ANN Based Intelligent Congestion Controller for High Speed Computer Networks

B. Shajahan[1] and Srinivasan Alavandar[2]

[1]Department of Computer Science and Engineering, CK College of Engineering and Technology, Cuddalore 607003, Tamil Nadu, India

[2]Department of Electrical and Electronics Engineering, Agni College of Technology, Chennai 600130, Tamil Nadu, India

ABSTRACT

This paper presents a controller design based on artificial neural networks for the avoidance of congestion in computer networks. The quality of service of networks is not guaranteed by conventional controller, due to the presence of non-linearity and uncertain characteristics. The controller designed with ANN doesn't require higher model accuracy. The ANN- controller is designed with multilayer neural network mainly to deal with the outgoing data packets, dropped data packets on the bottleneck with constant link capacity, variable link capacity, and variable link delay and with the specified number of transmitted interests, bottleneck band width, and bottleneck delay for a particular interval from various consumers. Around 1 to 6000 interest packets per second have been given and the analytical results for this controller are presented and they are compared with various training algorithms. The results show that the controller designed with artificial neural network is robust, provides faster response and tackles new parameters very well particularly TCP (Transmission Control Protocol) session and round trip time.

Keywords: Congestion control, artificial neural network, quality of service, packet loss, queue length.

1. INTRODUCTION

The computer networking and its uses in almost all fields have been experiencing tremendous growth since 1990's and it makes the users to worry about the network congestion. The development of computer networks has not only sophisticated the users but made the researchers to think of these serious and complex congestions. In the early days, these types of congestions were controlled by using TCP congestion controller. The TCP is not able to meet out the fast growing developments in computer networks, as it just drops the packets whenever the buffer gets full. It also instructs the routers to take part in controlling, by using its own sources [1] [2] and [3]. After these drawbacks, Active Queue Management (AQM) has started occupying the field of congestion controller design research. Some of the researchers have started using random Early Detection (RED) in routers for this technique and it provided some quality service, particularly it has overcome the problem of synchronization of flow by dropping packets intelligently. The trend has started neglecting the RED parameters because of the parameter tuning difficulty [4].From here, the feedback control system has been used to attain the main objectives in congestion controller by maintaining the smaller queuing time with higher throughput in support with the routers for dropping the packets.

Further, a round trip sequencing method has been introduced to avoid congestion, due to traffic which happens based on the level of bandwidth, quality of service and latency. These types of congestion are predominant in multimedia application in particular application dealing with voice and video transmission. Here, the efficiency of average queue size and data rate flow is monitored in each and every sequence of implementation [5]. Later, [6] tried to improve the fairness and robustness by combining AQM and TCP. The reason for merging is not only to improve these two but also to avoid failure and link bit error, which normally occurs in a network and it leads to weakness and congestion. By introducing this, chances of packet loss are reduced.

Moreover, [7] improved the performance of the network just by tuning the network parameters. To improve the size of a packet, time out with some linear transformation was included. The basic analyses such as adding, subtracting and multiplying the constants with present values have been done to parameters. As a result, the parameter selection and the constant were given much importance than the techniques. In [8], it is stated that quality of service is important in any computer network, but it degrades to poor state at the time of congestion. As per the authors, these types of congestion and other forms of congestion can be overcome by TCP-Friendly congestion control algorithm. Neural network is used to optimize a TCP and other related parameters mainly to improve the performance rate of the computer network. Here, bit error rate and round trip time are used to update the neural networks weight to reach the optimal range.

Then, [9] introduced a technique for differentiated control service and reduced the predicted time sensitive problems which normally present in the audio and video based network. Here, RED has been used to control the congestion by keeping active queue management. This active queue management is used mainly to reduce and remove packets and to notify the traffic in early. To perform the task in a better way, the threshold level and limits for dropping the packet are set by RED itself. The authors have also introduced many variants with RED. Then, [10] have developed a TCP which is an intelligent TCP. It improves the entire through puts of the network to

59% , which in turn reduces the energy consumption to 50%.To achieve this, an novel neural network concept has been used to attain reliable data delivery and to successfully create the variant with TCP. The main reason behind introducing the neural network is that the platform is loss and non-deterministic environment, which forces to think for better techniques.

The back propagation algorithm is used by [11] to the neural network to design a classifier in order to address the issues of packet loss which has normally been considered happening because of congestion and link bit error. The two above reasons are not identified by TCP properly. To know the reasons for packet loss, the TCP has considered the congestion as the prime factor for loss of packets and started reducing the data rate. These issues are perfectly addressed by the classifier designed with neural network. The classifier has been tested with TCP Vegas and TCP Westwood. The classifier has proved that it can work even in Adhoc network to determine the packet losses reasons.

