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Improving QOS using Artificial Neural Networks in Wireless Sensor Networks

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Abstract

The service provided by the Wireless Sensor Networks (WSN) should provide better quality as Quality of the network plays an important role in the improving the performance of the system. The dynamic topology and resource constraints of WSN are highly challenging in achieving QoS. Thus in this paper Quality of Service (QoS) is improved for some of the QoS parameters like packet loss and congestion. Categorization of nodes as qualified and unqualified is done using the parameters. The quality node then dynamically forms a network. A novel method to improve the QoS based on Artificial Neural Network (ANN) is used to train the unqualified nodes to make them as quality nodes. The structure of Artificial Neural Networks provides less complexity compared to other Computational Intelligence (CI) tools as wireless sensor networks are prone to many constraints like memory and energy it reduces the computation cost and time. Our Simulation results shows that the proposed system has better performance in improving the QoS by increasing the network lifetime and reducing the packet loss ratio.

Keywords: Artificial Neural Networks, Congestion Rate, Qualified Nodes, Quality of Service, Packet Loss Ratio, Unqualified Nodes, Wireless Sensor Networks

1. Introduction

WSN are collection of sensors that form a network which are made of tiny short life batteries. It performs three main functionalities such as sensing, processing and communication. Due to its wide applicability it is used in variety of applications such as fire detection, weather forecasting, Battlefield surveillance etc. But there are several constraints which degrade its performance such as coverage, connectivity and energy consumption. The wireless sensor networks must be capable of providing better QoS for these real time applications. The tasks done by the network are application dependent as it varies according to the application. Some applications need to maximize the network lifetime while the other need to increase the throughput of the system. For example, reliability is more important than network lifetime for battlefield surveillance whereas for a smart home automation the lifetime of the network should withstand for a longer period. The priority and importance of the service differs as the applications differ.

The definition of QoS varies according to different contexts. It could be simply defined as a measure of system performance. Quality of Service is important in wireless sensor networks due its limited resources. The service it offers should guarantee the quality and effective resource sharing. QoS can be measured using several metrics such as packet loss, throughput and delay and so on. The system must be capable of satisfying the user needs as it could be measured from the end user perspective.

Artificial Neural Networks (ANN) are used to overcome most of the issues in wireless sensor networks as most of the qualities of Artificial Neural Networks like parallelism, distributed nature and low computations are also significant characteristics of wireless sensor networks.

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The functions performed by ANN are similar to the biological neurons. It could be subdivided by three layers based on their functionalities namely Input layer, Hidden layer and Output layer. Input layers are fed with incoming signals from different sources. Hidden layer performs some actions on the received input and its output is fed to the output layer. Each node in the input layer is assigned with a random weight w(n) and these weights are multiplied with each input and passed on to the hidden layer. Once the network is designed it should be trained to achieve the desired output. Often, ANN uses supervised learning as it is provided with both inputs and outputs. Then it should proceed by performing actions to the inputs applied to the neurons and compare the results with the expected result. Difference between the actual and expected output is calculated in order to train the system and it continues until the desired output is reached.

The rest of the sections in this paper are sorted as follows: Section 2 provides a review of related papers done in improving QoS. Section 3 specifies about the quality based dynamic network formation using ANN. Section 4 shows the Simulation results where the performance of the proposed system is compared with the previous works. Finally Section 5 is concluded with the remarks.

2. Related Work

Several works have been done in improving QoS which is a very big challenge in wireless sensor networks. There are several factors which affect QoS like packet loss, congestion and delay. Due to these factors the overall performance of the system degrades. QoS is improved by considering multiple goals like coverage, connectivity and congestion using weighted cognitive map and Q-learning where there is more number of decision rules[1]. MAC layer is responsible for communication and QoS parameters could also be tuned in this layer. So QoS aware protocol at MAC layer provides better QoS where the data packets are handled by tuning the network parameters according to the system requirements. A survey about the QoS mechanisms and protocols at the MAC layer is compared[3]. Quality of service can be affected due to the collisions in the network. So previous work was done to reduce the hidden node collision problem which would significantly have an impact on increasing the network throughput and power saving.

H-NAME[4] is one such technique used to avoid the hidden node problem by dividing the clusters into a group of non-hidden nodes in order to provide better QoS but it only eliminates collision in the network which wouldn't increase the overall performance of the system. QoS can be provided by both layered and cross layered approach and QoS improvement is done by setting some patents as the field of providing QoS in WSN is emerging[5]. So additional network parameters must also be considered for the changing environment in order to satisfy the requirements of an end user. QoS can also be provided by reliable data transmission which in turn reduces the delay and routing overhead. Intermediate nodes are responsible for a reliable data transmission between source and destination and there are several issues to be considered for transmitting the data accurately. An Efficient Neighbor Coverage Routing Protocol (ENCRP) is used in order to provide efficient data transmission[12].

Several Neural networks based techniques have been used in wireless sensor networks to overcome the problems such as routing, localization, fault tolerance, clustering and several other constraints such as energy consumption, coverage, congestion and etc.

