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Increasing the lifetime of wireless sensor networks by Self-Organizing Map algorithm

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ABSTRACT

Wireless sensor networks are composed of a large number of sensor nodes with limited energy resources. One critical issue in wireless sensor networks is how to gather sensed information in an energy efficient way since the energy is limited. The clustering algorithm is a technique used to reduce energy consumption the performance of Wireless Sensor Networks strongly depends on their lifetime. As a result, Dynamic Power Management approaches with the purpose of reduction of energy consumption in sensor nodes, after deployment and designing of the network. Recently, there have been a strong interest to use intelligent tools especially Neural Networks in energy efficient approaches of Wireless Sensor Networks, due to their simple parallel distributed computation, distributed storage, data robustness, auto-classification of sensor nodes and sensor reading. This paper presents a new centralized adaptive Energy Based Clustering protocol through the application of Self organizing map neural networks (called EBC-S) which can cluster sensor nodes, based on multi parameters; energy level and coordinates of sensor nodes. We applied some maximum energy nodes as weights of SOM map units; so that the nodes with higher energy attract the nearest nodes with lower energy levels. Therefore, formed clusters may not necessarily contain adjacent nodes. The new algorithm enables us to form energy balanced clusters and equally distribute energy consumption. Simulation results and comparison with previous protocols prove that our new algorithm is able to extend the lifetime of the network.

Keywords: *Wireless Sensor Networks (WSNs), Algorithm Self-Organizing, Energy Resources, Map (SOM).*

1 INTRODUCTION

The main reason for the emergence and development of wireless sensor networks, applications and environments that achieve continuous monitoring and permanent human presence, it is difficult or impossible. wireless sensor is made up of hundreds or thousands node [2]. So the point is very important in the performance of sensor networks: a lifetime and the network coverage of the network, since monitoring applications are typically time-consuming tasks, Expected lifetime of sensor networks to be long enough. However, if we divide the whole network into virtual areas, usually in the region of several sensor nodes located [6]. So in case of death of one of the nodes, the nodes can be partially maintain network coverage. But if all the nodes in the network are dead zone virtually impossible to monitor the area and called the network coverage is lost. Thus, accidental death and dispersed sensor nodes, the better the accumulation of dead nodes in a region. Therefore, the solution to achieve the above objective, namely to increase longevity and maintain network coverage in sensor networks comes to mind, Reducing the energy consumption of nodes, while taking energy uniformly in all network nodes According to reasons mentioned above, the main aim of sensor networks, wise and rational management of energy resources. So you first need to know a good source of energy. Some of the energy consumption of sensor nodes may be helpful, such as[6]:1_ Send or receive data, 2_Processing queries requested, 3_ Send queries or data to the neighboring nodes.

2 REDUCE ENERGY CONSUMPTION IN SENSOR NETWORKS

With the appearance of microelectronics, as sensor nodes became cheaper, smaller and lower weight, their batteries became smaller too. The main and most important reason for Wireless Sensor Networks development was for continuous monitoring of environments where are difficult or impossible for human being to access or stay for a long time; Monitoring of environments like head of an active volcano, difficult terrain border lands, bridges, battlefields, roads, sluices etc. So, normally, there is often low possibility to replace or recharge the dead nodes as well. The other important requirement is that in most applications of WSNs, we need a continuous monitoring, so the lifetime and network coverage of these networks are our great concerns since the performance of WSNs severely depends on their lifetime. Therefore, energy conservation is a serious and critical issue in designing of WSNs with longevity. Energy conservation should be gained by wisely management of energy resources. The first step to reduce the energy consumption of WSNs is to know the most energy consuming parts of these networks which are important in choosing the appropriate method. Energy consumption of communication subsystem is much more than that of computation subsystem. It is shown that transmitting of a bit of data needs to same amount of energy as running of a few thousands of instructions [3]. So, there should be a trade off between communication and processing tasks. Energy consumption of radio in all modes of reception, transmit and idle is the same extent, while energy consumption of radio part is reduced at least an order of magnitude in sleep mode. Thus it is reasonable to turn off the radio as long as we can. According to specific application, sensory subsystem may be a considerable source of energy consumption. In this case, it should be considered in energy efficient approaches although it had not been greatly noticed so far. Instead many research studies around the world have been done to reduce the energy consumption of radio communications. Several energy conservation schemes have been proposed in the literature, while there are several survey studies on them, mostly focused on an especial layer of protocol stack; such as several MAC protocols that have been proposed in the literature and comprehensive survey studies on them as in [2,3] or several routing protocols and survey studies on them[4,5]. But more comprehensive survey studies on energy conservation approaches of WSNs with a different viewpoint have been presented in [6]. Authors in [1] also presented a perfect taxonomy which divides all energy efficient approaches into three main groups: 1_duty-cycling,2_ data reduction,3_and mobility based approaches (Figure1).

