ASIAN JOURNAL OF INFORMATION TECHNOLOGY
MEDWELL PUBLICATIONS SINCE 2000

Packet Switching Data Congestion Control Techniques using Artificial Intelligence

[1]A.I. Fasiku, [1]B. Ojedayo, [1]T.D. Obasanya, [2]O. Adetan and [3]O.E. Oyinloye
[1]Department of Computer Engineering, Faculty of Engineering, Ekiti State University, Ado-Ekiti, Nigeria
[2]Department of Electrical and Information Engineering, Landmark University, Omu-Aran, Nigeria
[3]Department Computer Science, Faculty of Science, Ekiti State University, Ado-Ekiti, Nigeria

Key words: Network, congestion, ANN, MATLAB, C-sharp

Corresponding Author:
A.I. Fasiku
Department of Computer Engineering, Faculty of Engineering, Ekiti State University, Ado-Ekiti, Nigeria

Page No.: 41-48
Volume: 20, Issue 2, 2021
ISSN: 1682-3915
Asian Journal of Information Technology

Abstract: Network technology is very popular now because most offices and households use the internet for communication and carry out their day-to-day transactions. With the present high demand for internet users, they may experience congestion because of the increase in the number of users and demand on the network. Hence, controlling congestion for packet-switched data on the wired and wireless network using an artificial intelligence technique is very important to replace the current TCP protocols. This research used the neural network technique to realize this goal by training the model with some data set values which its result was later compared with the predicted result. This research works demonstrate great potential to control congestion for packet-switched on both wired and wireless networks. MATLAB was used for both the training of genetic programming and the ANN simulation for the prediction. When the message sent is higher than the capacity of the router, it can cause congestion. Therefore, this application is designed to be installed on the server to control congestion before its occurrence and congestion prediction. If some of the packets are queuing up, the application controls it by passing a message to the sender that congestion is about to occur along with the link. Therefore, the sender adjusts the speed of transmitting packets by reducing the level of the message the sender is sending and the flow of packets is then regulated.

INTRODUCTION

The advancement in networking technology and the increase in the number of internet users make the internet the fastest growing technology in recent time. It goes across every facet of life: individuals, manufacturing industries, banking sectors, educational sector, etc. With an increase in the numbers of internet users, network congestion is bound to occur; hence, technical congestion control is needed to tackle the problem that limits the benefit of internet technology. Packet-switching is the basis for the Internet Protocol (IP). The messages are broken into small packets for easier transfer at the sending end and later gather together on getting to the destination end[1].

In networking, congestion is a problem that occurs on shared networks when multiple users contend for access gain to the same resources (bandwidth, buffers and queue). In a communication channel, congestions lead to packet loss, reduced throughput and channel quality degradation. Hence, the congestion control scheme is necessary to regulate the transfer of packets. It can be defined as a state of network devices wherein the network cannot guarantee the exchanged network performance for the already established connections. It may be caused by unforeseeable statistical variations in traffic flows or faulty situations within the network[2]. Without traffic and congestion control techniques, traffic from user node A can exceed the network's capacity, causing memory buffers of network switches to overflow and leading to data losses. Also, if the rate at which packets arrives and queue-up exceeds the rate at which packets can be distributed, the queue size increases without bound and the delay faced by a packet goes to infinity.

A congestion control schemes is an algorithm used to distribute the available resources between nodes within a network. Advancement in technology resulted in a more powerful computer with heterogeneous internet, hence, smart and more intelligent TCP congestion control technique is required to solve the congestion problem experience in packet-switched data should be developed[3]. Artificial Neural Network (ANN) was used in this research to address this problem. It's a mathematical structure consisting of interconnected artificial neurons that mimics human characteristics on a much smaller scale in how a biological neuron network or human brain works. An ANN can be able to program base on a specific algorithm. It can be used in carrying out a task such as prediction, regression, classification, clustering and others, depending on the researcher's specification[4-6].

