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Artificial Neural Network based Cluster Head Selection in Wireless Sensor Network

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ABSTRACT
The dispersed nature and vibrant topology of wireless sensor network have some basic requirements that include reduced energy utilization and extended network's lifetime. In this paper, we have focused on hierarchical protocols. In such protocol the nodes are arranged in clusters. To synchronize action and route data, cluster head are selected one per cluster. We have introduced a new approach in wireless sensor network for selecting the cluster-head by making use of artificial neural network in order to increase network's lifetime. We have used residual energy as a factor to make cluster-head. Radial basis function network model is used for cluster-head selection problem. The simulation results provide network's performance on the basis of some factors including number of dead nodes, total energy consumption, cluster head formation, number of nodes dying and the number of packets transferred to base station and cluster head. The performance of the proposed algorithm is compared with LEACH and LEACH-C based on energy efficiency and improved network lifetime.

Keywords
Artificial Neural Networks, Cluster Head Selection, Radial Basis Network Function, Residual Energy, Wireless Sensor Networks.

1. INTRODUCTION
Wireless Sensor Network is a group of tiny devices called sensors nodes. These nodes are randomly deployed over an area and are battery powered. These sensor nodes can be mobile or fixed, and are used to examine phenomena in a particular area where deployed [1]. This phenomenon can be any seismic events, forest fire, pollution, temperature, humidity etc.

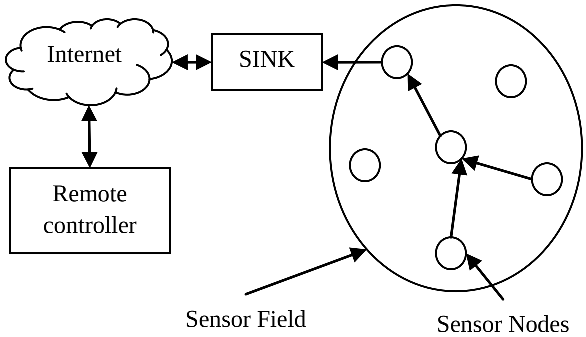

Figure 1: Architecture of Wireless Sensor Network (redrawn from [2]).

Sensor nodes also contain on-board processor; they do not transmit raw data to other nodes that are liable for fusion. A simple computation is carried out by the sensor nodes on data with their processing capabilities. Widely adopted WSN architecture is shown in Figure 1. Sensing sub-system, Processing sub-system and Wireless communication sub-system are the three main components found in sensors [3]. A sensing subsystem is used to sense data from the area where nodes are deployed. A processing subsystem is used to process the raw information. A wireless communication sub-system is used for the transmission of data to base station. In addition, a power source is also present which consists of non rechargeable batteries, thus principal focus in the design of system based on WSN is reduced energy consumption and longevity of network lifetime. Figure 2 illustrates the sensor node architecture.

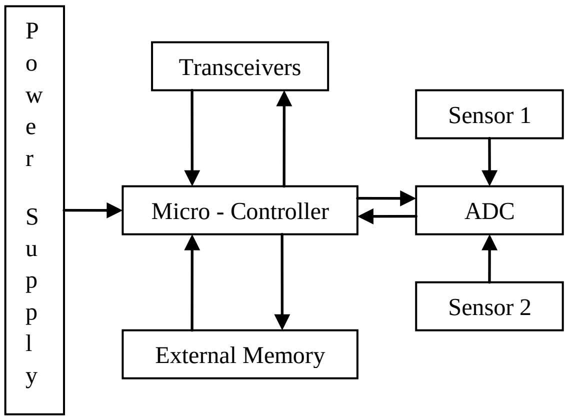

Figure 2: Architecture of a Sensor Node (redrawn from [4]).

There is an increasing demand on routing in WSN than other wireless networks. The routing protocols in WSN are classified on the basis of four schemes - network structure scheme, communication model scheme, topology based scheme and reliable routing scheme [1].

