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An Energy Efficient Method for Wireless Sensor Networks Using Non-overlap Sensing Range

D. Satyanarayana*, Abdullah Said Alkalbani

Department of Electrical and Computer Engineering, College of Engineering, University of Buraimi, Sultanate of Oman, Al-Buraimi
*Corresponding author email: degala.s@uob.edu.om

***Abstract*:** The high priority task in wireless sensor network (WSN) is energy saving as the energy is a scare resource. The Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol is proposed primarily for saving energy and increasing the network lifetime in WSN. In the LEACH protocol, the entire geographic area is covered with many clusters, each cluster has many sensor nodes and only one node is elected as the cluster head by a specific set of sensor nodes. The cluster head is responsible for collecting the data from the sensor nodes within the cluster. In the LEACH, the sensor nodes send some duplicated information to cluster head. This duplicated information consumes unnecessary energy for transmitting data from sensor nodes to cluster head. In this paper, we have considered this as problem and provided a solution to eliminate the information duplicating at the sensor nodes. The simulation results show that the proposed protocol gets improvement over the LEACH in reducing the energy consumption.

***Keywords*:** wireless sensor network, energy consumption, energy efficient communication.

1. Introduction

A wireless network provides services to the people to communicate, access applications, and access information without cables. There are various types of wireless networks, but a distinguishing the type of wireless network where the communication exists among the computer devices has significant demand due to automation systems. These computer devices include personal computers (PC), personal digital assistants (PDAs), laptops, smart phones, servers, and printers. A similar idea is considered for wireless sensor network while transferring the data from a remote environment to specific location. The wireless sensor networks have got considerable attention for the last 15 years as the technology of WSN is maturing enough to move out from pure research environment to commercial industry. The wireless sensor networks gather the information from the environment such as chemical plants, war fields, agriculture fields, and underwater areas, and transfer this information to the local stations. The wireless sensor networks are differentiated from the normal wireless networks by adding extra component called sensing device apart from the transceivers. Generally, the sensor nodes in WSN spread across the geographic area and once the battery power of a sensor node is exhausted, the node is considered dead. Hence, the energy component in wireless sensor network is become highest importance [1]. The major energy consumption in WSN is the energy consumption due to the communication. There are various energy efficient communication protocols for WSN. Among these protocols, Least Energy Adaptive Clustering Hierarchy (LEACH) is the first cluster based protocol defined for WSN in order to save the energy and increase the network lifetime [2].

In LEACH, the network is divided into several clusters, where each cluster is managed by a cluster head (CH). The sensor nodes collect the data from the environment and transmit to their cluster heads, which in turn retransmits the aggregated data to the base station, see Figure 2. In this scenario, each cluster has several sensor nodes randomly distributed inside the cluster. In this case, the sensing areas of two or more sensors may overlap the geographic area. For example, see Figure 1, the two sensor nodes S1 and S2 have overlapped area indicated with the shading. In LEACH, the sensor node S1 and S2 transmit the information of their areas to the cluster head without considering the overlaps. Thus, the cluster head receives some information two times from both S1 and S2. The issue is that the duplicated information from overlapped sensing area of the two sensor nodes will be transmitted to cluster head, which unnecessarily consumes extra energy.

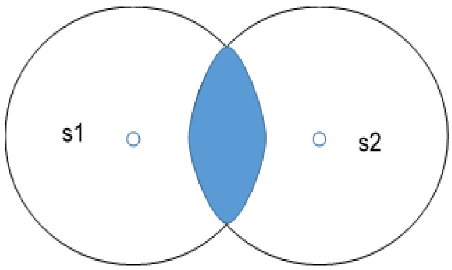

Figure 1. The overlapping area of the two sensor nodes

In this paper, we have proposed a new method by removing the data, which belongs to the overlapping area, while transmitting from the sensor node to the cluster head. However, the data which belongs to the overlapping area, will be transmitted once rather than multiple times. This reduction brings down the needed energy for transmitting the data.

The remainder of the paper is structured as follows: In Section 2, the related work in this area is given. Section 3 describes the proposed methodology. Section 4 describes experiments by simulations and proves the efficiency of the proposed algorithm. In the section 5 the paper is concluded.

2. Related Work

Wireless sensor networks have attracted significant attention because of their wide range of applications. These wireless sensor networks have a certain lifetime because the nodes have limited battery power through which the nodes can sense the environment, process the information, and communicate with other sensor nodes in the network. This means that all aspects of the node, from the sensor module to the hardware and protocols, must be designed to be energy-efficient. Decreasing energy usage by half can double system lifetime, resulting in a large increase in the overall usefulness of the system. Nevertheless, to reduce energy dissipation, protocols should be robust to node failures, fault-tolerant and scalable in order to maximize the system lifetime [3].

