ENERGY EFFICIENT LEACH-C PROTOCOL FOR WIRELESS SENSOR NETWORK

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Abstract: To prolong the overall lifetime of the network, development of energy efficient routing protocol is a major issue in Wireless Sensor Network. Clustering Protocols are one of the approaches to serve this purpose. LEACH-C is a cluster based protocol in which cluster heads are selected by the base station randomly. All the nodes having the energy above average are eligible to be cluster heads. Base station runs a simulated annealing algorithm to find the optimal solution with better positions to reduce the energy consumption of cluster heads. This paper presents an Energy Efficient LEACH-C (EELEACH-C) protocol, in which base station runs a sorting algorithm to obtain a list of candidate cluster head nodes sorted in descending value their residual energy. After examining the candidate cluster head nodes it selects those with maximum residual energy and than calculate the quadratic sum of the distances from each cluster heads to its member nodes to find the optimal solution. Experimental result attests that the proposed protocol improves network longevity.

Keywords: Wireless Sensor Networks, Energy Efficiency, LEACH-C, Network Lifetime.

INTRODUCTION

Wireless Sensor Networks are composed of thousands of tiny sensor nodes, where each sensor node is equipped with limited storage, power and processing capabilities [1]. Sensor nodes are densely deployed in unattended environment. Nodes ”sense” the environmental phenomenon and send the signals to the data collection center known as ”base station”. Since recharging of batteries of these nodes is not possible so it highly recommended to design energy efficient protocols for these networks. Additionally to send the data to the sink multihop communication is also needed. If base station and sensor nodes are not in the range of each other than they need some intermediate nodes to relay their message to the base station.

WSNs facilitate many applications like target tracking [2], environmental monitoring [3], habitat monitoring [4] and so on. Most of these applications require only the aggregated value to be reported at the base station (or sink). In such cases the data from various sensor nodes can be aggregated to collaborate the information they have sensed. For instance, in habitat monitoring application the base station is interested in getting average of the temperature instead temperature reading of every sensor node. In order to increase the network efficiency and scalability clustering algorithms are widely used by the research community. Clustering not only allows data aggregation but also reduces the data transmission within the cluster thereby reducing the channel contention [5]. The clustering algorithms involve the procedure of election of cluster heads in each cluster. These cluster heads are responsible for collecting the data from all the members of their cluster, aggregate it and send it to the base station. Clustering increases the network scalability, lifetime and efficiency. Several cluster based protocols are proposed in literature for WSNs like LEACH[12], LEACH-C [6], HEED [7], PEGASIS [8] etc. These algorithm “rotate” the role of cluster head among the nodes of a cluster in order to improve the energy efficiency.

An example application of our study is the environmental monitoring, where sensor nodes are deployed in large area. The sensor nodes share temperature readings with their respective cluster heads periodically, in order to build more complete view of the region that is being monitored. Cluster heads send the aggregated signals to the base station. The main contribution of this paper is modified LEACH-C (Centralized Low Energy Adaptive Clustering Hierarchy) protocol based on residual energy of the nodes. It takes node’s residual energy and the distance of the various nodes to the eligible cluster heads into consideration and form the cluster.

The rest of the paper is organized as follows. In Section 2 we review the relevant work. Section 3 describes the network model and necessary preliminaries of our work. We have also described a modified way for selecting cluster heads in this Section. EELEACH-C architecture is presented in Section 4. In Section 5, we evaluate through simulations the modified protocol and compare it to LEACH and LEACH-C. Finally in Section 6 we conclude the paper.

RELATED WORK

In cluster based routing protocols whole network is divided into multiple clusters. One node in each cluster play leading role known as ”cluster head” (CH). Cluster-head is the only node that can communicate to base station in clustering routing protocols. This significantly reduces the routing overhead of normal nodes because normal nodes have to transmit to clusterhead only ([6], HEED [7], PEGASIS [8]). LEACH is one of the most popular cluster based protocol for WSN and many pro-

tocols have been derived from LEACH with some modifications and applying some advanced routing techniques ([6], [9], [10], [11], [13], [15]).

Routing in LEACH-C

LEACH–C [6] is an improved version of LEACH, in which the cluster formation is done by the base station. At the beginning of every round all the nodes send their location and current energy to the base station. The base station calculates the average energy of the network and marks only those nodes which are having energy higher than the average energy, as eligible cluster head node. Now it applies simulated annealing [14] algorithm using candidate nodes to minimize the objective function. This algorithm attempts to minimize the amount of energy for the non-cluster head nodes to transmit their data to the cluster head, by minimizing the total sum of squared distance between all the non cluster head nodes and the closest cluster head. The resultant cluster head (CH) and their members will be broadcasted to the network. If the node's own ID matches with cluster head ID , it elects himself as cluster head otherwise it will find out the TDMA slot to send the data to corresponding cluster head. The data transmission phase of LEACH-C is similar to the LEACH. The advantage of LEACH-C is that, it can equally distribute energy consumption between sensor nodes by positioning cluster heads into the center of cluster. But every sensor node, however, should be loaded with GPS receiver set and it does not guarantee the balance of energy consumption of whole sensor networks.

