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IMPROVED LEACH PROTOCOL USING THE CLUSTER OPTIMIZATION IN WIRELESS SENSOR NETWORKS

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Abstract

A wireless sensor network is a wireless network consisting of a base station and multiple sensor nodes. Sensor nodes are generally energy-limited and hardly rechargeable in wireless sensor network. Therefore, prolonging wireless sensor network lifetime is a significant problem. There are some energy-efficient hierarchical routing protocols designed especially for wireless sensor networks, such as low energy adaptive clustering hierarchal (LEACH). In this paper, we propose an improvement on the LEACH routing protocol to reduce energy consumption and prolong network lifetime. We have to configure the cluster, taking into consideration the number of cluster utilizes, a technique for determining the optimal cluster. The simulation results show that the proposed algorithm is much better than the existing LEACH algorithm in terms of conservation of energy and prolonged lifetime of wireless sensor networks.

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I. Introduction

Applications of wireless sensor networks are widely used as the development of wireless communication technologies, low-power RF technology and development of sensor technology. A wireless sensor network is applicable technique at various applications such as health, environmental and disaster monitoring, military, home network, factory management to collect data of the surrounding environment [1].

A wireless sensor network is composed of a sensor node placed on a sensor field and a sink node connecting to external network. Sensor nodes are distributed sporadically in the sensor field and each sensor node monitors the ambient condition to collect data which be transmitted to the sink node through the wireless network. The biggest problem in the wireless sensor network is the limited energy resource of the sensor node. Designing an energy-efficient protocol is an important issue in order to overcome the problem.

Routing protocol in wireless sensor network is suggested for developing energy-efficiency of sensor nodes [3]. Data-oriented flat-node routing simply composes the routing path and nodes divided in Cluster units if all nodes have the same computing and data transfer capability. The selected cluster head is collected data sending to sink nodes based on the cluster. There are two techniques, namely, Hierarchical based clustering routing for Energy Efficiency and location based routing though location information of sensor nodes.

Data-centric routing structure is made in the data transmission path individually for the dispersed nodes transmitting data to sink node and path node to sink node. Energy consumption for each of the nodes of the path is produced and if the network structure is getting larger, collision can be occur by transmitting the duplicated data from each node. Therefore increase in energy consumption can occur. The proposed protocol, which is based on a hierarchical clustering method reduces the energy consumption and increases the network lifetime.

Clustering routing [3] is grouping of the sensor nodes in an arbitrary size which is distributed in a wireless sensor network and configuring the cluster then a particular node in the cluster is selected as the cluster head. Elected cluster head is a technique that sends data to the sink node to collect data within a cluster neighboring sensor nodes and communication. Low Energy Adaptive Clustering Hierarchal (LEACH) [2] is clustering algorithm for wireless sensor networks which is a simple, well-known as the energy efficiency, LEACH method thereby splits the sensor nodes randomly placed throughout the network to the cluster. The runtime behavior of the network is divided into rounds. The nodes in the cluster in each round are selected as the cluster head in a predetermined probability value. Every sensor node has even chance to become a cluster head. The even energy consumption for the entire sensor node in the network has the advantage of extending the life of the entire network.

II. Related Work

Wireless sensor network routing protocols can be classified as flat-based routing, hierarchical routing-based, location based routing and the structure of these characteristics are as follows:

(a) Flat-based routing

Flat-based routing is a data-centric routing protocol structure of a multi-hop routing. Each node connected to the network can perform the equivalent role, sensing events between nodes and transmitting data to the sink node through cooperation with neighboring nodes. The nodes present within the region wait for being transmitted. Data after sink nodes are questioning about particular area therefore this is called as data-centric. Unnecessary energy consumption is generated because duplicated data occurs. Representative routing protocols are such as Direct Diffusion (DD) [4], SPIN [5].

(b) Hierarchical routing-based

In general, a cluster is created among the nodes by clustering. Then a cluster head is selected from among the nodes to collect data from nodes in the cluster members and merged information is transmitted to the sink nodes. The redundant information occurs between neighboring nodes in a wireless sensor network and the cluster heads are merged with the redundancy data transmission to the sink node. Ineffective transitions take place due to the cluster head in the query requested by configuring clustering. Such exemplary protocols are LEACH (Low Energy Adaptive Clustering Hierarchy), HEED [7], TEEN [8], and PEGASIS [6].