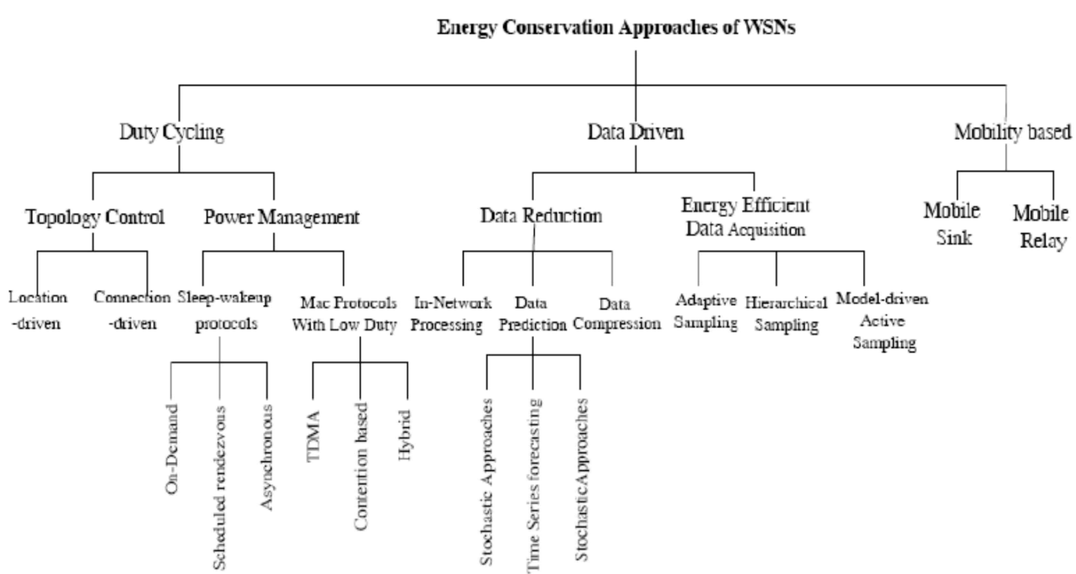


Fig. 1. The taxonomy of approaches to energy conservation of WSNs [1]

3 NEURAL NETWORKS AND ENERGY CONSERVATION OF WSNS

A Neural Network (NN) is a large system containing parallel or distributed processing components called neurons connected in a graph topology. These neurons are connected through weighted connections called synapses. Weight vectors (synapses) connect the network input layer to output layer. Indeed, the knowledge of NN is stored on weights of its connections and it doesn't need to any data storage. In other words, Artificial Neural Networks are arithmetic algorithms which are able to learn complicated mappings between input and output according to supervised training or they can classify input data in an unsupervised manner. One of the difficulties with NNs is choosing of appropriate topology for the problem. This selection depends on properties of the problem, the most possible methods for solving the problem and also the properties of NN. Moreover there are different types of training rules which are inspired from biology science which determine the way NNs learn. In most of these networks, training is based on learning by example. Thus, a set of correct input-output data are often given to the network and using these examples, the network should change the weights values so that by inputting new data the network can return correct answers as output what we call "learning". One of the most important properties of NN's is ability to recognize the data affected by noise or intentional change and to remove those variations after learning. There are different types of NN's topologies, each have different capabilities according to the application needed. The network's capabilities depend on its structure, dynamics and training rules. The most important applications of NN include prediction, classification and identification. The most important question is:

How can Neural Networks help to energy conservation of Wireless Sensor Networks?

