VOL. 11, NO. 23, DECEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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AN INTELLIGENT ROUTING PROTOCOL BASED ON ARTIFICIAL NEURAL NETWORK FOR WIRELESS SENSOR NETWORKS

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ABSTRACT

In WSNs, the existing routing and clustering schemes have demonstrated the effectiveness of traffic distribution to fulfill the quality of service requirements of applications. However, due to the non existence of intelligence in those routing and clustering algorithms might significantly affect the transmission performance, scalability, reliability, and security of WSNs. Thus, by considering the reliability, congestion control, and security for, it is desirable to design an intelligent routing scheme to provide efficient routing. This paper proposes an intelligent routing protocol (IRP) based on artificial neural network (ANN) for wireless sensor networks. IRP performs the cluster identification and cluster head (CH) election using ANN. This process causes less overhead and helps in achieving the real advantage of clustering in wireless sensor networks. Once the clustering is completed, the routing phase comes into action. In the routing phase, the table driven protocol is used to forward the data at the intercluster level and on-demand based protocol is used to forward the data at the intracluster level. Thus, the proposed routing approach works on a hybrid basis and is implemented in NS2 for performance analysis.

Keywords: artificial neural network, clustering, routing, intelligent protocol, wireless sensor networks

INTRODUCTION

With advancements in wireless and related technologies in last two decades, Wireless Sensor Networks (WSNs) become an integral part of our daily life as these networks are being used in wide areas of applications. WSNs consist of Sensor Nodes (SNs) which are equipped with low-power microcontrollers and transceivers to perform various operations in the network field [1]. There is large range of applications such as monitoring of environment, pollution control system, military operations, control of vehicle motion, detection of earthquake, tracking of target and surveillance system, monitoring system for patients [2], where WSNs can play an important role. Routing is one of the critical technologies in WSNs. Opposed to traditional *ad hoc* networks, routing in WSNs is more challenging as a result of their inherent characteristics [3, 4]. Firstly, resources are greatly constrained in terms of power supply, processing capability and transmission bandwidth. Secondly, it is difficult to design a global addressing scheme as Internet Protocol (IP). Furthermore, IP cannot be applied to WSNs, since address updating in a large-scale or dynamic WSN can result in heavy overhead. Thirdly, due to the limited resources, it is hard for routing to cope with unpredictable and frequent topology changes, especially in a mobile environment. Fourthly, data collection by many sensor nodes usually results in a high probability of data redundancy, which must be considered by routing protocols. Fifthly, most applications of WSNs require the only communication scheme of many-to-one, *i.e.*, from multiple sources to one particular sink, rather than multicast or peer to peer. Finally, in time-constrained applications of WSNs, data transmissions should be accomplished within a certain period of time. Thus, bounded latency for data transmissions must be taken into consideration in this kind of applications. Nevertheless, energy conservation is more important than quality of service (QoS) in most applications in that all sensor nodes are constrained with energy which is directly related to network lifetime. Based on network structure, routing protocols in WSNs can be coarsely divided into two categories: flat routing and hierarchical routing. In a flat topology, all nodes perform the same tasks and have the same functionalities in the network. Data transmission is performed hop by hop usually using the form of flooding. The typical flat routings in WSNs include Flooding and Gossiping [5], Sensor Protocols for Information via Negotiation (SPIN) [6], Directed Diffusion (DD) [7], Rumor [8], Greedy Perimeter Stateless Routing (GPSR) [9], Trajectory Based Forwarding (TBF) [10], Energy-Aware Routing (EAR) [11], Gradient-Based Routing (GBR) [12], Sequential Assignment Routing (SAR) [13], *etc*. In small-scale networks flat routing protocols are relatively effective. However, it is relatively undesirable in large-scale networks because resources are limited, but all sensor nodes generate more data processing and bandwidth usage. On the other hand, in a hierarchical topology, nodes perform different tasks in WSNs and typically are organized into lots of clusters according to specific requirements or metrics. Generally, each cluster comprises a leader referred to as cluster head (CH) and other member nodes (MNs) or ordinary nodes (ONs), and the CHs can be organized into further hierarchical levels. In general, nodes with higher energy act as CH and perform the task of data processing and information transmission, while nodes with low energy act as MNs and perform the task of information sensing. The typical clustering routings protocols in WSNs include Low-energy Adaptive Clustering Hierarchy (LEACH) [14], Hybrid Energy-Efficient Distributed clustering (HEED)

