Neural Network Based Classification Techniques For Wireless Sensor Network with Cooperative Routing

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Abstract— **Wireless Sensor Networks(WSN) are battery powered. Hence every aspect of WSN is to be designed with energy constrain. Communication is the largest consumer of energy in WSN. Hence energy consumption during communication must be reduced to the minimum possible. This paper focuses on reduced energy consumption on communication. Classification techniques are used to classify sensor data to reduce communication cost. Cooperative routing is used to communicate data. The co-operative routing protocol is designed for communication in a distributed environment. In a distributed environment, the data routing takes place in multiple hops and all the nodes take part in communication. This protocol has been designed for wireless sensor networks. The main objective is to achieve a uniform dissipation of energy for all the nodes in the whole network. The paper discusses classification technique using ART1 and Fuzzy ART neural network models. The classified sensor data is communicated further using cooperative routing. Ptolemy-II is used for modeling and simulation of the sensor network. Lifetime improvement of the WSN is compared amongst diffusion routing and cooperative routing with and without classification.**

Keywords- WSN; Neural Network; Clustering; Ptolemy-II; Visual sence, Life Time Modelling

1 INTRODUCTION

Advances in sensor technology, low-power electronics, and low -power radio frequency design have enabled the development of small, relatively inexpensive and low-power sensors, called microsensors. These wireless microsensor [1]networks represents a new paradigm for extracting data from the environment and enable the reliable monitoring of a variety of environments for applications that include surveillance, machine failure diagnosis, chemical/biological detection, habitat monitoring, environmental monitoring etc. An important challenge in the design of these networks is that two key resources - communication bandwidth and energy - are significantly more limited than in a tethered network environment. These constraints require innovative design techniques to use the available bandwidth and energy efficiently [2]. The communication consumes the largest part of the energy budget. Hence attempt must be done to implement techniques two save energy on communications. The paper discusses real time classifier using ART1 [3] and Fuzzy ART neural networks model. Real time classifier classifies the sensor readings and then only its class ID needs to be communicated further. This brings a saving of sufficient amount of energy. The implementation of Classifier using ART1 and Fuzzy ART is discussed in detail in [4]. Ptolemy-II is used to model the sensor networks. Ptolemy-II is the software infrastructure of the Ptolemy Project. Cooperative routing is implemented and simulated under Ptolemy-II environment. Classification techniques are easily incorporated by MATLAB. ART1 Classifier implemented as MATLAB code classifies this data. It is possible to interface MATLAB code with Ptolemy-II. The classified sensor data is then communicated further using cooperative routing protocol. This scheme gives the wonderful advantage of improving the network bandwidth by use of classification technique and energy conservation by use of cooperative routing.

2 WIRELESS SENSOR NETWORKS

A sensor network is composed of a large number of sensor nodes, which are densely deployed either inside the phenomenon or in its proximity . The sensor nodes may be randomly deployed in inaccessible terrains or disaster relief operations hence sensor network protocols and algorithms must possess self-organizing capabilities. One of the most constraints on sensor nodes is the low power consumption. Hence sensor network protocols focus on power conservation. Since the sensor nodes are often inaccessible, the lifetime of a sensor node must be assured. Lifetime of the sensor node depends on the lifetime of power resources. Power scarcity must be effectively managed. Power consumption can be divided into three domains: sensing, communication and data processing sensing power varies with the nature of applications. Sporadic sensing might consume lesser power than constant event monitoring. Of the three domains, a sensor node expends maximum energy in data communication. This involves both data transmission and reception

3 CLASSIFICATION TECHNIQUES

Wireless sensor network is highly data centric. Data communication in WSN must be efficient one and must consume minimum power. Every sensor node consists of multiple sensors embedded in the same node. Thus every sensor node is a source of data. These raw data streams cannot be straight away communicated further to the neighbouring node or the base station. These sensor data streams need to be classified. A group of sensor nodes forms a cluster. Each node transfer data to a cluster head and then cluster head aggregates the data and sends to base station. Hence clustering and classification techniques are important and can give new dimension to the WSN paradigm. Basically, classification system is either supervised or unsupervised, depending on whether they assign new inputs to one of a infinite number of discrete supervised classes or unsupervised categories respectively. ART1 and Fuzzy ART are unsupervised neural network models which are used for classification of sensor data. ART1 model is used for classification of Binary valued data. While Fuzzy ART model can be used for analog data, wherein the input data is fuzzy valued.