Literature review: There have been many significant works on network congestion control management; Deivanai and Sudha (2015)[7] used VANETs (Vehicular Ad Hoc Networks) for controlling congestion by designing a scheme that will allow time slots for beacons and emergency messages. Even when the vehicle density increases and the channel is easily exhausted, the scheme would allow vehicles to transmit messages by dynamically partitioning the beacon interval and increasing the length of the transmission. Hence, with this system, vehicles are allowed to relay emergency signals without beacons[8]. One of the setbacks of this method is that, while partitioning the beacon interval to increase message's transmission duration, the queue will keep increasing at the beacon level[9].

Nicholas developed a multicast performance assessment between PGM and MDP-CC under various network conditions. The MDP-CC protocol is an extension to the multicast dissemination protocol (MDP) which is a negative acknowledgment oriented reliable multicast (NORM) based protocol and has been implemented by the US Naval Research Laboratory. MDP was primarily used for fixed-rate operation and PGM has the advantage over traditional Multicast protocols. It ensures that the receivers in the group receives all packets of data from a transmission or retransmission or can detect unrecoverable loss of data packets.

Moreover, Ogbimi *et al*.[10] used a dynamic explicit feedback model to control congestion by using the model to keep the bandwidth stable which causes the flow transmission through paths to be balanced. The model must be monitored to ensure that the transmission is always balanced but the system network may experience congestion. The proposed model in this paper adopted the open loop congestion control technique by using an artificially intelligent technique which must have predicted some area where congestion might occur due to the learning from the previous scenario before the occurrence and suggest a way of resolving the congestion.

Computer network congestion: A computer network or data network is a telecommunication network that allows computers to exchange or transfer data from one medium to another. However, the network can also be referred to as a group of two or more computer systems linked together using LAN, WAN, MAN, etc. The review of several research works has made it clear that heterogeneous growth in internet use has been causing a bottleneck in the transfer of packet-switched data, resulting in queue or packet drop. The continuous increment in queue leads to what is known as congestion. Thus, congestion occurs when the number of packets transmitted through the network approaches the network's packet handling capacity[11]. Network congestion in data networking and queuing theory is the reduced quality of service that occurs when a node on the network carries more data than it can accommodate.

Causes of congestion: Congestion is bound whenever one or even more network elements such as router discarded packets, do not have buffer space. Hence, it can not decide what data flow rate within a network can be sustained between it source and the destination. If the source transfers data at a rate that is too fast to be managed between the source and the destination, one or more routers may start queuing the packets in their

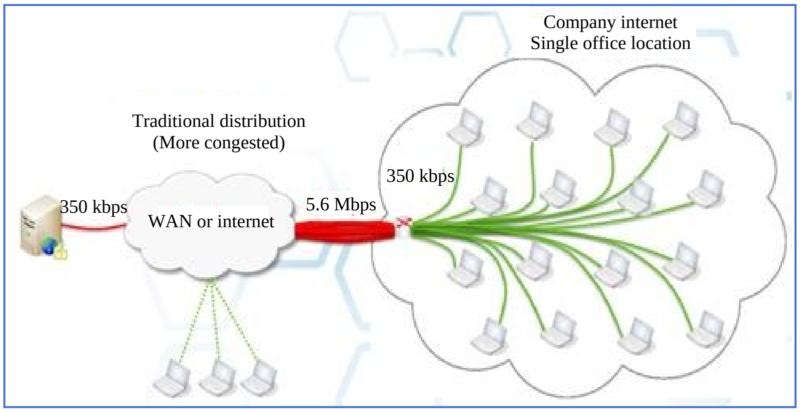

Fig. 1: Congestion of packet in a network

respective buffers. If the queuing up persists, the buffers will become full and packets from the source will be discarded, causing data losses[12].