A rate control algorithm has been proposed by [12] using neural network to control a congestion based on the sending time. Any network must be in a position to transmit a required amount of data as per the requisition by the users .This kind of request is cleared properly by the classifier and it estimates the desired round trip time. In this case, in every round trip time, only a single packet has been transmitted and its feature is derived from on-line model. Using back-propagation neural network, a novel congestion controller has been developed to solve the mismatch between the resources and the traffic in the incoming. This traffic is created mainly due to propagation delay in transmission and it is overcome by introducing feedback using resource management packets. This feedback process has a limitation, that is, it can't proceed further after few cycles of operation. An efficient predictive method has been developed by this feedback system in support with neural network to improve the quality of the network services [13].

A concept, which involves AQM technique designed with dynamic neural network has been introduced by [14]. Initially to avoid congestion, active queue management has been used and it has not avoided the congestion because of high non-linearity and time deviation property in the Transmission Control Protocol (TCP). To improve the throughputs of the network, neural network has been used in the router by [15], mainly to predict the congestion in the particular given link. Here, the entire process is carried out by taking in to consideration of an available constant by a name alone, not by seeing the information in the particular location. The method works simply by receiving the request from the customers. It is nothing but a pull based technique in support with the network caching. Even in this technique that is content centric, if the network faces a chunk, then the TCP based congestion will be more. Hence, the technique seems to be insufficient to avoid congestion in the computer networks.

Based on the literature survey, in the present work, the importance of neural network in congestion controller is discussed. Then, the proposed neural network approach has been designed to extract results in order to provide better performance. The entire work has been done by introducing congestion in a system to check the performance evaluation and before concluding, the results are compared with conventional approach.

2. Feed-Forward Neural Network

In any computer network, the corrupted packets, errors in the bit and congestion in channels .etc. are the main factors responsible for the packet loss. Based on the analysis made from the literature, it is very clear that the packet losses are only due to congestions. Packet loss is considered as a decent candidate while doing the analysis with neural network techniques. Packets based on the count have been used as a congestion manifestation which makes the analysis so interesting to design a new approach for early detection of congestion. Neural network learns the scenario from its environment and updates the information to improve the overall performance. It can even be varied 'n' number of times and ways, due to their architectural nature. The reasons and the condition for congestion particularly the drop rate train the neural network. Based on the condition and issues, the supervised learning method proves to be well suited for this type of problems. The neural controller is shown in the Figure 1. The packets, which have been labeled in a specific order, have been used to train the network. It has ultimately been used to identify the congestion there by, it has become useful to design an appropriate controller. Hence, feed-forward neural network is used here as a main network.

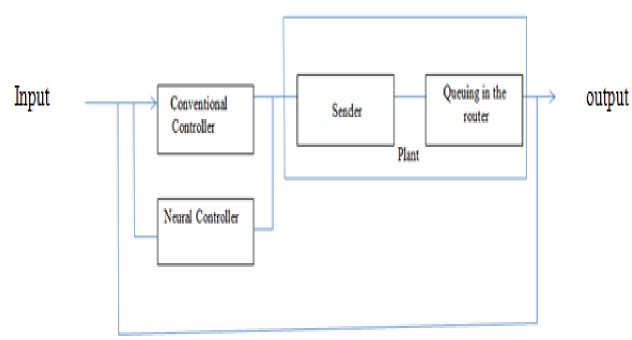


Figure 1. Neural controller

Multi-layer feed forward neural networks are the most popular networks, particularly a network trained with back-propagation algorithm. These neural networks are used in solving many engineering problems. This network consists of layers in which the neurons are orderly placed as shown in figure 2.The layers mapping and its function are used to describe the neurons which assign a set of neurons which consists of all ancestors and in the same way, another set of neurons with all predecessors. Generally, each neuron is connected with the nearby neurons between i^{th} and j^{th} neurons and they are characterized by the coefficient w_{ij} , which is nothing but the weight coefficient. Further, threshold coefficient v_i is characterized from the j^{th} neurons. The weight coefficient normally fixes the importance of the connection based on the problems in the neural network applications.

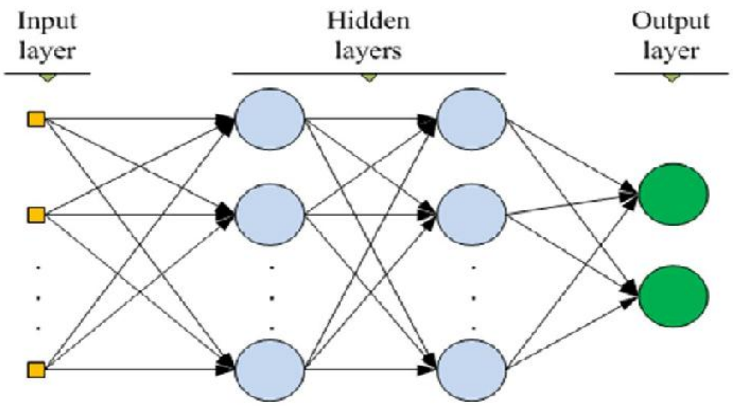


Figure 2. Neural network architecture

The i^{th} neuron output is determined from equations 1 and 2

$$x_i = f(y_i) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$y_i = v_i \sum_j w_{ij} x_i \quad \ldots\ldots\ldots\ldots\ldots(2)$$

Where y_i is the potential of the i^{th} neuron and
$f(y_i)$is the activation function.