The energy consumption for communication is much higher than the computation or sensing process in WSN. Hence developing the energy efficient communication protocols for sensor networks is important [1]. There were many protocols developed for energy efficient communication [4-7].

The LEACH [2] is the first network protocol that uses hierarchical routing for wireless sensor networks to increase the lifetime of network. All the nodes in a network organize themselves into the local clusters, with one node acting as the cluster-head. All non-cluster-head nodes transmit their data to the cluster-head while the cluster-head node receive data from all the cluster members, perform data aggregation, and forward the data to the remote local station. Therefore, being a cluster-head, the node is much more energy-intensive than being a non-cluster-head node. Thus, when a cluster-head node dies, all the nodes that belong to the cluster lose communication ability [2, 8]. The formula for making the sensor node as the cluster head in LEACH is based on the threshold formula given below.

$$T(n) = \begin{cases} \frac{P}{1-P*\left(r \bmod \frac{1}{P}\right)} & if\ n \in G \\ 0 & otherwise \end{cases} \quad (1)$$

P=probability of becoming the cluster head
r= the current node
G= the set of nodes that have not been cluster-heads

The node *n* selects a random number between 0 and 1 and having the value less than the threshold T(n) then the node becomes the cluster head for the current round.

There are few improvements proposed on LEACH to improve the performance of the protocol and increase the network lifetime. Yulin *et al*. [9] proposed E-LEACH protocol to increase the network lifetime. In this protocol, the selection of the cluster heads is based on the remaining energy level of the sensor nodes. The S-LEACH protocol has been proposed by Thakkar *et al*. [10] and the protocol can assure the network in which the required number of cluster heads is maintained at each round.

Bakaraniya *et al*. [11] proposed K-LEACH protocol which depends on K-mediods algorithm for selecting the cluster heads. The algorithm not only increases the network lifetime, but also balances the load of the network. A protocol called CS-LEACH [12] was proposed which saves the energy of sensor nodes during the data transmission. The protocol uses a method called Intelligent Sleeping Mechanism (ISM) to make some percentage of nodes in the network that goes under sleep mode.

Another variant of LEACH called Vor-LEACH [13] has been proposed. In this method, the formation of clusters is replaced with Voronoi regions, which represents the distance relationship among sensor nodes [14]. As the distance between the nodes is directly proportional to the energy required for communication, the Vor-LEACH saves energy during data communication.

A D-LEACH proposed protocol [15], observes the data coming from the sensor nodes to the cluster heads and assigns the probability parameters to each data frame to be transmitted. Taneja *et al*. [16] have proposed a hierarchical system, where all the nodes in the network are classified into three levels. The *level 1* nodes gather the information from the environment, whereas the *level 3* nodes come under the radius of the base station. The *level 2* nodes exist between *level 1* and *level 3*.

In the next section, we describe the non-overlapped methodology on LEACH protocol for wireless sensor network to save energy consumption of the sensor nodes.

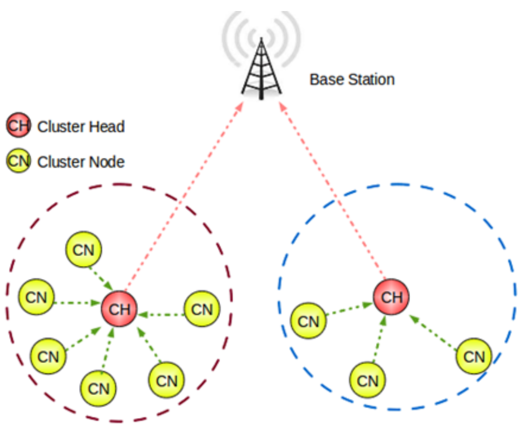

Figure 2. LEACH Protocol

3. Proposed Protocol

A wireless sensor network is a network where each node is equipped with transceiver as well as a device having sensing capability. These wireless sensor networks have become popular because of their wide range of applications. In many applications, generally, the nodes are scattered on the ground randomly and the network is formed. Once the battery of a sensor node is exhausted, the node is considered dead and the network lifetime is affected. One of the popular protocols is called LEACH [2] whose main responsibility is to increase the life time of the network during the data transmission. In the LEACH, each sensor node collects the data from the environment and transfers it to the cluster head. Once the cluster head receives the information from the sensor nodes, it aggregates the data and forwards it to the local station. In this procedure, the data aggregation is done to reduce the amount of data to be transmitted to the local station. However, there is no process found in the LEACH for reducing the data to be transmitted between sensor node and the cluster head. We have considered this observation and proposed a new protocol called Non-Overlapped LEACH (NOV-LEACH), whose main objective is to reduce the data to be transmitted from the sensor node to the cluster head. The energy consumption is directly proportional to the amount of data to be transmitted in the communication [17,18].