In fact, Neural Networks are not energy conservation methods and cannot independently help to conserve energy but they can help energy conservation methods as intelligent tools to work in more efficient, desirable and easier way. So the energy conservation methods are the same previous methods which can use neural network as a tool to better approach to their goals. However there is enough motivation to implement full ANNs on each single sensor node due to analogy between WSNs and ANN as in [Oldewurtel, Frank and Mahonen]. Neural Network based energy efficient approaches can also be classified according to the role Neural Networks play on them or according to the appropriated neural topologies applied [5].

4 SOM BASED ROUTING PROTOCOLS

Today, Neural Networks can be applied as effective tools in all aspects of reducing energy consumption such as duty cycling, data driven and mobility based approaches in WSNs. Dimensionality reduction, obtained simply from the outputs of the neural networks clustering algorithms, leads to lower communication costs and energy savings [5]. The Self-Organizing Map (SOM) is an unsupervised neural network structure consists of neurons organized on a regular low dimensional grid [6]. Each neuron is presented by an n- dimensional weight vector where n is equal to the dimensions of input vectors. Weight vectors (or synapses) connect the input layer to output layer which is called map or competitive layer. Every input vector activates a neuron in output layer (called winner neuron) based on its most similarity. The similarity is usually measured by Euclidian distance of two vector.

$$D_j = \sum_{i=1}^{n} \left\| W_{i,j} - x_i \right\|^2 \quad (1)$$

$$E_{SOM} = \frac{i}{N} \sum_{K=1}^{N} \sum_{j=1}^{M} h_{j,N\left(x(K)\right)} \left\| w_j - x^{(k)} \right\|^2 \quad (2)$$

Where xi is the ith input vector, Wi,j is the weight vector connecting input i to output neuron j and Dj is the sum of Euclidian distance between input sample xi and it's connecting weight vector to jth output neuron which is called a map unit. There are different applications for SOM neural networks in WSNs routing protocols. These applications can be divided into three general groups: deciding optimal route, selection of cluster heads and clustering of nodes. The authors in [2] used Kohonen SOM neural networks for clustering and their analysis to study unpredictable behaviors of network parameters and applications.Clustering of sensor nodes using Kohonen Self Organizing Map (KSOM) is computed for various numbers of nodes by taking different parameters of sensor node such as direction, position, number of hops, energy levels, sensitivity, latency, etc. Cordina and Debono [6] proposed a new LEACH like routing protocol in which the election of Cluster Heads is done with SOM neural networks where SOM inputs are intended parameters for cluster heads. LEA2C apply the connectionist learning by the minimization of the distance between the input samples (sensor nodes coordinates) and the map prototypes (referents) weighted by an especial neighborhood function. After set-up phase, the cluster heads of every cluster are selected according to one of the three criterions, max energy node, nearest node to BS and nearest node to gravity center of each cluster. Then the transmission phase starts and normal nodes send their packets to their CHs and on to the BS. In the case of using max energy factor for cluster head selection, the protocol would have a cluster head rotation process after every transmission phase. The transmission phase continues until the occurrence of first dead in the network. After that, the reclustering (set-up) phase will repeat. The simulation results show the profit of LEA2C over another LEACH-based protocol, called EECS [8].

