Research on WSN Dynamic Routing Protocol Based on Energy Balance

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Abstract

Due to limited energy resources of sensors, some of them die early after several rounds of data transmission, which causes the route interruption. Route reselection causes additional energy consumption. Based on the characteristics of the sensors, this paper proposes WSN routing protocol based on energy balance. We set a fixed energy threshold for the cluster heads firstly. When the remaining energy of the cluster heads reaches this threshold, they will notice their member nodes. Then, member nodes will select the cluster head which has minimum consumption cost based on dynamic routing mechanism. Simulation results show that the protocol effectively balances the energy of sensors in the network and extend the network lifetime. At the same time, it increases the amount of collection data in the networks.

Keywords

Wireless Sensor Networks; Energy Balance; Threshold; Dynamic Routing; Network Lifetime

I. Introduction

Wireless sensor network (WSN) as a new technology for data collection, achieves the region detection. But, due to its limited energy, energy supply difficulties and other problems, it becomes a problem for researchers to use energy efficiently as well as prolong the life of the network [1].

The cluster member nodes of cluster routing protocol only open communication module in the time slot allocated by cluster heads and adopt data fusion technology to reduce the amount of data transmitted[2] .It largely reduces the energy consumption of the network. Furthermore, in order to assign the network energy consumption to each sensor uniformly to extend network lifetime, classic clustering routing protocol LEACH uses the way of changing cluster head periodicity. However, LEACH cluster heads election is based on the settings probability of the network to elect randomly, without considering the residual energy of the sensor. When a sensor has less residual energy, it is still possible to become a cluster head, which would lead to the sensor premature death. DCHS (Low Energy Adaptive Clustering Hierarchy with Deterministic Cluster-Head Selection) proposes an improved method for LEACH deficiencies. The algorithm adds the residual energy considerations to the original LEACH in the process of cluster head election. The sensors with more remaining energy have more chances becoming cluster heads. To a certain extent, this way makes up the shortage of LEACH and extends the lifetime of network.

However, DCHS routing protocol considers the residual energy of the sensors only in the process of the cluster head election and the sensors with much remaining energy only have great probability to be selected as cluster heads. There is a certain uncertainty. Meanwhile, when the sensors with less residual energy are elected as cluster heads or the cluster heads have excessive load, the cluster heads will die early. In this paper, the real-time residual energy detection mechanism for the cluster heads is adopted. The algorithm is based on DCHS protocol. When cluster heads remaining energy detected reaches a certain threshold, their members will collect data based on dynamic routing transmission mechanism. The article introduces the background of the topic firstly. Then, the set of threshold and the dynamic routing workflow is introduced. Finally it is verified by simulations.

II. Energy Threshold Analysis

This paper assumes M / 2 is the radius of the monitoring area. Monitoring area is divided into k concentric rings and the interval between rings is δ .Cluster heads are distributed in concentric rings uniformly, where the optimal number of cluster heads is

$$k_{opt} = 0.1 * n \text{ .}$$

Before the algorithm starts,it needs to configure the overall information S of the monitoring area and the S is defined as

$$S = \{M / 2, n, k\}$$

The sink sensor calculates the sensors energy threshold of each ring by the general information S after n sensors are deployed completely and the sensors energy threshold of each ring is $E = \{E_{cluster\_threshold}(i) \mid i \in 1, 2, ..., k\}$. Then, the general information S, the position of the sink sensor pos_{sink} , and the cluster heads energy threshold of each ring are packaged as SINK_MSG message and the message is broadcasted by flooding mechanism on the network. The network sensors calculate the distance with sink sensor which is d(, pos_{sink}) according to their own position pos_i after the network sensors receive SINK_MSG. Finally, the sensors can calculate the serial number of the ring which they locate and they can match the number of the ring with the message E received.

Multi-hop routing between the cluster heads is shown in Fig. 1.

