INCREASE THE LIFETIME OF WIRELESS SENSOR NETWORKS USING HIERARCHICAL CLUSTERING WITH CLUSTER TOPOLOGY PRESERVATION

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ABSTRACT

Wireless sensor networks consist of hundreds or thousands of nodes with limited energy. Since the life time of each sensor is equivalent to the battery life, the energy issue is considered as a major challenge. Clustering has been proposed as a strategy to extend the lifetime of wireless sensor networks. Cluster size, number of Cluster head per cluster and the selection of cluster head are considered as important factors in clustering. In this research by studying LEACH algorithm and optimized algorithms of this protocol and by evaluating the strengths and weaknesses, a new algorithm based on hierarchical clustering to increase the lifetime of the sensor network is proposed. In this study, with a special mechanism the environment of network is layered and the optimal number of cluster head in each layer is selected and then recruit for the formation of clusters in the same layer by controlling the topology of the clusters is done independently. Then the data is sent through the by cluster heads through the multi- stage to the main station. Simulation results show that the above mentioned method increases the life time about 70% compared to the LEACH.

KEYWORDS

wireless sensor network, lifetime, hierarchical clustering, cluster heads, cluster topology, multiple hop.

1. INTRODUCTION

Wireless Sensor Networks are special type of wireless networks that hundreds or thousands of sensor nodes-are working together[1]. In general, wireless sensor network consists of a large number of small wireless devices which are called sensor nodes these sensors have multiple tasks like detection, computation and communication[2]. The network has developed in recent years and is widely used in many applications including environmental monitoring, object recognition, event tracking and security surveillance applications. Wireless sensor networks are severely limited resources. Limitations include the limited energy resources, short-range connectivity, low bandwidth, limited amount of memory and processing at each sensor. Since sensor nodes are working with battery, they have a limited life and battery charging for sensor nodes is often difficult[3]. Operators such as sensing, communications and computing consume sensor energy;

information transfer is the main source of energy consumption. Each wireless sensor node has the capability of collecting data and sending them to the base station. In fact, the base station is the interface between sensor networks and the user, which needs information. Scalability is considered one of the most important factors in the in wireless sensor networks. Due to the limited energy of nodes, simultaneous operation of all nodes, drains node energy and reduce their longevity. Therefore, the issue of energy in wireless sensor network is considered a crisis.

Clustering protocols, is a good way to increase the lifetime of wireless sensor network. In clustering, hole network is divided into clusters. In every cluster, a node is selected as cluster head. Cluster members transfer their processed information to cluster head in a single-stage or multi-stage manner. Then, after gathering information, cluster head transmits to the base station through the single-stage or multi-stage line[4, 5].

2. ROUTING PROTOCOLS

Routing protocols can be discussed in four categorized groups. The four groups are:

- Data-Centric Protocols or flat routing
- Location-based protocols
- Protocols aware of service quality
- Hierarchical protocols

In this study, we work on hierarchical protocols[6, 7].

2.1.Hierarchical Protocols

In this protocols the network is divided into different sub-sections which is called cluster, in each of clusters, cluster head (CH) takes duties such as combining data and removing duplicate data.

As previously mentioned, as well as other telecommunications networks, scalability, or the ability to expand the network is one of the most important design parameters in of wireless sensor networks. To enhance network capability to cover larger areas without any problems occur in the quality of network services, network segmentation into several clusters have been proposed [5, 6].

2.2.The Concept of Clustering

Clustering is an efficient approach for load balancing between sensor nodes and prolong the life of the network. With clustering, transmitted data of nodes within the cluster is integrated by cluster head, and are transmitted to base station either directly or through an intermediary with other cluster heads. So your communication overhead that nodes can send their data to the base station comes straight down. So nodes can reduce their communication overhead that results from straight transmission of their data to base station comes down. The aim of utilizing the clustering

approach in sensor networks, is to reduce the volume of data sent and received, and finally reducing power consumption for communications between nodes.