5 PROPOSED ALGORITHM (EBC-S)

In order to use the effectiveness of cluster-based routing algorithms in increasing of WSNs lifetime, we tried to present a new Energy Based Clustering Self organizing map (EBC-S). The motivation of creating EBC-S was inattention of previous clustering algorithms to energy level of the nodes as a key parameter to cluster formation of the networks. We tried to develop the classic idea for topological clustering and incorporate a topology energy based clustering method in order to approach to our main goal in WSNs, extending life time of the network with enough network coverage. In our idea, energy based clustering can create clusters with equivalent energy levels. In this way, energy consumption would be better balanced in whole network. The proposed algorithm is more like LEACH-C and LEA2C protocols. Thus the assumption about BS cluster formation tasks and energy consumptions models of normal and cluster head nodes are the same as previous. The operation of the algorithm is divided into rounds in a similar way to LEACH-C. Each round begins with a cluster setup phase, in which cluster organization takes place, followed by a data transmission phase, throughout which data from the simple nodes is transferred to the cluster heads. Each cluster head aggregates/fuses the data received from other nodes within its cluster and relays the packet to the base station. In every cluster setup phase, Base Station has to cluster the nodes and assign appropriate roles to them. After determining the cluster heads of current round, BS sends a message containing cluster head ID for each node. If a node's cluster head ID matches its own ID, the node is a clusterhead otherwise it is a normal node. BS also creates a Time Division Multiple Access (TDMA) table for each cluster and affects this table to CHs. Using TDMA, schedules the data transmission of sensor nodes and also allows sensor nodes to turn off their antennas after their time slot and save their energy. So the energy cost for cluster formation is just for BS and there are no control packets for sensor nodes. We assume that BS has no constraint about its energy resources. Also we assume that BS has total knowledge about the energy level and position of all nodes of the network (most probably by using GPS receiver in each node). The other important assumption of the protocol is random distribution of nodes in network space. The sensor nodes are homogenous, means they have the same processing and communication capabilities and the same amount of energy resources (at the beginning). The protocol uses a two phase clustering method SOM followed by K-means algorithm which had been proposed in with an exact comparison between the results of direct clustering of data and clustering of the prototype vectors of the SOM[5].

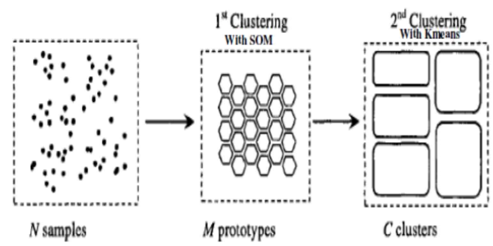


Fig. 2. (Two successive clusterings: SOM followed by K-means [5])

The authors in [7] used Kohonen SOM neural networks for clustering and their analysis to study unpredictable behaviours of network parameters and applications. Clustering of sensor nodes using Kohonen Self Organizing Map (KSOM) is computed for various numbers of nodes by taking different parameters of sensor node such as direction, position, number of hops, energy levels, sensitivity, latency, etc. We selected SOM for clustering because it is able to reduce dimensions of multi-dimensional input data and visualize the clusters into a map. In our application, dimensions of input data relates to the number of variables (parameters) that we need to consider for clustering. The reason for using SOM as preliminary phase is to make use of data pretreatment (dimension reduction, regrouping, visualization...) gained by SOM [7].

6 SIMULATION RESULTS

MATLAB is used to simulate and compare the proposed algorithm (EBC-S) with previous works. The value of m (the number of nodes with a maximum power level that the weights of neural networks are self-employed). This number is experiments on determination by the amount that we expect to have the optimal number of clusters depends. In the first stage (with 100 nodes), we posit m =20 or m =16 and the second stage (400 nodes) m =80 or m =50 Also, we assume are specified that the values of the coefficients of the cost function based on the importance of selecting cluster heads to trial the decision criteria. So the best performance of EBC-S (with CH maximum energy) has been compared with two other previous protocols; The comparison was done through using of three metrics: the number of round (time) when first node dies (First dead time), the number of round (time) when half of nodes die (Half dead time) and the number of round (time) when last node dies (Last dead time).the results are shown in Table (1, 2)

