Simulated Annealing Based Neural Network for Dynamic Clustering In Wireless Sensor Network

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***Abstract* - Wireless Sensor Networks finds its utility in several applications and has gained significant attention from researchers in recent times. Clustering forms one of the main phases for efficient implementation of transmission algorithms. There have been attempts to address this problem using static clustering but these approaches are unable to utilize several information of the nodes which can further improve the efficiency of the network. This paper proposes a novel approach for dynamic clustering in WSN using an improved Simulated Annealing based Neural Network. Clusters are formed dynamically based on the information present in the nodes. A cost function based on residual energy and distance is optimized when a threshold criterion is satisfied. Re-clustering of nodes takes place when the residual energy of battery falls below the proposed threshold. Routing is done using DSR algorithm. Simulated Annealing technique is used to optimize the weights of Neural Network in back propagation method. Results show several improvements over the static clustering techniques in terms of throughput, delay and energy.**

***Keywords* - Dynamic Clustering, Simulated Annealing, Neural Networks, Energy Aware Clustering, Wireless Sensor Networks.**

I. Introduction

Wireless Sensor Network (WSN) has become one of the most emerging fields gaining worldwide attention in recent years. It is a set of sensor nodes deployed in a sensor field [1]. A large-scale sensor network consists of a large number of sensors with limited resources: limited battery power, low memory, little computing capability, very low data rates, low bandwidth processing, variable link quality, etc. are connected as a wireless network, through which the data extracted from the sensor nodes is sent to a remote base station (BS). The applications of WSN varies from surveillance, environmental monitoring to telemedicine [2]. The scaling of networking protocols must be optimized well to support large number of nodes, adaptive to dynamic nature of the network, energy efficient in terms of energy spent from delivering the packets from source node to sink node must be minimized and power aware means selection of a route which have nodes with higher residual energy.

The network lifetime of a node in WSN can be defined as the time elapsed before the battery of the node in the network is completely drained [3-5]. In a WSN, in addition to minimizing energy expenditure, a protocol design should be designed so that it should also achieve sharp edge effect [5], i.e. individual nodes drain out of energy at similar time. Hence, when the sensor node in the network loses its functionality, remaining active nodes have little residual energy. Many researchers have focused their work on the optimization of most important aspects related to any routing protocol i.e. it should be energy efficient and power aware.

The rest of the paper is organized as follows: section II presents the literature study about the WSN and its routing and clustering protocols. Section III describes the problem formulation. Section IV presents the proposed methodology. Section V presents the simulation results. Section VI describes the conclusion and future scope. Section VII describes the references.

II. Literature Study

Clustering in WSN

Clustering in WSN can be categorized as Static and Dynamic Clustering. In static clustering the boundaries of the clusters are fixed and are formed at the time of network deployment. The clusters are formed usually from heterogeneous nodes. In this case, the size of cluster, CH is immobile. The deployment of sensor nodes in static clustering is easy and are used in the scenarios where number of participating sensors and the area it covers is predefined, the monitor nodes are immobile and maintenance of the sensor nodes is easy [2].

In dynamic clustering the boundaries of the clusters are not fixed and re-clustering is performed after every round of data transmission. Sensor nodes in dynamic clustering may not belong to any one cluster but dynamically support different clusters at different times. Formation of cluster can be triggered by the detection of a big change in attributes which are monitored regularly or with the initiation of a special message signal within the cluster [2].

There are many static and dynamic clustering algorithms present in the literature. In static clustering a Divide and conquer [3] approach is used, in which the boundaries of clusters are predetermined and fixed, and the node whichever comes in one cluster remains in the same cluster. While in dynamic clustering the most popular approach is low energy adaptive clustering hierarchy (LEACH). In LEACH [6], the selection of the CH is based on random selection. And the CH position is rotated in a cluster in order to maintain the balance of the energy levels of nodes in a cluster. The number of nodes, the optimal size of clusters and the number of clusters in the network is assumed to be a known quantity for the design of the network. In another approach a genetic algorithm [7] was proposed to form clusters in terms of a few fitness parameters such as the remaining energy of each node or the sum of all the distances from each sensor to the base station (BS). A new approach based on the calculation of the ratio of the remaining energy of the node to the reference maximum energy for the CH selection shown as HEED (hybrid energy efficient distributed) clustering [8].

