{\max}}$ is greater indicating the node's energy consumption is more slowly, or explain the faster the node energy consumption, the new *T (n)* calculation preferred the slow energy consumption as the CH.

HEED (Hybrid Energy-Efficient Distributed Clustering) introduces the probability of CH election which is combined the factor of residential energy with node degree [3].

EEUC (energy-efficient unequal clustering) is a distributed unequal clustering algorithm that elects CHs based on the residual energy of nodes. The clusters closer to the base station have less node than those farther away from the base station, so the CH closer to the base station consume less energy. In this way, the energy consumption among CH is balanced.

Muti-Weight based clustering algorithm (EACA)

Network Model

To simplify the network model, we adopt few reasonable assumptions as follows:

(1) There are N sensor nodes that are deployed randomly in an M ×M square field.

(2) All the sensor nodes are heterogeneous.

(3)All the nodes can use power control to vary the amount of transmit power. The CH can transferred data to the base station directly.

We use a simplified model to compute the radio hardware energy dissipation, which is the first order radio model. The energy spent for transmission of a k-bit packet over distance d is [6-10]:

$$E(k,d)=\begin{cases} k\times E_{elec}+k\times\varepsilon_{fs}\times d^2 & d<d_0 \\ k\times E_{elec}+k\times\varepsilon_{mp}\times d^4 & d\geq d_0 \end{cases} \quad (3)$$

In this mode, E_{elec} is the base energy required to run the transmitter or receiver circuitry. ε_{fs} and ε_{mp} are the consumption energy of amplify transmission power of these models, *d* is the transmission distance, *k* is the length of the packet. Here, to simplify the energy model, we denote the equation as[6-8] :

$$E(k,d)=k\times E_{elec}+k\times\varepsilon_{s}\times d^{n} \quad (4)$$

Also in this model required energy to receive k-bit data over distance d is calculated from:

$$E_{RX}(k)=k\times E_{elec} \quad (5)$$

Description of EACA

CH is randomly determined in LEACH. and it brings unbalance of energy consumption, during clustering procedure, low energy nodes protection should be considered. Nodes with special high energy can act as CH to burden the pressure of data transmission.

In order to prevent early death due to excessive energy expenditure, all nodes should be alternately take turns to become CH, CH election need to consider many factors , In EACA the following factors is considered:

(1) Current energy. Since the initial energy of each node is the same, Nodes with high energy can act as CH to for fear of energy exhaustion.

(2) Degree indicates the number of node's neighbors, node with high degree acting as CH can efficiently solve the problem of energy consumption for nodes around.

Considering the above two factors, the weight of node i can be defined as below:

$$w_i=\alpha\frac{E_{residuali}}{E_{\max}}+(1-\alpha)\deg_i \quad (6)$$

For a node, W_i is its weight, $E_{resdalu}$ is the residual energy of node i, and E_{max} is the maximum residual energy of node in the network, deg_i is the degree of node, α is weighted factors whose value is in [0, 1]. Based on the specific application, Weight α is to maximize the network life cycle. The node with the largest weigh W_i has more chances to be elected as the CH.

It is important for the algorithm application to elect the CH, Several control messages are needed. The descriptions of these messages are shown in Table 1.

Table 1 .The description of control messages

MESSAGE	DESCRIPTION
Compete_ message	Compete CH
CH_message	broadcast electing message of CH
Join_message	joining message of CM
Neighbourinfo_message	Get neighbors information

Data structure of node in EACA is described as following:

```
Node {
Id ;                    // node's id
Current_energy;    // node's residual energy
Neigh_list:neigh_id, neigh_energy, neigh_degree;
//neighbour list includes id, residual energy and degree
 CM_list:CM_id;   //cluster member list
```

Rotations of CH election algorithm are described as follows:

1 While (cluster C is empty)

2 {node i in C compute degi, $\frac{E_{residuali}}{E_{\max}}$ and w_i;

3 broadcast compete_ message;

4 receiving Neighbourinfo_message from node j;

5 Select the max w_k of node *k* broadcast CH_message

6 CH broadcast CH_message;

7 CH receives join_message from CM;

8 };

Simulation analysis

To evaluate the performance of EACA, the simulation will be conducted in NS-2[8-12] .Networks with 100 nodes will be distributed randomly on a sensing field of 50m×50m. Results are taken from the average of 50 simulations. The parameters of simulations are listed in Table 2.