4 BASICS OF ART1 ALGORITHM

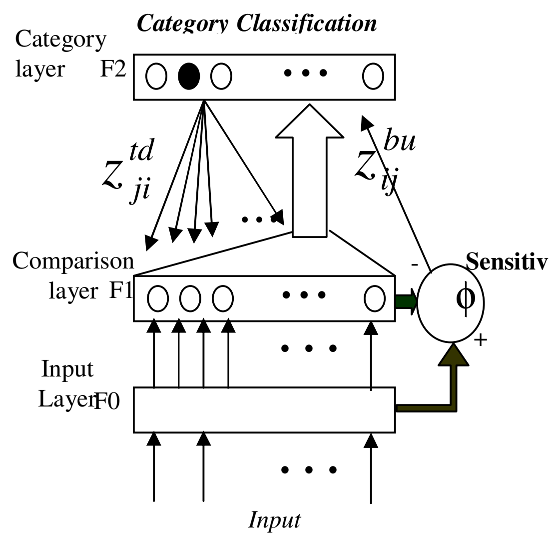
The ART1 model is described in Fig. 1[3]. It consists of three layers (basically only two layers), Layer F0, which is the input layer, which copies the inputs to the F1 layer and has N nodes (one for each binary bit of input pattern). Layer F1, which is the comparison, layer and layer F2 is the recognition or category layer. Layers F0, F1, F2 are constituted of N, N and M neurons respectively. Each node in the F2 layer represents "cluster" or "category". In this layer only one node will become active after presentation of an input pattern $I \equiv (I_1, I_2, ...I_N)$. The F2 layer category that will become active would be more closely represent the input pattern I. If network detects novel input for which there is no preexisting category, a new category will be formed. Each F1 node - x_i is connected to all F2 nodes - y_i through bottom up connection weights z_{ij}^{bu}, so that the input received by each F2 node y_i is given by

$$T_j = \sum_{i=1} z_{ij}^{bu} I_i \qquad (1)$$

Bottom up weights z_{ij}^{bu} take any real value in the interval [0,K], where

$$K = \frac{L}{L-1+N}, \text{ and } L > 1$$

$$y_J = 1, \text{ if, } T_j = \max_k \{T_k\} \quad \text{otherwise} \quad y_J = 0$$



$$I \equiv (I_1, I_2, ..., I_N)$$

Fig. 1: Architecture of ART1 model

Once an active F2 node is accepted by the vigilance criterion, learning takes place. The weights will be updated according to the following algebraic equations,

$$z_J^{bu}\,|_{new} = \frac{L(\mathrm{I} \cap (\mathrm{z}_\mathrm{J}^{\mathrm{td}})_{old})}{L-1+|(\mathrm{I} \cap (\mathrm{z}_\mathrm{J}^{\mathrm{td}})_{old}|} \quad (2)$$

$$z_J^{td}\,|_{new} = \mathrm{I} \cap (\mathrm{z}_\mathrm{J}^{\mathrm{td}})_{old}$$

The weights of the connections touching the F2 winning node y_J are only updated.

5 CLUSTERING ARCHITECTURES FOR WIRELESS SENSORS NETWORK

The strength of the ART1 model is its unique ability to solve a *stability plasticity* dilema, in fast learning mode it take extreamly short training times, it can generate incrementally growing number of clusters based on the variations in the input data. The network runs entirely autonomously ; it does not need any outside control, it can learn and classify at the same time, provides fast access to match results, and is designed to work with infinite stream of data. All these features make it an excellent choice for applications in wireless sensor networks.

For organising the distributed data of the sensors this ART1 neural network can be used in three different clustering schemes for sensors network. *(1)One cluster head collecting all sensors data*: In this architecture the sensor nodes send the sensory reading to one of them chosen to be a clusterhead, where an FA neuron is implemented . This model, as shown in Fig. 1, brings advantages in that we need not to fix in advance the number of clusters (categories) that the network should learn to recognise. *(2) Each unit being a clusterhead clustering data with different level of details:* In this architecture each unit receives the input data from all sensor nodes in one cluster by broadcast. Then each unit classifies the sensor data with different sensitivity threshold, thus providing a general overall view on the network, Instead of having only one cluster, since the data is broadcast anyway, in this architecture all sensors node collect data from all over units and they all have FA implementations. So we can use different sensitivity thresholds with which we achieve different kinds of views over the same data, coarser with smaller number of categories or more detailed with bigger number of categories. *(3)Clusterhead collecting only clustering outputs from the other unit:* Each sensor node has FA implementations classifying only its sensor readings. One of these unit can be chosen to be a clusterhead collecting and classifying only the classifications obtained at other units. Since the clusters at each unit can be represented with binary values, the neural network implementation at the clusterhead is ART1 with binary inputs.

