LA-LEACH: A NEW APPROACH TO INCREASE THE LIFETIME OF WIRELESS SENSOR NETWORKS

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Abstract- One of the main issues in the context of clustering protocols in wireless sensor networks (WSN) is the selection of cluster head (CH). Many researches select the CH based on the value of the residual energy of the nodes. In other many approaches it is selected based on the number of the neighboring nodes or the distance among them. In this paper, a new method based on learning automata (LA) named LA-LEACH is proposed to increase the lifetime of WSNs. That is, a LA is resident on every sensor node. In the proposed method, CH is selected on the basis of both factors the residual energy and Euclidean distance. Then, using its residing LA, the selected CH communicates with its associated cluster members. The simulation results demonstrate that LA-LEACH outperforms W-LEACH, HCDD, and CSME in terms of load balancing and energy usage.

Keywords- clustering, learning automata, mobile sink, wireless sensor network, lifetime

I. INTRODUCTION

In general, wireless sensor networks (WSNs) are employed to monitor different activities or track many events and report the changes to sink nodes. In recently performed researches, attentions have mainly been focused on the applications in which many unpredictable conditions may be occurred [1]. In WSNs, the sensor nodes are deployed in the environment that can wirelessly communicate with each other. However, when the energy of a sensor node comes to an end, it no longer provides any services such as sensing, data processing and/or communication. When this happens, the sensor is considered as a 'dead' member and is eliminated from the network topology. Lifetime of a WSN is defined as the time interval from its establishment until a 'critical' number of sensor nodes deplete [2]. Lifetime of a sensor node is seriously dependent on its battery. Dead sensor nodes directly affect the lifetime of the network and probably, due to lack of sensing the data and reporting the environmental events, it results in losing a great amount of the data obtained. Therefore, for the practical use of WSNs for the continuity of their lifetime the issue of efficient consumption of energy is very important in the design and establishment of such networks. For this, in this paper a new method for prolonging the network lifetime is proposed. The rest of this paper is organized of follows: in section 2, related works are presented. The proposed protocol will be introduced in section 3. Simulation results come in section 4. Finally, section 5 concludes the paper.

II. RELATED WORKS

From the existing methods, it is observed that there are three major methods in dealing with the issue of rising the lifetime of WSNs. The first group is dedicated to methods which are based on mathematical optimization examining the issue on the basis of mathematical analysis. For example, the issue of maximizing the WSNs lifetime by sensors with limited energy and mobile sinks is considered in [3]. To collect the data from individual sensors, the sink travels to different locations. As long as the sensors and the sink are at the communication range of each other, sensed data can be disseminated and relayed among the sensors toward the sink. Data transmission consumes the energy of both transmitter and receiver nodes. Here, a vital issue is that an increase in the stop time of the sink together with frequently changes in flow patterns reduces the lifetime of the network. Column generation approach is employed to solve this problem. This approach is based on the use of specific structures of linear programming (LP) formulation in which all sub-problems of the shortest path are solved by non-negative costs. Although, these methods lead to optimal solutions, some applications of WSNs are in presence of unpredicted conditions [4,5,6]. However, solutions based on mathematical methods do not necessarily result in executable and practical solutions and hence, regarding the scale of WSN, remains out of scope of this paper. Clearly, because of the nature of WSNs and its related issues, the solution space will be very great and as a result, the use of mathematical-based methods leads to more memory demands as well as more time complexity.

Another group of methods employ heuristic and meta-heuristic solutions which try to maximize the lifetime of large-scale network [7]. The sensor nodes near the sink node suffer from high consumption of energy due to traffic relay. The rational of the sink mobility approach is that the sink node moves around until it is possible to reduce the energy discharge danger at some of the nodes. Simulation results demonstrate that this approach attains the lifetime of the optimal network even at a rather slow speed of the mobile sinks. However, among the methods enjoying some form of intelligence, some methods can be found that not only lead to applied and practical

results, but they are also acceptable in energy saving time point of view. We therefore followed these methods. Since the use of mobile sink nodes are preferred to fixed sink nodes and also since the network clustering brings about many advantages including more balanced energy consumption in the sensor network, the strategies employing clustering were adopted. In continue, it is tried to use the learning automata along with clustering to increase the lifetime of WSNs to obtain better results.