Network structure scheme is further divided into two categories of protocols [5] – Firstly, flat protocols in which all the nodes present in the network plays same role, Secondly, hierarchical protocols where the network of nodes is arranged in clusters and cluster head for each cluster are selected on the basis of various assumptions. Cluster-Head are responsible for forwarding packets and managing activities.

Communication model scheme is further divided into three categories [5] – Firstly, Query based protocols in which the destination node broadcast a query for some data, the nodes receiving the broadcast and having the data (which matches the query) sends the data back to the destination node, secondly, Coherent and Non-coherent protocols, in coherent routing, the data is forwarded to the aggregators after some minimum processing. But in non-coherent routing the raw data is locally processed by the nodes and is sent to other nodes for further processing, lastly, Negotiation based protocol in which meta-data negotiations are used to reduce repeated transmission.

Topology based scheme is further divided into two categories [5] - Firstly, Location based routing in which nodes maintains the topological information and consumes energy by sending data to required region, Secondly, Mobile agent based routing in which data from sensed region is sent to destination.

Reliable routing scheme is further divided into two categories [1]– Firstly, QoS based routing in which sensor network balances in between the data quality and energy consumption, Secondly, Multipath routing in which load balancing is achieved at the time of high data traffic in the network.

Our focus in the paper is on hierarchical routing protocols. LEACH (Low – Energy Adaptive Clustering Hierarchy) is an example of hierarchical routing protocols [6]. Amount of energy consumption is always a key issue in routing protocols thus LEACH uses randomization to share out the energy loads evenly amongst the sensors in the wireless network. In LEACH the nodes arrange themselves into clusters where one node is acting as cluster-head. Unlike conventional clustering algorithm LEACH uses a concept of randomized rotation [7] of cluster heads where nodes chosen as cluster head will not be able to become cluster-head in the next few rounds, resulting in maximizing the network lifetime by not draining the energy of a single sensor present in the network. The operations of LEACH is broken up into rounds where each round is divided in to two phases- First, setup phase and Second, steady state phase [8].

Setup Phase - In this phase clusters are created first and each node decides to become cluster head for existing round or not. The decision of becoming a cluster head depends on how far the node has become cluster head and the suggested probability of cluster head for the network [9]. The node decides to become a cluster head by choosing a random number between 0 and 1 which is compared with the threshold value given in equation 1.

$$T(n) = \begin{cases} \frac{P}{1-P*(r \bmod \frac{1}{p})} & if\ n \in G \\ 0 & otherwise \end{cases} \quad (1)$$

Where,
P → the desired probability of cluster head
r → existing round
G → set of nodes that have become cluster heads in last $\frac{1}{p}$ round.

If random number in less than threshold value than the node can become cluster head. Thus each node will become cluster head in $\frac{1}{p}$ rounds. Thus after $\frac{1}{p}$ rounds all the nodes are again suitable of becoming a cluster head. The nodes those are chosen as cluster head will transmit a message to other nodes to advertise. The non cluster head nodes now decide to which cluster the node must belong the nodes must inform the cluster head that it is the member of cluster.

Steady – State Phase - In this phase all the non-cluster head nodes transmit the data in the allocated time slot to their corresponding cluster and cluster head perform some functioning over the data and passes it to base station.

An artificial neural network contains artificial neurons [10]; that are an engineering approach to biological neurons in human body. To create an intelligent behaviour, artificial neural network tries to imitate the structure and functioning of human brain [11]. Neural networks are made up of simple processing units that are able to store acquired knowledge and use it again. Based on some measures the process of improving performance is defined as learning. To know if the system has learned we need to define a measure of success or target [12]. The measure is not how well the system performs on trained experiences but how well it performs for the new experience. A standard way to measure the success is to divide the data set in to two sections training and testing set. A representation of output is build using training set and performance and accuracy of the system is measured by the test set. Learning is classified as Learning with teacher, and Learning without teacher [12]. Classification of learning is shown in Figure 3.