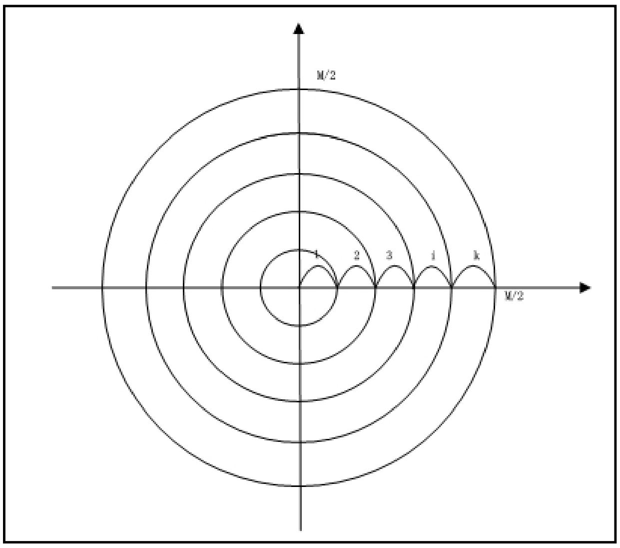

Fig.1: Inter-cluster Multi-hop Routing

Adopting the same wireless communication energy consumption model as literature [3] showed. The energy consumption model is shown as formula(1),where it represents the sensor energy consumption of sending, receiving and integrating unit bit data from the sensor in the position of *d*.

$$E_t(l,d) = lE_{elec} + l\varepsilon_{amp} d^{\beta} \qquad E_r = E_{gather} = E_{elec} \qquad (1)$$

Where E_{elec} refers to the energy consumption of receiving and integrating unit data, ε_{amp} refers to unit energy consumption of sending amplification circuit and β refers to path loss index. If the transmission distance is less than the threshold value d_0□β is 2 and the loss of power amplification adopts free-space model $\varepsilon_{amp} = \varepsilon_{fs}$ .On the contrary, β is 4 and the loss of power amplification adopts multipath fading model $\varepsilon_{amp} = \varepsilon_{mp}$.

Data fusion rate γ .When $\gamma = 1$ □it adopts perfect fusion. When $\gamma = 0$ □it does not adopt any fusion[4].

Discuss the cluster heads energy consumption situation in the different districts at the stage of data transmission T_{data} as follows:

(1) The energy consumption of cluster heads in district *k*.

Because the cluster heads in district *k* can't transfer data, so the energy consumption is

$$E_{cluster\_threshold}(k) = lE_r\left(\frac{n}{k_{opt}} - 1\right) + lE_{gather}\left(\frac{n}{k_{opt}}\right) + lE_t\left(\frac{\gamma n}{k_{opt}}\right) = l\left[\left(19 + 10\gamma\right)E_{elec} + 10\gamma\varepsilon_{amp} d^{\beta}\right]$$

(2) The energy consumption of the cluster heads in district *i*.

The paper assumes that the data here from different cluster heads can't be fused further. In other words, the relay sensors can only forward the data coming from other cluster heads.

As we can see from the Figure 2, the number of the cluster heads outside ring *i* is

$$n_{i\_out} = k_{opt}\frac{\pi(M/2)^2 - \pi(i\delta)^2}{\pi(M/2)^2} \qquad (2)$$

The number of the cluster heads in ring *i* is

$$n_{i\_in} = k_{opt}\frac{\pi(i\delta)^2 - \pi((i-1)\delta)^2}{\pi(M/2)^2} \qquad (3)$$

The ratio N_i of type (2), (3) denotes the average number of packets of the relay sensor in each ring *i.*

$$N_i = l * \frac{\gamma n}{k_{opt}} * \frac{n_{i\_out}}{n_{i\_in}} = l\frac{\left(M/2\right)^2 - i^2\delta^2}{\left(2i-1\right)\delta^2} * \frac{\gamma n}{k_{opt}}$$