(c) LEACH protocol overview

LEACH Protocol is represents routing protocol based hierarchical and it is formed in a two-step. First of all, a cluster head is selected during the cluster forming step. Each cluster head is selected by the nodes. When probability value of the formula (l) gives certain value, a cluster head would be selected. Cluster head selection shall be made in each round and check whether a cluster head is selected. Selected cluster head broadcasts the advertising message to the node members present in the cluster. Member nodes, which receive the advertisement message, choose the cluster and send the join messages to the cluster that becomes a member of the cluster. Cluster heads are assigned the scheduling of a data transmission time in the member nodes TDMA (Time Division Multiple Access) method, and inform it to the member nodes. Next, a member of the cluster nodes, which have scheduling set in the cluster forming step, transmits data to the cluster head during the cluster stabilization step.

LEACH algorithm considers the energy efficiency of the wireless sensor network by equalizing the energy consumption between nodes to maximize network lifetime. The probability function of the cluster head is as follows:

$$P_i(t) = \begin{cases} \dfrac{k}{N - k \times (r \bmod N/k)}, & C_i(t) = 1 \\ 0, & C_i(t) = 0 \end{cases} \quad (1)$$

where i is the node identifier, t is the time, N is the total number of nodes in the network, k is the number of cluster heads, r denotes a round. $C_i(t)$ is during the last r mod N/k round, if it was a cluster head then it will be 0, if not then it will be 1. In other words, all nodes are performing as a cluster head and thereafter will serve as a member node. In general, LEACH routing does not consider the state of neighboring nodes; disproportionate cluster can be configured. Disproportionate energy consumption is caused by the number of sensor nodes in the cluster.

III. The Proposed Clustering Algorithm

For an existing algorithm, LEACH and HEED do not consider number of sensor nodes within a cluster and use the pre-defined cluster. Therefore, a cluster is not balanced. In addition, according to the energy consumption model of a wireless sensor network from the research, length of the message and distance of transmission affect the energy consumption of the network. Data collected from the sensor nodes is merged by cluster heads in the cluster. Since the data to be transmitted to the sink node is the combined data of the data collected from the sensor nodes within a cluster, the length of the data is also affected by the number of sensor nodes.

$$E_{Tx}(l, d) = \begin{cases} lE_{elec} + l\varepsilon_{fs} d^2, & d \le d_0 \\ lE_{elec} + l\varepsilon_{mp} d^4, & d > d_0 \end{cases} \quad (2)$$

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

where l is the data bit for transmission, d represents the transmission distance. E_{elec} is consumed energy per bit in circuit. According to the transmission distance d it is divided into free-space model and a multi-path model. In addition for transferring 1 bit energy, ε_{fs} is required energy to amplify the signal to the transmission range (d^2). In free space model and ε_{mp} is the energy needed to amplify the signals on the transmission distance (d^4) in a multi-path model. Equation (3) shows the energy required receiving l bit.

In this paper, the optimal cluster is established according to the cluster size, the sync position, the number of sensor nodes in a cluster in the network and cluster head is selected using cluster head selection method of HEED.

(a) The appropriate number of clusters

The selection of cluster head was proposed as optional probability of a cluster head by all the sensors in the sensor network, or energy remaining for each node or data transfer capability. The whole network energy is inefficient because of the distance between sensor node and the cluster head, the distance between a cluster head and the sink node and different amount of transferred data.

In this paper, the overall energy efficiency of the network is improved according to appropriate size of sensor field and structure of node by selection of the best number of clusters [11]. Appropriate number of clusters is selected by considering location of sink, size of sensor field and the number of nodes.

$$K_{opt} = \sqrt{n}, \tag{4}$$

$$K_{opt} = \sqrt{n}\,\frac{M}{\sqrt{M^2 + 6B^2}}. \tag{5}$$

Equation (4) shows obtaining the optimum number of cluster when the sink location is in the center position of the sensor field. And equation (5) shows obtaining optimum number of clusters when the sink location is on the outskirts. The symbols n, M and B represent the total number of sensor nodes, the size of one side of the sensor field size and the distance between center and outskirt sink of the sensor field, respectively.

If a part of the sensor nodes is congested forming clusters, then the consumed energy of the cluster head would be unbalanced when the sensor nodes are randomly distributed in the network. In other words, unbalanced energy consumption of sensor nodes affects the life of the network. A new cluster head is selected by splitting the single cluster into two clusters to form a balance when the number of sensor nodes in the cluster is higher than threshold value M given by

$$M = \left\lceil \frac{n}{K_{opt}} \right\rceil + c. \tag{6}$$

Equation (6) is used to create the appropriate cluster for the entire network, and place the ideal sensor nodes within the cluster.