[15], Distributed Weight-based Energy-efficient Hierarchical Clustering protocol (DWEHC) [16], Position-based Aggregator Node Election protocol (PANEL) [17, 18], Two-Level Hierarchy LEACH (TL-LEACH) [19], Unequal Clustering Size (UCS) model [20], Energy Efficient Clustering Scheme (EECS) [21, 22], Energy-Efficient Uneven Clustering (EEUC) algorithm [23], Algorithm for Cluster Establishment (ACE) [24], Base-Station Controlled Dynamic Clustering Protocol (BCDCP) [25], Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [26], Threshold sensitive Energy Efficient sensor Network protocol (TEEN) [27], The Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN) [28], Two-Tier Data Dissemination (TTDD) [29], Concentric Clustering Scheme (CCS) [30], Hierarchical Geographic Multicast Routing (HGMR) [31], and *etc*. Clustering routing is becoming an active branch of routing technology in WSNs on account of a variety of advantages, such as more scalability, data aggregation/fusion, less load, less energy consumption, more robustness, *etc*.

In recent years, according to the researcher in [32] with the development of computational intelligence, routing protocols based on intelligent algorithms have been proposed to improve the performance of WSNs. Intelligent algorithms provide adaptive mechanisms that enable or facilitate intelligent behavior in complex and changing environments, which can be brought to design all-in-one distributed real-time algorithms. Such algorithms have proved to work well under WSN-specific requirements like communication failures, changing topologies and mobility. Thus our main objective in this paper is to propose an intelligent routing protocol (IRP) based on artificial neural network.

INTELLIGENT ROUTING PROTOCOL (IRP)

The proposed intelligent clustering routing scheme is based on artificial neural network. Two issues are addressed by this routing approach. They are clustering and routing. When the source node wants to send data to a destination, and has information about its CH, then the packets are sent to the CH. The CH takes care of further processing. When the source has no information about the CH, then it initiates the clustering process by sending the cluster formation request.

Cluster formation using ANN

The cluster formation consists of two steps. The first step uses the 20/80 rule to identify the number of clusters. This process is used in order to reduce the number of clusters to be formed in the network. The second step uses the ANN based method to identify the required clusters and its cluster head. This clustering structure is adopted because monitoring nodes in the entire network cause bigger overhead than watching less number of nodes in the cluster.

Cluster identification

In this paper, the competitive neural network based algorithm is used for cluster identification when the locations of the node set are non-overlapping. Figure-1 depicts the overall architecture of this cluster identification module.