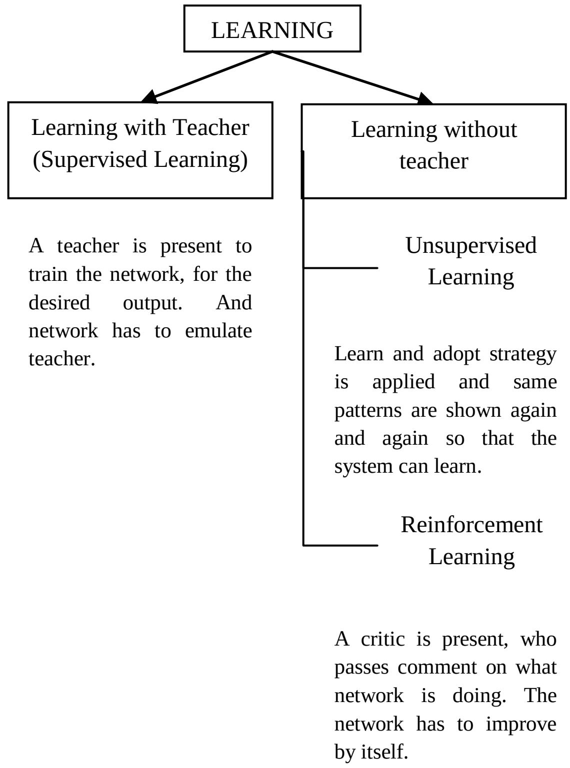

Figure 3: Classification of Learning.

Radial Basis Network function: -Radial functions are special kind of functions. Their attribute is that their output is increases or decreases monotonically from the centre. Distance scale, centre, shape are the parameters of the model, these parametric values are fixed if it is linear. An RBF network is non linear if the function change size or move or the numbers of hidden layers are more than one [13]. Radial functions are Gaussian and are presented as in equation (2) -

$$h(x) = exp\ (-\frac{(x-c)^2}{r^2}) \quad (2)$$

A Gaussian Radial basis function decreases uniformly with distance from centre. Figure 4 illustrates the Radial Basis Function Network.

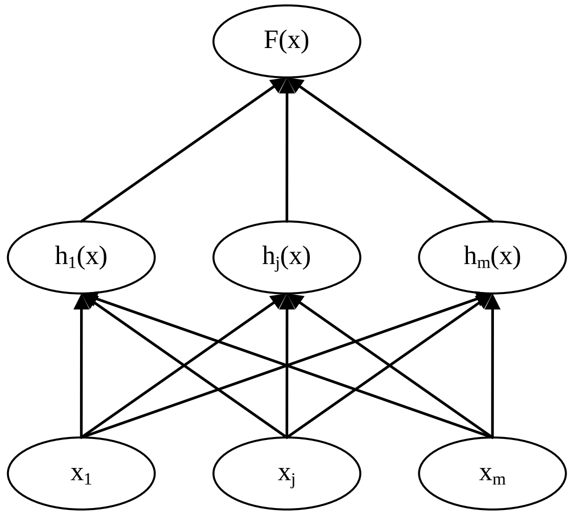

Figure 4: Radial Basis Network Function (redrawn from [13]).

The rest of the paper is organized as follows. The review of the related work is given in section 2. The background review and the proposed algorithms for Cluster head selection are discussed in section 3. The experimental results are given in section 4. The conclusion and future work are given in section 5.