Summary, the cluster heads in district *i* need transfer data and the energy consumption is

$$E_{cluster\_threshold}(i) = lE_r\left(\frac{n}{k_{opt}} - 1\right) + lE_{gather}\left(\frac{n}{k_{opt}}\right) + lE_t\left(\frac{\gamma n}{k_{opt}}\right) + N_i\left(E_r + E_t\right) = l\left(19 + 10\gamma + 20\gamma\frac{k^2 - i^2}{2i-1}\right)E_{elec} + l\left(10\gamma + 10\gamma\frac{k^2 - i^2}{2i-1}\right)\varepsilon_{amp} d^{\beta}$$

When the remaining energy of the cluster head $E_{cluster\_left} \le E_{cluster\_threshold}$, its members select new route again according to dynamic routing discovered mechanism.

III. Dynamic Routing Strategies

Data transfer model used in this paper is single-hop in the cluster and inter-cluster multi-hop mechanism [5].

For the members of the cluster head whose residual energy reaches a threshold, they adopt dynamic routing strategies based on RPL (Routing Protocol for LLN) routing protocol defined by the Internet Engineering Task Force. The member sensors will increase the scope of the route request by the unit of hop constantly until find the destination sensor. As we can see, the total cost of the dynamic route discovery mechanism is $T_c = \left(\sum_{i=1}^{\sigma}\eta_i\beta_i t_c\right) - at_c$ where σ refers to the number of requesting hops, η refers to the number of sensors included in each hop, β refers to the number of neighbor sensors, α refers to the number of the sensor which has received the request. The cost of sending *W* bit data is $t_c = w(\omega) * c(e)$ where $c(e)$ refers to the cost of sending unit bit data. So, the cost of dynamic routing strategies is far less than the cost of the entire network broadcasting needed [6].

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The next section introduces the process of the dynamic route discovery mechanism.

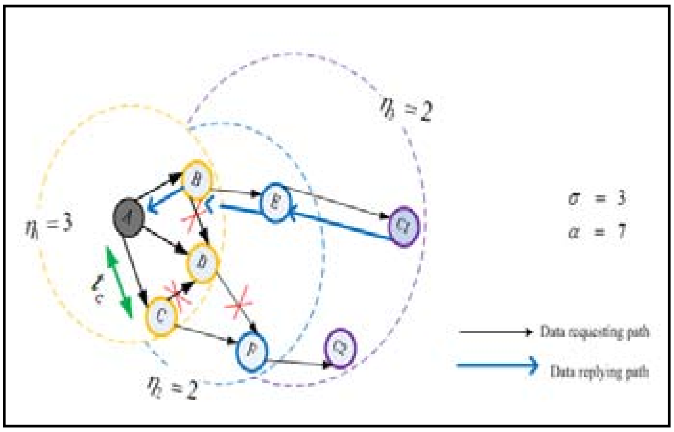

Fig. 2: Network Topology

As shown in the Fig. 2, when the energy of the cluster head of the sensor A reaches a certain threshold, the member sensor A will pass the data collected to the cluster head by dynamic routing discovery mechanism.

But, when a larger number of sensors pass the data to a fixed cluster head with a relatively small remaining energy, it will result in the premature death of the sensor, the original route interruption and has a bad influence on the overall life of the network. Therefore, this paper considers the distance between two sensors and the remaining energy of the sensor. It combines the two factors into a cost function. The sensor chooses the route according to the cost function.

Meanwhile, the member nodes of the cluster head sensor with remaining energy reaching the threshold calculating the cost with surrounding cluster heads separately, it will increase the amount of computation. In order to avoid it, the cluster heads which remaining energy reaches the threshold calculate the cost with the surrounding cluster heads according to the cost function first, and then they notify their members ID of the least cost cluster head, such as node C1shown in Fig.2.