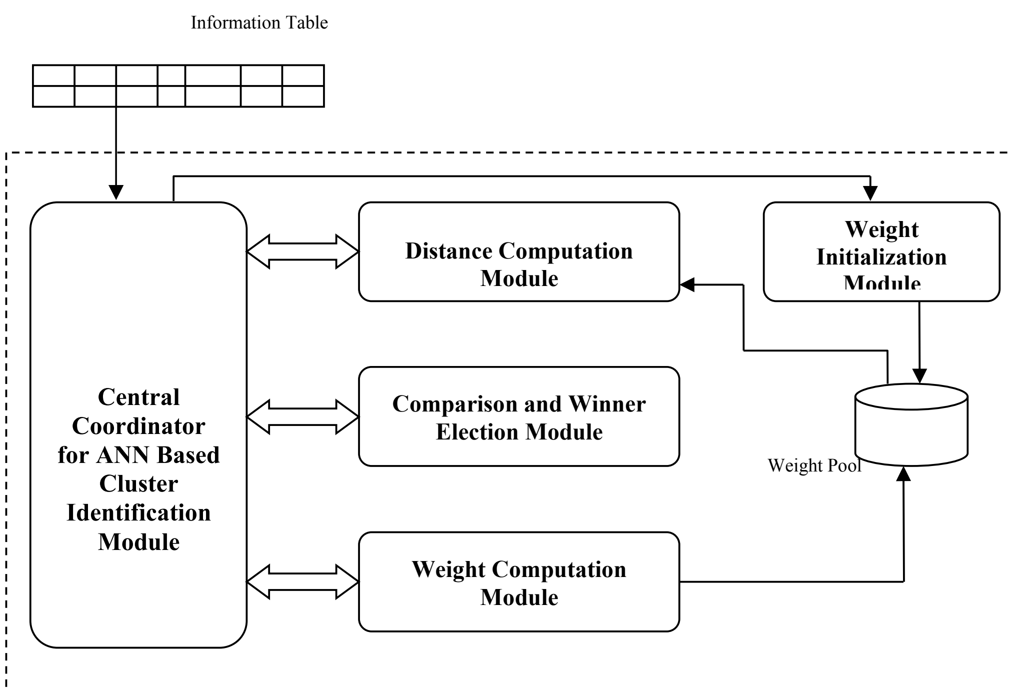

Figure-1. System architecture for ANN based cluster identification.

VOL. 11, NO. 23, DECEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

The locations of the various nodes are extracted and provided as an input to the neural network which identifies the clusters in the node set. The algorithm starts the identification process by computing the distance between the input nodes and weight nodes. On the basis of smallest distance value, the winning neuron is decided. The corresponding input node falls in the cluster of the winning neuron and the weights of neurons other than the winning neuron are updated. By using this approach, the use of disproportional amount of network resources is avoided. The algorithm for ANN based on clustering is shown in Figure-2.

Initialize the structure of the ANN;
Initialize weights w_{c1}, w_{c2} for each cluster c;
Initialize the learning rate constant α ;
Initialize n as number of nodes;
Initialize c as number of clusters;
For each node n do
Obtain location LX_n, LY_n;
For each c do
Compute $D_{nc} = (w_{c1} - LX_n)^2 + (w_{c2} - LY_n)^2$;
End For
The node n which is having its D_{nc} minimum, is assigned to cluster c;
Update the weight of the winning unit
$w_{c1}(new) = w_{c1}(old) + \alpha[LX_n - w_{c1}(old)]$;
$w_{c2}(new) = w_{c2}(old) + \alpha[LY_n - w_{c2}(old)]$;
End For

Figure-2. Algorithm for ANN based cluster identification.

CH Election

The back propagation neural network based CH Election system is trained with various input and output patterns and is used to elect a CH in each identified clusters. This ANN based election method uses the reliability of the nodes as input for election. The reliability of each node u is calculated as $G_u = g_H * g_B$, where g_H is the reliability of nodes hardware and g_B is the reliability of the battery of the node. The values of g_H and g_B depend upon various constraints and also $0 \le g_H < 1$ and $0 \le g_B < 1$. Figure-3 depicts the overall architecture of this cluster head election module.