TABLE 1: Comparision of algorithms results (first scene)

	Algorithm	First death	Half death	Last death
Number of node=100 (First sence)	LEACH	576	781	1857
	LEA2C(maximum energy)	626	738	977
	EBCS(maximum energy)	862	878	897
	EBCS(nearest to BS)	47	996	1206
	EBCS(nearest to GC)	47	834	1558

Table 2: Comparison of algorithms results (second scene)

	Algorithm	First death	Half death	Last death
Number of node=100 second sence	LEACH	713	958	2184
	LEA2C(maximum energy)	867	1045	1087
	EBCS(maximum energy)	959	999	1053
	EBCS(nearest to BS)	18	1120	1421
	EBCS(nearest to GC)	22	1057	1712

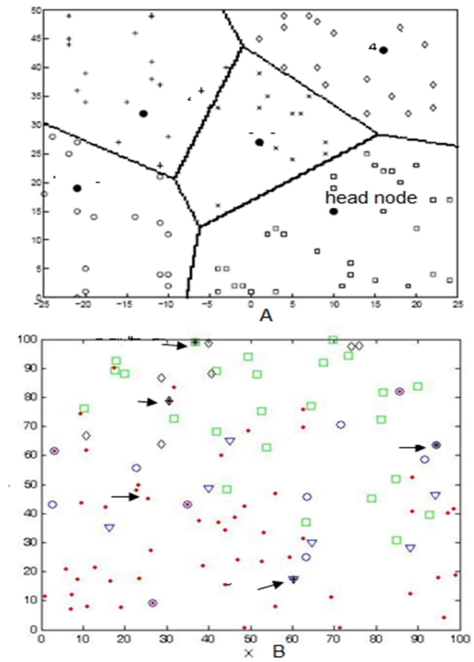
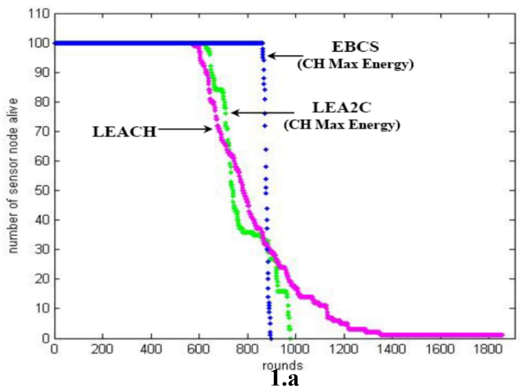


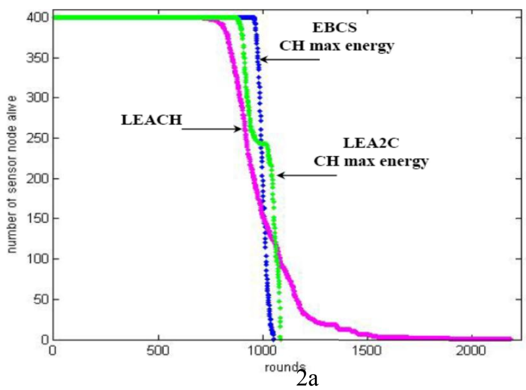
Fig. 3. (A,B). The cluster formation in (A) LEACH and (B) EBCS protocols. All nodes marked with a given symbol belong to the same cluster, and the cluster head nodes are marked with _inLEACH and with _ in EBCS.

6.1 *EBCS Comparison with previous protocols in terms of network lifetime*

In figures (1.a, 2.a) you can see the advantages of the proposed protocol compared with others. The results on figures (1.a, 2.a) show that the proposed algorithm can insure total survival (network coverage) during 95% of network lifetime in first scene and 90% in second scene. As shown in figure (1.a), the new algorithm can increase the lifetime of the network up to 50% over LEACH and 38 % over LEA2C protocols (for the first scene and with maximum energy CH criterion). Also results shown on figure (2.a) prove that the new algorithm increase the lifetime of the network up to 27% over LEACH and 11% over LEA2C protocols (for the second scene and with maximum energy CH criterion).