With this architecture[4] a great dimensionality reduction can be achieved depending on the number of sensor inputs in each unit. At the same time communication savings benefit from the fact that the cluster number is a small binary number unlike raw sensory readings which can be several bytes long real numbers converted from the analog inputs.

If the number of sensors in each unit is s , the clusterhead collects data from h units, and the number of different categories in each unit can be represented by b – byte integer, while the sensor readings are real numbers represented with p bytes, then the communication saving can be calculated as:

$$\frac{s.h.p}{h.b} = \frac{s.p}{b}.$$

Since the communication is the biggest consumer of energy in the sensor node, this leads to bigger energy savings as well.

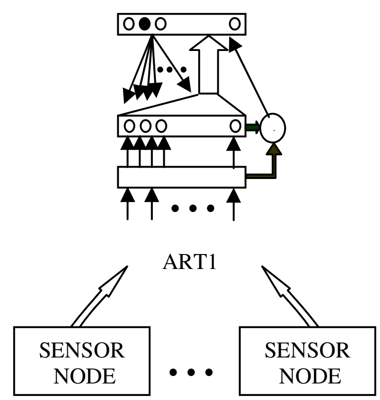


Figure 1. One cluster head collecting all Sensors data The sensor nodes send the sensory reading to one node, which is chosen to be a cluster head, where an ART1 neuron is implemented.

6 CO-OPERATIVE ROUTING

The proposed protocol aims to enhance lifetime by using sub optimal paths. While this constitutes the basis for almost all the approaches for enhancing lifetime, but the best attempt is must to ensure more equitable distribution of the energy consumption. Further, these current protocols either use probabilistic method for using a path We introduce a deterministic method for choosing a path. It uses updating mechanism which adds extra overhead in the current protocols

In our approach to increase network lifetime, we use a completely different set of parameters to use optimal and sub optimal paths. We propose the use of local group average to make a decision regarding the rejection of an optimal path and switching over to a sub optimal path. The local average that we use is the average of the residual energies of all the directed nodes in a local group. Therefore the name of this protocol is co-operative routing protocol. The local group averages need to be updated and we propose a mechanism for these updates without spending any extra energy for communicating these updates. Thus apart from this inherent advantage of automatic update, our protocol ensures the usage of optimal path for maximum number of times without creating any hotspots. We have important assumptions for this implementation. (1) While designing Co-operative routing protocol, we have assumed that the Gateway node has renewable energy resources thereby has the power to perform unlimited number of operations. (2)The nodes in the network are stationary between two setup phases. (3)The transmission range of the Gateway node is large enough to cover the whole cluster. (4) All the nodes are having equal and fixed transmission range. (5) The initial residual energy of all the nodes in a cluster (except the gateway node) is assumed to be equal.(6) Energy required to transmit over a constant range is constant. (7) Each node is having two radios, one is the normal data transmission radio which operates at a higher bit rate and its operation consumes most of the energy spent in communication and the other is MAC radio which operates at a lower bit rate and its operation consumes very less energy as compared to the normal transmission radio.

7 Modeling and Simulation

7.1 Modeling the Lifetime of the Network:

Lifetime of a network is defined as the time after which certain fraction of the network runs out of battery and therefore ceases to function properly, resulting in a failure in transmission of data.

One part of the node that consumes a large share of the battery power present with the node is its transceiver. Apart from this, the data processing unit of the sensor node constitutes a big quota of consumed power. That is why the network lifetime calculations need to be based on both the routing protocol as well the data processing units. A lot of work in the UbiSens[5] research project was aimed at inventing a routing protocol that would minimize the transceiver consumption. Lifetimes of WSNs have been studied earlier [6] [7]. This paper focuses on modeling the network lifetime and further evaluating the efficiency of the Co-Operative Routing Protocol. We are assuming uniform distribution of the sensor nodes. Life time of the network is counted as