In fact, the cluster head nodes operate as a gateway between the base station and sensor nodes. In other words, cluster head is such as sink for the cluster nodes and base station is such as sink for cluster heads. The main station, is the processing center of the data received from the sensor nodes and also where data is accessed by the end user. Usually this station is designed in a fixed local and with a long distance from the sensor nodes. In addition, the structure formed between the sensor nodes and cluster heads and base stations, can be repeated as many times as needed and create multiple layers in a hierarchy wireless sensor network[8-10].

3.RELATED WORK

3.1 LEACH Protocol

LEACH protocol aims to cut wireless sensor network energy consumption through the process based on clustering. To achieve this goal LEACH protocol dynamically elects the nodes as cluster head, eventually forms cluster. Communication within the cluster is single-stage. After receiving information CH sends information to the base station or ahead CHs. For uniform distribution of energy among the nodes, LEACH periodically changes the CH. LEACH performance is controlled via execution round. CH is selected at the beginning of each round. Each turn consists of two phases, the preparation and maintenance. In the preparation phase, the cluster heads are selected and cluster is formed. Then the cluster communication schedule is determined. In the second phase data transmission to CH and after that to base station is performed based on the schedule of the first phase. Duration of maintenance phase to reduce overhead is more than preparation.

Preparation consists of three stages of declaration, cluster configuration and scheduling. LEACH Executes at the beginning of each round and elects heads randomly. Initially, each node selects a random number between 0 and 1. If the random number is less than T(n). T(n) is calculated as follows [9]:

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

In Eq.(1), p is the perfect percent of CH, r ongoing round, G the set of not selected nodes in the end 1 / p. Selected CH is announced to neighbors as the new CH. To send this announcement, LEACH uses the CSMA to avoid collision of announcements. When nodes receive the announcement message, they select their CH based on the received signal strength. If a node receives announcement messages from a CH, automatically becomes a member of that cluster.
After the announcement phase, the cluster is formed. CSMA is utilized to prevent from collision between messages of nodes. Finally, the scheduling is performed. After the formation of cluster, the maintenance begins. During the maintenance phase, the nodes begin to sense and send

information to CH. Then CH compresses the information and sends them to the base station. After the maintenance phase the preparation phase begins again. This trend continues during the lifetime of the network. The continuous change of CH leads to an equal distribution of power between the nodes. During the maintenance phase, only one node is active at any moment. Which will lead to increased longevity. LEACH ends in a few execution rounds. LEACH doesn't guarantee about the location and number of CH, and change in cluster size is high. Therefore, other versions of LEACH have been proposed[11-13].

4. PRESENTATION OF PROPOSED APPROACH

LEACH protocol is one of the most famous clustering protocols in wireless sensor networks in which the selection criteria for cluster head is a random probability function in the entire network. In the proposed mechanism the network environment is layered and the basis of this layering is such that every layer environment from the side of main station to the end of network environment is increased with a certain factor. Then in the execution of the algorithm the environment of every layer is treated like the environment of entire network. Due to layering of the network environment instead of using a single phase transmission, the multi-stage transmission of data from lower layers to higher layers up to the base station is utilized.

4.1 Modeling the Consumed Energy

Consumed energy in the wireless sensor network consists of three parts: data, data reception and data processing. Energy model is given in Eq. (2)[7,12]:

$$\begin{cases} P_T(K) = E_{elec} * K + E_{amp} * d^{\gamma} * K \\ P_R(K) = E_{elec} * k \\ P_{cpu}(K) = E_{cpu} * k \end{cases} \quad (2)$$

P_T, P_R and P_{cpu} represent the consumed energy of transmission, receiving and processing k bits of data respectively. $E_{elec}E_{amp}$ and E_{cpu} represent energy consumption (nJ / bit) per bit transmission in radio domain, required energy for transmitting in a larger domain than E_{elec} and required energy to processing per bit, respectively. According to Eq.(2), the total energy consumption of **k** bits is as shown inEq.(3)[8, 14].

$$P_{Total} = P_{Trans,it} + P_{Reseive} + P_{Process} \quad (3)$$

(4) $P_{Total} = k(2E_{elec} + E_{cpu} + E_{amp} \times d^{\gamma})$

In Eq. (3,4), we will see that energy consumption has a direct relationship with the amount of data transmission. If the transmitted data is less, we will use less energy. If the transmission distance is less than the threshold, the consumed energy will have a relationship with d^2. If the transmission distance is greater than the threshold, it has a relationship with d^4. Therefore, as the transmission distance is lower, energy consumption can be reduced.

