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PDH-Clustering in wireless sensor networks

Hamta Sedghani[1] and Mina Zolfy Lighvan[2]
[1, 2] *Faculty of electrical and computer engineering, University of Tabriz, Tabriz, Iran*

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ABSTRACT

In this paper a Priority based dynamic clustering with hierarchical cluster head method named PDH-Clustering is presented. Wireless sensor network (WSN) with hundreds of sensor nodes are distributed to receive data from the environment. They are able to analyze and monitor the environment. Nowadays, using of WSNs is increasing. Thus, detection of its obstacles and consideration of them is important. One of the major obstacles in WSN is an energy-efficient routing protocol to enhance the network life time. Many energy-efficient routing protocols proposed for WSNs are based on clustering method. In this paper, a new energy effective routing method is presented which is based on dynamic clustering. The proposed algorithm is verified with MATLAB simulator. Simulation results show that the new method could balance the energy consumption and increase the stable period of network compared to LEACH protocol.

Corresponding Author:

Departement of Electrical and Computer Engineering,
Tabriz University, Tabriz, Iran
Email: [1]*h.sedghani91@ms.tabrizu.ac.ir*, [2]*mzolfy@tabrizu.ac.ir*

1. INTRODUCTION

Each Wireless Sensor Network (WSN) consists of a Base Station (BS) and a number of wirelessly connected tiny sensor nodes. These nodes receive information from the environment and send it to the BS according to a routing method. The sensor nodes are usually distributed in areas that are not easily accessible by humans, such as war zones or in forests. So, they are not usually rechargeable. Therefore, energy efficiency is one of the most important issues in these networks [1]. One of the most effective issues on energy consumption is the routing method because incorrect routing will result in imbalance energy consumption which cause fast energy level reduction of nodes. So with increasing the nodes lifetime, the network lifetime will be increased.

In direct method, each sensor sends the information to BS directly. Because of the long distance between nodes and the BS, direct method consumes a lot of energy. Against, the methods, that shorten communication distance, can

prolong the network lifetime. Therefore, multi-hop routing is more efficient and cost-effective than one-hop routing. But, in multi-hop routing communication between nodes consumed a lot of energy [2].
One of the solutions for this problem is clustering. Clustering means division of nodes to several groups in the network where each group has a CH(Cluster Head) that collects data from other nodes in the cluster and send it to BS. Clustering can reduce communication cost between nodes [3]. Many routing protocol are based on this method, for example LEACH [4], DEEC [3], TEEN [5], SEP [6], and PEGASIS [7,10], are some of them.
In this paper an efficient clustering method has been presented in which some clusters include a pair of cluster heads.
The organization of the rest of this paper is as follow. Section 2 includes the related work part. Then, the proposed method will be described in Section 3. In Section 4 the simulation result will be shown. And then, in Section 5, conclusions are done.

2. RELATED WORK

So far, several routing algorithms have been presented for wireless sensor networks. One of the clustering based algorithms is Low Energy Adaptive Clustering Hierarchy (LEACH)**.** It is an adaptive and self-organized clustering protocol proposed by Heinzelman [4, 8, 9]. The operation of LEACH is composed of some rounds where each round begins with a setup phase followed by a steady-state phase.

The clusters are organized in setup phase, and then in the steady state phase the data is transferred from nodes to the CH and then to the BS(Base Station).

In this algorithm, at the beginning of every round each node makes the decision of being the cluster head or not. This decision is made based on the random number generated by the node. If the value of T(n) function was smaller than the generated random number, the node will be selected as the cluster head. Otherwise, the node will be act as a normal node. T(n) is calculated with equation (1) [4].

$$\mathbf{T(n)} = \begin{cases} \dfrac{P}{1-P*(r \bmod 1/P)} & \textit{if} \quad n \in G \\ 0 & \textbf{otherwise} \end{cases}$$

P is the ratio of the cluster heads to total nodes. r is the current round number. G is the set of the nodes that have not been chosen as the cluster head in the first 1/P rounds. After the clusters get formed, the nodes begin to transmit data to their cluster heads. Cluster heads also sends received data to the BS.