2. RELATED WORK

Review of literature survey has been conducted on the use of artificial neural networks with wireless sensor networks. The authors in paper [1] explain four main schemes on which the energy efficient routing protocols are based: network structure, communication model, topology based and reliable routing. The routing protocols are further classified as flat or hierarchical, query-based or coherent and non-coherent based or negotiation-based, location-based or mobile agent-based, QoS-based or multipath based. The author in paper [3] describes the concepts of wireless sensor network and focuses on various sensor network application, and factors affecting the sensor network. The authors in paper [10] provide a brief introduction of artificial neural networks and its various learning techniques. The authors in paper [11] the paper focuses on the novel structure of artificial neural network, which is composed of highly interconnected neurons working together to solve a problem. The paper also discusses about the model of neural networks given by McCulloch Pitt's model. It is said that neural networks have the ability to derive meaning from complex and inaccurate data, which is used to extract patterns. The authors in paper [12] describes various learning paradigms like Learning with teacher and learning without teacher which are further divided as supervised, unsupervised and reinforcement learning techniques. The authors in paper [13] provides a brief introduction of radial basis function, properties of RBF network, different types of radial basis function and their comparison with other kinds of network. The authors in the paper [14] explain that it is quite necessary to find the exact positions of node for the efficient routing of packets and location aware services. They have used time difference of arrival (TDOA) with artificial neural network to find the exact location of nodes. This TDOA data is used to find the distance between base-station and sensor nodes. This information is then used for training and testing the artificial neural network. The authors in the paper [15] have proposed a coverage and connectivity aware neural network based energy efficient routing protocol in WSN. They have created a two-layer feed-forward neural network that implements the idea of competitive learning, where the sensor nodes of each cluster are provided as input to the neural network and the output of the network is node that is chosen as cluster head i.e. the node having minimum E_{id} value. The authors in the paper [16] has described that communication amongst the sensor nodes consumes a large amount of energy. Thus their focus is to reduce the amount of data traffic from the nodes hence reducing the energy consumption. This sensor data is classified using ARTI neural networks. The network ensures the uniform energy dissipation of all the nodes present in the environment. The authors in [17], explains various methods for base-station positioning in WSN, anchor – free localization technique for single hop wireless sensor network and ways to balance energy consumption in wireless sensor network. The authors in [18] have developed a SIR Protocol. SIR elects the intermediate nodes running an AI-algorithm. Thus, the path created by SIR avoids the election of intermediate nodes that are prone to failure because of battery draining, interference or noisy environment. Further- more, the average dissipated energy is less in SIR when the number of nodes in the sensor goes up. The authors in [19] introduced a neural network based approach which results in a more efficient routing path discovery and sensor power management. A set of attributes are defined based on sensors' location and neighbourhood and we use them as inputs of our neural network and the output of the neural network will be used as a factor in the route path discovery and power management.

3. PROPOSED WORK

The key issue while working with wireless sensor network is reducing the amount of energy consumption and therefore increasing the network lifetime, prior to data transmission a fixed amount of initial energy E_0 is provided to all the nodes. LEACH is based on the probability and the random numbers chosen by nodes, the nodes can become cluster head whether or not it has enough energy to for data transmission and aggregation. We are using neural networks as an energy conservation method, through which we can reduce the energy consumption of the wireless sensor network, now it can help independently to conserve the energy. But, neural networks can be used with any of the energy conservation methods as an intelligent tool to work in a more efficient, desirable and easier manner; thus it can help to provide better results [20]. We are introducing maximum energy concept in LEACH-C so that the nodes which have maximum energy amongst all other nodes are selected as cluster head. We are using artificial neural network approach for finding the nodes having maximum energy then other nodes.

3.1 Algorithm for Cluster Head Selection using Artificial Neural Networks

a) A random deployment of the sensor nodes in an area where, X – axis = 200m and Y – axis = 200m.

b) The algorithm is broken into rounds and each round has two phases, setup phase and steady – state phase. For few initial rounds LEACH – C protocol is applied, as all the nodes are provided with the same initial energy E_0.

c) In the setup phase, based on a random number J, cluster are created and cluster heads are formed i.e. J represents the number of clusters to be formed for the existing round. The decision of becoming a cluster head depends on the amount of energy left in the node, i.e. the nodes having maximum energies will become cluster heads.