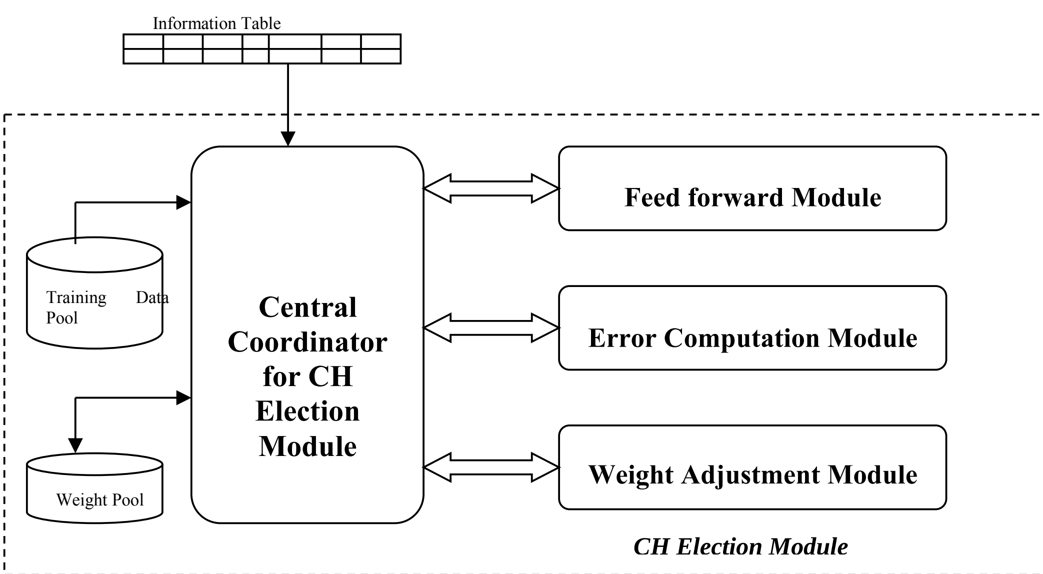

Figure-3. System architecture for cluster head election.

VOL. 11, NO. 23, DECEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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In this method, the input causes a response to the neurons of the first layer which in turn causes a response to the neurons of the next layer, and so on, until a response is obtained at the output layer. The obtained response is then compared with the target response, and the difference (the error signal) is calculated. From the error difference at output neurons, the algorithm computes the rate at which the error changes, as the activity level of the neuron changes. Here, the algorithm steps back one layer before the output layer and recalculate the weights of the output layer so that the output error is minimized. The algorithm continues by calculating the error and computing new weight values, moving layer by layer backward, toward the input. When the input is reached and the weights do not change, then the algorithm selects the next pair of input-target patterns and the process is repeated. Once the training process is over, the back propagation network is ready for election.

Routing

Once the clustering is over, the network is ready for communication. The information about the clustering process is broadcasted into the network. The CH in each clusters take care of communication in the network. When a node wants to transfer data to its destination, it sends the packet to the CH, which checks whether the destination is in its cluster. If the destination is found in the cluster, the packet is then transferred to the destination with the help of intracluster routing protocol. This protocol is an on-demand protocol. If the destination is not found in the cluster, then the packet is transferred to the other CH with the help of intercluster routing protocol, which is a table-driven protocol. The ad-hoc on-demand distance vector protocol and destination sequenced distance vector protocol are modified to implement the proposed routing scheme.

RESULTS AND DISCUSSIONS

The results of the proposed Intelligent Routing Protocol (IRP) are studied in two stages. In the first stage, the ANN based clustering method is compared with other existing clustering methods called LEACH. The second stage conducts routing based on IRP and LEACH separately and comparison of the routing metrics.

First stage: ANN based clustering

About 100 nodes were placed randomly as 20 sets of clustered data points. These data points are plotted in Figure-4.

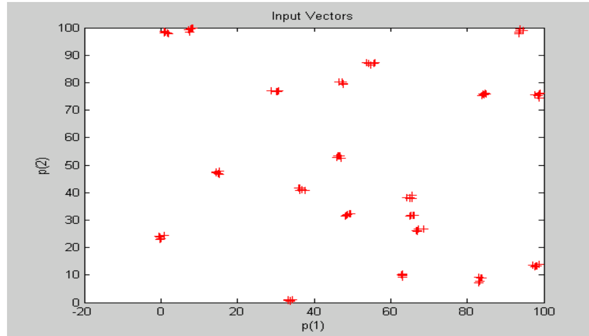

Figure-4. Location of the nodes for ANN clustering.

The ANN based method is used to identify the clusters in these data set. The identified clusters by this method are shown in Figure-5.

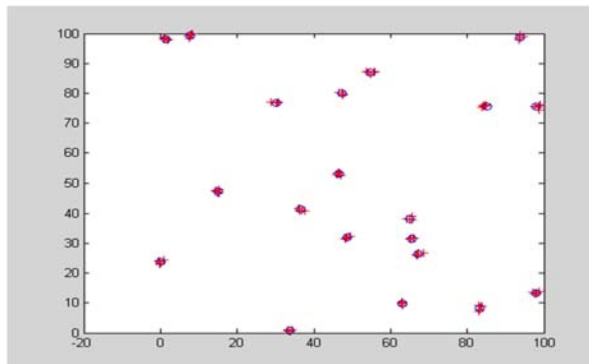

Figure-5. Identification of different clusters by ANN.

