Performance evaluation of fuzzy and BPN based congestion controller in WSN

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Abstract—In a Wireless Sensor Network when an event is detected, the network traffic increases. It in turn increases the flow of data packets and congestion. Congestion in Wireless Sensor Network plays a vital role in degrading the performance of the network. Hence it necessitates, developing a novel technique to control congestion. In this paper, soft computing based congestion control technique is proposed. Fuzzy logic and neural network are the soft computing tools used for estimating the packet drop. The performance of the proposed technique is evaluated using Accuracy. From the results, it is proved that neural network based congestion control technique provides better results than fuzzy based congestion control technique.

Keywords—Wireless Sensor Networks (WSNs), Congestion, Fuzzy Logic Controller, Neural Network.

I. INTRODUCTION

Wireless Sensor Network(WSN) consists of widely distributed autonomous sensor node to monitor various parameters in remote areas[19]. Each sensor node collects the information from various nodes and transmits to the sink node. When the data traffic in the network is light, the number of data packets generated is less but when the data traffic is heavy, more number of data packets are generated which leads to congestion. Congestion not only brings significant performance degradation to the network, but also affects energy efficiency[10]. As WSN is a multi-hop network, congestion at a single node may diffuse to the whole network and degrade its performance drastically [18].

There are various reasons for congestion. They are Buffer overflow, Channel contention, Packet collision, Many-to-one nature, etc. [2,11]. Buffer overflow occurs when the number of incoming packets is greater than the available buffer space. [13] Channel contention occurs between different flows and different packets of a flow. Packet collisions indicate lower level congestion and leads to packet drops. Many-to-one nature of event communication between multiple sources and sink causes bottleneck around sink. Thus the overall work is to investigate the occurrence of congestion and controlling mechanism to improve the performance of the network through extensive design and analysis.

On detecting congestion, the network is said to enter into unstable state. This results in packet drop, reduction in network throughput which in-turn results in retransmission of data packets[16,14]. In this paper, soft computing tools have been implemented to improve the network performance for a non-linear data set.

II. RELATED WORKS

Topology-Aware Resource Adaptation (TARA) scheme [1] activates appropriate sensor nodes whose radio is off to form a new topology that has enough capacity to handle increased traffic. As soon as hotspot node detects that its congestion level is above watermark, it needs to quickly locate 2 important nodes :a) Distributor node a) Merger node. The distributor node distributes the traffic between original path and detour paths. The detour paths are formed by backup nodes around hotspot node that are woken up. The merger node merges these two flows. Thus TARA serves the dual purpose of alleviating congestion during crisis state and conserving energy during dormant states.

In Receiver Assisted Congestion Control (RACC) method [4] sender performs loss based control and receiver performs delay based control. Receiver maintains two timers, one for recording the packet inter arrival time and other for measuring Round Trip Time. Sender uses this information from receiver to adjust the congestion window. The receiver can estimate the rate the sender should adapt to make best use of measured bandwidth based on packet inter arrival timer. Based on the Round Trip Time the receiver detects the arrival of the next packet and also detects packet drop if timeout occurs. Since receiver detects packet drop earlier than sender, it can send ACK to inform sender thereby reducing the waiting time of sender to retransmit a lost packet.

In Local Cross Layer Congestion Control method [7] is based on buffer occupancy. The input given to the buffer is of two types: a) Generated packets and b) Relay packets. A sensor node has two duties a) Source duty and b) Router duty. During source duty, the sensing unit of the node senses the event and generates packets to be transmitted. A node as a part of router duty receives packets from its neighbors to be forwarded to sink. It has two measures: a) It explicitly controls the rate of generated packets in source duty. b) It regulates the congestion in router duty based on current load on node.

Buffer based Congestion Avoidance method is based on lightweight buffer management [29]. It prevents data packets from overflowing the buffer space of intermediate sensors. When buffer at an intermediate sensor node is filled, the forwarding rates of its upstream sensor nodes are forced to slow down according to its forwarding rate. When the buffers at the upstream sensor nodes are filled up, the further upstream sensors are forced to slow down. This process repeats towards the furthest sensor nodes and eventually the whole network adapts towards the maximum congestion-free-throughput. Thus the buffer based scheme automatically adapts sensor nodes' forwarding rate to nearly optimal without causing congestion.

Learning Automata based Congestion Avoidance Scheme (LACAS) [27] deals with congestion problem for many-to-one traffic patterns. A simple autonomous learning machine called automata that can be constructed as small pieces of code capable of taking intelligent actions is stationed at each intermediate node of network. It intelligently learns from the past and controls the rate of flow of data at intermediate nodes based on probabilistically how many packets are likely to get dropped if a particular flow is maintained. In Hop-by-Hop congestion control technique [28], the EQL (Effective Queue Length) is calculated and it is used the occurrence of congestion. The proposed technique is called CONSEQ (CONtrol of Sensor Queues). CONSEQ aims to reduce congestion and thereby, decrease the delay and energy consumption due to packet losses and retransmission in WSN.