The transfer function is given by the equation 3.

$$f(y_i)=\frac{1}{1+\exp(-y)} \quad \ldots\ldots\ldots\ldots\ldots..(3)$$

To minimize the sum squared error, the supervised learning varies both the weight and threshold coefficient $w_{ij}$and v_i .The process is repeated between the computed output value and the required one.

The minimization function is accomplished by equation 4. This function is the main objective of any learning technique that has been implemented in to the neural networks

$$E \sum_0 \frac{1}{2}(x_0 - \bar{x}_0) \quad \ldots\ldots\ldots\ldots\ldots \ (4)$$

Where x_0 is computed output value and
$\bar{x}_0$is the required output value.

3. Result and Discussion

Any computer network, while in operation will undergo zero traffic to heavy traffic. Hence, the chances of congestion are more, when the load exceeds the capacity of the network. This congestion will influence the performance network. In this work, interest from the consumers and its transmission rate are dynamically varied while running the simulation to make congestion to play major role in the analysis. The load of 1 to 6000 interest packets are transmitted per second. This interest is the interest shown by the consumers. These interest rates are randomly generated to carry out the simulation. Figures from 3 to 5 are the interest send by the consumers at various transmission rate based on their applications and the tasks.

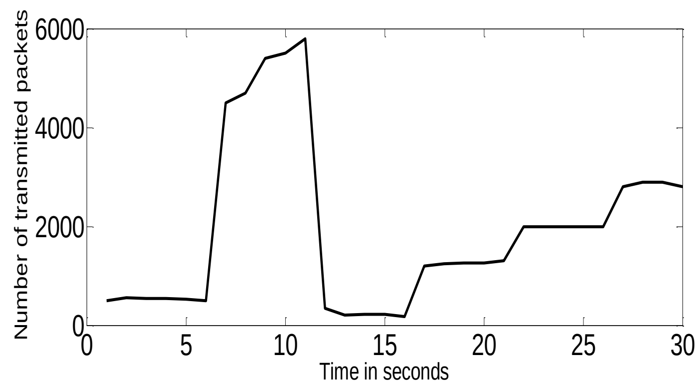


Figure 3. Interest packets transmitted per second by consumer-1

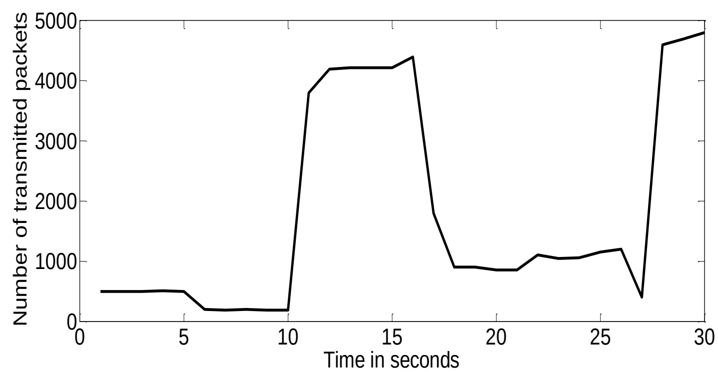


Figure 4. Interest packets transmitted per second by consumer-2

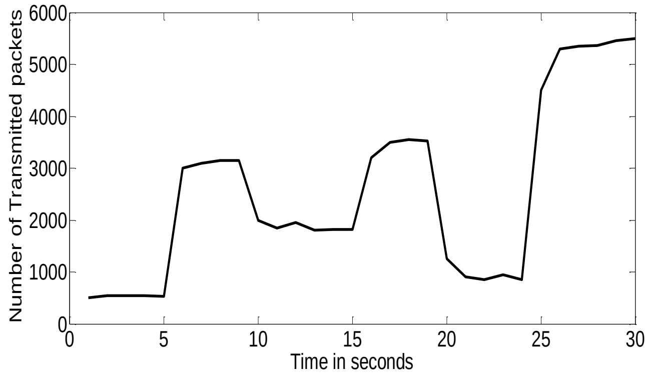


Figure 5. Interest packets transmitted per second by consumer-3

These interests before sending, it is been aggregated in the router and then it is sent to the link particularly the bottle neck link. Figures 6 and 7 depict the interest rates by the routers. From the Figure 6, it can be observed that both the routers send the interest rate in a similar fashion except at the end. Next, the router will try to check the packets in the store where many packets will be stored. If the packets requested by the customer are available, the router information returns to the incoming faces. Figure 7 shows the router 2's incoming interest, which must be equal to outgoing and dropped interest packets.