Finally, cluster head which remaining energy reaches the threshold sends a notification message to its members to select the route again. Sensor A requests route in the area σ and the request message broadcasts in the region σ by flooding mechanism. If sensor A receives a reply message of cluster head C1, it will transport data through the path of replying message. Otherwise, sensor A will expand the broadcast area and request the route again until it reaches the maximum number of routing request. If it has reached the maximum number of routing request, sensor A will broadcast the routing request message throughout the network. Intermediate sensors transit messages and maintain routing. At the same time, they adopt monitoring mechanism to monitor the data packets which has been received to avoid data redundancy.

The overall algorithm flow is shown below.

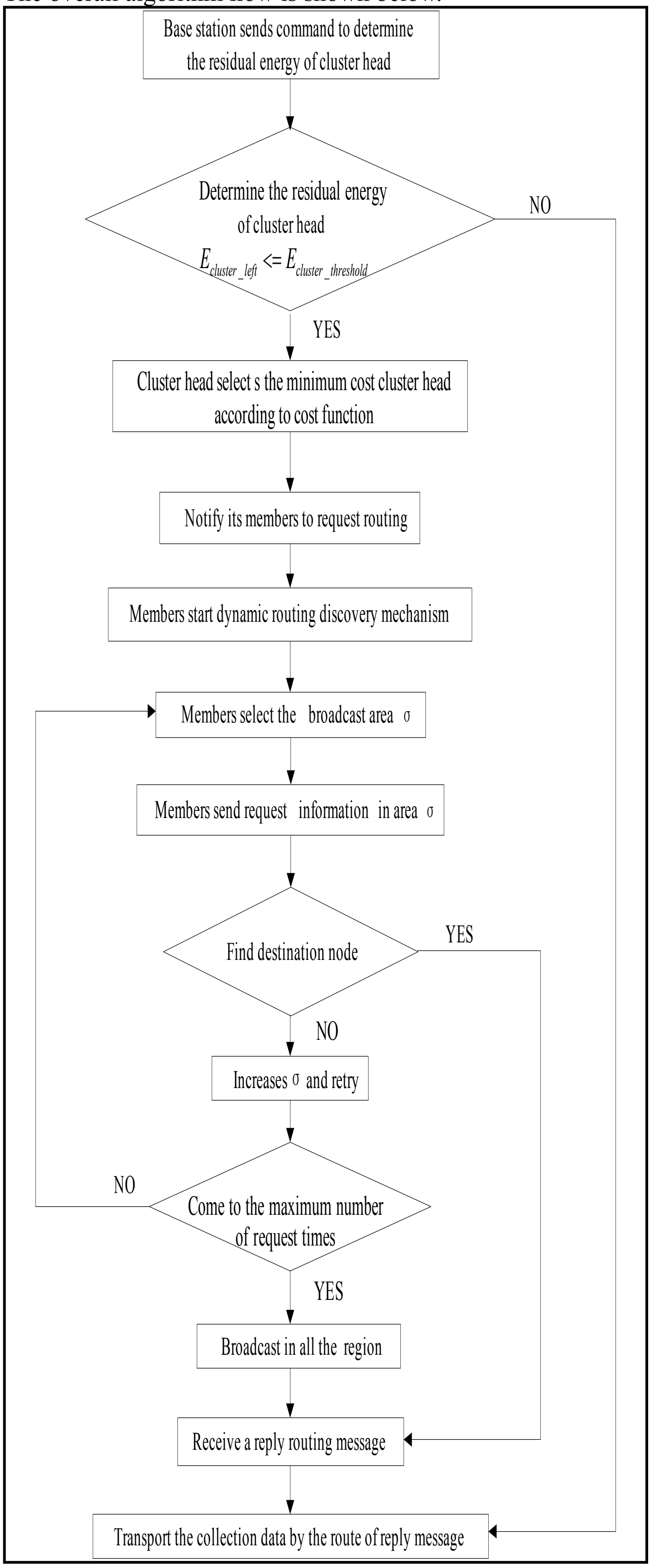

Fig. 3 : Algorithm Flow

The detailed routing discovery process of sensor A is shown in Table.1. It includes the actions and receiving packet type of each sensor involved in request route of sensor A.