THE PROPOSED MODEL

In this section we describe our system model of a Wireless Sensor Network. We particularly present the setting, the energy model, and how the cluster heads are selected. We consider a sensor network that is hierarchically clustered. The LEACH-C protocol [6] maintains such clustering hierarchy. In LEACHC, the clustering is triggered every T_{round} second to select new cluster heads. Each node transmits to the closest cluster head so as to split the communication cost to the base station (which is much higher then the computation cost). Only the cluster head has to report to the base station and may expend a large amount of energy. In LEACH-C many nodes with higher energy can not be selected as cluster head because of their below average energy which can actually still allow them to full-fill the task of being cluster heads. The proposed clustering protocol is aimed to choose the cluster head with higher residual energy to make it an energy-efficient protocol, avoiding the fast energy depletion of sensor nodes. We name the protocol EELEACH-C , from the initials of the words Energy Efficient LEACH-C protocol.EELEACH-C exploits the residual energy of nodes to achieve network lifetime prolongation. One of the main parts of the proposed protocol is the estimation of the eligibility of sensors to become cluster head. The intuition is that if we discover those energy-efficient nodes which are residing in the path of base station and other nodes, then these are the cluster coordinators for the clustering protocol.

Cluster Head Selection Algorithm

Considering E as the set of energy of all the N nodes, K is the expected number of clusters and X and Y are the set of locations of various nodes in the Wireless Sensor Network the algorithm for cluster head selection in EELEACH-C works as follows:

Algorithm CH-Selection (E, N, K, X, Y)

1. Asc - sort(E)
2. i = 1
3. **while** I ≤ N **do**
4. **if** (E_i>=E_{Avg} and i<= k) **then**
5. Eligible(i) = True
6. **else**
7. Eligible(i) = False
8. **end if**
9. i=i + 1
10. **end while**
11. **if** ($dist_i$ > $dist_j$ and Eligible (i)) **then**
12. CH_i=CM_j
13. **end if**
14. **return** (CH_i , CH_j)

Here, we explain in detail our new energy efficient EELACH-C protocol whose goal is to increase the longevity of the network. Let us assume that all the sensor nodes are equipped with equal amount of initial energy. We assume that all nodes are distributed uniformly over the sensor field. Our approach is to assign a weight w_i to the probability of a node to become cluster head p_{ch}. This weight must be equal to the initial energy of each node divided by the residual energy. Only nodes which are having the highest weights will be eligible to become a cluster head (CH) in next round. The probability of a member node (CM) to be the node to die first is less than the probability of an already chosen cluster head node to die. Simulation results attest our expectation.

SIMULATION RESULTS

To validate the performance of EELEACH-C, we simulate a wireless sensor network in a field with dimensions 100m × 100m using NS-2 simulator. The total number of sensor nodes N = 100. All the nodes randomly distributed over the field. The base station is at the centre of the field so, the maximum distance of any node from the sink is approximately 70 m. The size of the message that nodes send to their cluster heads as well as the size of the (aggregate) message that a cluster head sends to the sink is set to 4000 bits. Figure 1 shows the snapshot of Wireless Sensor Network set-up.

We have used first radio RF models [16] for our simulations. In this section, we compare the performance of our EELEACH-C protocol with LEACH and LEACH-C in the same simulation settings. Numbers of nodes die in LEACH and LEACH-C is more than EELEACH-C over the same amount of time. The number of nodes dies very fast and as a result the sensing field becomes sparse very fast. On the other hand in EELEACH-C the nodes die in a slow fashion. When a significant number of nodes are dead the network will stop its functioning. From Fig. 1,,it is clear that how the number of alive nodes are varying in case of LEACH , LEACH-C and EELEACH-C.

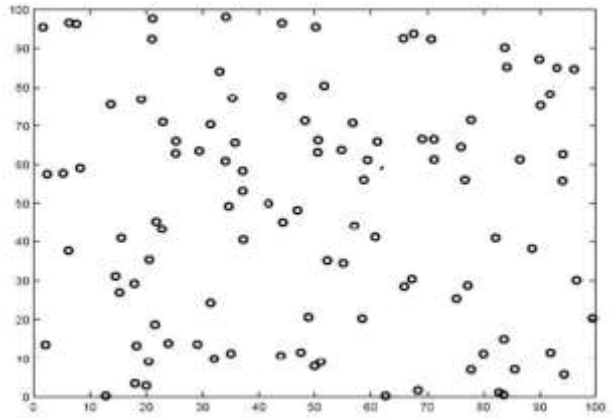

Figure 1. A snapshot of Wireless Sensor Network

Fig.2 shows that the total energy consumption of the network in EELEACH-C is lower than in LEACH and LEACH-C. It's because in LEACH the distribution of cluster head is uneven, in the sense that, in some region the cluster heads are too concentrated, while some region do not have any cluster heads. Furthermore, Some nodes are far away form the cluster heads which will lead to the waste of energy. Although the situation has been improved in LEACH-C but EELEACH-C gives us better results compared with LEACH-C.