A classification technique to reduce the data traffic of the node using an ART[1] network model and co-operative routing is used to reduce the energy consumption[2]. Energy Based Clustering Self Organizing Map (EBC-S)[6] is a neural network based method which mainly concentrates on network lifetime and coverage. Although the main constraints of the WSN has been considered, the requirements of the system or user changes according to the application and environment. A clustering algorithm for cluster head selection is used to reduce the energy consumption by using BP neural network where the nodes are assigned weights and the average weights for a node is calculated and the base station decides the highest probability nodes to become a cluster head[7]. A neural network based model is used to detect the presence of congestion and to find the sources causing that congestion in the network. The network is also trained to reduce the flow rate of the sources in order to avoid congestion[8]. The Adaptive Resonance Theory 2(ART2) RED based Active Queue Management (AQM) scheme is used for congestion control by increasing the queue length using unsupervised neural networks[9].

The causes of Packet Loss are distinguished using supervised learning. Losses could be caused because of congestion and link error. Thus the machine learning

classifies the losses based on these two causes[10]. The amount of variable bit rate traffic is predicted using neural network in order to avoid congestion. A control mechanism is applied such that the sources which cause the traffic are restricted to use the remaining resources[11]. Semantic web service selection method is compared based on the QoS attributes and several methods are used for QoS based selection[12].

The above listed papers have been dealt with several problems in wireless sensor networks but additional works has to be done to increase the quality of service considering multiple objectives. Most of the papers have used neural networks concepts only to increase network lifetime and congestion but the proposed system has also attempted to reduce the congestion rate along with packet loss ratio which is the major cause to degrade the network quality and thus the overall network lifetime of the system could also be increased. Due to the design constraints of the WSN, the proposed system has used ANN which is less complex compared to other tools.

3. Proposed System

The solution to achieve better QoS in wireless sensor networks is designed by forming a quality based network using an Artificial Neural network concept is showed in Figure 1.

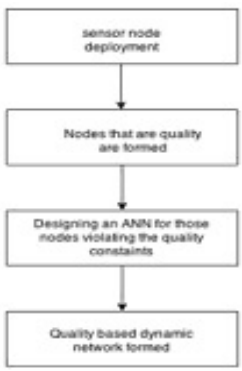

Figure 1. System Architecture.

3.1 Node Initialization

Nodes are deployed within the geographical area it wants to sense the event and the nodes are dispersed randomly due its distributed nature. Uniform random deployment of sensors is widely used in most of the WSN applications as it is considered to be more of ease and low cost in deployment of nodes but it requires large number of nodes than precise deployment.

3.2 Quality based Dynamic Network

A quality node can be estimated using various parameters like Packet Loss Ratio (PLR), congestion rate, energy consumption and coverage. In this system, each node in the network has to be identified whether it is a quality node or not based on the parameters such as PLR and congestion rate.

3.2.1 Packet Loss Ratio

The packets are sent from source to destination to communicate within the network. Packet loss is termed to be those packets which are missed at the receiver side. Packet loss could be caused due to congestion, delay and link failure.

$$Packet\ Loss\ Ratio\ [PLR] = \frac{Sent\ packets - Received\ packets}{Total\ no\ of\ packets\ sent} \times 100$$

3.2.2 Congestion Rate

If the capacity of the network is overloaded then congestion occurs. Congestion could be caused due to limited bandwidth and high data traffic. It affects the network throughput due to the reduced response time. Congestion could be identified using Data arrival rate, channel utilization and queue length.

If a node is with low packet loss ratio and if the rate of congestion and energy consumed by the node is minimum, the node is said to be a quality node as the overall performance of the network would be increased because of this node. A threshold value is fixed to differentiate the quality nodes and nodes that are not quality.

For each node PLR is calculated and the average of all the nodes PLR is estimated and taken as threshold. Those nodes which have PLR below the threshold value is considered as quality node and which are above the threshold value is said to be unqualified nodes.

The nodes which violate the conditions are left unclustered. All the nodes within the cluster should be a quality node satisfying the above mentioned conditions.

3.3 Designing an ANN for the Unqualified Nodes

An Artificial neural network is built for the nodes that are unqualified in order to make them as a quality node. In our proposed system ANN with multiple layers such as input, hidden and output layer is designed.

Transmission power and Queue length are considered to be the input and Quality nodes with respect to PLR and Congestion ratio are assumed to be the outputs of the neuron. In between, a hidden layer is used where the weights are applied and it represents the weighted sum of inputs. The training is done till the threshold is met. At each iteration, weights are updated to reduce the number of unqualified nodes. Then the ANN is trained for different inputs. Figure 2 illustrates the inputs and the corresponding outputs to design a Quality based dynamic network using ANN.