Table.1: Sensor A Routing Discovery

Node	Packet Type	Receiver	Action
A	Route request	B, C D	Broadcast a route request
B	Transits route request	D, E	D drops data packet, E transits data packet
C	Transits route request	D, F	D drops data packet. F transits data packet
D	Transits route request	F	F drops data packet
E	Transits route request	C1	C1 receives and responds to information
F	Transits route request	C2	C1 receives and responds to information

IV. Performance Evaluation

Simulation tools used in this paper is MATLAB7.0 [7].

Table. 2 : Simulation Parameters

Parameters	Value
Number of sensors Round	100 5000
Range of monitor area (Unit:m)	100*100
Sensors initial energy E_0	0.5J
Amplifier amplification factor ε_{fs}	10pJ/bit/m^2
Amplifier amplification factor ε_{mp}	0.013pJ/bit/m^4
The energy consumption of receiving/fusing 1bit data E_{elec}	50nJ/bit

Experimental results analysis

The protocol is improved from original cluster routing protocol. In the paper [8], the time of the first sensor death is an important parameter. The agreement claims the sensor to detect the residual energy of the cluster heads in network. When the remaining energy of the cluster head reaches a certain threshold, the members of this cluster will start a dynamic route discovery mechanism to seek route again. This way passes the energy consumption of this cluster heads to the minimum cost cluster head. It balances the energy consumption of the cluster heads in the network effectively. As shown in Fig. 4, the death time of the first sensor in the network has significantly extended. Meanwhile, it also increases the energy consumption of an ordinary sensor in the process of selecting route. So, in the consecutive data transmission, the number of death sensors in the network will significantly increase. However, when the number of death sensors in the network comes to 20% of the total number of sensors, the network will part and form monitoring blind area. But, it can be seen from Fig. 4, compared with the classical clustering routing protocol DCHS, when the sensor death ratio is 20 %, the number of rounds in the dynamic routing protocol is 1900. However, the DCHS protocol is 1700. It improves about 11 %. As shown in Fig. 5, compared with DCHS protocol, the dynamic routing protocol also improves significantly on the amount of data collected.

