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An Energy-Efficient Density-based Clustering Approach for Wireless Sensor Networks

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Abstract

In recent years, the use of Wireless Sensor Networks has been widely increased cause of applications that they provide. These networks consist of many sensor nodes that deployed in the area of interest and collect data from that area. The energy consumption is an important issue in these networks since the sensor nodes are very small and usually deployed in an environment where there is no possibility of charging batteries. Clustering the sensor nodes is one of the solutions to reduce energy consumption. Since the deployment of sensor nodes are random and non-uniform, the number of nodes in some regions is more than other regions. In this paper, a clustering method which considers the nodes density is proposed for sensor nodes. By defining a neighborhood radius for sensor nodes, those nodes that are located within the vicinity of each other are placed in a cluster. Simulation results show that the proposed method was able to increase network lifetime by reducing energy consumption than LEACH protocol.

Keywords: Clustering, Density, Wireless Sensor Networks, Energy Efficiency.

1. Introduction

Wireless Sensor Networks have many applications such as environmental monitoring [1], military operations [2], healthcare programs [3] and smart buildings [4]. These networks contain of many sensor nodes that deployed in an environment and are able to collect information from that area, process them and forward them to the base station [5]. Each Sensor node has five main components including memory, power supply, sensors, communication device and controller. Memory unit can save programs and data. A controller is used for processing data and can control other components. Communication devise is used to transmit and receive data over a wireless channel, power supply is to provide energy for other components and sensors are used to sense and collect data from network area [6, 7]. These sensor nodes have limitations in terms of energy consumption because they are battery operated. Thus, energy conservation is a critical issue in wireless sensor networks. There are various techniques to overcome this issue [8–12]. The most efficient technique to reduce energy consumption is clustering. The process of dividing the network area into several groups is called clustering and each group is defining as a cluster [13]. The clustering process can provide scalability and preserve energy of wireless sensor network. In this process, there is a node that can manage other nodes which known as cluster head (CH) and other nodes are normal or non-cluster head nodes. Non-cluster head nodes collect information from network area and transmit them to their CHs. Then each CH node aggregates these received information and send them directly to base station. Base station acts like a bridge between the sensor network and end user and collects data from entire network's

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nodes. Generally this node is considered as a node with no energy constraints. The main objective of clustering is to extend the network lifetime by reducing the energy consumption. An example of a clustered network is shown in Figure 1.

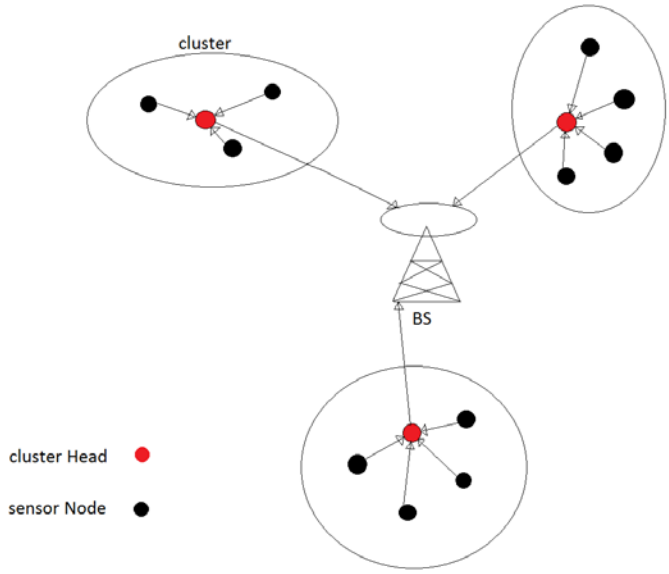

Figure 1: Clustered network

So far various clustering algorithms are presented with different applications for wireless sensor networks. One of the most known clustering algorithms for wireless sensor network is LEACH (Low-Energy Adaptive Clustering Hierarchical) [13]. So many clustering techniques are presented based on LEACH like LEACH-C [14], SEP (Stable Election Protocol) [15], LEACH-ICA [16], etc. [17– 19]. In this paper a new clustering method based on each nodes density is proposed to save energy and extends the network lifetime. Density is the number of nodes in neighborhood of a sensor node. Proposed method does not need to specify the number of clusters and can form clusters in an arbitrary shape. The rest of this paper is organized as follows: In section 2 an overview of some clustering protocols is presented, we describe our proposed method in section 3, simulation and evaluation results are shown in section 4 and conclusion is presented in last section.