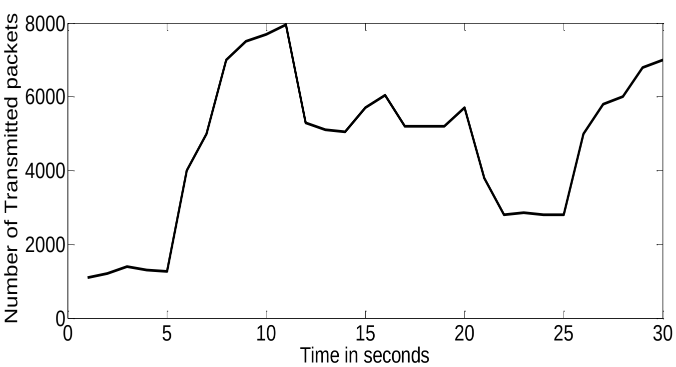


Figure 6. Interest packets transmitted per second by router-1

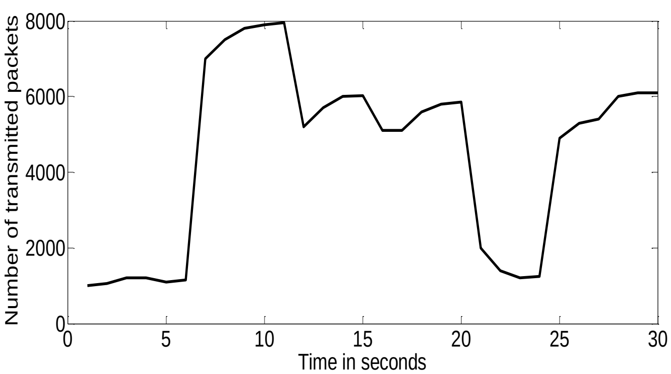


Figure 7. Interest packets transmitted per second by router-2

The bandwidth of any computer network or communication link is characterized by the number of bits connected in the link for the given interval, but practically speaking, it is always a constant value. So, while dealing with the congestion and its impact, it is very important to see the band width particularly in the dropped packets. Here under various situations, with different bottleneck bandwidth is connected. Figure 8 shows the number of transmitted data packets and dropped data packets in the routers under the default situation. In one round of simulation, the bottle neck bandwidth is taken as 10 Mbps for all time intervals.

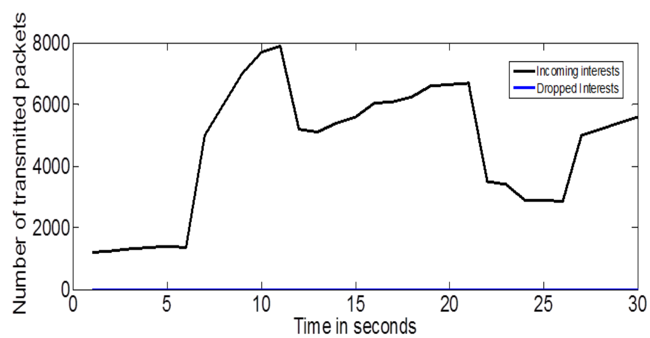


Figure 8. Incoming interest Vs Dropped Interest

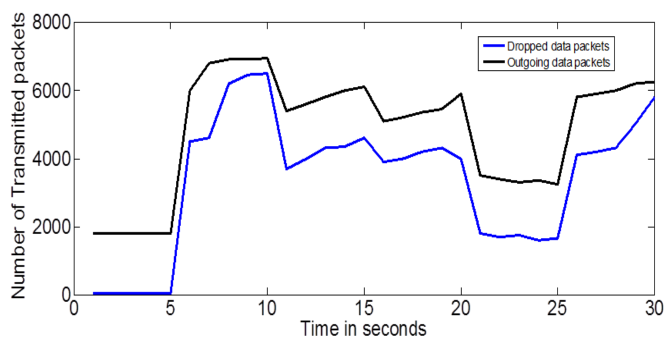


Figure 9 Comparison plots between number of outgoing and dropped data packets based on the constant line capacity

Figure 9 presents the comparison plots between number of outgoing and dropped data packets.

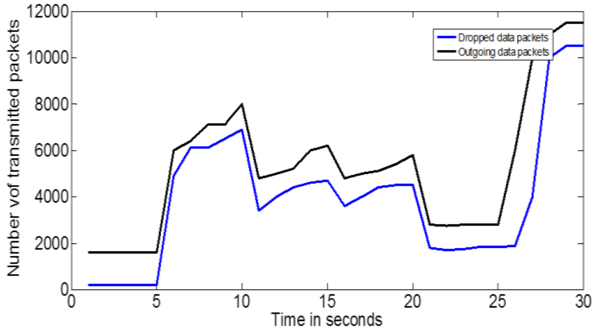


Figure 10 depicts the dropped data packets and outgoing data packets which have been considered under various hypothetical situations by just changing the bottleneck bandwidth in regular intervals. Each router has its own capacity and limit to place packets on to the queue. This limit is said to be a queue length. During heavy traffic, it gets filled and the packets start waiting for transmission to happen