4.2 Layering Model

In the proposed mechanism by using Eq.(5), the network environment is layered proportional to the distance from the base station.

$m=y-k$ (5)

$k=\sum_1^i L_{(i)}$

$$L_{(i)} = \begin{cases} L_{(i)} = 2^{i+2}, & m \geq 2^{i+1} \\ else & \\ L_{(i)} = m, & m > L_{(i-1)} + \frac{1}{2} L_{(i-2)} \\ else & \\ L_{(i-1)} = L_{(i-1)} + m, & m < L_{(i-1)} + \frac{1}{2} L_{(i-2)} \end{cases}$$

In Eq.(4), the value of y is the network environment length, k is the aggregation of layers, m is difference of network environment length and aggregation of layers and L _ ((i)) is the size of the ith layer. In allocation of environment to each layer, conditions of (4) equation should be analyzed. Numerous values of L_i and L_{i+1} with different relationships can be extracted. This is, indeed, the main conceptbeing in accordance with Y = L1 + L2 + ... + Li. Also, in the covering of clustering,the principle of optimality of layers is important.

4.3 The Optimal Number of Cluster Heads

The optimal number of cluster heads in LEACH protocol is a system parameter that is calculated analytically and given as the optimal percentage of cluster heads to the total number of nodes in the beginning of the implementation of the Protocol.

In the proposed mechanism the optimal number of cluster heads in each layer is different. In it has been stated that if one node has less than $0.074\times \log(n)$neighboring nodes, the network connection is likely to be cut and if a node has more than $0.074\times \log(n)$ neighboring nodes, the network is connected. In the proposed mechanism,Eq. (6) has utilized as an idea for the optimum number of members for a cluster with regard to maintaining communication and network coverage[12].

$$Q_{\min} = \lfloor 5.1774 \times \log(n) \rfloor \quad (6)$$

In relation Eq. (6), n is the total number of nodes in the network and Q min determines the optimal number of members for a cluster. According to the assumptions, the optimum number of cluster heads for the total network is obtained using Eq.(7).

$$=K_{opt}\frac{n}{\lfloor 5.1774\times\log(n)\rfloor} \quad (7)$$

In the proposed method, the optimal value of cluster head for each layer is calculated separately, for this purpose,Eq. (8) is used.

$$K_{opt\,i}=\lceil\frac{n_i}{\lfloor 5.1774\times\log(n_i)\rfloor}\times\frac{L_i}{y}\rceil+1 \quad (8)$$

In relation Eq.(8),n_i،L_i ، y و $K_{opt\,i}$ are the nodes in the ith layer, the size of the ith layer, the length of network environment and the optimal number of cluster heads in the ith layer respectively. In this stage, by taking into consideration the size and number of nodes per layer and the number of nodes in every layer, the optimum number of cluster heads in every layer and equivalent to that layer is obtained.

4.4 Clustering Model

In the clustering algorithms, cluster head acts as a central controller.Clusterheads,by collecting data from members of the cluster and transmitting the data after compression through the multi-stagepath, have an important role. Thus the energy consumption in cluster heads is more important than other nodes[9]. To conserve cluster heads energy and preserve the connection link of cluster heads near to the main station, it is better that the number of members of clusters near to the main station be less, so that the cluster heads near to the main stationallocate more of their energy to receiving data from lower layers and transmitting data to the higher layers or main station.