Hierarchical clustering algorithms increase lifetime of WSN considerably. In [11] the paper focus on heterogeneity of nodes regarding their energy. It is assumed that the sensor nodes are equipped with small amount of energy and the nodes are not mobile. It is also given that the heterogeneous networks contained two types of nodes namely, type-1 node and type-0 node, where type-1 node has more battery power than type-0 node. Cluster formation and cluster head selection are done based on weighted election probabilities of each node.

In [12] an energy aware routing protocol is proposed to perform admission control, appointment of bandwidth requirements and the evaluation of sensor's residual energy. By adopting selective forwarding method in accordance to the sensor location, the delay of carried flows is optimized. The major limitation regarding this work is that the work completed with static sensor nodes without the consideration of node's mobility.

Another well-known algorithm is PEGASIS [7]. The main idea of this method is that each node receives data from its nearest neighbor and sends it to the next nearest neighboring. In this way, data transmit between the nodes as a chain. In every round, one node is randomly selected as the leader. The leader receives information from the neighboring nodes, collects and combines it, then sends it to the BS.

For example, in Figure 1, C2 is chosen as the leader node and receive data from C1 and C0 and then sends it to the BS. So each node will be selected as the leader one time in each n rounds [7, 10].

$$c0 \rightarrow c1 \rightarrow c2 \leftarrow c3 \leftarrow c4$$
$$\downarrow$$
$$BS$$

Figure1. Chain in PEGASIS.

A coverage based energy efficient algorithm is proposed in [13]. This paper emphasize that multi-hop short range communication among the sensor nodes are more energy efficient than single-hop long range communication comparatively. Moreover, the paper is involved in making uniform distribution of CHs using non-overlapped cluster areas. The main purpose is achieving higher packet reception rate irrespective to network longevity.

Another work in [14] propose MG-LEACH (Multi Group Based LEACH) that also focuses on the aforementioned criteria in a different domain such that same redundant nodes are located in the same area.

3. PROPOSED METHOD

Routing in wireless sensor networks is very important. And in clustering, two critical subjects for cluster heads selection are: 1) remaining energy of nodes 2) nodes to sink distance
Remaining energy of nodes: cluster heads collect data from other nodes of the same cluster and send it to the sink which consumes a lot of energy. Because of higher energy consumption level in cluster heads, those should be having more energy compared to the other nodes. Thus, the more the reminding energy of a node is, the more the chance of being a cluster head will be.
Nodes to sink distance: The more distance cause the more energy consumption. Thus, the nearer nodes to the sink have more chance for becoming a cluster head.
The method proposed in this paper considers both of *Remaining energy of node*s and *nodes to sink distance* criteria. It is inspired from the Highest Response Ratio Next (HRRN) algorithm that is being used in operating systems for Scheduling Processes. HRRN is a non-preemptive algorithm in which each node has its own defined priority. The node with the maximum priority is being selected for resource allocation. The priority value is calculated as equation: [15]

$$\text{Priority} = \frac{\text{wating time} + \text{estimated run time}}{\text{estimated run time}}$$

3.1 PRIMARY CLUSTER HEAD SELECTION

In this paper, a priority has been given to each node which is calculated as equation:

$$\text{Priority} = \frac{\text{reminding energy} + \text{distance from sink}}{\text{distance from sink}}$$

The node with the maximum priority value will be selected as a cluster head. For example, if there are n nodes in a field and $P \times n$ cluster heads are required, $P \times n$ nodes with maximum priorities will be selected.

3.2 SECONDARY CLUSTER HEAD SELECTION

A secondary cluster head will be selected if at least one of the following conditions is satisfied:

1) The reminding energy of the primary cluster head is less than the average reminding energy of total nodes.
2) The distance of the primary cluster head to sink is more than the average distance from each node to sink.