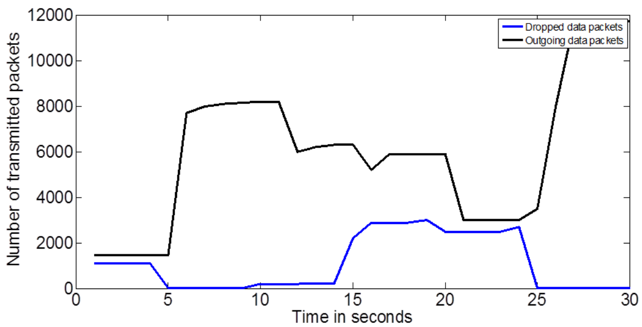


Figure 11. Dropped data packets and outgoing data packets by just changing the bottleneck bandwidth in regular intervals

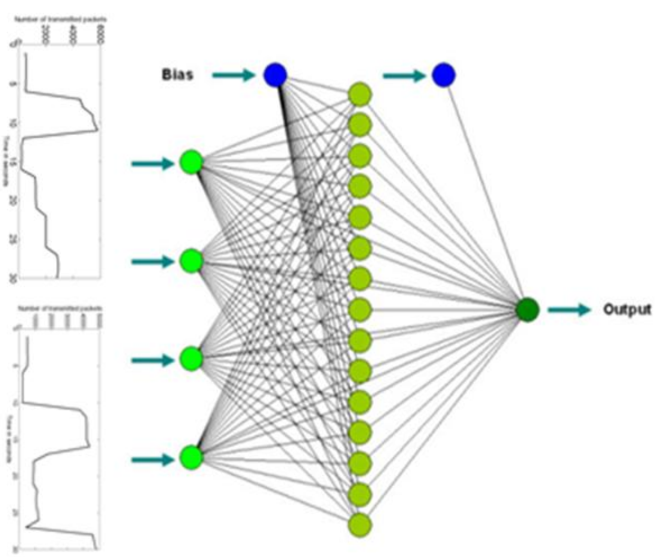


Figure.12 Input parameters to feed-forward neural network

Under this situation, the router starts dropping packets till the queue relieves packet stress. So during congestion, the queue length allows the queue to hold as much numbers of packets. These plots and data are used to train the neural network mainly to predict the dropped data packets and outgoing data packets with variable link delay and queue length. It is shown in Figure 12.

The MATLAB nntool multilayer architecture is shown in Figure 13.Neural network architecture has been used to provide a rational in choosing the appropriate parameters for training, validation and testing.

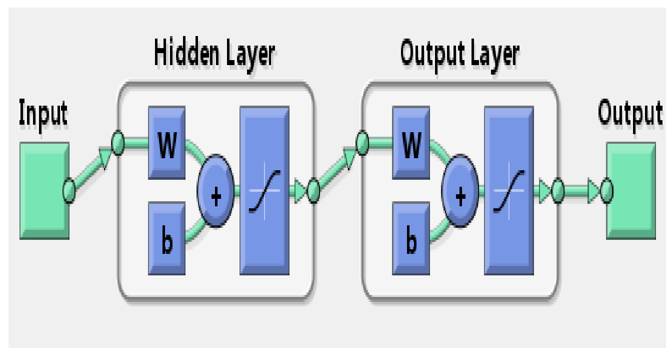


Figure 13 Multilayer architecture

Initially, the training and its paradigms are examined and compared .This training phase is very important phase to deliver the results particularly the prediction of number of packet drops .This training is carried out for all the considered approaches. Back propagation algorithm is used under supervised learning and it maps a set of input data in to a set of outputs. It is shown in Figure 14.

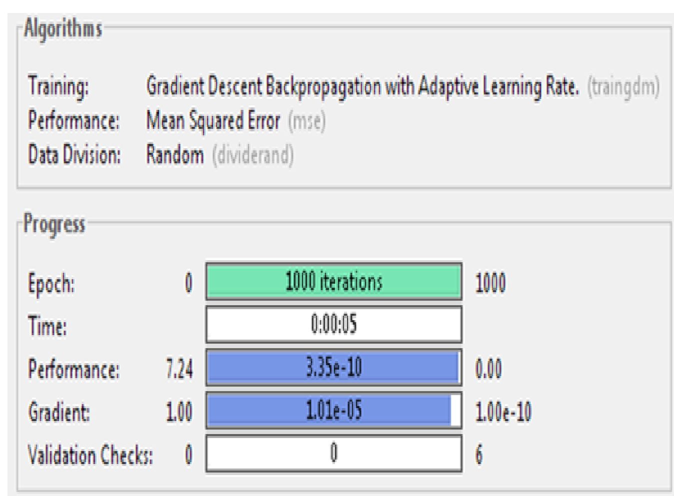


Figure 14 Neural network performance phases

The difference between the actual and the desired output has been estimated at each and every iteration to check the error reduction which is the main principle behind the back-propagation. So in general, the back propagation algorithm always looks for minimum error. During the estimation, at every iteration, there will be changes in the weight and bias and these types of iteration are called epochs. In some cases, the learning will not be allowed to prolong and it is mainly to avoid over fitting. Hence, the entire thing is to check the magnitude of gradient related with performance, number of validation and epochs. Among this, the validation and number of epochs are used to stop the process.