After layering network environment, the nodes will be informed by the base station that in which layer they are placed and it becomes clear that how many nodes exist in each layer.Cluster formation in each layer is done independently. In each cluster, cluster head, receives data from the member and after data aggregation, sends them to the upper layer or base station. If the number of nodes near the base station is large, the cluster size in that layer (i.e. clusters with more members) will be large and this leads to early energy discharge of clusters close to the main station, because these nodes in addition to the routing for lower layers, they are responsible to data integration from the members. If the cluster size is too small, the number of nodes in cluster becomes very small number and the small size of cluster leads to early discharge of cluster head. Therefore, in the proposed algorithm for the propose of correlated clustering of each layer to layer to the distance from the base station and the size of that layer, by using Eq.(7) in the section C, calculates the optimum number of heads for each layer separately. As a result, in each layer the optimal numbers of CHs are obtained, so that from the premature energy discharge in the cluster headsare prevented in the upper layers that are the bottleneck for other layers.

4.5 Making Symmetric the Size of Clusters

In section C, the problem of the uncertainty of the optimal number of cluster heads in LEACH algorithm has fixed, but there is still the problem of the uncertainty about the balance of clusters. In the proposed mechanism for each layer, clustering is executed separately. After determining the optimal number of nodes per layer in relation E.q(8), the number of cluster nodes in a layer minus the optimal number of CH in that layer according to Eq.(9) is divided to the optimum number of CH in the layer.

$$C_i = \left\lfloor \frac{n_i - K_{opt\,i}}{K_{opt\,i}} \right\rfloor \tag{9}$$

In the relationship Eq.(9), n_i،$K_{opt\,i}$ C_i are the number of nodes in the ith layer, the optimal number of CH in the ith layer and the number of cluster members for the ith layer, respectively. Therefore the maximum cluster members in the ith layer are equal to C_i.

With the implementation of this algorithm in the proposed mechanism, the equal numbers of members are placed in each cluster. Hence the same time is spent for combining data in CHs and also the energy of CHs is consumed equally at all clusters. As a result, we will have load and energy balancing in the network.

4.6 Routing Model

In the proposed mechanism,routing between the layers is done from the lowest layer to the upper layers. The algorithm then serves so that the CHs of lowest layer exchanges messages with itsupper layer. Taking into account the residual energy and the distance from CHs of upper layer, the most appropriate cluster head or the best path to the upper layer is selected and with a message reports its status and request to the considered cluster head.This action is done for each cluster head separately.

The algorithm works for all the layers so that the first layer is the closest layer to the base station. In this layer, there is no need for routing and CHs of this layer transmit data to the base station directly. Fig. 1.shows the routing model in of the proposed mechanism.

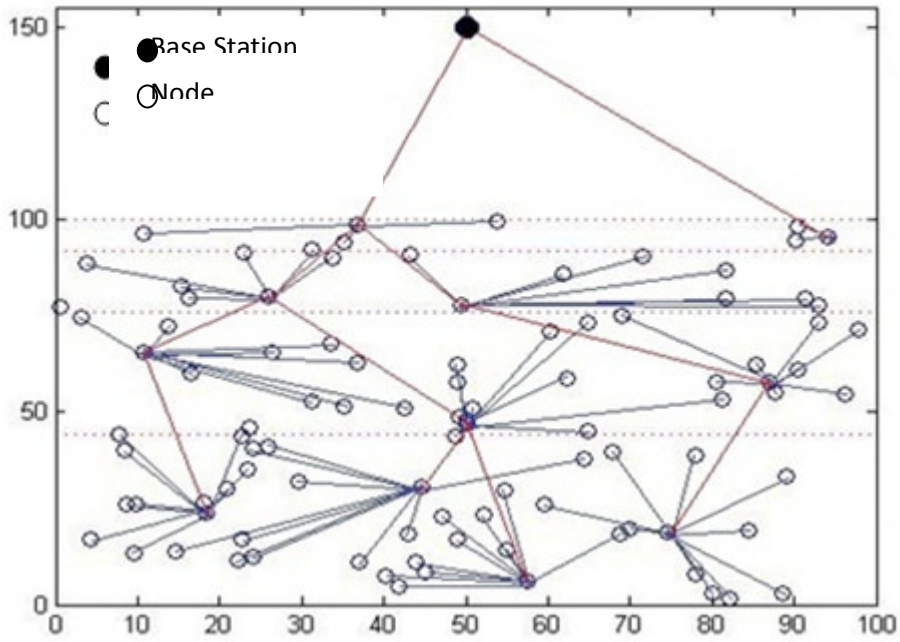

Figure. 1**:** A view of a layered model, clustering, making symmetrical and routing model in the proposed mechanism