Moreover, as the load exceeds the capacity of the network, as shown in Fig. 1, the buffers in the routers begin to fill up. This increases the response time (time is taken data in the network to move between source and destination) and decreases the throughput. Adding more memory can also not help in some situations; if routers have an infinite amount of memory, even then instead of reducing congestion, it gets worse; as packet gets to the output line at the head of the queue, they must have already timed-out (repeatedly). All the packets will be forwarded to the next router up to the destination and increase the network load more and more[13, 3].

In a network, when a device sent a packet and did not receive an acknowledgment from the recipient, in most cases, it can be presumed that intermediate devices have dropped the packets as a result of network congestion. The source or intermediate router can infer the level of congestion on the network by monitoring the rate at which packets are sent but have not been acknowledged in a network. In the following section, the ill effects of congestion shall be discussed[13].

Effects of congestion: Congestion effects are in two basic categories, namely throughput and delay. The throughput increases linearly with the offered load because utilization of the network increases as more packets are continuously sent over the network. However, as the offered load increases beyond a certain limit, like 65% of the network's capacity, the throughput decreases. If the load provided increases further, a point would be reached when no single packet is sent to any destination which is commonly known as a deadlock situation[14].

An increase in offered load also increases the delay. Whatever technique is used for congestion control, the delay grows continuously (non-stop) as the load exceeds the system capacity. Initially, it should be noticed that there is a longer delay when implementing a congestion control policy. However, the network can saturate at a lower load without any congestion control[15].

Congestion control techniques: So, many factors cause congestion in computer networking. Some of the most common ones are packet loss, the delay caused by overloading the buffer, defective hardware devices, intermixing of old and new modern technologies and unstable bandwidth flow resulting from positive feedback[10]. Congestion control of packet-switched data on the wired and wireless network is referred to as the congestion control mechanisms and techniques used to keep the traffic below the network capacity. The congestion control techniques can be divided into two categories:

Open loop: The type of protocols under this category are used to prevent or avoid the congestion of packets. This is done to ensure that the systems (or network under consideration) never experience congestion[16]. This kind of system or protocol attempts to solve the problem by a good design as in Fig. 2, to ensure that congestion did not occur at all. The most important point here is that they decide without considering the network's current state[16]. The open-loop algorithms are further divided base on the function, whether it acts on the source or the destination.

Closed loop: Unlike the open-loop system, the close loop system uses protocols that allow the system to enter the congested state, detect it and remove it. This category is based on the concept of feedback. During operation (packet transfer), some system parameters are measured and feedback to portions of the subnet in the form of acknowledgment so that it can take action to reduce the congestion.

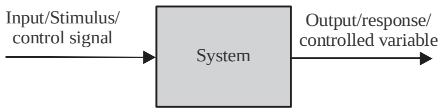

Fig. 2: Open-loop system architecture

MATERIALS AND METHODS

Experimental setup: An Artificial Intelligence (AI) technique and object- oriented programming and C-sharp (C#) were used to develop a congestion control model that can avoid queuing and reduce packet loss to the lowest minimal level. The proposed model will be used to monitor the flow of data, predict where there will be congestion and immediately respond by notifying the sender to stop/reduce the level of transmission. MATLAB[17] was used for both the training of Genetic Programming (GP) and the simulation of the ANN for the prediction.

The model formulates rules or policies of when to decide, accept traffic, discard it, make scheduling decisions, etc. It forms the basis of the method that was adopted in this proposed technique. Figure 3 shows the flow chart of the mechanism of congestion control using the AI technique. The congestion control system adopted in this study is the open-loop system whereby congestion is being avoided before it ever happens. Since a message is broken into packets using packetization. Packets are sent through the routers from source to destination(s). A message is transmitted to the first router which acted as a buffer. The message remains in the buffer for a while until there is an available router that packets can be routed on the way to their destinations. If the level of a message sent is higher than the router's capacity, it can cause congestion.