III. THE PROPOSED PROTOCOL

The goal of presenting this algorithm is to increase the lifetime of WSNs due to the fact that in the most cases the last node dies (LND) metric is intended in defining the network lifetime. Therefore, here, the objective is to increase LND. A function proportional to the energy consumption of the sensors is defined, so that the minimization of the function results in the reduction of energy consumption of the sensor which in turn will result in increase in the lifetime of WSN. The algorithm works in rounds. Every round is composed of tree phases which are explained in the next sub-sections.

3-1- Phase 1. cluster head selection

At the beginning of each time slice, the sink node is informed of the position of the sensors by transmitting a control message to all of them. Also, it is assumed the sensors know the position of their neighboring nodes.

In the majority of the existing methods like those studied in [8], [9], [10], [11], [12], and specifically the MSRP algorithm, the selection of algorithm is considered either on the basis of the value of the node remaining energy or the criterion for selection is the number of the neighbors or the congestion of the nodes around it. However, in the proposed method, both of these factors are considered for the selection of the cluster head. The main goal in the proposed algorithm is to determine the cluster heads in a manner that the selection of these cluster heads minimizes the value of the intended optimization function. This function is directly made on the basis of the first-order energy model [13].

$$E_T(l,d)=\begin{cases} l*E_{elec}+l*\varepsilon_{fs}*d^2, & d<d \\ l*E_{elec}+l*\varepsilon_{mp}*d^4, & d\geq d \end{cases} \quad (1)$$

$$ESensor(i)-CH(j) = l*(Eele*d(Si,CHj)+\varepsilon mp*(d(Si,CHj))^2) \quad (2)$$

$$ECH(j)-S = l*(Eele*d(CHj,S)+\varepsilon mp*(d(CHj,S))^2) \quad (3)$$

3-2- Phase 2. Cluster head communication with its associated members

In order to prevent interference in communication among the members of a cluster with their own cluster head, the hierarchical communication protocols employ different methods. The mechanism normally used for the communication between the cluster members and the cluster head is TDMA used in a great number of protocols. The TDMA scheduling mechanism does not differentiate between a member of a cluster that always has some data for transmission and a member that has no data for transmission; it provides identical timing slot for both to communicate with the cluster head. However, a member of the cluster might happen to be in a zone whose environmental information is continuously changing, but other cluster members do not feel such changes in their environment. Therefore, a member whose local information is always changing should have more time compared to other members to establish communication with the cluster head. In what follows, a method based on learning automata named LA-LEACH is proposed for this purpose.

In LA-LEACH, each cluster head is equipped with a learning automaton (LA). By the use of LA, the cluster head selects the cluster member that it has to communicate with. In the proposed mechanism, it is assumed that if the cluster member has a packet for transmission at t time, most probably it also has a packet for transmission at time t+1. For the same reason, if the selected member has some data for transmission, the probability of its selection at the next stages increases; otherwise, it decreases.

In the proposed method, the number of actions of each LA is equal to number of its corresponding cluster members. Selection of one action by the LA means the selection of one member of the cluster to communicate with whom. The action probability vector of the LA residing on each cluster head is initialized according to Eq. (4), where, n is the number of the cluster members and i denotes the index of actions.

$$p_i=\frac{1}{n} \quad \forall_i\ i\leq \text{number of cluster members} \quad (4)$$

In this phase, the residing LA on each CH selects one of its actions. This action is corresponding to the selection of a member of the cluster. The cluster head asks for a packet from the member selected by the LA. If the cluster member has a packet for transmission, it transmits; in this case, the taken action is awarded. Otherwise, the taken action by LA will be punished. To reward or punish the selected action, Eqs. 5 and 6 are used, respectively, where a is the reward parameter and b is the punishment parameter.

$$\begin{aligned} p_i(n+1) &= p_i(n)+a.(1-p_i(n)) \\ p_i(n+1) &= p_j(n)+a.p_i(n) \quad , \forall_j\ j\neq i \end{aligned} \quad (5)$$

$$\begin{aligned} p_i(n+1) &= (1-b).p_i(n) \\ p_i(n+1) &= \frac{b}{r-1}+(1-b).p_j(n) \quad , \forall_j\ j\neq i \end{aligned} \quad (6)$$

This algorithm continues up to the new period of clustering. After several time slices, the cluster head

transmits the received data from its members to the sink node.

