A Novel Clustering Approach for Extending the Lifetime for Wireless Sensor Networks

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Abstract

A new energy efficient clustering algorithm based on the highest residual energy is proposed to improve the lifetime of wireless sensor network (WSN). In each cycle, a fixed number of cluster heads are selected based on maximum residual energy of the nodes. Each cluster head is associated with a group of nodes based on the minimum distance among them. In such scheduling, all the nodes dissipate uniform energy and subsequently remain alive for long time. The simulation results show that our proposed clustering approach is more effective in prolonging the network lifetime compared with the existing protocols such as Low-energy adaptive clustering hierarchy (LEACH) and Distributed hierarchical agglomerative clustering (DHAC).

Keywords: *Wireless Sensor Networks, Homogeneous, Clustering.*

I. Introduction

Recent advances in micro-electromechanical systems and low power digital electronics have led to the development of micro-sensors having sensing, processing and communication capabilities equipped with a power unit. These sensors are randomly deployed down in a remote location for sensing the ambient conditions such as temperature, humidity, lightening conditions, pressure, noise levels etc. [1,2]. They are also used for a wide variety of applications such as multimedia surveillance [3], storage of potential relevant activities such as thefts, car accidents, traffic violations and health and home applications. The wireless sensor network consists of a large number of sensor nodes with limited power capacity and a base-station which is responsible for collecting data from the nodes.

One of the major issues (in wireless sensor network) is to minimize energy loss during collecting data from the environment and transmitting it to the base-station. In this context various methodologies and protocols have been proposed and found to be efficient [4]. However further improvement is required in order to enhance the wireless sensor network. We have made an attempt to design an efficient clustering protocol for extending the lifetime of the network. Clustering of nodes is found to be an effective way to increase lifetime of network. Clustering is the classification of the objects of relatively similar objects [5]. The variety of clustering methods has been effectively used in many science and technology fields. In WSN, these sensor nodes are classified into clusters based on their attributes (e.g. location, signal strength and connectivity etc) [6]. In this article, different methodology for selecting cluster head is discussed.

II. Background

Several protocols have been developed till now to improve the lifetime of the network using clustering techniques. The main goal is to use the energy of the nodes efficiently and performing data aggregation to decrease the number of transmitted messages to the base-station and transmission distance of the sensor nodes. In this context, low-energy adaptive clustering hierarchy (LEACH) [7,8] is the most popular distributed cluster-based routing protocols in wireless sensor networks. LEACH randomly selects few nodes as cluster heads and rotates this role to balance the energy dissipation of the sensor nodes in the networks. The cluster head nodes fuse and aggregate data arriving from nodes from every cluster and send an aggregated data to the base-station in order to reduce the amount of data and transmission of the duplicated data. Data collection is centralized to base-station and performed periodically. When clusters are being created, each node decides whether to become cluster head or not depending upon a probability. In LEACH, the optimal number of cluster heads is estimated to be about 5% of the total number of nodes. All the nodes will find their nearest cluster head and will send their data in their time slot in each round.

Another method reported as adaptive decentralized re-clustering protocol (ADRP) [9,10] is a clustering protocol for Wireless Sensor Networks in which the cluster heads and next heads are elected based on residual energy of each node and the average energy of each cluster. The selection of cluster heads and next heads are weighted by the remaining energy of sensor nodes and the average energy of each cluster. The sensor nodes with the highest energy in the clusters can be a cluster heads at different cycles of time. By means of the former, the role of cluster heads can be switched dynamically. However, Attea et al. [11] alleviates the undesirable behavior of the evolutionary algorithm when dealing with cluster routing problem in WSN by formulating a new fitness function that incorporates two clustering aspects, viz. cohesion and separation error. Their simulation results in heterogeneous environment show that the evolutionary based clustered routing protocol (ERP) increases the network lifetime and preserves more energy than existing earlier protocols.

Energy efficient heterogeneous clustered scheme EEHC [12] adopts the heterogeneity of the nodes in terms of their initial energy i.e. a percentage of nodes are equipped with more energy than others. In order to improve the lifetime and performance of the network system, this paper reports on the weighted probability of the election of cluster heads, which is calculated as a function of as a function of increased energy. Performance is evaluated against LEACH using *ns-2* simulator and it shows that the lifetime of the network has extended by 10% as compared with LEACH in the presence of same setting of powerful nodes in a network. DHAC [13] is a hierarchical agglomerative clustering algorithm, which adopts a bottom-up clustering approach by grouping similar nodes together before the cluster head is selected. This algorithm avoids re-clustering and achieves uniform energy dissipation through the whole network. The clusters are formed on the basis of quantitative (location of nodes, received signal strength) as well as qualitative data (connectivity). After the formation of clusters using some well known hierarchical methods like SLINK, CLINK, UPGMA, and WPGAM, the cluster heads are selected having minimum id in the group. The simulation results show the improved lifetime of the network as compared to the LEACH protocol.