To attain the best solution and to keep it as a generalized one, the learning has been stopped with minimum validation set error. By testing the scenario, the regression has been highlighted for training, validation and testing of all considered learning techniques .Based on the results and statistics, it is clear that the performance of the neural network is suitable to meet the requirements of the computer network routers and it also performs better to predict the congestion in every link.

4. Comparison with various training methods

4.1 Batch gradient Descent

In batch steepest descent, traingd is a training function. The weight and bias are adjusted towards negative gradient and they are repeated in each and every iteration. The learning rate will be multiplied with negative gradient to get the main changes in the weights and biases. The convergence time will either be large or small and it totally depends on the learning rate. If the learning rate is fixed, small means algorithm takes more time for convergence and if it is fixed with larger value, the algorithm becomes unstable. The entire validation performance is shown in Figure 15.The predicted plot for number of outgoing data packets with the number of dropped data packets based on variable link delay is shown in Figure 16. Figure 17 shows the predicted value for number outgoing data packet with number of dropped data packets based on the queue length.

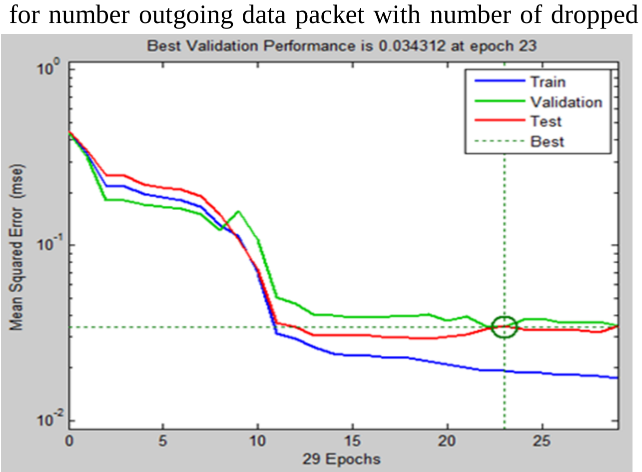


Figure 15.Validation performance using Batch gradient Descent

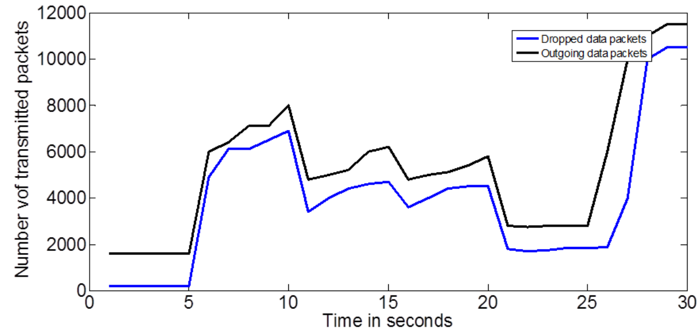


Figure 16.The predicted plot for number of outgoing data packets with number of dropped data packets based on variable link delay using Batch gradient Descent

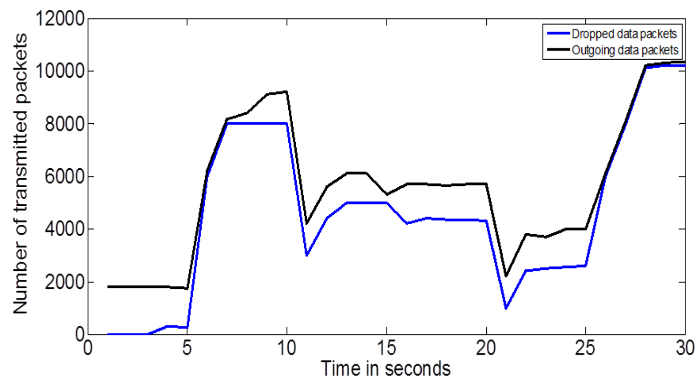
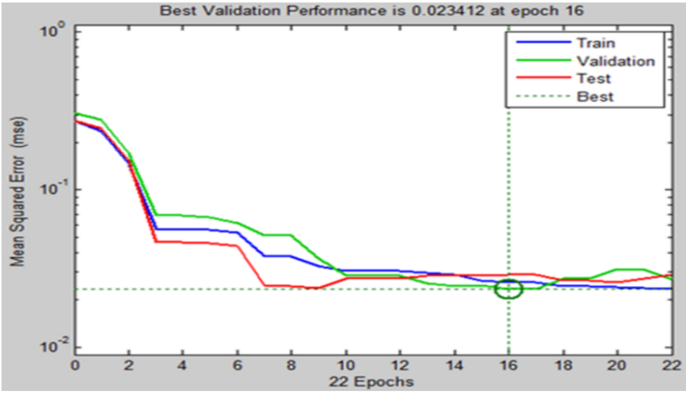


Figure 17.Predicted plot for number outgoing data packet with number of dropped data packets based on the queue length using Batch gradient Descent

4.2 Batch Gradient Descent with Momentum

This training method provides faster convergence because of the presence of steepest descent with momentum. Addition of momentum in the training phase will change the response to the desired value both to the local gradient and mew trends on the errors. So, momentum is very important to get low error, otherwise, the process will get stuck to local minimum and will lead to erroneous output. The changes in weight and updating of weights are determined by sum of fraction of the weight that has been generated recently. This entire weight adjustment and further development are carried out default in the back propagation algorithm and it has been generally used in all the training methods. The entire validation performance is shown in Figure 18.The predicted plot for number of outgoing data packets with number of dropped data packets based on variable link delay is shown in Figure 19. Figure 20 shows the predicted value for number outgoing data packet with number of dropped data packets based on the queue



length.