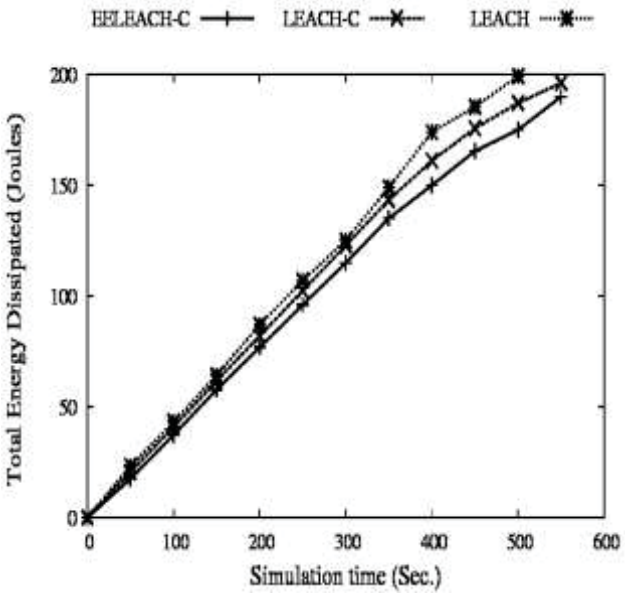

Figure. 2. Total Energy dissipated by all the nodes over time

From Fig. 3 we can see the how network lifetime increases in case of EELEACH-C as compared to LEACH and LEACH-C. Since EELEACH-C distributes the loads among all the nodes evenly as compared to the LEACH or LEACH-C, so the overall network lifetime is highest in case of EELEACH-C.

In case of LEACH, the nodes are loosing there energy in cluster formation after every round along with data transmission so they are out of energy soon. But in case of LEACH-C cluster formation is done by Base Station and in case of EELEACH-C the cluster formation is done in an energy efficient manner so the number of nodes alive in case of EELEACH-C is greater than the LEACH-C as observed from Figure 4.

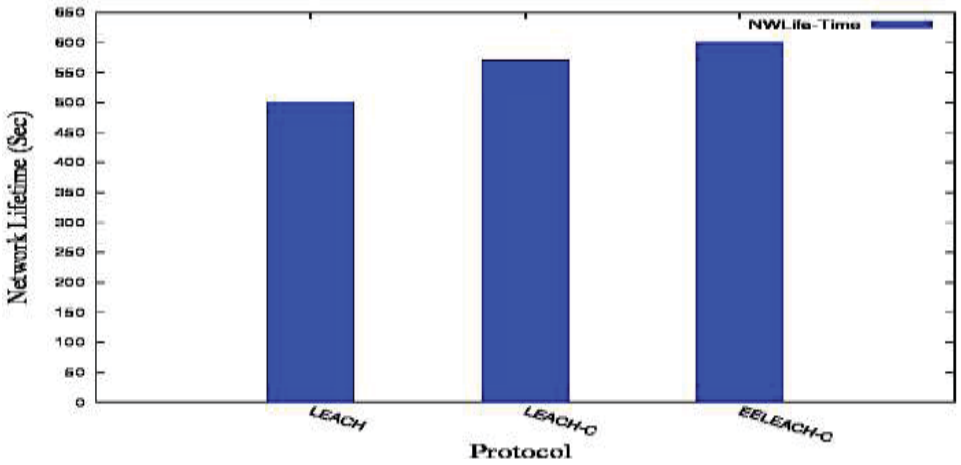

Figure. 3 : Comparison of Network Lifetime in three protocols

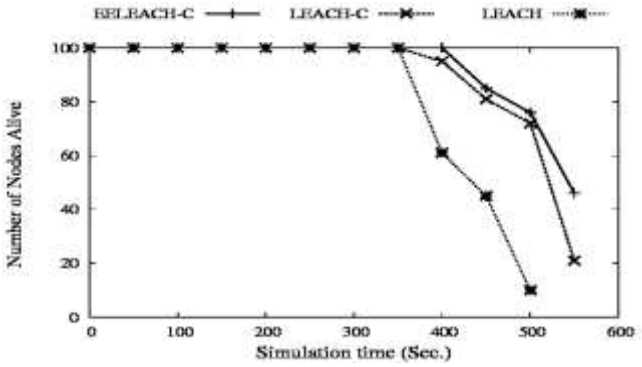

Figure 4. Comparison of LEACH,LEACH-C and EELEACH-C in terms of number of nodes alive

CONCLUSIONS

Wireless sensor networks are used in lots of monitoring applications. Energy efficient clustered based routing is paramount to extend the lifetime of the network. In this paper we have provided energy efficient LEACH-C for Wireless Sensor Network. In order to improve the lifetime of the network system this paper focuses on a modified version of the cluster head selection based upon their residual energy. Simulation results show that the EELEACH-C has extended the lifetime of the network by 10% in the as compared to LEACH and 5% as compared to LEACH-C as well as it also reduces the total energy consumption of the whole network ,in the presence of same simulation settings. Hence we can say that performance of proposed routing is better in terms of network lifetime and energy saving.

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