An energy-efficient protocol [14] is designed to improve the clustering scheme in which the cluster head selection is based on a method of energy dissipation forecast and clustering management (EDFCM). EDFCM considers the residual energy and energy consumption rate in all nodes. Simulation results in MATLAB show that EDFCM balances the energy consumption better than the conventional routing protocols and prolongs the lifetime of networks obviously. An energy efficient multi-hop clustering algorithm [15] is designed for reducing the energy consumption and prolonging the system lifetime using an analytical clustering model with one-hop distance and clustering angle. The cluster head will continue to act as the local control center and will not be replaced by another node until its continuous working times reach the optimum value. With the mechanism, the frequency of updating cluster head and the energy consumption for establishing new cluster head can be reduced. The simulation results in MATLAB demonstrate that the clustering algorithm can effectively reduce the energy consumption and increase the system lifetime. DEEC [16] is an energy efficient clustering protocol in which the cluster-heads are elected by a probability based on the ratio between residual energy of each node and the average energy of the network. The nodes with high initial and residual energy will have more chances to be the cluster-heads than the nodes with low energy. The simulation results show that DEEC achieves longer lifetime and more effective messages than current important clustering protocols in heterogeneous environments.

Another scheme considers the strategic deployment [17] for selecting the cluster head. The clusters are formed in the form of multiple-sized fixed grids while taking into account the arbitrary-shaped area sensed by the sensor nodes. The simulation results show that the proposed scheme alleviates high energy consumption and a short lifetime of the wireless sensor networks supported by existing schemes. Soro et al. [18] presented a unique method at the cluster head election problem, concentrating on the applications, where the maintenance of full network coverage is the main requirement. This approach for cluster-based network organization is based on a set of coverage-aware cost metrics that favor nodes deployed in densely populated net-work areas as better candidates for cluster head nodes, active sensor nodes and routers.

III. METHOD AND RESULTS

The present results are analyzed for homogenous network, where all the nodes are equipped with the same initial energy before they begin to transmit their data in the clustered network. The nodes keep on sensing the environment and transmit the information to their respective cluster head. We describe our system model of homogeneous sensor network in a 100 m x 100 m sensor field with 100 nodes placed [19] as shown in Figure 1. The whole network is divided into a fixed number of clusters (ten clusters are considered in this study). Each cluster contains a cluster head, which is responsible for data collection from all the nodes (within the cluster) and finally sending it to the base-station. These cluster heads are selected on the basis of highest residual energy of the nodes. After each round of data transmission, ten new nodes of maximum residual energy are selected as new cluster heads in the entire network. Clusters are reformed for each cluster head based on relative distances between the nodes. In this way, all the nodes are associated with one of the maximum residual energy nodes (cluster head) and sending data in their respective TDMA schedule.

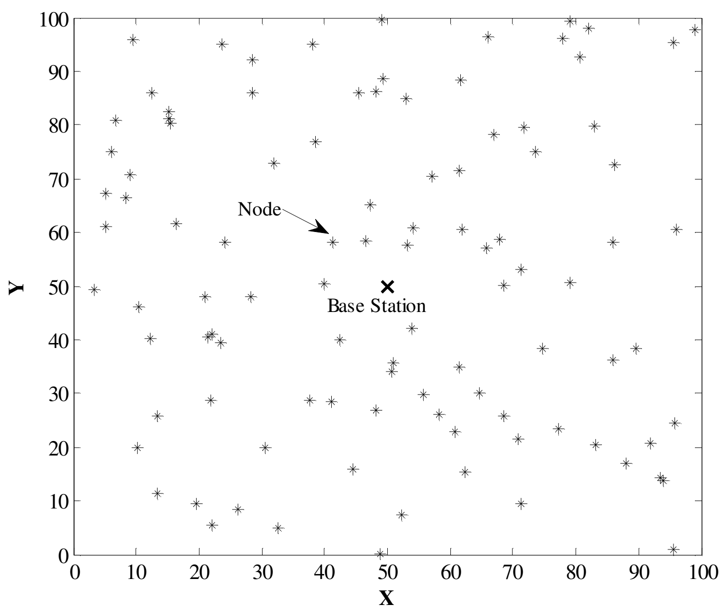

Figure 1. Node placement in Homogeneous Model

It is to be noted that distance plays an important role in overall energy dissipation and as per radio energy dissipation model [20] (as shown in Figure 2) in order to achieve an acceptable Signal-to-noise ratio (SNR) in transmitting a k bit message over a distance d, energy expanded by the radio is given by