III. Proposed Work

Congestion leads to loss of data packets which in turn reduces the overall network efficiency[31]. This necessitates the need for the proposed congestion control technique. The key parameters namely priority, buffer occupancy and loss rate are considered for estimating the amount of critical packets that are to be dropped, so that the network throughput is not affected. Priority plays a major role out of all the other parameters. When an incoming packet is having a high priority, then the probability of dropping that incoming packet is very less. For medium and low priority data packets, probability of dropping depends on buffer occupancy of the node.

From expert knowledge the amount of data packets dropped for the various combinations of priority, buffer occupancy and loss rate has been considered as the data set. Since a non linear relationship is possessed between the input and the output datasets, fuzzy logic based congestion control algorithm is proposed.

A. *Fuzzy Logic Based Congestion Control*

Since the input parameters have non-linear characteristics, fuzzy tool is implemented for further improving the network performances [26,12,32]. In this technique, the input linguistic variables considered are priority, buffer occupancy and loss rate. Packet drop is considered as the output linguistic variable. The membership values assigned for the input and the output variables are given in Table 1. After assigning the membership values, fuzzy rules were framed. Fuzzy rule base consists of 27 rules which are listed in Table 2.

TABLE I
Membership Values for the Input and Output Variables

Variable	Linguistic Variable	Membership Function
Input	Priority	Low
		Medium
		High
	Buffer occupancy	Low
		Medium
		High
	Loss rate	Low
		Medium
		High
Output	Packet drop	Low
		Medium
		High

As shown in Table1, each input and output variable are assigned with low, medium and high membership values. Triangular membership function is assigned for input and output variable. The same data set from the expert knowledge is considered as the input for the fuzzy logic controller.

Error is calculated by finding the difference between the actual and the desired packet drop. To reduce error obtained from the fuzzy logic based congestion control algorithm, Back Propagation Network (BPN) based congestion control algorithm is proposed.

TABLE II
Rule Base for Fuzzy Logic Based Congestion Control Technique

Priority	**Buffer Occupancy**	**Loss Rate**	**Packet Drop**
L	L	L	L
L	L	M	L
L	M	L	M
L	M	M	M
L	M	H	M
L	H	L	H
L	H	M	H
L	H	H	H
M	L	L	L
M	L	M	M
M	L	H	M
M	M	L	M
M	M	M	M
M	M	H	L
M	H	L	H
M	H	M	H
M	H	H	H
H	L	L	L
H	L	M	L
H	L	H	L
H	M	L	L
H	M	M	L
H	M	H	L
H	H	L	L
H	H	M	L
H	H	H	L

B.BPN Based Congestion Control

BPN network is a type of neural network that learns from the set of exemplars (input output pair) and predicts the actual output for a new set of input. In the proposed architecture priority, buffer occupancy and loss rate are regarded as the input parameters and number of packet dropped is the output parameter. A set of 100 exemplars were considered of which 50 exemplars were used for training and the remaining was used for testing. Five layered network architecture is considered with one input layer, three hidden layers and one output layer. The number of neurons in the input and the output layers are three, one respectively in order to reflect the number of inputs and outputs in each exemplar. The number of neurons in the hidden layer are six,three,two respectively. The activation function of the hidden layer is tansigmoidal whereas pure linear is used in the output layer[33,34]. The learning and the momentum parameters are 0.6 and 0.8 respectively [12,20,30].

IV. RESULTS AND DISCUSSIONS

The Fuzzy Inference System (FIS) designed for the proposed fuzzy based congestion control algorithm is shown in Figure 1. Priority, Buffer Occupancy and Loss Rate are the inputs given to the FIS and packet drop is the output. The rule base developed for the proposed system is shown in Figure 2. For various combinations of the node parameters, packet drop gets varied based on the rules that are framed. A set of 25 exemplars given as the input to the FIS and its corresponding obtained packet drop is noted and listed in Table 1.

To further improvise the performance, a BPN based approach is proposed and the architecture designed is shown in Figure 3. After training the BPN, the same set of exemplars used in FIS are given as the test data to the designed BPN and the output i.e. packet drop is noted. The packet drop obtained using the proposed soft computing based congestion control techniques is shown in Table 1. Accuracy is the metric used for evaluating the performance of the proposed techniques. From the last three column of Table 1, it is found that BPN based system provides more accurate results than fuzzy based controller. It is because, the performance of fuzzy not only depends on the input and output relationship but it is also dependent on the choice of the membership functions, expert knowledge in framing the rules and linguistic variable. However BPN trains accurately based on the relationship between the given input output pairs. Accurate performance of BPN is also emphasized by lesser error between the actual and the desired output. Performance is also shown in Figure 4.