2. Related works

Heinzelman et al. presented LEACH protocol which is the most known clustering protocol and the basis of further protocols. LEACH is a single-hop hierarchical clustering protocol. The main goal of LEACH protocol is evenly distribute energy consumption between network nodes to improve network lifetime. The performance of the LEACH is divided into two phase including setup phase and steady state phase. In setup phase, CHs are determined and clusters are formed then in the steady state phase each CH receives data from their non-CH nodes, aggregate them and forward them to the base station. At the beginning of each round, each node selects a random number from 0 to 1, and then compares this number with threshold value in equation (1) [13].

$$T(i) = \begin{cases} \frac{P}{1-P \times (r \bmod \frac{1}{P})} & if\ i \in G \\ 0 & o.w \end{cases} \tag{1}$$

If the selected number is less than threshold value, this node become a cluster head for current round; otherwise, remain as a non-CH node. Each CH node in current round broadcast an advertise message to neighbor nodes, then non-CH nodes that receive these advertise messages decide to join to the nearest CH based on signal strength of the message. After cluster formation, the process of data

transmission begins from non-CH nodes to related CH nodes. When CH node collects all information from their members, aggregate them and transmit them to base station. This process is repeated periodically. CH nodes randomly change after a period of time to balanced nodes energy consumption. The strength of LEACH protocol is the mechanism of cluster heads and data integration. However, one of LEACH's drawbacks is that there is no guarantee of location and number of cluster heads in each round.

An improvement of LEACH protocol is presented in [14] which is known as LEACH-C. This protocol uses a combination of central clustering algorithm and LEACH phases together. In setup phase of LEACH-C, each node forward its location and remaining energy level information to the base station. In addition, to appropriate allocation of clusters, the base station should ensure that the energy load is evenly distributed among all network nodes. To do so, the base station computes average energy of each node and determines that, which node has less energy level than average energy. This process can prolong the network lifetime than LEACH protocol.

In [16], authors use imperialist competitive algorithm (ICA) in LEACH for clustering in wireless sensor networks. Imperialist competitive algorithm is an optimization algorithm which is inspired by social phenomenon. This algorithm considers the colonization process as a stage of socio-political evolution. In this method, the performance of LEACH algorithm is improved by imperialist competitive algorithm in terms of energy consumption, coverage and uniformity of clusters. This process will find the best location for placement of the cluster head in the cluster. Also this method can improve the anomalies that exist in LEACH algorithm.

Another improvement of LEACH algorithm is presented in [20] that known as V-LEACH. In this method there is a candidate CH node in each cluster in addition to CH nodes. This node acts like a CH to transmit information to the base station to avoid disconnection for when the CH node dies and no need to selects a new CH. This will increase the network lifetime and the problem of uneven distribution is solved in V-LEACH.

A density-based clustering method is proposed based on LEACH algorithm called D-LEACH in [21]. This method uses the same phases in LEACH but the probability for each node to join the CH is depends on the density around that CH. This parameter value for N nodes and k clusters is defined as equation (2). This protocol calculates local degree of each node and compares it with D. If the local degree is less than D, this node joins to the cluster for current round; otherwise, its probability to join the cluster is low.

$$D = [\frac{N}{K}] \tag{2}$$

3. Proposed method

Since sensor nodes are randomly deployed in the area, network might have high density and low density regions which means that a large number of nodes are deployed in some regions and in some areas nodes are deployed further away from each other, so a clustering approach is needed for such a network which consider the density of each node to form the clusters. In this paper, a clustering technique is proposed for wireless sensor network which is considers the nodes density. In this proposed method, after random and non-uniform deployment of sensor nodes in network area, the cluster formation is begins.

We use the Eps parameter for determining the maximum radius of the neighborhood and MinPts parameter for determining the minimum number of nodes in a cluster for clustering in proposed method. Clustering process begins with a random selection of a node then nodes that are located in Eps distance of selected node are determined. If the number of these nodes is more than MinPts value, then selected node is considered as core node and the first cluster begins to form. After that, individual nodes in neighborhood radius must be checked in accordance with defined procedure.

If the condition is true for neighboring nodes, each of them is become core node and nodes which are within the neighborhood added to the first cluster. In this procedure, the clusters are formed. If the condition is not true for a node, this node is considered as a non-core node and must wait till CH selection process. After cluster formation, the CH selection process is starts. There are different criteria for CH selection in different articles [22– 25]. In this paper we use residual energy and distance of the node from base station to select CH nodes. This means that each node with more residual energy and less distance to base station in each cluster is selected as a CH node of the cluster. After CH selection process, the nodes that were consider as non-core nodes join to the cluster which has shortest distance to its CH node. Then the first round of the network starts and collected information from non-CH nodes send to CH nodes and CH nodes forward them to the base station.