$$E_{TX} = \begin{matrix} k * Eelec + k * \varepsilon fs * d^2 & if \ \ d \le do \\ k * Eelec + k * \varepsilon mp * d^4 & if \ \ d \ge do \end{matrix} \qquad (1)$$

where E_{elec} is the energy dissipated per bit to run the transmitter or the receiver circuit, ε_{fs} and ε_{mp} depend on the transmitter amplifier, and d the distance between the sender and the receiver. By equating the two expressions at d = do, one can get

$$do = \sqrt{\frac{\varepsilon fs}{\varepsilon mp}} \quad (2)$$

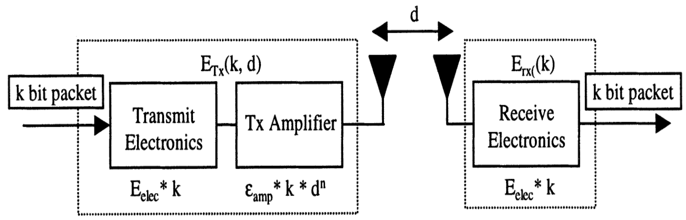

Figure 2. Radio Energy Model

To receive a k bit message, the radio expends $E_{RX} = k * E_{elec}$. Ultimately the total energy consumption per round is calculated and the lifetime of the network is plotted in terms of "Number of alive nodes" per round.

We have considered first order radio model similar to LEACH and the simulation parameters for our model are mentioned in Table 1. The base-station is in the center and so, the maximum distance of any node from the base-station 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 base-station is set to 2000 bits. The performance of the proposed protocols is measured in terms of network lifetime, which represents the number of alive node vs time. The difference in the extension of the lifetime of our protocol is compared with LEACH and DHAC as shown in Figure 3. It is clear that the present method of selecting cluster head works efficiently than the reported protocols (DHAC and LEACH) for similar input parameters.

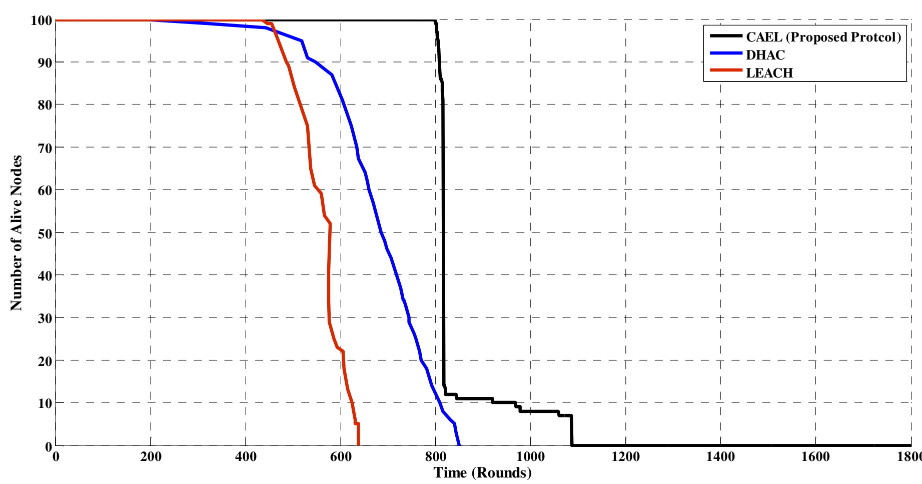

Figure.3: Number of Alive Nodes vs Time using various protocols

Table 1. Transmission parameters value

Description	Symbol	Value
Number of nodes in the system	N	100
Energy consumed by the amplifier to transmit at a short distance	ε_{fs}	10 pJ/bit/m^2
Energy consumed by the amplifier to transmit at a longer distance	ε_{mp}	0.0013 pJ/bit/m^4
Energy consumed in the electronics circuit to transmit or receive the signal	E_{elec}	50 nJ/bit
Data aggregation energy	E_{DA}	5 nJ/bit/report

IV. CONCLUSIONS

We have proposed an energy efficient clustering scheme for wireless sensor networks. A fixed number of nodes are selected as cluster heads with highest residual energy in the whole network and the role of cluster heads is switched dynamically between other nodes on the basis of residual energy. Simulations in MATLAB shows that our protocol has extended the lifetime of the network as compared with LEACH and DHAC in the presence of same input parameters of the nodes in a network. The performance of the proposed system is better in terms of lifetime and is 28 % higher than DHAC and 70 % higher than LEACH. Further study is required to improve WSN by inclusion of multi criterion for the cluster head selection such as consideration of distance between nodes and cluster head and base-station and cluster head. Also the optimal number cluster heads need to be derived using optimization techniques.

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