$$E \infty D \qquad (2)$$

Here E is the energy required for communication and D is the amount of data to be transmitted. In other words, the energy consumption for network is reduced if the protocol reduces the data to be transmitted. From the observations on LEACH protocol, each sensor node collects the data from its sensing range, which is normally in the circle shape for many sensor nodes. However, there could be overlaps area between two sensor nodes if these two nodes are closer to each other. See Figure 1. The data collected from the overlapped area will be transmitted more than one time. In other words, it is sufficient that only one node can transmit the full information and other nodes can avoid sending the overlapped area information. Hence, reducing the data to be transmitted from sensor node to the cluster head, in turn reduces the energy consumption of the sensor node as well as the cluster head for receiving data.

The following algorithm describes the step by step procedures for the NOV-LEACH protocol.

Step 1: All the sensor nodes broadcast the hello-packets, which contains ID and location information.

Step 2: Each sensor node collects its hello- packets and stores them as neighbors.

Step 3: Each node broadcasts its neighbor list and collects the 2-hop neighbor information.

Step 4: Follow the procedure of LEACH for selecting the cluster head.

Step 5: Each sensor node calculates the overlap area with its neighbors.

Step 6: Each sensor node sends the data related to the non-overlapping area to cluster head.

Step 7: The sensor nodes, which are overlapped and have highest ID will send the complete sensed data to the cluster head.

Step 8: The cluster head receives the data from the sensor nodes, aggregates it, and forwards it to the local station.

In the algorithm, to form the clusters, we need at least one hop neighbor, which is done with the first and second step. After collecting the neighbors, selection of the cluster head among the given sensors is based on the heuristics given in the LEACH protocol [3]. Once the cluster head selection process is finished, the data transmission takes place between sensor node and cluster head. Steps 5, 6, and 7 make sure that the duplicated data to be transmitted from sensor node to the cluster head will be reduced. In other words, all the sensor nodes send only data related to the non-overlapping area, except only one sensor node that sends the complete data in its sensing range including data related to overlapping area.

To calculate the overlapped area of a sensor node, we have defined an overlap matrix. The overlap matrix can provide the information about the number of overlaps in the network from each sensor node to other sensor nodes. The size of the overlap matrix is *n* x *n*, where *n* is the total number of nodes in the network. The overlap matrix is a square-upper-triangle matrix. An element in the matrix is non zero which indicates that the overlap area exists between two sensor nodes in the network and the value for the area is assigned to the element.

$$a_{ij} = \begin{cases} = k, & \text{if } i^{\text{th}} \text{ sensor node overlaps} \\ & j^{\text{th}} \text{ sensor node} \\ = 0 & otherwise \end{cases} \qquad (3)$$

where $i=[1:n], j=[1:n],$ k is the real value which is equal to the area of the intersection of the nodes.

$$\begin{bmatrix} 0 & a_{12} & a_{13} & a_{14} & \cdots & a_{1n} \\ 0 & 0 & a_{23} & a_{24} & \cdots & a_{2n} \\ 0 & 0 & 0 & a_{34} & \cdots & a_{3n} \\ 0 & 0 & 0 & 0 & \cdots & a_{4n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 0 & 0 & 0 & 0 & \cdots & 0 \end{bmatrix}$$

The value of an element in the overlap matrix is zero for two cases. The first case could exists if there is no overlap between two sensor nodes as the distance between them is greater than or equal to 2*S, where S is the sensing range of a node. The second case could happen to the node n_1 if the node n_1 overlaps with the node n_2 and the node n_2 has higher ID number than n1. The total overlapping area for a node n_i is

$$A_{ij} = \sum_{j=0}^{n} \frac{n_{ij}}{l} \qquad (4)$$

where $i \neq j$ and j > i, 1<=l<=n

4. Simulation and Results

We have written the code to simulate the protocols LEACH and the proposed method NOV-LEACH with the required network parameters. In the simulation, we have done three experiments to check the performance of the proposed protocol. The first experiment is about the relationship between the overlapped area and the number of sensor nodes in the network. For this experiment, we have distributed the sensor nodes randomly in the quantity of 10, 15, 20, 25, 30, 35, and 40 in the square grid area of 1000x1000 m^2. From the graph, we say that the overlapped area increases with the increase of number of nodes in the network, see Figure 3.