Routing in WSN

Once the clusters in the networks are formed, the routing protocols are used in order to find the optimal route in terms of both energy required for sending the data and distance between nodes with other nodes or CHs or the BS. They are also categorized into Proactive and Reactive routing protocols. In proactive the route to the BS from the CH is first established before the start of data transmission while in reactive the route is set up in real time. Few reactive routing protocols flood the network with the data and destination address while others transmit a beacon signal or special message in the network for route discovery. In AODV (Ad hoc On demand Distance Vector) [9], most of the overhead can be removed and routing table is updated. The communication between nodes and the BS or between the nodes and the CHs can be intra-cluster or inter-cluster. Intra-cluster communication comprises the message exchanges between the participating nodes and the CH. Inter-cluster communications includes the transmission of messages between the CHs or between the CH and the BS. In either case the data collected from the nodes in the cluster can be transferred to BS is only through CHs. Also if the CH is only transmitting data or information out of the cluster helps avoiding the data congestion in and out of the cluster [2].

Improvement in finding an energy-efficient and shortest path to the BS is a priori to many network designers. This classical optimal routing problem with energy constraint [10], can be solved by evaluating the energy expenditure in each stage of routing. The objective is to maximize the network lifetime of each node in the network by efficient energy aware routing [11], or the number of successful deliveries until the connection is lost [12]. There are many gradient, heuristic or other searching algorithms [13] [14] can be used to find the optimal route in terms of both energy and distance from BS. Two different energy efficient routing metrics were proposed which plays an important role in optimizing the network performance: minimum cost per packet and minimum energy per packet [15]. A more general link cost was proposed in [16] which can be calculated by the total energy expenditure in transmitting and receiving of information and the initial and residual battery power of a node. Also the energy metrics proposed in [7] and [16], minimum total energy routing [MTE] and the maximum residual energy routing [MRE] can be expressed as special cases for link cost function.

Neural Networks

An artificial neural network is a system based on the operation of biological neural networks, in other words, is an emulation of biological neural system. A neural network can perform tasks that a linear program cannot. When an element of the neural network fails, it can continue without any problem by their parallel nature. The Artificial Neural Network is built with a systematic step-by-step procedure to optimize a performance criterion or to follow some implicit internal constraint, which is commonly referred to as the learning rule.

Neural networks have solved a wide range of problems and have good learning capabilities. Their strengths include adaptation, ease of implementation, parallelization, speed, and flexibility. A two - layer feed forward neural network that implements the idea of competitive learning is depicted in Figure 1 above. The nodes in the input layer admit input patterns of sensor nodes competing for CH and are fully connected to the output nodes in the competitive layer. Each output node corresponds to a cluster and is associated with weight Wj , j = 1,2,...., m , where m is the number of clusters.

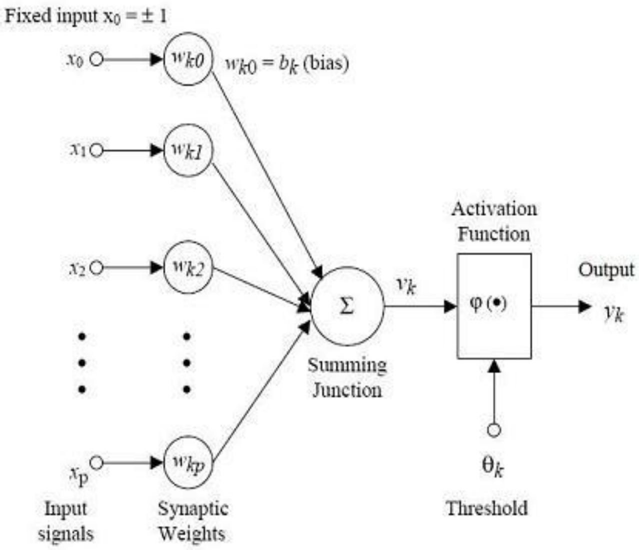

Fig 1: A two Layer Feed Forward Neural Network

Simulated Annealing

Simulated Annealing (SA) is motivated by an analogy to annealing in solids. The idea of SA comes from a paper published by Metropolis etc al in 1953 [Metropolis, 1953). The algorithm in this paper simulated the cooling of material in a heat bath. This is a process known as annealing.