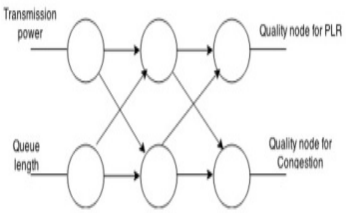

Figure 2. Neural Network Structure.

The nodes which have high Packet Loss Ratio and congestion rate are the unqualified nodes in the network. Such nodes have to be made as quality nodes by performing some actions on it, for example if a node with high PLR will degrade the performance of the system so in order to overcome this the node's transmission power is increased and if congestion occurs, then length of the queue is increased. As a result the nodes will become quality nodes. The network lifetime is calculated for the entire network to evaluate the overall performance of the entire system.

$$Network\ Lifetime = \frac{E_i}{P_t} \times no.of\ quality\ nodes \ldots\ldots\ldots (1)$$

$$P_t = e_t + e_r \ldots\ldots (2).$$

Where,

E_i = Initial energy in Joules.

P_t = Total energy consumed by sensor node.

e_t = Transmitting energy.

e_r = Receiving energy.

4. Simulation Results

In 500x500 area randomly 50 nodes are deployed. The initial energy, Queue length transmission power, receiving power and sensing power is initialized for the network as listed in Table 1. The Packet Loss Ratio and congestion rate are found using the trace file generated by ns2. The simulation is obtained by using Java. In the proposed model some of the unqualified nodes are made as quality nodes using ANN where the more number of quality nodes are gained. Thus the overall network lifetime and throughput is achieved.

Table 1. Simulation Parameters

Parameters	Ranges
No of Nodes	50
Transmission Energy	0.8
Receiving Power	0.2
Initial Power	1J

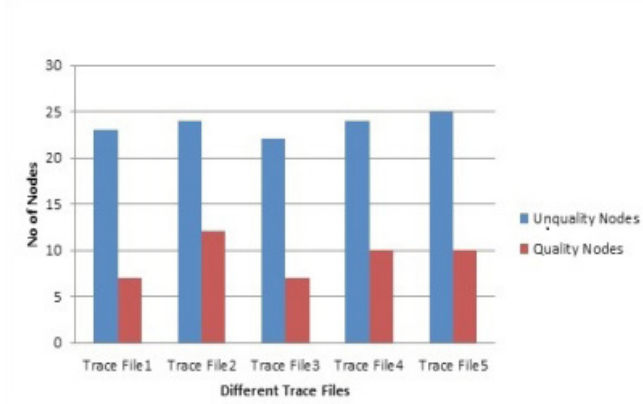

Figure 3. Analysis of Packet loss ratio.

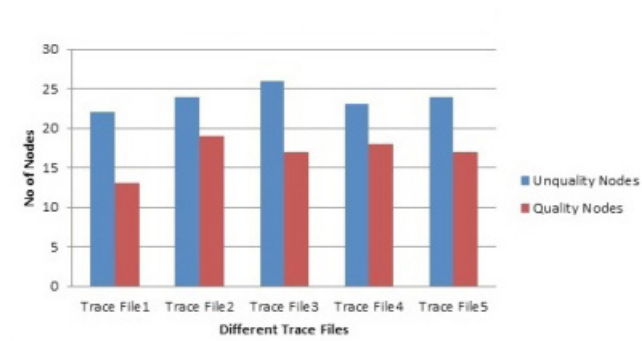

Figure 4. Analysis for congestion.

In the above analysis, the number of nodes and different trace files are considered as the x -axis and y-axis respectively. While analyzing the graph the amount of unqualified nodes get reduced for example in case of PLR, in trace file 1 there are 22 unqualified nodes which is turned into 13 quality nodes which is shown in Figure 3 and with respect to congestion, in trace file 1 there are 23 unqualified nodes which is then turned to 7 quality nodes which is shown in Figure 4.

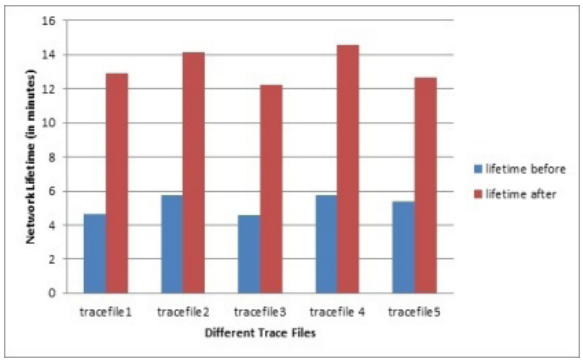

Figure 5. Graph for Network Lifetime.

In the above Figure 5, the network lifetime for each trace file is shown for the quality nodes that are dynamically formed and for nodes that are unqualified which are turned into quality nodes by using ANN. The overall network lifetime is gradually increased.

5. Conclusion

The performance results in the proposed system has low complexity compared to other existing artificial Intelligence techniques as ANN performs only simple calculations for training the network and it is highly adaptable due to memory and power constraints in WSN. The node costs are also saved efficiently by changing most of the unqualified nodes with respect to PLR and congestion rate into quality nodes.

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