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Use of Neural Network in WSNs: A survey

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Abstract *– Advancements and miniaturization with high processing capabilities in electronics enabled sensor devices which can communicate with each other easily. Increase in signal processing power and miniaturization of the device with powerful wireless communication trans-receiver unit attached to this sensor unit forms a node in wireless sensor network. Collection of these sensor networks, we call them as wireless sensor networks. The nodes are autonomous in collection of the data and forward the same to data collection point, called as sink node. Sink node is responsible for further processing of the data and providing it to application. The sensor devices use power provided mostly by the batteries. When battery is exhausted then mostly node dies or becomes of no use. To avoid this failure in network, maximum research being carried out in energy saving schemes in Wireless sensor networks. In this paper, we present survey on currents trends using of Artificial Neural Network concepts in sensor networks.*

Keywords*: Wireless sensor, Wireless sensor network, Neural Network.*

I. Introduction

Sensors are widely being used in industrial, domestic, and military environments for sensing of environment parameters. This sensing provides data for controlling the systems which are doing some useful work in that environment. The size of these sensors units is decreasing as the time is passing. Now a days with advancement in manufacturing process and also in microelectronics the complete units is becoming so small that they can be utilized efficiently in many locations, where previously considered to be difficult. A complete unit of the Wireless Sensor comes with components as a sensor component, signal processing unit, signal transmit and receive unit, power unit, if this wireless sensor is mobile then additional unit of mobility and navigation [1]. Wireless sensors when used in large number, then a network of these sensors becomes a unit called as a wireless sensor network (WSN). Use of the WSNs is being done in monitoring of the different environments like head of the active volcano, bridges, battlefields etc. Most of the applications of WSNs are continuous monitoring of environment parameters [2]. When the concept of continuous monitoring comes into picture then the operational life of the sensor unit becomes a concern the unit must consume extremely less power, Operate in high volumetric densities, low cost, dispensable and autonomous, operate unattended, and be adaptive to the environment [3]. When power management unit of the sensor is using the battery then the battery life extension or energy conservation is major parameter under research. The battery life is dependent on the power drawn from battery by the complete wireless sensor unit. The power extraction or the power use by wireless sensor unit dependant on different parameters such as consumption of the power in sensor signal conditioning and then in signal processing and trans-receiver unit, mobility management unit. Most of the power is consumed in the trans-receiver unit while communication to the data collection center unit. Now in network of the wireless sensor one unit will be data

collection unit. This may be termed as a node for collection of data from all other sensor units, a node for synchronization of the communication amongst the sensors, a cluster head of the sensors if the sensors are spread over an area. When we talk about the sensor unit there are different deployment approaches. Here we assume of the static deployment of the sensor for an application where sensor unit tasks are clearly defined. In this situation we can calculate the power consumption in the sensing and processing unit for fixed time duration. There we must have some tradeoffs for sensing and processing of the sensed signals. As the sensing of the signals is application dependant we will try to consider an application independent situation and will try to focus on the communication of information through the trans-receiver unit. There are lots of survey papers those describe the protocol dependant energy conservation approaches [4]. These approaches are 3 different groups (Explained in figure1.) like duty-cycling, data reduction and mobility based approaches. Looking at the architecture of the wireless sensor network and communication between them, they resemble with neuron network in the brain. The fuzzy nature is involved in parameter communication, which enhances the interest to use Artificial Neural Network (ANN) concept for data prediction and communication amongst the WSNs. The capability of the ANNs to predict the data in communication helps to avoid unnecessary data communication and thus saving energy in WSNs [5]. This paper presents survey of latest trends in the classification of ANN based energy saving approaches and methods.

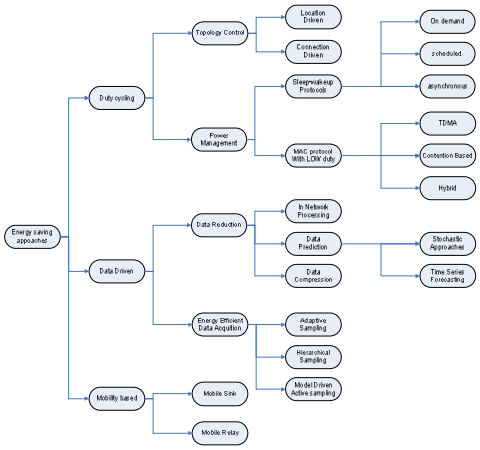

Fig.1. The taxonomy of approaches to energy conservation of WSNs

As the WSNs can form adaptive network using communication property, each node represents a process unit, and the links between nodes specify the causal relationships between the connected nodes. All or part of the nodes are adaptive, which means the output of these nodes depend on modifiable parameters pertaining to these nodes. The learning rule specifies how these parameters should be updated to minimize the prescribed error measure, which is mathematical expression that measures the discrepancy between the network's actual output and a desired output. In other words, an adaptive network is used for system identification [6].

A Neural Network 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. By applying this ANN concept for prediction, classification and identification in communication data we can devise methods to save energy in WSNs. Following table gives classification of ANN based energy saving methods [7].