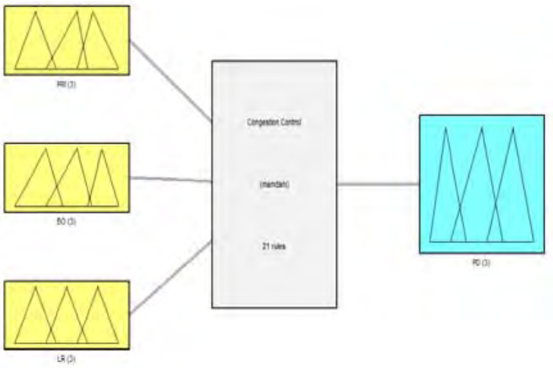

Fig. 1. Fuzzy Inference System for Congestion control

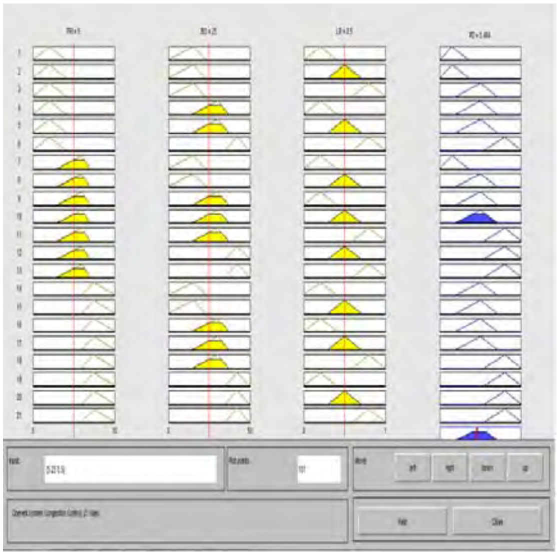

Fig. 2. Rule Base for fuzzy based congestion control

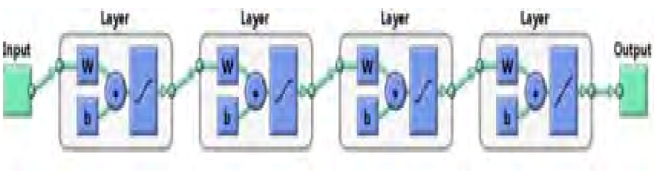

Fig. 3 Architecture of BPN based congestion control

TABLE III
Performance of fuzzy and BPN based congestion control

Sample No.	Priority	BO	Loss Rate	Packet Drop		
				Actual	Fuzzy	Neural
1	8	0.36	0.4	0.35	0.30	0.46
2	7	0.04	0.5	0.34	0.65	0.45
3	6	0.22	0.9	0.35	0.46	0.5
4	9	0.36	0.2	0.18	0.17	0.2
5	10	0.64	0.6	0.3	0.19	0.45
6	8	0.74	0.8	0.34	0.18	0.77
7	6	0.62	0.1	0.29	0.68	0.5
8	10	0.88	1	0.25	0.18	0.5
9	3	0.26	0.1	0.18	0.24	0.17
10	7	0.16	0.7	0.49	0.71	0.5
11	6	0.14	0.8	0.51	0.62	0.5
12	5	0.68	0.2	0.47	0.78	0.46
13	3	0.38	0.5	0.31	0.25	0.3
14	4	0.7	0.9	0.35	0.45	0.77
15	7	0.9	0.4	0.79	0.81	0.78
16	6	0.76	0.6	0.77	0.45	0.78
17	5	0.58	1	0.55	0.43	0.5
18	3	0.36	0.3	0.29	0.20	0.28
19	1	0.06	0.7	0.35	0.72	0.45
20	4	0.38	0.2	0.34	0.30	0.33
21	1	0.34	0.5	0.26	0.24	0.25
22	3	0.38	0.8	0.47	0.39	0.46
23	4	0.64	0.4	0.55	0.80	0.45
24	2	0.92	0.5	0.57	0.78	0.5
25	3	0.76	0.9	0.79	0.54	0.78

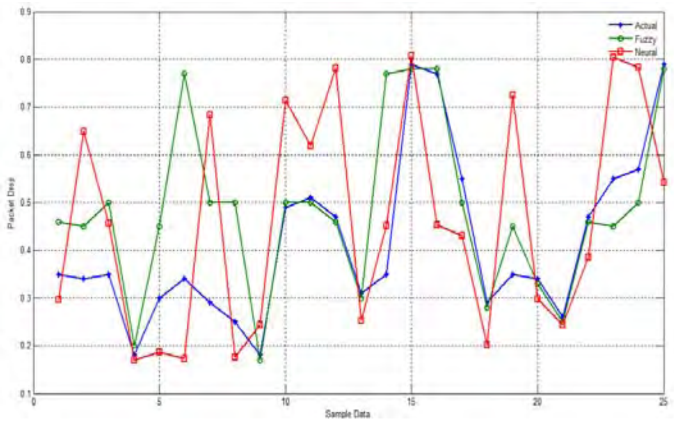

Fig. 4. Comparison of fuzzy and BPN based congestion control

V. CONCLUSION

An effective congestion control technique can reduce the number of packets dropped due to congestion. In this paper, soft computing based congestion control technique has been proposed for deciding the number of packets to be dropped. This technique considers the parameters namely Priority, Buffer Overflow and Loss rate. BPN based congestion control gives more accurate results compared to that of fuzzy based congestion control technique. Thus BPN based congestion control technique improves the network performance.

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