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Research on LEACH-Based Wireless Sensor Network Routing

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Abstract. Routing technology is one of the main supporting technologies of wireless sensor networks. Only by using routing algorithm reasonably or finding better routing optimization algorithm, can the function of wireless sensor networks be maximized. Therefore, the research of routing technology for wireless sensor networks has important theoretical and practical significance. Based on the analysis of existing routing protocols in wireless sensor networks, this paper focuses on LEACH protocol.

1 Introduction

Wireless Sensor Networks (WSNs) have been widely applied to battlefield investigation, rehabilitation therapy and field environment monitoring [1]. Numerous sensing nodes are deployed in the above-mentioned application environment. Sensing nodes can sense the environment data in real time and then transmit the data to the data management center so as to realize environment monitoring. However, due to limited energy supplied by sensing nodes, the energy consumption of these nodes is the key factor affecting the data collection efficiency of WSNs and shortening the network lifework. Once the nodes run out of energy, they cannot sense the environment data, which forms loopholes in WSNs coverage and shortens its lifetime[2-4].

Consequently, it's the research focus to enhance the energy utilization of WSNs. Currently, the inter-cluster

2 Problem description

The Low Energy Adaptive Clustering Hierarchy (LEACH) protocol generates cluster heads at random and takes into account the residual energy of node. Specifically, a node (supposed as node i) generates randomly a uster head in this round if $\gamma > \lambda(i)$. The threshold of node i , namely $\lambda(i)$, is defined as shown in Equation (1):

$$\lambda(i) = \begin{cases} \dfrac{p}{1 - p \times \left(r \bmod \dfrac{1}{p} \right)}, i \in G \\ 0, \quad\quad\quad\quad i \notin G \end{cases} \tag{1}$$

Where: p represents cluster head proportion, namely the larger the number of cluster heads in networks, the greater the possibility that the node becomes a cluster head. r represents the number of current round while G indicates the set of nodes failing to become cluster heads in the previous round (r -1). According to Equation (1), the nodes that have become cluster heads in the previous round are not considered as candidates for cluster heads in this round, aiming to balance node energy.

Notwithstanding the LEACH protocol takes into account energy balancing, there are still some shortcomings as follows:

(1) The threshold doesn't consider the residual energy of node. If a node with a little residual energy is chosen as the cluster head, its energy will be used up quickly, which makes direct impact on network lifetime;

(2) Under the LEACH protocol, the proportion of cluster heads p is fixed, which doesn't consider network energy distribution information;

(3) The spacing between nodes is not considered when setting the threshold. If the spacing is too large, the number of hops for data transmission will be increased and thus the energy consumption will be increased.

Thus, based on the LEACH protocol, the paper revises its threshold and meanwhile considers the heterogeneous sensor networks, namely there is a difference in the initial energy of node.

3 Network model

The network model[8-9] shown in the Figure 2 can be considered, namely the source node forwards the data packet to the destination node (sink) through the relay nodes. The relay nodes between the source node and the sink nodes are also called forwarding nodes.

In addition, since the paper considers heterogeneous networks with three-level energy, namely node energy is divided into three levels and node energy varies from level to level, these nodes of various energy levels are respectively called advanced nodes, intermediate nodes and normal nodes. Advanced nodes contain highest

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energy while normal nodes have lowest energy. These nodes of various levels have different proportion. It's supposed that the proportion of advanced nodes and intermediate nodes in network nodes are m and m_0 respectively. It's supposed that the energy of normal nodes is E_0 and that of advanced nodes and intermediate nodes are represented by $E_0(1+\alpha)$, $E_0(1+\beta)$ respectively, where α and β are coefficients.

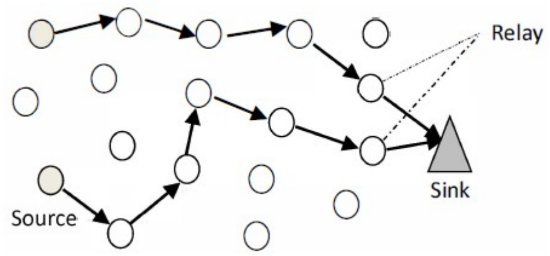

Figure 1. Network Model

4 Performance simulation

4.1 Simulation parameters and performance indicator

In order to better analyze the performance of the CTICR protocol, a simulation platform is established with the assistance of MATLAB and the LEACH and LEACH-D protocols are adopted as reference to compare their performance. It's supposed that 100 nodes are randomly distributed within $100m \times 100m$ network area. Specific simulation parameters are shown in Table 1. Each experiment is carried out independently for repeatedly 100 times and the average value is taken as the final experimental data.

Table 1. Simulation Parameter

Parameter	Value
Simulation area	$100m\times100m$
Number of nodes	80
Node distribution	Random distribution
E_0	$0.5J$
E_{elec}	50nJ/bit
E_{friis}	10nJ/(bit*m^2)
E_{tworay}	0.0013pJ/bit/m^4
E_{DA}	5nJ/bit/signal

In addition, three indicators including network lifetime, stability duration and the number of data packet successfully received by the Base Station shall be adopted to assess the protocol. Network lifetime refers to the number of rounds when the last failure node occurs in the network; the stability duration refers to the number of rounds when the first failure node occurs in the network.

4.2 Data analysis

The CTICR protocol considers the heterogeneous networks with three-level energy. Thus, during the experiment simulation, $m = 0.4$, $m_0 = 0.4$ while $\alpha = 2$, $\beta = 3.5$.

(1) Stability duration and network lifetime

The stability duration and network lifetime of the LEACH, DDEE and CTICR protocols are shown in Table 2. Data of 10 experiments are listed in Table 2.

Table 2. List of stability duration and network lifetime

Experiment	Stability duration (rounds)			Network lifetime (rounds)		
	LEACH	DDEEC	CTTCR	LEACH	DDEEC	CTTCR
1	969	1355	1717	5536	5673	8638
2	926	1355	1716	5553	5670	8637
3	970	1342	1718	5537	5673	8636
4	967	1357	1716	5532	5674	8643
5	972	1365	1714	5538	5676	8640
6	945	1358	1720	5539	5675	8640
7	936	1350	1718	5530	5668	8638
8	978	1355	1719	5534	5670	8640
9	976	1359	1716	5538	5673	8641
10	969	1355	1716	5530	5675	8641

According to Table 2, the proposed CTICR protocol has the longest stability duration reaching 1,717 rounds while that of the LEACH and DDEEC protocols are 969 rounds and 1,355 rounds respectively. The cause is that the CTICR protocol reduces the energy consumption and balances network energy consumption through revising the threshold so as to prolong the stability duration. In addition, according to Table 2, the CTICR protocol has the longest network lifetime, far higher than that of the LEACH protocol.

It's not hard to figure out that the CTICR protocol can effectively improve network utilization rate, balance energy consumption and prolong network lifetime according to the experimental data. The mainly cause is that the CTICR protocol always attempts to choose the optimal node as the cluster head in each round so as to balance the energy consumption.

5 Conclusion

Data-centric wireless sensor networks have limited computing power, limited storage capacity, limited wireless communication capacity and limited power supply capacity. How to obtain as much and effective feature information as possible and transmit it to user nodes for processing in such a limited resource environment is the focus of current research. Therefore, designing energy-efficient routing strategies to prolong the lifetime of wireless sensor networks has become a key issue. Based on the analysis of existing routing protocols in wireless sensor networks, this paper focuses on LEACH protocol.

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