The law of thermodynamics state that at temperature, *t*, the probability of an increase in energy of magnitude, δE, is given by

$$P(\delta E) = \exp(-\delta E / kt) \qquad (1)$$

Where k is a constant known as Boltzmann's constant.
The probability of accepting a worse state is given by the equation

$$P = \exp(-c/t) > r \quad (2)$$

Where
c = the change in the evaluation function
t = the current temperature
r = a random number between 0 and 1

III. Problem Formulation

The problem of dynamic clustering has been dealt by using novel simulated annealing technique to improve back propagation method in neural networks. A cost function based on residual energy and distance of all the nodes from the BS must be optimized. the cost is given by the equation:

$$\text{Fitness Factor (ff)} = \sum(\alpha.Bp + \beta.D^2) \quad (3)$$

Where α and β are constants , Bp is the residual energy and D is the distance of all nodes from BS.

First clustering needs to be done and CH needs to be selected using LEACH protocol. Once CH selection is done, data packets are routed using DSR protocol and after each round of transmission fitness factor needs to be calculated and re-clustering is done depending on the value of ff. If ff value is less than threshold, re-clustering needs to be done using improved neural network technique.

IV. Proposed Methodology

An improved neural network algorithm is used to solve the problem of dynamic clustering in WSN. Simulated annealing is a technique which is used to improve the back propagation algorithm in neural networks. For this, firstly after the initialization of all the nodes in the network, LEACH protocol is used for clustering and CH is selected using the probabilistic model used in the LEACH for the first round.

After clustering, an optimized route is computed using DSR protocol and data is transmitted from source node to CH and CH to BS. Each node in the network updates its routing table with the information related to residual energy and distance from BS. This information is further used to calculate the fitness factor (ff) which is given by equation 3. If the value of the ff is greater than threshold then the process of Dynamic re-clustering continues using the LEACH protocol, and if the value of ff is less than certain threshold value then dynamic re-clustering and CH selection is done using the simulated annealing technique to improve the back propagation method for training of neurons in neural network. Complete methodology of improved neural network is depicted in figure 1.

Fig 2: Proposed algorithm of Improved Neural Network based Dynamic Clustering in WSN

V. Results and Discussion

Improved Neural Network algorithm has been implemented for dynamic re-clustering and CH selection and shows improvement as compared to the LEACH protocol. All the simulations have been done in Network Simulator 2.35, on Ubuntu platform. Figure 2 shows the delay in the network after applying the proposed algorithm and shows promising results over LEACH protocol. Figure 3 shows the total energy of all clusters in the network and figure 4 shows total throughput calculated after applying improved neural network algorithm, and it is observed clearly that our new algorithm performs better than the previous one.