5. SIMULATION AND ANALYSIS OF RESULTS

In this section, we analyze the proposed algorithms and compareit with the past algorithms. MATLAB software is used for simulation. The initial parameters for the simulation of wireless sensor network for simulation of 100 nodesare given in TABLE.1 below.

TABLE.1: The initial parameters of the wireless sensor network

Parameter	Value
Size Of Environment	$100\times100m^2$
Primary Energy	0.5 (J)
E_{cpu}	7(nJ/bit)
E_{elec}	50 (nJ/bit)
E_{amp}	0.659 (nJ/m^2)

Size Of paket	4000Bit
Base Station Point	50×150

5.1 The Assumptions Considered in the Simulation

- The position of base station is fixed and it has unlimited energy.
- The position of base station is outside of the network and it has already been identified.
- Network environmentis square withdetermined number of sensors.
- All sensors in the homogenous condition are uniform and they have equaland limitedinitial energy.
- Heterogeneous sensors have initial energy double times of typical sensors.
- Sensors have random uniform distribution.
- Sensors have been placed in a fixed manner.
- Sensors are aware of their location.
- Initial energy of sensor is clear.
- Identifier of each sensor is unique.

5.2 Simulation Results

The lifetime of proposed mechanism has been compared with E-LEACH LEACH protocols with regard to assumptions in Table.1. As can be seen in Fig.2 and3, the proposed mechanism compared to other protocols has increased network lifetime.

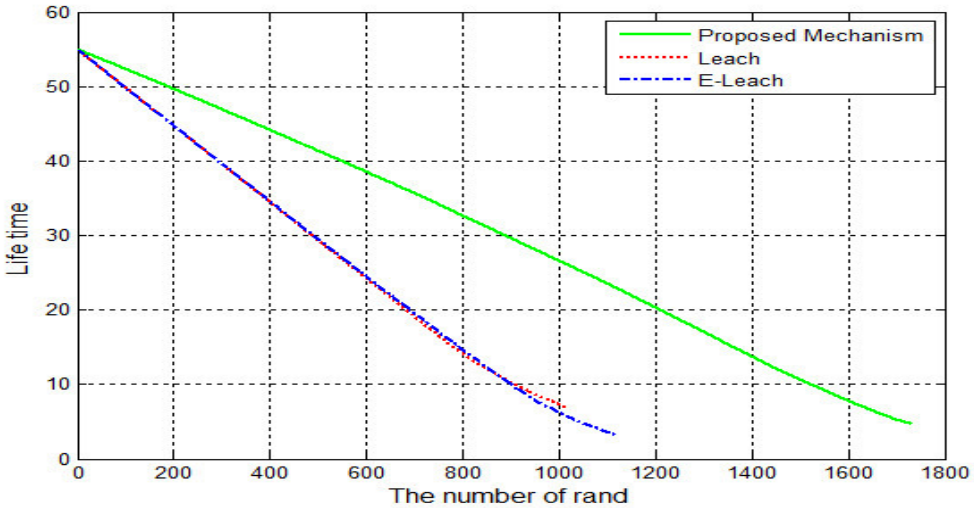

Figure.2: Comparison of the lifetime of the proposed mechanism with LEACH and E-LEACH protocols.

As is shown in fig. 2, related curve to the life of proposed method moves with a lower slope than the other methods.