TABLE I

Sr No.	**ANN concept role**	**ANN Topology applied**	**Energy saving class**
1	Energy efficient path discovery	SOM[8,9,10],BP[11]	Duty cycling-routing
2	Energy efficient Nodes clustering	SOM [12,13 ,Our proposed EBCS]	Duty cycling-Cluster-based routing
3	Cluster head selection	SOM[14]	Duty cycling-Cluster-based routing
4	Data aggregation/ fusion	SOM[5,15,16],BP[17], RBF[18]	Data reduction-In network processing
5	Data association	Hopfield	Data reduction-In network processing
6	Mobile data association	Competitive Hopfield	Data reduction-In network processing
7	Context /Data classification	SOM[5, 19], MEMs[18] and ART1[20]	Data reduction-In network processing
8	Data prediction	BP[21], Elman[22] ARMA& RBF[18]	Data reduction-data prediction and duty cycling

APPLICATIONS OF ANN IN WSNS

If we take a look at above table we can see that SOM (Self Organizing Map) concept of ANN have more application than other concept. In next sections we will survey important methods.

II. Routing and Energy Saving

Routing is related to the communication between the nodes which ultimately associated with the trans-receiver section which consumes lots of energy [23]. Due the concern associated, routing should be done to balance the loss of energy.

II.1. Routing path discovery using Self Organizing Map (SOM)

Possibility of using artificial intelligence with tread off between consumption of energy in processing and in transmission gave a chance of using Self Organizing Map or Kohonen self-organizing Networks concept [8]. This is competition-based network paradigm for data clustering. Networks of this type impose a neighborhood constraint on the output units, such that a certain topological property in the input data is reflected in the output unit's weights [6]. The learning procedure of the Kohonen feature maps or SOM is similar to that of unsupervised – competitive learning networks. That is a similarity measure is selected and the wining unit is considered to be the one with the largest activation. A node which is connected to base station and in routing path of the other nodes is termed as hotspot. To predict hotspots the nodes can be assigned with attributes and by measuring the power levels of each, hotspots can be predicted and used in agent based WSN route discovery and task management.

In [10] MODABER algorithm is designed using the SOM neural network concept. Every node is assigned with attributes like distance from sink, distance from edge, number of neighbors, agent's accessibility. Along with these attributes node form input vector. The set of input vectors used to define importance of the node and this is used for either to drop or route the packet. In [12] SIR is routing protocol which is Quality of Service driven and based on SOM Neural Network concept.

II.2. Nodes Clustering

Clustering is a key technique to improve the network lifetime, reduce the energy consumption and increase the scalability of the sensor network [24]. A scalable sensor network is obtained by means of clusters. A cluster head (CH) could be elected or pre-assigned. Various clustering algorithms have been studied namely LEACH [23], PEGASIS [25], TEEN [25], APTEEN [27]. Energy efficient routing is possible by means of cluster based routing.

Advantages of clustering are -Reduces the size of the routing table by localizing the route setup within the cluster, conserves communication bandwidth, prolonged battery life of individual sensor, no topology maintenance overhead, reduce rate of energy consumption.

Low Energy Adaptive Connectionist Clustering (LEA2C) in [13] is another LEACH-Centralized [23, 28] clustering protocol and these are based on SOM concept. The cluster formation is done in a centralized way by Base Station. LEA2C uses a two phase clustering method, first phase uses SOM and that is followed by second phase of K-means techniques as in [24]. The simulation results show the advantages of LEA2C over another LEACH based protocol, called EECS [29]. 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. In [12] authors used Kohonen SOM neural networks for clustering and their analysis to study unpredictable behaviors of network parameters and applications. Using SOM as preliminary phase data pre-treatment is done in Energy Based Clustering Self organizing map (EBC-S) [30]. This is a new topologic energy based clustering method which using Self Organizing Map neural networks concept can efficiently extend the network lifetime and network coverage.

II.3. Cluster head selection

- Cluster properties
  - For a generated cluster, the clustering scheme can be related to the internal structure of the cluster. The following are the relevant attributes.
  - Cluster count: Numbers of cluster heads are preset in some of the published approaches [31], [32], [33]. CH selection algorithms generate variable number of clusters in general.
  - Intra-cluster topology: Certain sensors communicate directly to their designated CH, but sometimes multi-hop sensor to CH connectivity is required.
  - Connectivity of CH to base station: Connection can be direct or indirect (single link or multi hop link).
- Cluster head capabilities
  - Mobility. CH can be stationary or mobile. But movements are limited within the region for better network performance.
  - Node types. Deployed sensor nodes

- equipped with more computation and communication resources are selected as CHs.
- Role. CHs relay the traffic, fuse or aggregate the sense data.