4. Simulation results

In this section the results of the simulation and evaluation of the proposed method is presented. We use MATLAB simulator to evaluate the performance of proposed method. To demonstrate the effectiveness of proposed method compared it with LEACH protocol in terms of the number of living nodes and energy consumption. It is assumed that the numbers of 100 nodes are unevenly located in a 100m×100m area and fixed. The BS is located in the center of the network and nodes are using a simple energy model in [14].

Table 1: Simulation parameters

Description	Value	Parameter
Location of base station	50m×50m	X_s, Y_s
Energy consumed by radio electronics	50nJ/bit	E_{elec}
Energy consumed by power amplifier for short distance	10pJ/bit/d^2	E_{fs}
Energy consumed by power amplifier for long distance	0.0013pJ/bit/d^4	E_{mp}
Initial energy	0.02J	E_0
Data packet size	2000bit	L

The comparison of LEACH algorithm with proposed method is shown in Figure 2 and Figure 3. Figure 2 shows the number of dead nodes per round. As seen, the number of dead nodes per round in proposed method is more than LEACH algorithm. Thus, nodes are live longer in proposed method than LEACH. After some rounds the energy of nodes decreased and nodes die. The results show that the proposed method lives longer than the other one. In LEACH, the death of last node occurred in round number 251 but in proposed method the death of last node is happen in round 547. These results are also shown in Table 2.

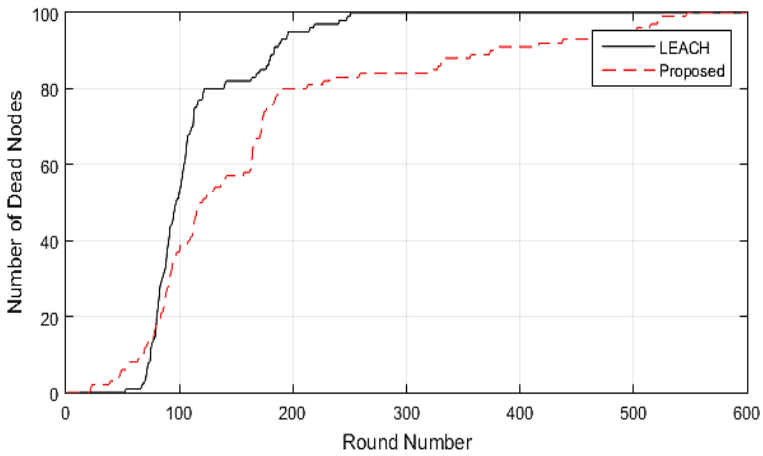

Figure 2: Number of dead nodes per round

Table 2: Rounds number of dead nodes in different types

Method	First node dead	Half node dead	Last node dead
LEACH	53	97	251
Proposed	22	118	547

Figure 3 shows the average energy of nodes per round. As seen in this figure the average energy of each node per round in proposed method is higher than LEACH algorithm, thus energy consumption in proposed method is better than LEACH, so causing to increase the lifetime of the network.

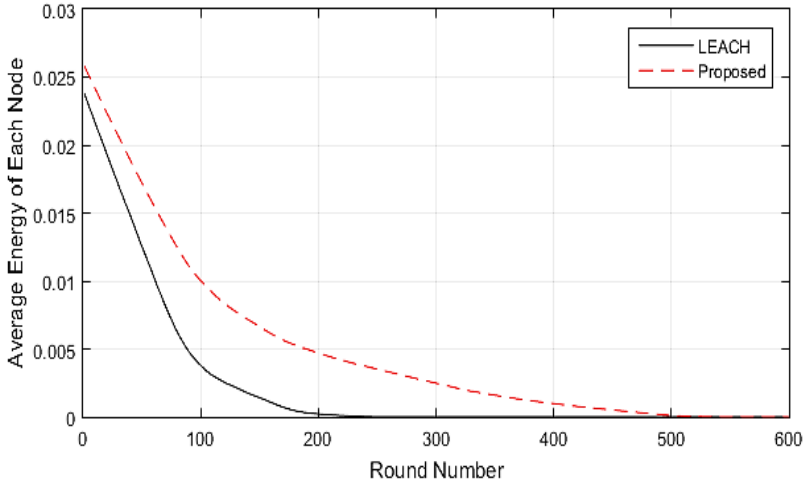

Figure 3: Average energy per round

Conclusion

The energy consumption of wireless sensor network is very important due to the limited energy resources of sensor nodes. Several solutions are proposed to decrease the energy consumption of wireless sensor networks. One of these methods is clustering. Duo to this issue, a density based clustering solution is proposed in this paper for reducing energy consumption in these networks. The proposed method considers the density around each node and begins the clustering process based on this density. As seen in simulation results, the proposed method is able to prolong the network lifetime by reducing the energy consumption of nodes than LEACH algorithm.

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