(b) Structure of clusters

The goal is to design an energy efficient network by applying the technique of LEACH cluster to determine the optimum division techniques [11], configuration of a balanced cluster and placing suitable sensor nodes within the cluster by reducing the energy consumption of the sensor node.

Data loss or energy consumption as a disconnection of the path could be caused by increased cluster head during a round without considering the residual energy of the sensor node in LEACH scheme. In this paper, it is assumed that the sink is fixed in a particular position. HEED method selects a cluster head only by their energy without the remaining amount of energy of all the nodes.

$$CH_{prob} = C_{prob} \frac{E_{residual}}{E_{\max}}. \tag{7}$$

CH_{prob} is the proportion of the cluster head occupied within the entire network, $E_{\max}$ is the initial energy of the node i, and $E_{residual}$ is the residual energy of the node i. Cluster head is multiplied by the energy ratio and the percentage of the cluster head. The cluster head is selected when the CH_{prob} value of nodes increases the probability of two-fold value until the first one has one or more values. However, the lowest value of AMRP (average minimum reachability power) nodes is selected as a cluster head when CH_{prob} value of nodes is the same.

IV. Result and Analysis of Simulation

In this paper, MATLAB is used for simulation in analyzing the performance of the existing clustering method and proposed algorithm. Table 1 shows the parameters given to the energy model for the simulation. Network simulation was configured for distribution to an arbitrary sensor node in the coordinate space of the 100×100 square randomly and sink node is placed at the position of coordinates $(x = 0, y = 0)$. Mobility of the nodes and additional nodes are not considered. The initial energy of all the nodes is assumed to be the same. The sink knows the information of all the sensor nodes distributed in the network in advance, and all sensor nodes know their remaining energy. It has the same (Homogeneous) starting characteristics under the same conditions and the energy of all the sensor nodes assumes a periodic data transfer until the depletion.

Table 1. Simulation energy model

Initial simulation settings		**First order Radio model settings**	
Parameters	***Value***	***Parameters***	***Value***
Number of Sensor Nodes	100	E_{elec}	50 nJ/bit
Size of Network	100×100	ε_{fs}	10 pJ/bit/m2
Location of Sink Node	0×0	ε_{mp}	0.0013 pJ/bit/m4
Initial energy of Node	$0.2 \sim 0.25\,\mathrm{J}$	E_{DA}	5 nJ/bit/signal
CH_{prob}	0.05		
Size of data packet	4,000 bit		

Simulation is performed in different environments for obtaining a more accurate result depending on a variety of network environments, such as the distance between the sensor nodes and distribution. The entire network lifetime is focused and analyzed by survived sensor nodes and energy consumption depending on the performance evaluation.

Figure 1 shows the number of live nodes in the graph at the time by setting 100 nodes. Survived living number of nodes during time is more when the proposed algorithm in this paper is used compared to LEACH technique.

Figure 2 shows the remaining energy of sensor nodes depending on the increase in time when the number of nodes is set at 100. The proposed algorithm consumes less energy than LEACH techniques and the time that all of the energy is depleted in the network can be seen to be much longer.

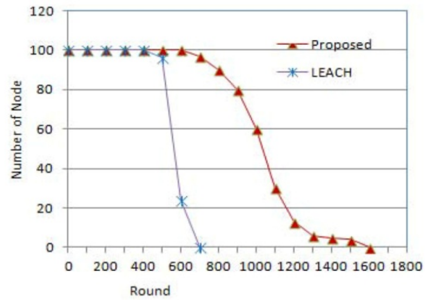

Figure 1. The number of nodes alive.

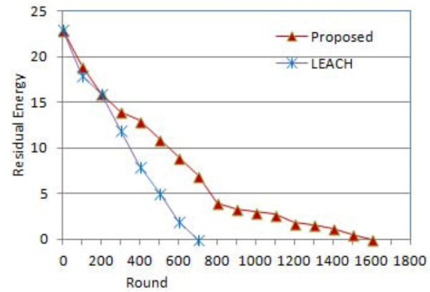

Figure 2. Residual energy.

V. Conclusion

In this paper, the problem of typical algorithm LEACH in cluster-based wireless sensor network is analyzed. In order to maximize the energy of the network, the technique was used to determine the optimal number of clusters by considering the location of sink and size of the cluster. The performance of the proposed algorithm was compared with LEACH through simulations. The simulation results show excellent survival rate of sensor nodes over time, energy efficiency of sensor nodes, less consumption of remaining energy and increase in the entire network lifetime by proposed algorithm.

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