3-3- Phase 3. Data transmission from cluster head to the sink node

[11] tackles the hot spot problem with forming the clusters and selects the CHs on the basis of their residual energy. In this method, thanks to existing of mobile sinks, energy concentration in a small region of the sensors is prevented. On the basis of the remaining energy of the cluster heads, sinks always gets closer to the cluster head with the most residual energy and those cluster heads relay the data received from other cluster heads. In [11], the issue of hot spot was taken into consideration to lengthen the lifetime of WSN. In this reference, sinks move toward the cluster heads to collect the data sensed from them. During the collection of the data, the mobile sink acquires the date from the CHs with more residual energy. In contrast, in the proposed method, LA-LEACH, initially, exploits the Euclidean distance in addition to remaining energy metric. The sink node in the third phase just needs to meet the nodes of the cluster head optimally selected in the first phase and collects its data. Subsequently, the issues of hot spots due to the regular movement of the sink are death with. This fact leads to a balanced energy consumption of the WSNs increasing the lifetime of the network.

IV. SIMULATION RESULTS

Performance of the proposed method, LA-LEACH, was evaluated in network simulator omnet++. In LA-LEACH, every cluster head is equipped with a learning automaton and is in charge of the control of the cluster head communication with its members. The learning automata residing at the cluster member nodes gradually learn to provide more chance for the members of the cluster with more information for transmission to establish communication with the cluster head. The LA-LEACH method can be executable in different hierarchical protocols. One of the first and the most famous hierarchical protocols presented for sensor networks is the LEACH protocol. The LEACH method has some defects including that the selection of the cluster heads is random; while, the cluster head should have enough energy to receive its cluster data and transmit them to the sink. However, since newer improvements have been made on LEACH, it is better to perform the comparison on them. The W-LEACH has been chosen from among the recent improvements [14]. This method selects the nodes with higher energy levels as the cluster head. Here, data of all the nodes in cluster are not transmitted in every period. That is, data of the nodes with the least weight are transmitted. Therefore, by limiting the transmissions to urgent transmission, we contribute to the reduction of energy consumption. We have also used hierarchical cluster-based data dissemination (HCDD) for comparison, since this method is for the dissemination of information to the mobile sink and reduces the control overhead as well. The sensor nodes in [15] are self-organized and can find the path without location information of the nodes. The cluster-based mobile sink exploration (CMSE) is a new algorithm that forwards the data packets towards the sink node. In this method, a sensor node can identify the location of the sink node without knowing about the location of the nodes. Also, to increase the lifetime of the network, variable paths from the node towards the sink are considered [16].

Experiment 1. The goal of this experiment is to study the load balancing. In this experiment, 600 nodes were deployed on a plain 100*100. Since the classic LEACH randomly selects the cluster head in the beginning, it might happen that the selected primary cluster head is not near the locations subject to data change. Therefore, as it is shown in Fig.1, the curve associated with the LEACH is lower than that of the other methods. The load balance of the proposed method is compared with methods W-LEADCH, HCDD, and cluster-based mobile sink exploration (CMSE) in Fig. 1. In the first phase and with regard to the intended criteria, the proposed method is engaged with clustering and selection of the cluster head. For this reason, the load is less balanced than that of the W-LEACH and CSME methods. But, from the time when the first phase ends and the cluster heads communicate with the members and the sink node approaches them, the conditions of the proposed method gradually improves further.