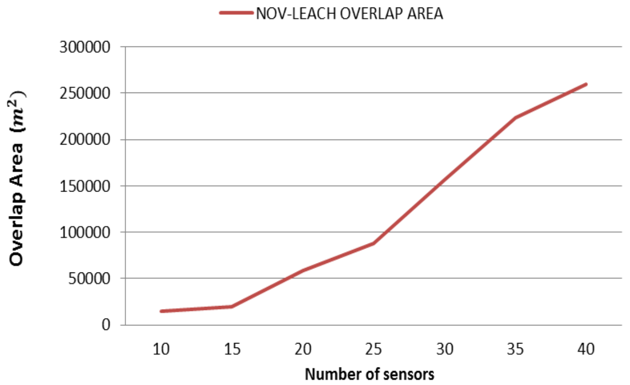

Figure 3. Overlapped area versus the number of nodes

The second experiment is on calculating the total energy consumed during the data transmission from the sensor node to the cluster head in both LEACH and NOV-LEACH protocols. For this experiment, we have considered the sensor nodes randomly distributed in the sizes of 10, 15, 20, 25, 30, 35 and 40 in the grid area of 1000x1000 m^2. From Figure 4, we say that the total energy consumed in the network is high for the LEACH protocol compared to the total energy consumed in the NOV-LEACH protocol. This happens because the sensor nodes in NOV-LEACH do not send the duplicated information from the sensor node to the cluster head. In other words, the duplicated data transmission makes LEACH to consume more energy.

The third experiment is about calculating the total area of sensor network from which the sensing information to be considered for transmitting from the sensor node to the cluster head in both NOV-LEACH and LEACH protocols. For this experiment, we have considered the same number of nodes and the grid area size mentioned in the experiment two. From the graph, we say that the total area to be covered in the LEACH is higher compared to the area in the NOV-LEACH protocol. This happens because NOV-LEACH eliminates the overlapped area if the distance between the two sensor nodes which is less than or equal to 2S, where the S is the sensing range of the node.

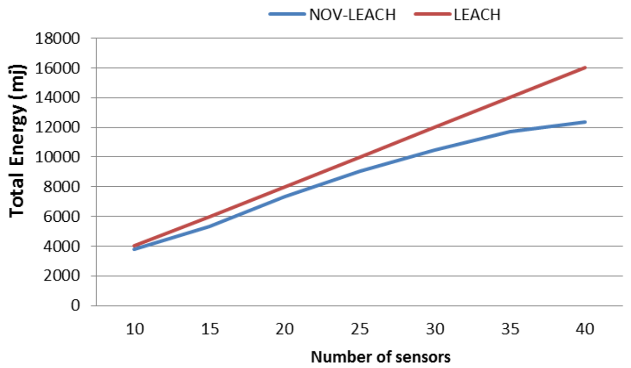

Figure 4. Energy consumption versus different network sizes for NOV-LEACH and LEACH

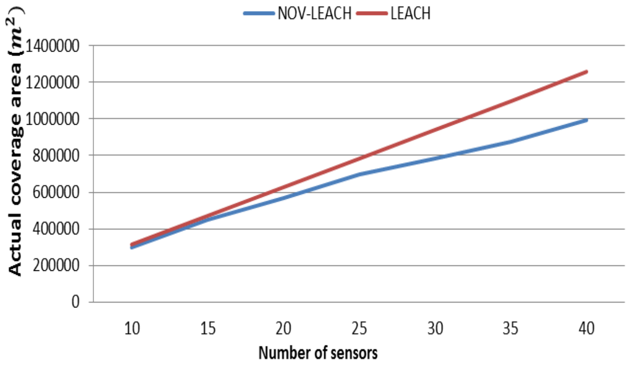

Figure 5. Actual Area covered by sensors versus different network sizes for OVER-LEACH and LEACH

5. Conclusions

The energy saving in wireless sensor network is very significant because sensor nodes have limited energy. In this paper, we have proposed a new protocol to reduce the energy consumption. This protocol reduces the energy consumption by removing the duplicate information while sending the data from sensor nodes to cluster-head. Because of this elimination, energy is saved as redundant information is reduced from sensor nodes while transmitting the data. The simulation results show that the energy consumption is reduced in the proposed protocol compared to the LEACH protocol.

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