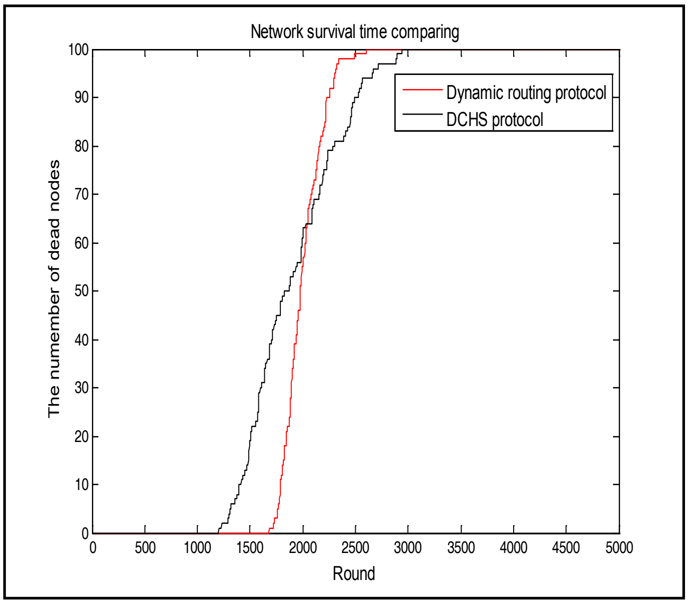

Fig. 4: Network Survival Time Comparing

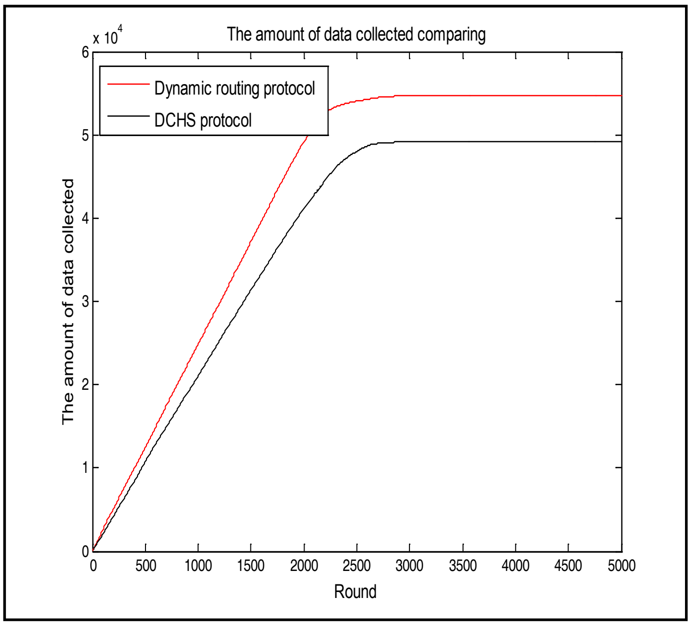

Fig. 5: The Amount of Data Collected Comparing

V. Conclusion

Based on the original cluster routing protocol, the paper sets a certain energy threshold for cluster heads. When the remaining energy detected by the cluster head sensor reaches a given threshold, its members will select the minimum cost cluster head by the dynamic routing mechanism. Simulation results show that, compared with the existing routing protocols, the dynamic routing protocol has significantly improvement on the overall network lifetime and data collection.

References

[1] *WEN Mengfei, PENG Jun, ZHANG Xiaoyong, et al. Concentric tree based on routing algorithm in wireless sensor networks [J]. Journal of Central South University: Science and Technology, 2012, 43 (009): 3490-3495.*

[2] *MHATRE V, C ROSENBERG. Design guidelines for wireless sensor networks: communication, clustering and aggregation [J]. Ad Hoc networks, 2004, 2(1):45-63.*

[3] *Zou Y, Zhang H, Jia X. Zone-divided and energy-balanced*

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clustering routing protocol for wireless sensor networks[C]// Broadband Network and Multimedia Technology (IC-BNMT), 2011 4th IEEE International Conference on. IEEE, 2011: 112-117.

[4] WANG Yi, ZHANG Deyun, LIANG Taotao. Cell Energy Balanced Uneven Clustering Hierarchy Scheme for Wireless Sensor Networks [J]. JOURNAI OF XI'AN JIAOTONG UNIVERSITY, 2008, 42(4): 389-394.

[5] LI Xiaoya, HUANG Daoping,WU Hongyan. Selectivity of Single-hop or Multi-hop Routing for Wireless Sensor Network [J]. Computer Engineering, 2009, 35(3): 13-14, 5.

[6] Nazir B, Hasbullah H. Mobile sink based routing protocol (MSRP) for prolonging network lifetime in clustered wireless sensor network[C]//Computer Applications and Industrial Electronics (ICCAIE), 2010 International Conference on. IEEE, 2010: 624-629.

[7] Jian-qi L, Bin-fang C, Li W, et al. Energy optimized approach based on clustering routing protocol for wireless sensor networks[C]//Control and Decision Conference (CCDC), 2013 25th Chinese. IEEE, 2013: 3710-3715.

[8] Aziz A A, Sekercioglu Y A, Fitzpatrick P, et al. A survey on distributed topology control techniques for extending the lifetime of battery powered wireless sensor networks[J]. Communications Surveys & Tutorials, IEEE, 2013, 15(1): 121-144.