d) We are using artificial neural networks (RBF Network) to find the maximum energy values amongst all the nodes as in equation (3) –

$$C(n) = \begin{cases} 1 & maxEnergy \\ 0 & otherwise \end{cases} \quad (3)$$

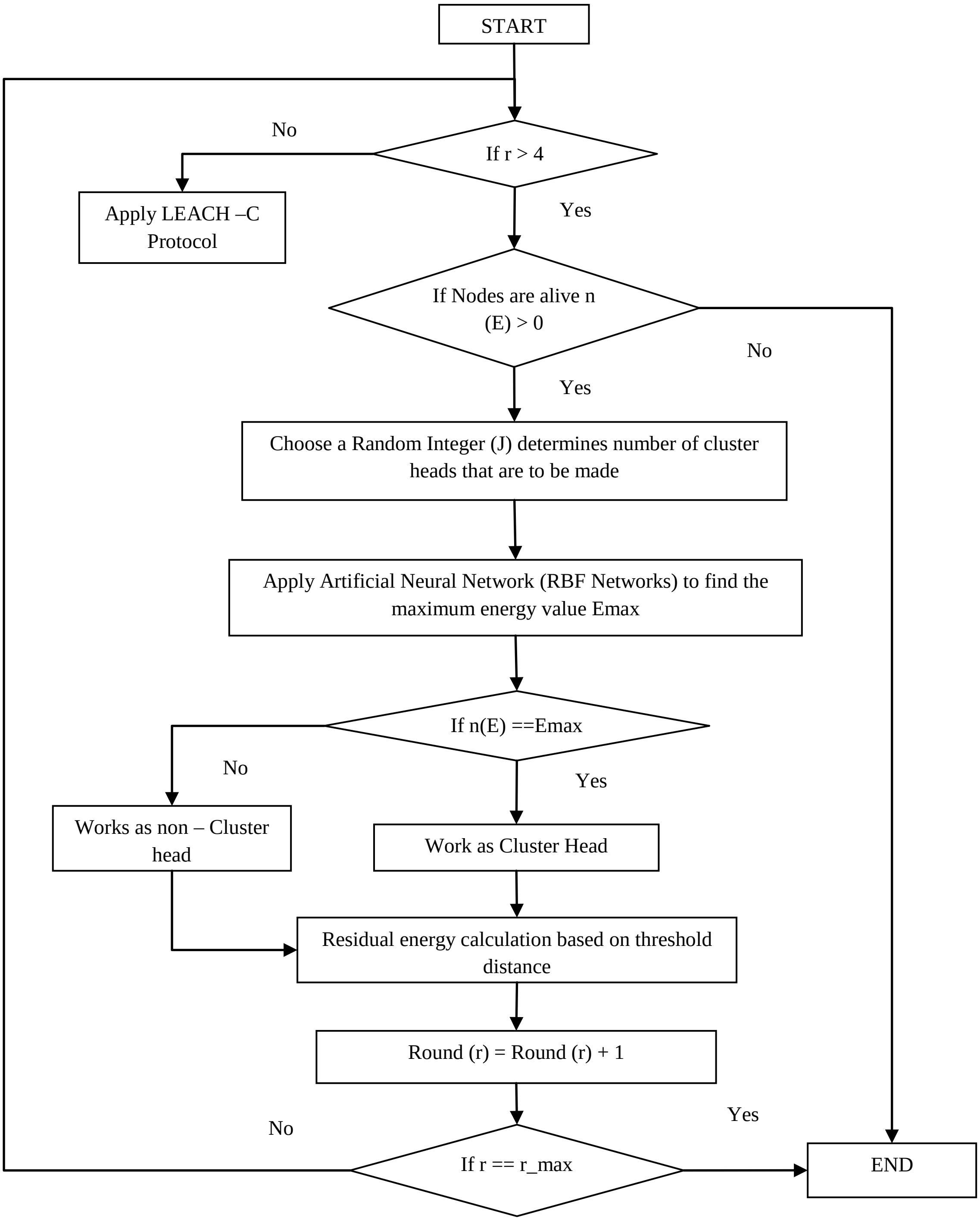

Figure 5: Flow chart of Enhanced LEACH-C with ANN

e) In the steady - state phase non cluster head nodes transmit data to the corresponding cluster heads nodes, after some processing by the cluster heads the data is sent to the base station.

f) When the maximum number of rounds is reached the algorithm ends.