Figure 18.Validation performance using Batch Gradient Descent with Momentum

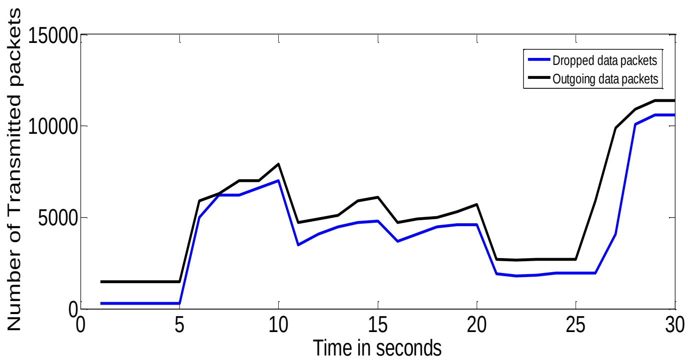


Figure 19. The predicted plot for number of outgoing data packets with number of dropped data packets based on variable link delay using Batch Gradient Descent with Momentum

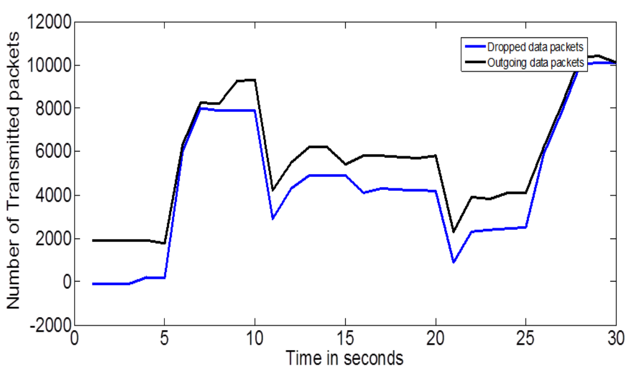
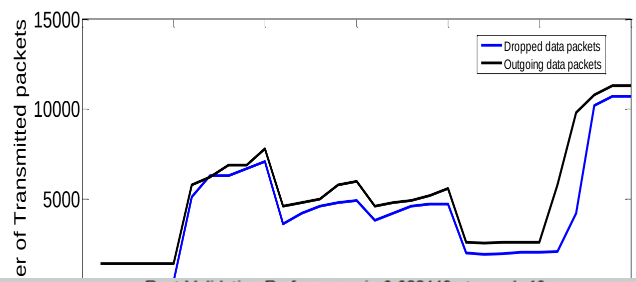


Figure 20. Predicted plot for number outgoing data packet with the number of dropped data packets based on the queue length using Batch Gradient Descent with Momentum

4.3 Conjugate gradient algorithm

In any back propagation algorithm, the updation and changes in weights basically happen in negative direction of the gradient. By this, the function produces faster convergence, as the function decreases rapidly along with the negative direction. In conjugate gradient technique, the search process is along with the conjugate direction and it makes the algorithm to converge at faster rate generally than any other techniques. The entire validation performance is shown in Figure 21.The predicted plot for number of outgoing data packets with number of dropped data packets based on variable link delay is shown in Figure 22. Figure 23 shows the predicted value for number of outgoing data packet with number of dropped data packets based on the queue length.

Figure 21.Validation performance using Conjugate gradient algorithm



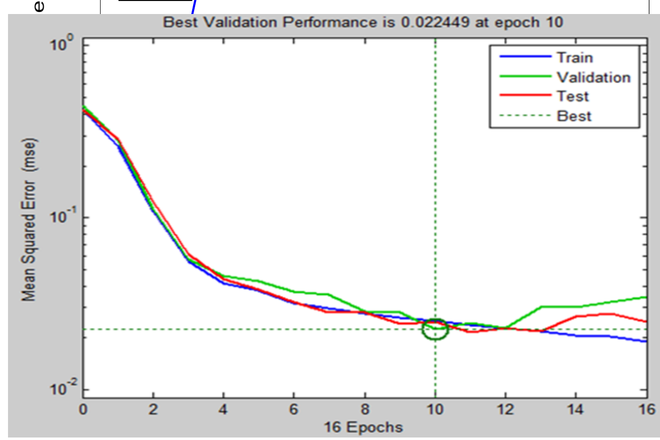


Figure 22. The predicted plot for number of outgoing data packets with number of dropped data packets based on variable link delay using Conjugate gradient algorithm