From Figure-6, it is clearly seen that the ANN based method identifies less number of clusters than the other method. The number of clusters formed is less than the number of clusters formed with the help of existing algorithms and also 20/80 rule is applied in the proposed ANN based clustering method to reduce the number of clusters.

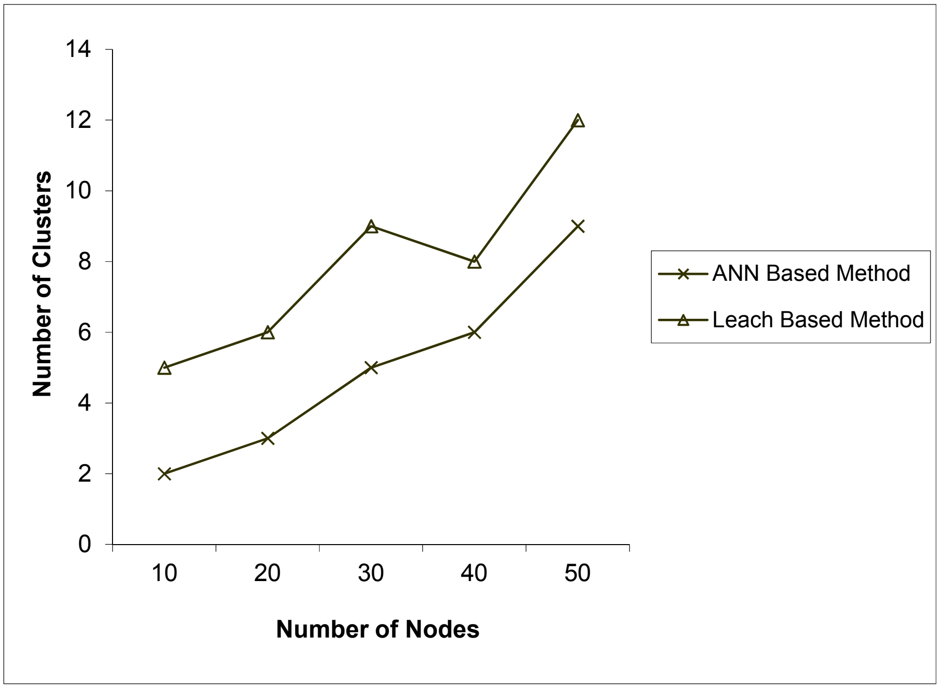

Figure-6. Comparison using number of clusters for ANN clustering.

Second stage: Routing

In order to perform routing related simulation, data packets are generated. The packet size is fixed as 512 bytes. Packet sending rate is fixed as 2 packets/sec. The pause time of the node is kept as 30 seconds and the mobility speed is kept as 30 m/s. In this section, the proposed IRP protocol is denoted as ANN based method and is compared with LEACH. Figure-7 shows the number of packets received with the increase in number of nodes.

It is clearly seen in Figure-7 that the IRP has given better results than the LEACH routing protocol. The IRP performs better than the other protocol because the IRP uses modified AODV protocol for intracluster routing and modified DSDV protocol for intercluster routing.