The flow chart of the proposed Enhanced LEACH – C with ANN is shown in Figure 5.

R	Represent the number of rounds that are carried out.
n(E)	Energy of nodes
J	Random integer that decides the number of clusters that is to be formed.

4. SIMULATION RESULTS

In this section, we have demonstrated the practicability of the proposed cluster head selection approach. We have enhanced LEACH-C routing protocol and then used it for data transmission, the proposed algorithm is based on single hop routing i.e. nodes can only transmit data to cluster heads or base-station [21]. We have compared the results of Enhanced LEACH-C with ANN, LEACH and LEACH-C Protocol. We have simulated the proposed scheme in Matlab. The standard values used in simulation are given in Table 1.

Table 1: Simulation Parameters for Cluster Head Selection

PARAMETERS	VALUES
Area	200m X 200m
Number of Nodes	100
Initial Energy Per Node	0.5 J
Total Energy	50 J
Transmitting Energy, ETX	50nJ/bit
Receiving Energy, ERX	50nJ/bit
Data Aggregation Energy, EDA	5 nJ/b/message
Probability of Becoming Cluster Head Per Round	0.05
Size of Data Packets	4000 bits
Threshold distance, d_0	87.7m
Transmit Amplifier Energy	
Energy for Free Space Loss, E_{FS}	0.0013 pJ/b/m^4
Energy for Multi-path Loss, E_{MP}	10 pJ/b/m^2

4.1 Energy Consumption for Transmitting Data to the Base Station

a) If the distance of the node to the base station is greater than d_0 than the energy required to transmit and to receive the data is given by equation (4) and (5) -

$$E_{trans}(k,d) = Eelec * k + Emp * k * (d)^{\rho} \quad (4)$$

$$E_{recv}(k,d) = Eelec * k(d)^{\rho} \quad (5)$$

Where,

P Path loss exponent taken to be 4

K Size of message being transmitted and received

E_{trans} The amount of energy required to transmit the data packets

E_{recv} The amount of energy required to receive the data packets.

b) If the distance of the node to the base station is greater than d_0 than the energy required to transmit and to receive the data is given by equation (6) and (7) -

$$E_{trans}(k,d) = Eelec * k + Emp * k * (d)^{\rho} \quad (6)$$

$$E_{recv}(k,d) = Eelec * k(d)^{\rho} \quad (7)$$

Where,

P Path loss exponent taken to be 2

K Size of message being transmitted and received

E_{trans} The amount of energy required to transmit the data packets

E_{recv} The amount of energy required to receive the data packets.

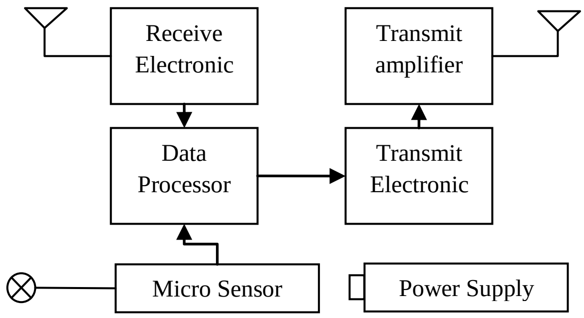

Figure 6: Energy Model Used for Cluster Head Selection (redrawn from [22]).

Figure 6 illustrates the energy model used for transmitting data packets.

4.2 Cluster Head Selection using RBF Networks

The result of Enhanced LEACH-C is compared with LEACH and LEACH-C base on various factors such as number of nodes dead, energy consumption of the network, cluster head formation, and nodes dying etc. The comparative result of number of nodes dead with respect to number of rounds for Enhanced LEACH-C, LEACH-C, and LEACH are shown in Figure 7. The key concern for every routing protocol is to decrease the energy consumption and to increase the network lifetime. We have enhanced the LEACH-C protocol by applying maximum energy concept, in which few nodes having maximum energy amongst all the other nodes are selected as cluster head. Using the concept network lifetime of the sensor network is improved by around 200 rounds.