Based on the conditions above, a cluster may have a secondary cluster head. If a cluster needs a secondary cluster head, the node with maximum energy will be selected. Secondary cluster head collects data from normal cluster nodes and if the distance between the secondary cluster head and the sink is less than the distance between the primary cluster head and sink, secondary cluster head sends collected data to the sink. Otherwise, secondary cluster head sends collected data to the primary cluster head and it forward them to sink.

.3 FIRST-ORDER WIRELESS TRANSMISSION MODEL

First-order wireless communication model has been used for data transmission in this paper, which is shown in Figure 2.

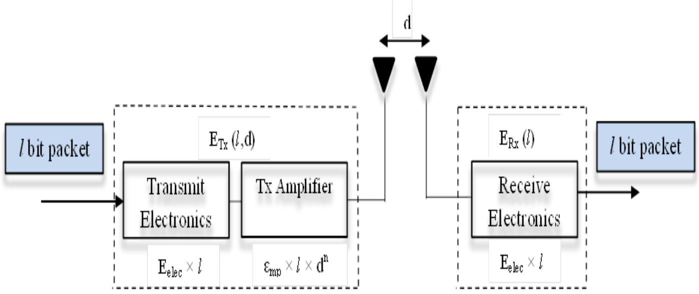

Figure 2. The wireless communication model.

The total energy consumed in the model showed in Figure 4 is calculated by formula (2) and (3)[10]:

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

$$E_{Rx}(\text{L}) = LE_{elec} \quad (3)$$

Where E_{elec} represents the energy consumed to send or receive one bit message, ε_{fs} is the amplification coefficient of free-space signal, ε_{mp} is the multi-path fading signal amplification coefficient which depends on the circuit amplifier model; d represents the distance between sender and receiver; L is the length of sending information in bits.
d_0 is calculated by formula (4)[10]:

$$d_0 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \quad (4)$$

4. SIMULATION AND ANALYSES

Matlab7.8.0 has been used as simulation platform to evaluate the performance of the new PDH-Clustering algorithm and compare it with LEACH protocol.

4.1 SIMULATION PARAMETERS

Simulation scenarios in this paper are:

1. Sensor nodes are distributed in a square region randomly.

2. Sensor nodes are homogeneous and each node has a unique ID number throughout the network and nodes' energy is limited. The node's site is fixed after deployed.

3. The base station is in the center of circles with fixed location.

4. Nodes communicate with BS via single-hop or multi-hop methods

In this simulation, 200 nodes are spread randomly within the square area of the 100m*100m, the base station is located in the center, the base station coordinates is (50, 175).

Specific parameters are shown in table 1.

TABLE1. Simulation environment parameters.

Parameters	Parameters
area 100*100	Packet size 4000bits
Nodes number 200	Eelec 50nJ/bit
Initial energy 0.5J	Efs 10pJ/bit/m2
CH proportion p=7%	Emp 0.0013pJ/bit/m4
BS location (50,175)	EDA 5nJ/bit

4.2 SIMULATION RESULTS ANALYSIS

In WSN, the network life is divided into stable and unstable period. Stable period usually means the time from the beginning of the simulation until the first node dies, the unstable period refers to the time from the death of first node to the end of simulation[16].

When nodes start to die, the network operation may become unstable and data transfer may become unreliable. Therefore, the longer stable period causes the higher network performance.

The proposed method increases the stable period of the network compared to the LEATCH method which uses a dynamic clustering protocol. Figure 3 shows the comparison of the network lifetimes in these methods.