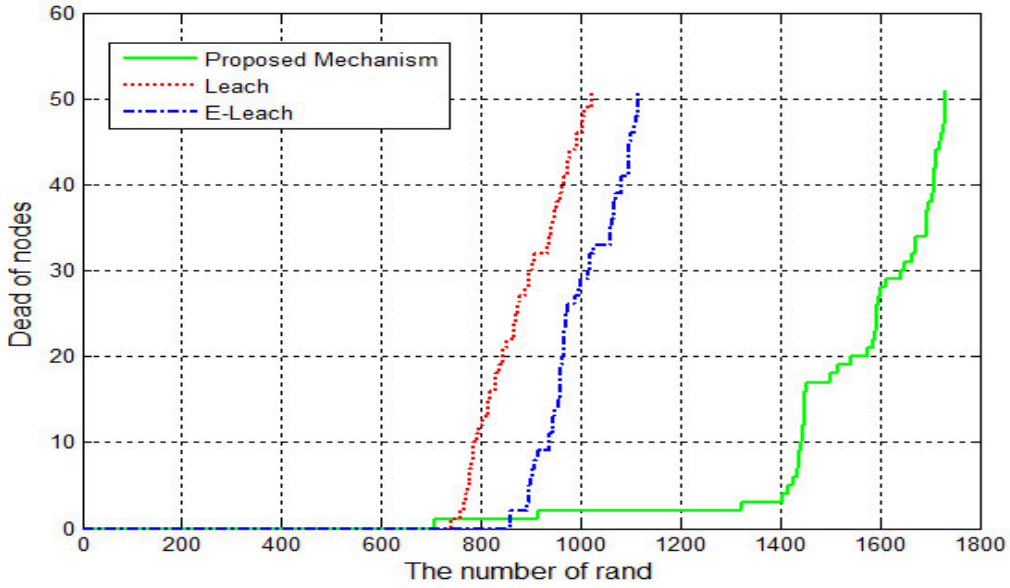

Figure.3: Comparison of the lifetime of proposed mechanism with LEACH and E-LEACH protocol

Fig.3 has compared the lifetime of the proposed mechanism with E-LEACH and LEACH protocols. As shown in the figure, time interval of the last dead node in the proposed mechanism compared to other protocols is nearly double.

Table.2 shows death of nodes in three cases, the death of the first node, death of 50% and death of 80% of the nodes.

Table.2: comparison of the death ofthe nodes in proposed mechanism withE-LEACH and LEACH protocols, with different lifetimes compared to turn of execution

Lifetime			
Death of 80 % of nodes	Death of 50 % of nodes	Death of first node	**Method**
1972	1600	791	Proposed mechanism
1160	944	788	LEACH
1320	1035	797	E-LEACH

According to Table. 2, the proposed mechanism in the death first sensor node is nearly equal to compared protocols. However, during the performance of the network, while 50% of sensor nodes disable due to energy depletion, the proposed mechanism displays a better performance.

6. CONCLUSION

In this study, a method is presented to increase the lifetime of wireless sensor networks using hierarchical clustering which operates based on layering network environment, as if divides the network environment into heterogeneous sections. The size of layers of network increases with distance from the base station, and in each layer after determining the number of sensor nodes, using a new method,the optimal number of CHs in each layer can be determined separately. In the proposed mechanism, heterogeneous clustering is a function of size of layer and the number of nodes in the layer. Also the method of transmitting data in the proposed mechanism is from the lower layers to the upper layers in a multi-stage manner. In chapter four, the proposed mechanism has been discussed in detail.Simulation results show that the mechanism of layering and making symmetric the clusters and multi-stage transmission of data to the base station in the proposed mechanism is working properly. Comparison of the life in the proposed mechanism with the E-LEACH and LEACH protocols has shown an increase about 70% and 60%.

In future research in line with this study, the following are recommended:

- To inter-cluster routing and data transmission to the base station in the proposed mechanism in each layer of ant population algorithm should be utilized independently.
- Layering of network environment should be done dynamically and with regard to abundance of nodes in the network environment and the network environment size.
- The optimal time to replace CHs in the proposed mechanism be considered.
- The mobile sensor nodes or mobile base stations should be used.

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