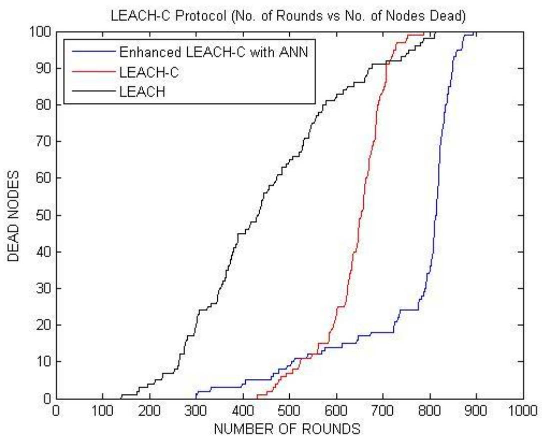

Figure 7: Number of nodes dead in Enhanced LEACH-C with ANN, LEACH-C, and LEACH.

The plot shown in Figure 8 compares the total amount of energy consumed by Enhanced LEACH with ANN, LEACH and LEACH-C over a session of 1000 rounds. From graph the amount of energy consumed by Enhanced LEACH with ANN is less than energy consumed by LEACH and LEACH-C protocol thus prolonging the networks lifetime.

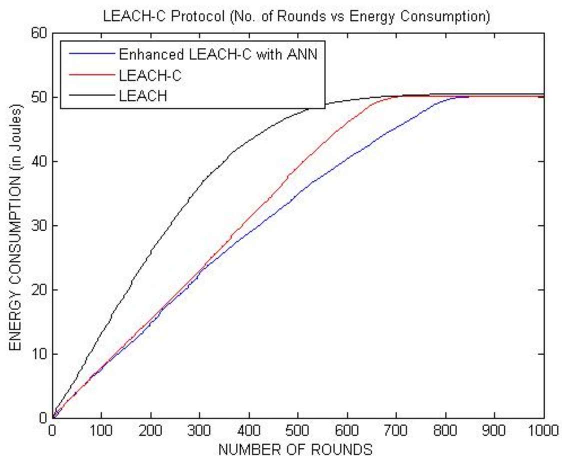

Figure 8: Energy Consumption of Enhanced LEACH-C with ANN, LEACH-C, and LEACH.

Also, Table 5.9 shows the amount of energy consumption v/s number of rounds for Enhanced LEACH-C with ANN, LEACH-C, and LEACH for a session of 1000 rounds. It is show that Enhanced LEACH-C with ANN reduces amount of energy consumption to some extent.

Table 2: Energy Consumption for Enhanced LEACH-C with ANN, LEACH-C, and LEACH

Enhanced LEACH-C with ANN		LEACH-C		LEACH	
ROUNDS	EC	ROUNDS	EC	ROUNDS	EC
1	0	1	0	1	0
250	18.4	250	18.9	250	30.9
500	34.7	500	38.9	500	47.3
750	47.3	750	49.8	750	49.7
894	50	788	50	810	50

The plot shown in Figure 9 gives the comparative results of cluster head formation for a set of 1000 rounds. The graph shows the number of cluster formed every sixty rounds. As LEACH is a clustering based algorithm the Figure shows the number of nodes that are chosen as cluster head per round. The nodes having maximum energy are selected as cluster head. Enhanced LEACH-C with ANN survives till large number of rounds i.e. upto 900 rounds.