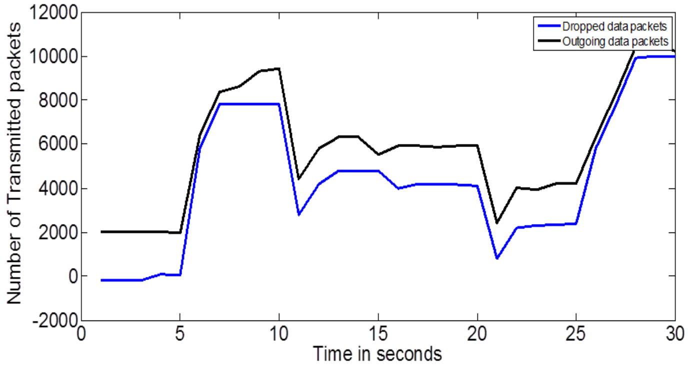


Figure 23. Predicted plot for number outgoing data packet with number of dropped data packets based on the queue length using Batch Gradient Descent with Momentum

5. Conclusion

A neural network based controller has been proposed to overcome the congestion in the high speed computer networks .The design is mainly focused on outgoing data packets with dropped data packets on the bottleneck along with constant link capacity, variable link capacity, and variable link delay and with specified number of transmitted interests, bottleneck band width, and bottleneck delay for a particular interval from various consumers. The reasons and the condition for congestion are used to train the neural network. Based on the condition and issues, supervised learning method has been used. To validate, the proposed technique has been implemented in NS2 network simulator and assessed the number of outgoing data packets with the number of dropped data packets on the bottleneck with variable link delay and queue length for various training algorithm. The simulated result shows that the congestion controller designed using neural network proves to be more superior to traditional controller and provides faster response. It also tackles new parameter very well particularly TCP session and round trip time.

References

[1] M. Allman, V. Paxson, W. Stevens.”rcp congestion control”, RFC2581,1999

[2] Yang Yang. “Network Congestion Control”, PHD dissertation, The University of Texas at Austin, August 2001.

[3] S. Floyd, K. Fall. "Promoting the use of end-to-end congestion control in the internet". IEEEIACM Transaction on Networking, 1997 vo1.7. 00.4, 458-472

[4] B. Braden, D. Clark. J. Crowcroft el CIl., "Recommendations aliqueue management and congestion avoidance in the internet," RFC2309.Apri11998.

[5] Shilpikaura and A. K. Vatsa,” A Novel Architecture and Mechanism for Congestion Control in High Speed Network”, International Journal of Next-Generation Networks(IJNGN) Vol.3, No.1,March201

[6] T. Karthikeyan and B. Subramani, “A New Congestion Control Algorithm Based on Novel AQM”, T. Karthikeyan et al, / (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 5(3), 4440-4443, 2014

[7] Scott A. Starks, VladikKreinovich and Prakash Narasimhamurthy,” How to Avoid Congestion in ComputerNetworks”, 0-7803-2125 1 IEEE, 1994.

[8] Sachin Kumar Saxena, Dhaneshwar Kumar, Astha Sharma, Nikita Gupta, Radhika Kochhar, “Congestion Control in Wired Network for Heterogonous Resource Using Neural Network”, Uttarakhand India, Vol 3, 2013.

[9] TranXuan Truong, Le Hung Lan, Nguyen Duy Vie and Mai Vinh Du, “Congestion Control in TCP/IP Differentiated Service Network Using Neural Network”, IEEE Seventh International Conference on Natural Computation.978-1-4244-9953-3, 2011.

[10] A. B. M. Alim AI Islam and Vijay Raghunathan, “End-to-End Congestion Control in Wireless Mesh Networks using a Neural Network”, IEEE WCNC, West Lafayette, 2011.

[11] Gong Changqing Zhao Linna and Wang Xiaoyan, “Using Neural Network Classifier of Packet Loss Causes to Improve TCP Congestion Control over Ad Hoc Networks”, IEEE 2007 International Symposium on Microwave, Antenna, Propagation, and EMC Technologies for Wireless Communications, Tongliao,China,2007.

[12] George A. Rovithakis and Christos N. Houmkozlis, “A Neural Network Congestion Control Algorithm for the Internet”, IEEE International Symposium on Intelligent Control Limassol, Cyprus, June 27-29, 2005.

[13] N. Xiong, Member, Y. Yang, Jing He and Yanxiang, “On Designing QoS for Congestion Control Service Using Neural Network Predictive Techniques”, IEEE 1 4244-0134-8, 2006.

[14] Hyun C. Cho, M. Sami Fadali, Hyunjeong Lee, “Neural Network Control for TCP Network Congestion”, American Control Conference June 8-10, Portland, OR, USA 2005.

[15] Bazmi, ManijehKeshtgary,” A neural network based congestion control algorithm for content-centric networks”, Journal of Advanced Computer Science & Technology, 3 (2) 214-220, 2014.