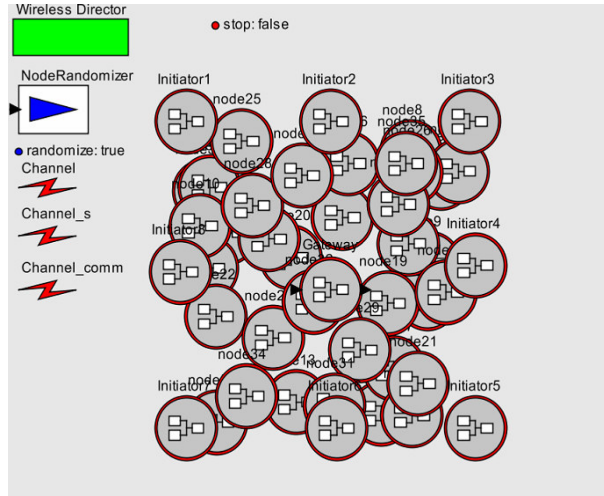


Figure 3. Pre-initialized Sensor Network

Gateway node clock pulse till any one of the node in the network fails. This clock count is proportional to ampere-hour of the battery modeled at each sensor node.

7.2 Introduction to Ptolemy-II

Ptolemy II is the current software infrastructure of the Ptolemy Project. It is published freely in open-source form. Ptolemy II is the third generation of design software to emerge from UC Berkley. The Ptolemy-II[8] is very helpful to study heterogeneous modeling, simulation, and design of concurrent systems. *VisualSense*- is a modeling and simulation framework for wireless and sensor networks that builds on and leverages Ptolemy II. Modeling of wireless networks[9] require sophisticated modeling of communication channels, sensors, ad-hoc networking protocols, localization strategies, media access control protocols, energy consumption in sensor nodes, etc. This modeling framework is designed to support a component-based construction of such models. It supports actor-oriented definition of network nodes; wireless communication channels, physical media and wired subsystems.

8 Implementation of Co-operative Routing

8.1 Topology of the Network:

Sensor Network implemented in Ptolemy-II is shown in Fig. 3. The Nodes that are seen scattered all over the network are the actual nodes, which carry the data from the initiator to the destination. Thus these form data-path in the network. Ptolemy-II plays an important role in the placement of the nodes. A randomizer has been used to set the locations of the nodes. This

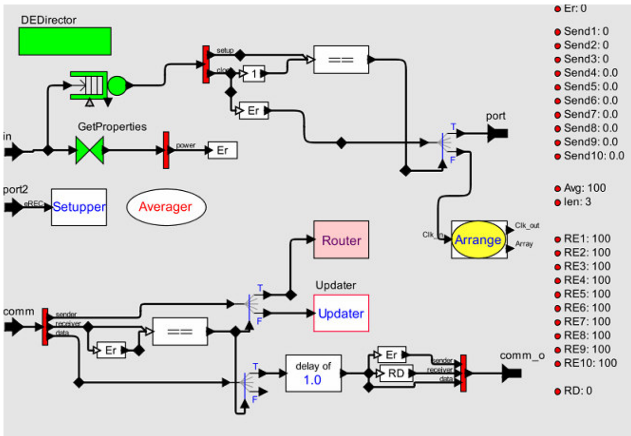


Figure 4. Internals of a Sensor Node

experiment is repeated for different seeds of randomization.

The Gateway Node is the central controller of the network. It is assumed as to be omni-powerful i.e. it could transmit over its entire cluster. Again, there are no power constraints on the Gateway. It is the controller of the network in the sense that it controls the establishment of communication between the nodes. The entire process is assumed to be source initiated.

8.2 Implementing the Setup Phase

The complete internals of the sensor node implemented in Ptolemy is described in Fig. 4. It consists of different functional block implemented by using different Ptolemy actors - Setupper, Averager, Arranger, Router, DataGen, and Updater.

During setup phase, the network is established. The gateway initiates this setup at time 0.The gateway initiates this phase by setting a global variable 'Setup' 1. The status of this variable is globally transmitted and then the nodes act accordingly. The gateway is the one to stop the phase as well. It does it by resetting the 'Setup' flag. The actor 'Setupper' performs the setup function in the nodes and the initiator. When the setup flag is transmitted by the gateway, the nodes' receivers find out the received energy. The 'getProperties' actor is used to find the received energy. The received energy is stored in a variable called 'Er'. The nodes check if the 'Setup' flag is unity, and if true, transmit a packet containing their ID and Received Energy. If the setup period is going on, the receiving node disassembles the packet and stores the ID in its list of neighbors. This leads to a new definition of setup phase which states that setup is the phase of discovery of neighbors.