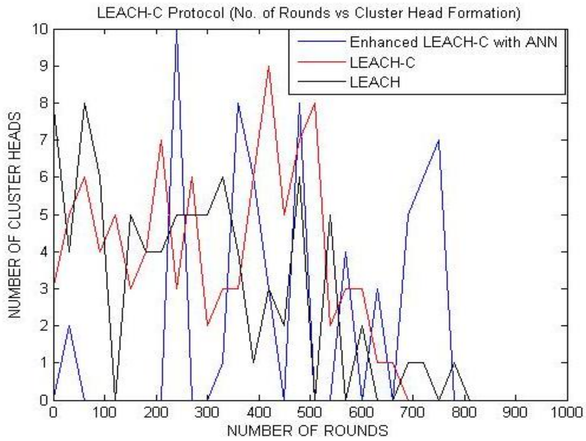

Figure 9: Cluster Head Formation for Enhanced LEACH-C with ANN, LEACH-C, and LEACH.

As it is illustrated from Figure 10, the number of nodes dying to number of rounds which shows that Enhaced LEACH-C with ANN is improving the lifetime of the network than LEACH-C, and LEACH in terms of First Node Dies, Half Network Dies, and Full network dies.

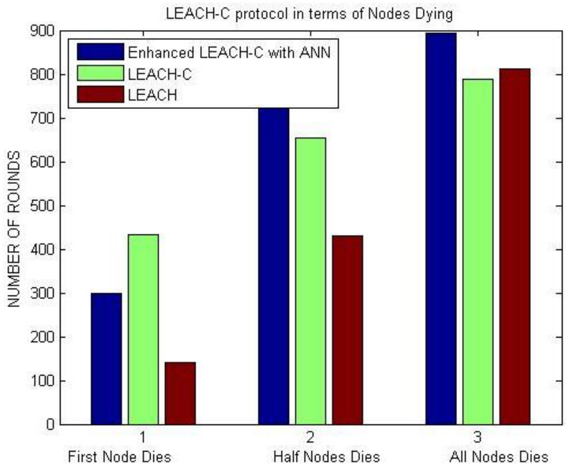

Figure 10: Number of Nodes Dying with Respect to Number of Rounds for Enhanced LEACH-C with ANN, LEACH-C, and LEACH.

Table 3: Number of nodes dying with respect to number of rounds for Enhanced LEACH-C with ANN, LEACH-C, and LEACH.

NODE DYING	Enhanced LEACH-C with ANN	LEACH-C	LEACH
First Node dies	300	432	141
Half Network dies	813	653	430
Full Network dies	894	788	812

Also, Table 3 shows the number of nodes dying for Enhanced LEACH-C with ANN, LEACH-C, and LEACH. It is show that Enhanced LEACH-C with ANN have increased lifetime over the other two protocols.

Table 4: No: of Data Packets being transmitted to Base-Station and to the Cluster Heads in CH Selection.

PROTOCOL USED	PACKETS TO BS	PACKETS TO CH
Enhanced LEACH-C with ANN	38641	36727
LEACH	5196	39702
LEACH-C	3895	60060

The total Number of packets that are transmitted to the base-station and to the cluster heads by using LEACH with ANN, LEACH and LEACH-C protocol are given in Table 4.

5. CONCLUSION AND FUTURE WORK

The purpose of the study is to select the cluster heads; that aggregates the data and pass it to base station, by the use of artificial neural networks in such a way that it improves the lifetime of the network. When working with artificial neural network type of learning becomes an important factor. The proposed method for Cluster head selection uses the concept of maximum energy left with the nodes to become cluster head i.e. a node is chosen cluster head when the amount of energy left with the node is maximum amongst all the other nodes. The type of artificial neural network chosen to select the cluster head amongst the node is radial basis network function. The proposed algorithm is analyzed on various factors including number of nodes dead to number of rounds, energy consumption of the protocols, cluster head formation, number of nodes dying with respect to number of rounds and the total number of packets sent to the base station and the cluster head. It has been observed that Enhanced LEACH-C with ANN protocol provides better results in comparison to LEACH and LEACH-C protocols, i.e. the use of artificial neural network are improving the lifetime of the network to some extent.

In our work we have focused on Hierarchical routing protocols but ANN can be applied to other routing protocols like Location Based protocols, Query based protocols etc. Use of Self organizing Maps, Principal Component Analysis and Support Vector Machine can further enhance the lifetime of wireless sensor networks.

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