➢ Selection criteria for Cluster Head
- Initial energy. When any algorithm starts it considers the initial energy of the CH and the initial energy must be high.
- Residual energy. After few rounds of selection, the CH election should be based on remaining energy of the node.
- Energy consumption rate.
  This rate is defined as
  $Vi(t) = [Initial – Ei(t)] / r$
  Where
  Initial- is the initial energy,
  Ei(t)- is the residual energy and
  r- is the current round of CH selection.
- Average energy of the network. It is the reference energy (ideal energy) of each node in current round to keep the network alive.

In [14] a new LEACH like routing protocol is presented. In this the selection of Cluster Heads is done with SOM neural networks where SOM inputs are intended parameters for cluster heads. A minimum separation filter is applied on SOM output to ensure a minimum separation distance between selected CHs.

III. Data categorization

In WSNs data is generated by sensor node. This data is associated with set of parameters. With help of these set of parameters a context is generated. Collection of this data from cluster node involves the technique of compression and fusing by the in-network processing. ANN is used to do this task. The events in WSNs define a pattern. The SOM is used to classify events patterns [5]. Using this classification, reliable decisions can be taken by the WSNs. Multiple elastic neural network modules (MEMs), generalize principles of self organizing model to enable management of wide range of complex optimization problems such as computer vision. Automatic context classification/recognition, usually by the analysis of measurement data from many sensor nodes, is a fundamental problem WSNs interaction. Generally, mapping the sensor data to a context is quite difficult because of the requirement of real-time classification and possibility of training patterns which contain sensor noise. In [19] author presents, context classifier based on Kohonen Self-Organizing Map and online classification of sensor data.

Sensor data have too much redundancy; this must be classified by ANN in each node. This classified data then transmitted. In [20] authors focused on using classification methods based on ART1 neural networks with the goal of reducing data traffic of node resulting in energy conservation. In [34] authors used cooperative routing and also Directed Diffusion.

IV. Sensor Data Prediction

With the help of ANN concepts nodes are capable to develop sensing methods with energy efficiency through prediction of sensor measurements. This reduces the communication amongst the sensors. Most of the time linear models of prediction using ANN are not effective. In noisy multidimensional non-linear processes, these methods become defective. In [22], authors proposed a framework integrated with non-linear time series models to approximate measurements and can reduce energy consumption by learning of a mapping that adapted with long lasting properties of needed process. This eliminates the demand for continual re-estimating of parameters of the model. Researchers used recursive Elman Neural networks to do so. Also they used methods based on second order Newton for training of the neural network. Neural networks have been used in [21] for Dynamic Power Management of WSNs. The authors used ANNs to schedule duty cycling of sensor nodes by event prediction. They considered that the time of next event is a non-stationary series that can be predicted using Wavelet Neural Networks as accurate as possible. The nodes which are at deeper sleep, consumes more energy to wake up. So state of the nodes can be determined with prediction of time series of next event and by defining a threshold relative to remained energy of nodes and comparing of those with each other.

V. Sensor Data Fusion

Looking at the sensor networks when different parameters being sensed, it generates a need of data fusion. Data fusion is important task as it expected to have different sources, automatic, accurate and efficient. In [26/15] when there is no statistical method for error estimation, we can use rule based sensor data fusion, fuzzy logic or ANN concepts. In [35], [36], [37], [38], [39], [40] authors successfully used ANN concepts for data fusion. Even though sensor data have environmental or intentional jamming; trained ANN will help to

eliminate bad data. Specific structures are considered while processing of sensed data statistics and sensor properties. A neural network method based on Hopfield structure proposed in [16] for this problem which always finds the optimal solution in 17.4 percent of the times and finds a way that approximate the proper solution in remained time. In [17] authors applied a back propagation Neural Network. In this data is provided to input and the difference between input and output is calculated. Weights are changed to improve the results. Once the Error is minimized the trained network is used for operations. Multi-layer networks explicitly need long training time while Radial Basis Function neural networks (RBFs) learn faster than Back Propagation networks because only one layer of weights needs to be modified. Research is going on problem in determining appropriate hidden units in multilayer network. To solve this problem Dynamic Node Creation system is proposed in [41]. Authors in [18] proposed a new approach for optimal designation of duties by elastic neural network in tracking objects. Compared with conventional methods, simulation results showed that the tracking accuracy improved greatly demonstrating the effectiveness of elastic neural network in handling optimized task allocation problem of multi-sensor multi-target tracking and the energy consumption of the tracking system was reduced significantly.

VI. Conclusion

Energy saving in wireless sensor networks is the prime concern. Considering the area of the parameter sensing and processing data using ANN offers a great advantage over other methods. This paper presented a survey and classification for the most important applications of neural networks in energy efficiency of WSNs, with reference to the research studies that have been done so far. ANN is an intelligent tool to deal with the problems associated in sensing and processing data at the sensor node end, also while interacting with the network of the node. It helps to improve routing and hence helping to reduce energy consumption in network interaction. The most important application of neural networks in WSNs can be summarized to sensor data prediction, sensor data fusion, path discovery in routing, sensor data classification and nodes clustering which all lead to less communication cost and energy conservation in WSNs. As future work, more research work is needed in ANN topologies and associated conservation of energy in WSNs.

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