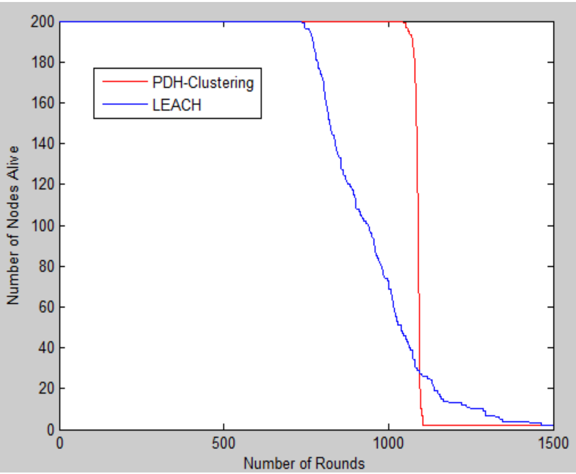

Figure 3. The network lifetime of total nodes.

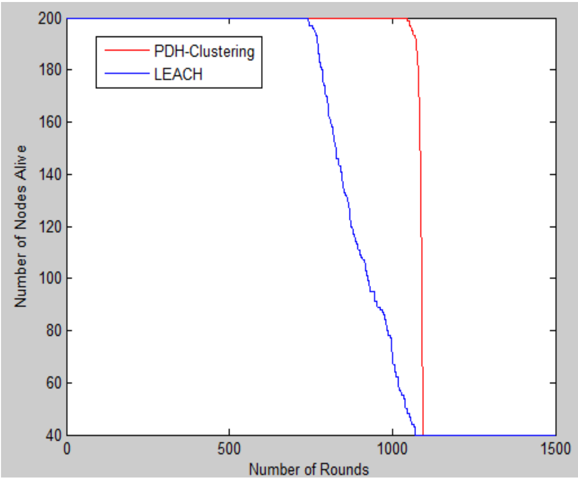

Figure 4. The network lifetime until the death of 160 nodes.

Figure 4 shows network life time until the death of 160 nodes. First node dies in the round 813 in LEACH protocol where in the new proposed method the first node dies in the round 1240. Therefore, the proposed method increases the network stable period to about 400 rounds. The percentage of stable period in whole lifecycle of the network in LEACH Protocol is 55% where in our PDH-Clustering protocol is 88%. The stable period percentage in PDH-Clustering algorithm has 31% improvement. This indicates that the performance of improved protocol is much better than the LEACH Protocol.

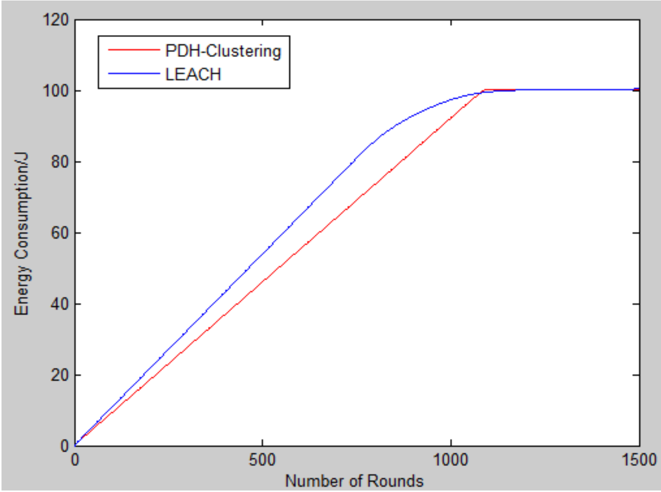

Figure 5. The total energy consumption.

Figure 5 shows the energy consumption diagram which proves that the proposed method consume lower energy compared to LEACH protocol.

5. CONCLUSION

In this paper, we introduce a novel dynamic clustering method for wireless sensor networks. In the proposed PDH-Clustering method a priority has been considered for each node and primary cluster heads has been selected based on this priority. Then, in some cases based on the illustrated condition a secondary cluster head has been selected. Matlab simulation results of these methods proves that PDH-Clustering method in compared to the algorithms with dynamic clustering, such as LEACH, has lower energy consumption and longer network lifetime.

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