In our algorithm, the routing is done through forwarding tables. Therefore we are interested only in the neighbors with higher directivity. As is evident from previous treatment, the received energy is symbolic of directivity. During the setup we reject the neighboring nodes with lesser directivity. Not storing the ID previously saved is also of prime importance because replication of IDs leads to faulty routing. The 'Setupper' takes precautions for this as well.

8.3 Implementing the Communication Phase

The setup phase ends when the gateway resets the 'Setup' flag to 0. This also marks the beginning of the communication phase. The communication phase implies that all the nodes have discovered the forward links and if the data arrives at any of these nodes, it can be easily routed to the gateway. That is why the initiators are inhibited from generating data until the onset of communication phase or till the end of setup.

After the completion of setup phase, the Poisson clock in the initiator is triggered. This is same as data generation. Generated data is a pointer to the initiator in which it is generated. This helps in verifying the correct disposal packets. The initiator is also a simple node but does not forward the packets. Rather, it generates data packets. So it also detects neighboring nodes during the setup and routes the data to the most suitable one during the communication period. Another actor called the 'Router' performs the job of routing the packets. The router is the most important part of the design as it is the one taking decisions based on the proposed algorithm. As defined in the algorithm, the router has to find out the most cost effective link. Such link is the one, which is most directed as well as farthest from dying out. Computation of cost of the links is based on the Er of the node and the difference between the residual energy of the node and the average energy of all the forward nodes. Therefore the router simply has to select the node which has maximum directivity among the nodes with residual energy greater than the average energy. Now the significance of arranging the nodes in descending order of directivity becomes obvious. The router simply scans through the list or the forwarding table and selects the first node that is found to be above the average. 'Averager' finds the average of the residual energies of all the nodes in the forwarding table, excluding the nodes with zero ID. 'Updater' gets the residual energy of the neighboring node in a local group and keeps it updated. The controlling parameter in all the routing decisions that are being made through the proposed algorithm is the average energy of the forward paths in a particular local group.

9. RESULT AND ANALYSIS

The table presents the network lifetime of the proposed algorithm in comparison with and without cooperative routing. The comparisons have been made for same number of nodes. The difference in all the sets of simulation is the seed used for randomization. The seeds for randomization determine the network topology. The centralized clock in the Gateway node that measures the time right from setup phase till the first node dies, that calculates the lifetime. The life time count shown in the table is proportional to the ampere-hour of the battery modelled in every sensor node

It is clearly evident from the above table that there is an appreciable improvement in the network lifetime. The improvement varies according to the network topology. It is clearly visible that the improvement in lifetime is consistently around 45%. The maximum network lifetime improvement is found to be 47%

Table 1: describes the Lifetime of Network for Co-operative Routing With and Without Classification. Here with classification the network life is improved by around 45%.

Table 1: Lifetime of Network for Co-operative Routing With and Without Classification

Number of Nodes	Co-Operative Routing		Performance Improvement (%)
	Without Classification	With Classification	
50	172.99	251.38	45.32%
50	165.4	240.35	45.32%
50	185.4	272.96	47.23%
50	188.62	270.51	43.42%
50	170.51	246.59	44.62%
50	166.25	245.75	47.82%

VIII. CONCLUSION

The proposed scheme is modeled and simulated using Ptolemy-II. MATLAB interface is available with Ptolemy. Visual sense is the framework of Ptolemy-II for wireless sensor network. WSN is being used for monitoring environmental data with huge population of sensors. Sensor node being battery driven, functions under energy constrain. Hence every aspects of WSN is designed keeping in view energy constrain.

Classification techniques are implemented using ART1 model in MATLAB. Sensor data is classified at each node and then the class ID is communicated further. This effectively improves the bandwidth of the communication channel and also reduces the energy consumption.

Cooperative routing protocol with the addition of updater is a new concept, designed for communication in a distributed environment. The routing takes place in multiple hops and all the nodes takes part in communication. It achieves uniform dissipation of energy for all the nodes.

The life time of the network is improved by 45% on an average because of classification of sensor data when tested with 50 nodes network with cooperative routing

Thus classification technique gives the advantage of both improving the network bandwidth and enhancing the lifetime of the WSN. Ptolemy-II provides very facilitating environment for modeling and simulation of the Wireless Sensor Network.

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