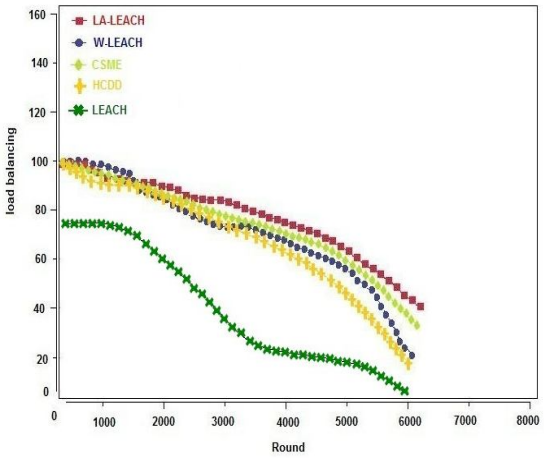


Figure.1 load balancing in different methods

Experiment 2. In this experiment, energy consumption of the proposed approach compared with aforementioned methods are analyzed. The results are averaged by 18 different repetitions. As it is depicted in Fig. 2, LA-LEACH works worst than other in the earlier times. The reason is that the proposed method in the beginning phase was engaged in clustering and selection of the cluster heads and required transmissions for sending / receiving the data. However, in the following periods LA-LEACH

outperforms other representative methods in terms of energy consumption. The result of LEACH is higher than that of other methods.

Experiment 3. This experiment was mainly conducted to study the impact of the number of the sink nodes on the average lifetime of WSNs. For this purpose, 600 sensor nodes and 6 sink nodes are taken into consideration. The results demonstrate that an increase in the number of the sink nodes, although requiring an increase in cost, the load on the network will be more balanced and the lifetime of the network increases as illustrate in Fig. 3.

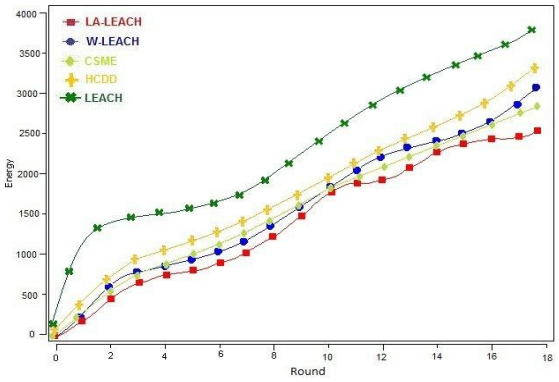


Figure.2 Energy consumption of different methods

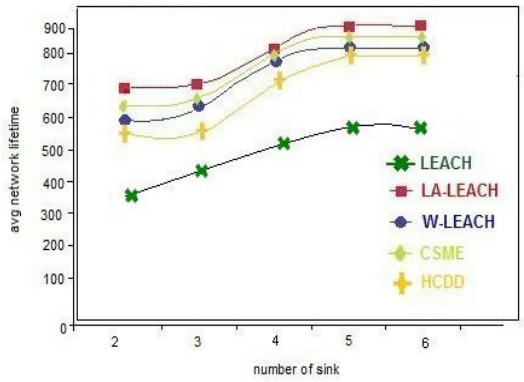


Figure.3 Comparison of the lifetime versus the number of sink nodes

Figure 4 depicts that an increase in the number of the nodes up to 500 can lead to an increase in the average lifetime of the WSN in almost each of the five methods. However, when the number of the sensor nodes outnumbers the threshold, the behavior of the algorithms, except for the LEACH algorithm, will be almost equal.

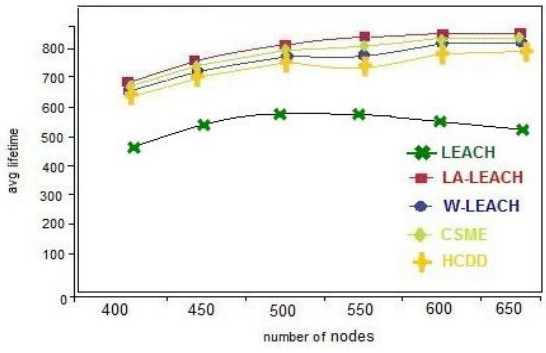


Figure.4 Comparing the lifetime as a function of the number of sensor nodes

CONCLUSION

A method based on learning automata was proposed in this paper. Both factors of Euclidean distance and highest residual energy at the nodes were employed in the phase of cluster head selection. Then, a new timing mechanism based on learning automata was used for the communication of the selected cluster head with its associated cluster members. It is based on this principle that if a node has data for transmission at a time instance,

it is most likely located in a frequently environmental changes requiring data transmission in the following times. The next phase of the proposed method might be somehow an improvement on MSRP in which the sink only moves toward the cluster heads with the highest residual energy. The results obtained from the simulations confirm the efficiency of the LA-LEACH.

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