Table 2.Main simulation parameters

PARAMETER	VALUE
Link Bandwidth	1Mbps
Init_Energy /J	0.6
Eelec/ nJ/bit	50
ε_{fs} /pJ/bit/m^2	10
ε_{amp} /pJ/bit/m^4	0,0013
EDA /nJ/bit/m^2	5
Route protocol	EACA,LEACH

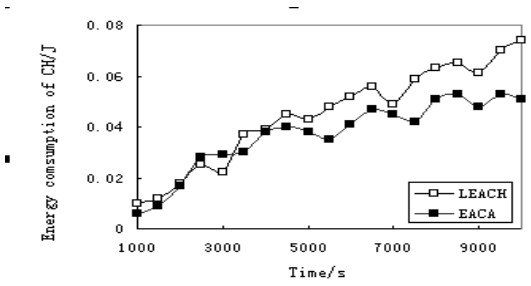

Fig.1. The energy consumption of CH between EACA and LEACH

Fig 1 illustrates the energy consumption of CH in EACA and LEACH. It is obviously that the CH energy consumption of EACA is lower than the LEACH. The reason is that EACA take into consideration the node's current energy and degree. The mechanism of EACA enables to balance the node's energy consumption.

Fig 2 illustrates the number of death nodes between EACA and LEACH. As shown in Figure 2, the number of

last dead node of LEACH is higher than EACA. Since the energy consumption in LEACH is becoming unbalanced with the increasing time of network. However, the energy consumption of EACA is balanced . Thus the EACA avoid generating more death nodes than LEACH.

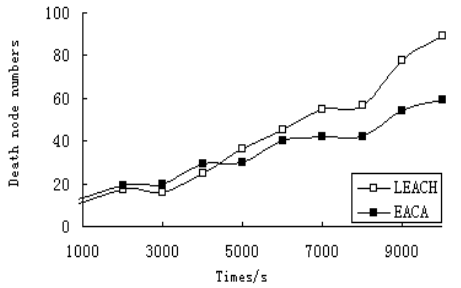

Fig.2. Number of death nodes over time between EACA and LEACH

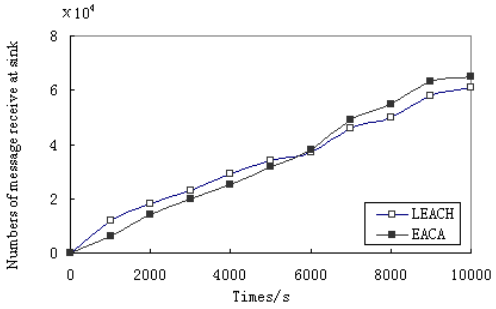

Fig.3. Number of messages received at the sink over time between EACA and LEACH

When it comes to the number of messages received at the sink, fig 3 shows that using EACA, the measured value which reflects both of the network throughput and the amount of effective data is higher as expected due to its extended stability and lifetime.

Conclusions

Routing algorithm in WSNs is a very hot research topic, because it has great research significance in saving energy and prolonging network lifecycle. In this paper we propose a new cluster routing scheme-EACA for energy efficient in WSNs. The performance evaluation in terms of CH energy consumption was conducted using the NS-2 simulator. We compared the LEACH with the EACA under the same simulation conditions and parameter values. Results show that the new proposed EACA has improved the energy consumption among CH is balanced effectively.

Acknowledgments

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