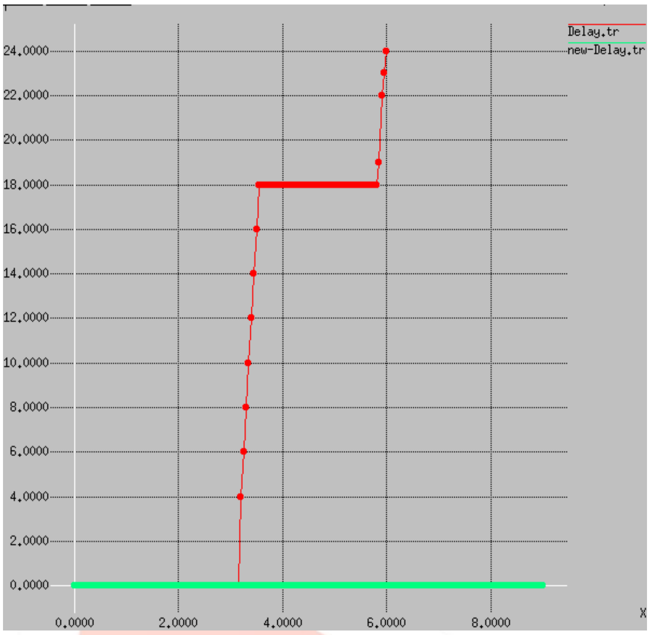

Fig 3: Plot showing Delay after applying Improved Neural Network Algorithm

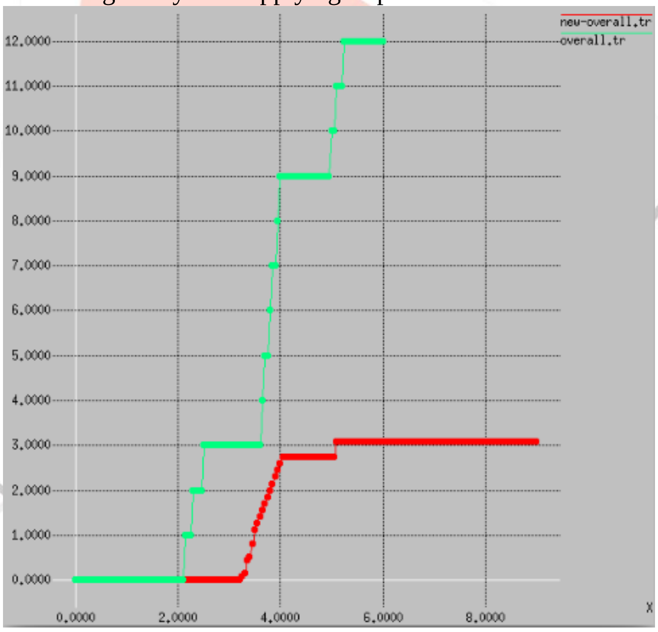

Fig 4: Plot showing Energy calculated after applying Improved Neural Network Algorithm

VI. CONCLUSION

Dynamic clustering and cluster head selection problem have been solved using the improved neural network approach. Neurons in the neural network are trained using the improved back propagation method which is done using the simulated annealing concept which is motivated by an analogy to annealing in solids. Results shows significant improvement in terms of energy and throughput by using the proposed algorithm. In future, other machine learning algorithms would be used to solve the problem.

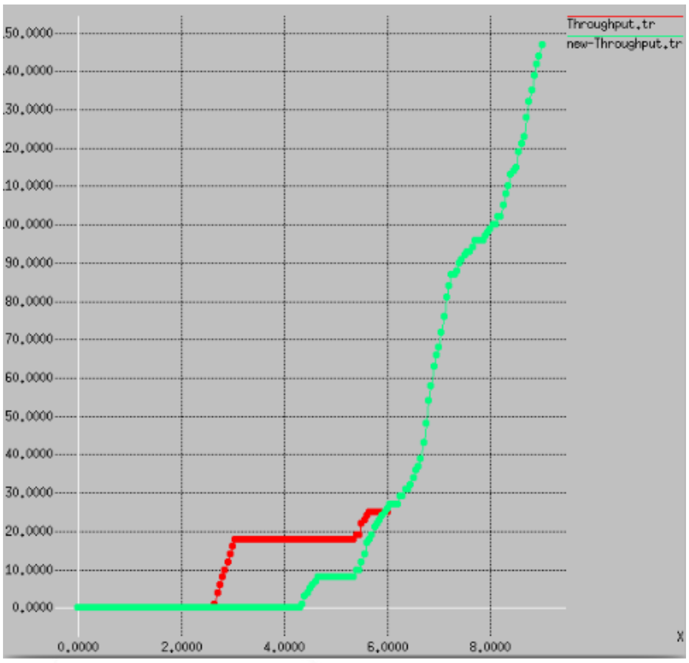

Fig 5: Plot showing Throughput calculated after applying Improved Neural Network Algorithm

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