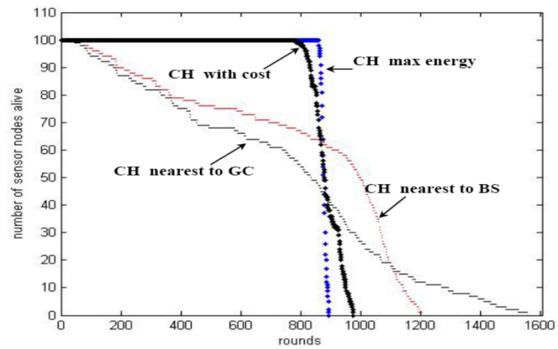
1.a



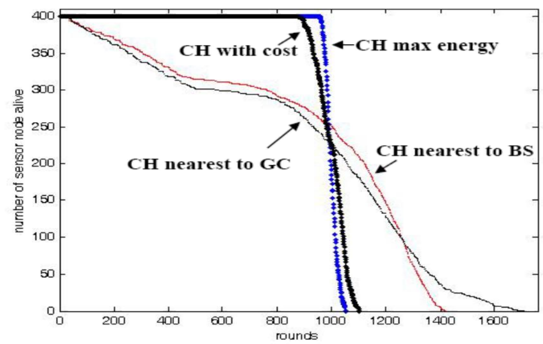
2a

Fig. 4. (1.a,2.a).Number of alive nodes VS time (1.a) comparing in LEACH,LEA2C and EBC-S (First Scene) and Number of alive nodes VS time (2.a) in LEA2C with different CH criterions(Second scene).

In Figures 4 (1.b, 2.b) the performance of using two other CH selection criterions (nearest node to Gravity Center of the cluster and nearest node to Base Station) have been compared to maximum energy criterion. As you can see, the performances of two other criterions are very near to each other while they are too far from maximum energy criterion performance. The comparison of active regions percentage show that LEACH has 84%network coverage while EBC-S still has 92% network coverage left. Moreover, the comparison of network coverage between LEA2C and EBCS in half dead time in figure.3 show that in EBC-S, nodes dies more randomly than in LEA2C. Also network coverage in LEA2C is 56% while there is still 80% network coverage left in EBC-S in half dead time.



1.b



2.b

Fig. 5. (1.b,2.b). (1.b) comparing in EBCS (Proposed algorithm) with different CH criterions (First Scene)and (2.b) in EBCS (proposed algorithm) with different CH Criterions and in LEACH (Second scene)

7 CONCLUSION

In this paper we proposed a new Energy Based Clustering protocol through SOM neural networks (called EBC-S) which applies energy levels and coordinates of nodes as clustering input parameters and uses some nodes with maximum energy levels as weight vectors of SOM map units. Nodes with maximum energy attract nearest nodes with lower energy in order to create energy balanced clusters. The clustering phase performs by a two phase SOM-Kmeans clustering method. The simulation results show 50% Profit of new algorithm over LEACH and 38% profit over LEA2C (in first scene) and 27% profit over LEACH and 11% profit over LEA2C (in second scene) in the terms of increasing first dead time while ensuring total coverage during 90% up to 95% of network life time in two scenes. Also the way of cluster formation in EBCS is different from other algorithms besides it shows 8% more network coverage over LEACH and 24% more network coverage over LEA2C in the same conditions. As future works, the following research areas would improve the protocol results:

1) Combination of proposed algorithm with multihoping routing protocols.
2) Applying other useful parameters for clustering
3) Applying different structures for SOM and K-means algorithms.
4) Applying different criterions for Cluster Head selection of the protocol.
5) Applying different neighborhood functions to optimize SOM clustering.

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