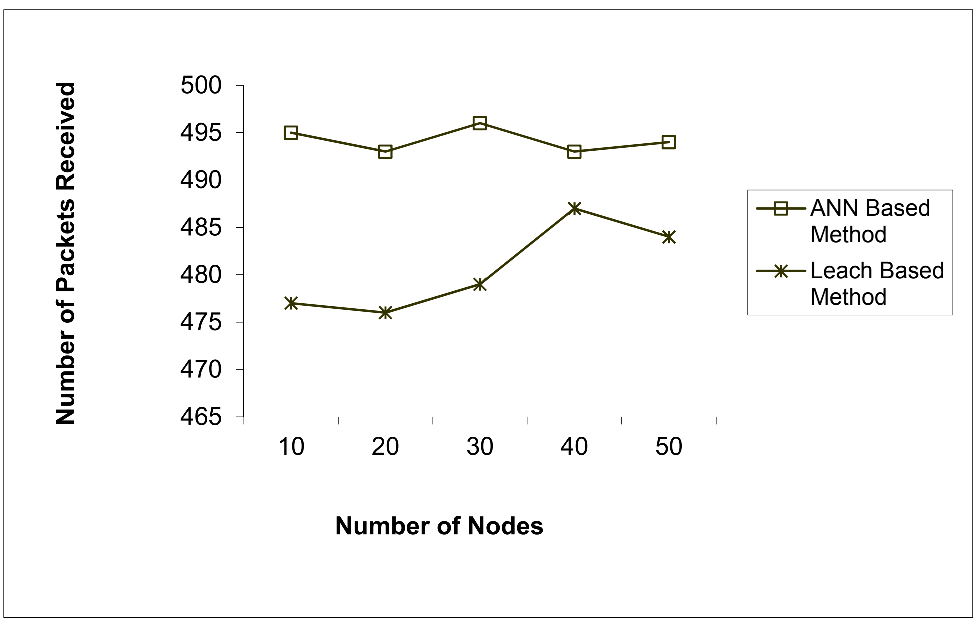

Figure-7. Comparison using number of packets for IRP.

Figure-8 shows the End-to-End delay with respect to the increase in the number of nodes. In this Figure, it is seen that the IRP gives higher throughput than the LEACH routing protocol. The reason for this result is that the average delivery fraction of the IRP protocol is quiet higher than the existing LEACH protocol.

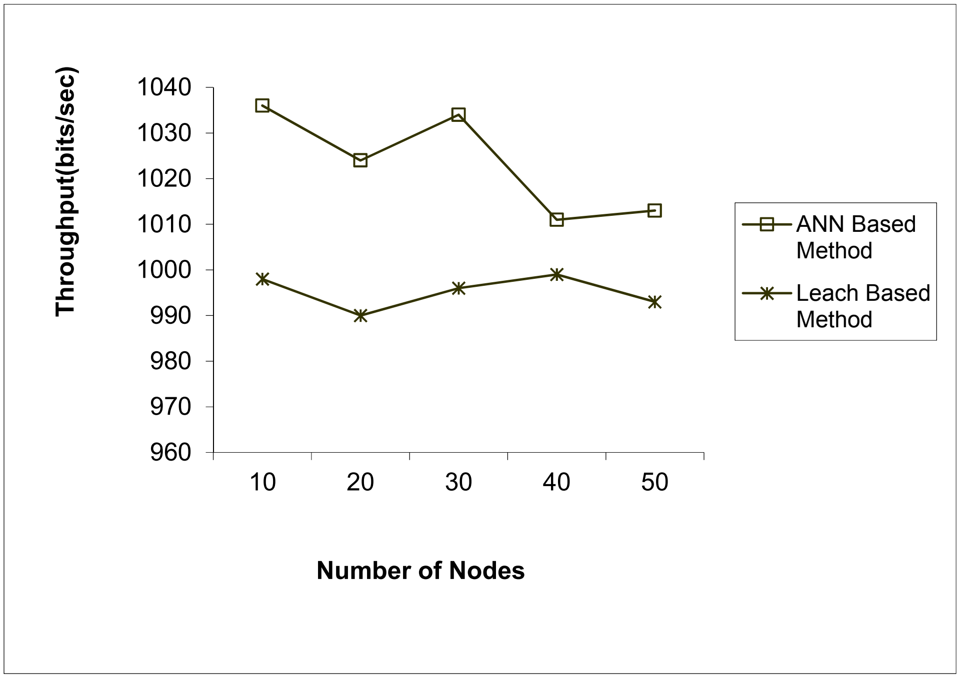

Figure-8. Comparison using throughput for IRP.

CONCLUSIONS

The intelligent routing protocol proposed in this paper clearly outperforms the existing routing protocols of WSN. Hence, the intelligent routing protocol is considered as a better routing protocol than other existing protocols in WSN.

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