The training process was carried out using an artificial neural network in MATLAB. The training was done by loading the data generated into the table provided in MATLAB. After setting the epoch and the number of hidden neurons, it generated the graph for performance evaluation and the simulation was done after getting the best performance evaluation. The extracted data used to train the model and GP system will use data set that reflects the past and present situation and the future buffer utilization to achieve good training. Therefore, the data set will be fragmented in windows and every window will be processed as a new sample. Every window includes an account of buffer utilization in the previous instants and future buffer utilization. The research result will be summarized in intervals and every interval may be represented by the maximum, the minimum and the mean buffer utilization. Therefore, the prediction's accuracy can be made; tables and graphs will be generated to show the research work results.

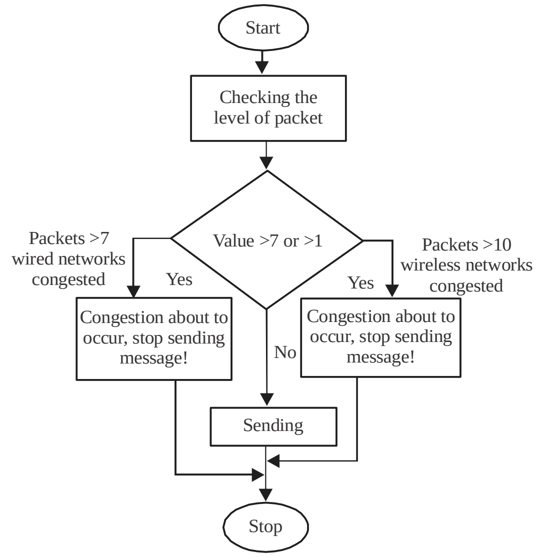

Fig. 3: Flow chart mechanism for congestion control

RESULTS AND DISCUSSION

The training and prediction for this model were done with MATLAB using the artificial intelligent technique extracted and applied to the application interface designed using C#. The model was modified and applied to packet-switched data on the wired and wireless network by setting the maximum value of packets at the wired phase to be lower than that of the wireless network due to larger-scale users of wireless networks. The following modified parameters then modeled the model interface for packet flow in packet-switched data of wired and wireless network:

- The maximum value of packets on a wired network = 7
- The maximum value of packets on a wireless network = 10

Figure 4 shown when messages have been sent successfully without congestion while Fig. 5 displays a warning sign that congestion is about to occur in any of the routers. Suppose the total value of packets being sent on the wired network is >7 or >10 on the wireless network since the gradient on the trained value graph is 9.9679e06. In that case, it will automatically pop up a warning window that congestion is about to occur in one of the routers.

The training carried out for this research is to achieve the objectives of the research. The order of generating the result is through training, data prediction and graphical analysis. Many tables and graphs were generated as a result of model training. Also, each value in the tabular cells represents the packet's level in the message that will

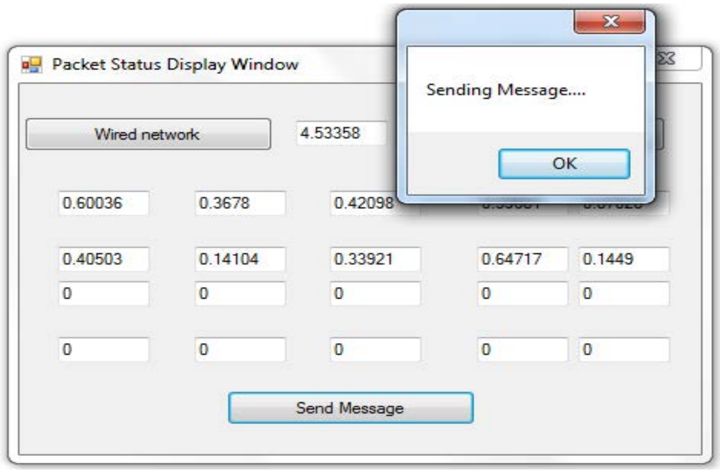

Fig. 4: Message successfully sent on both wired and wireless network

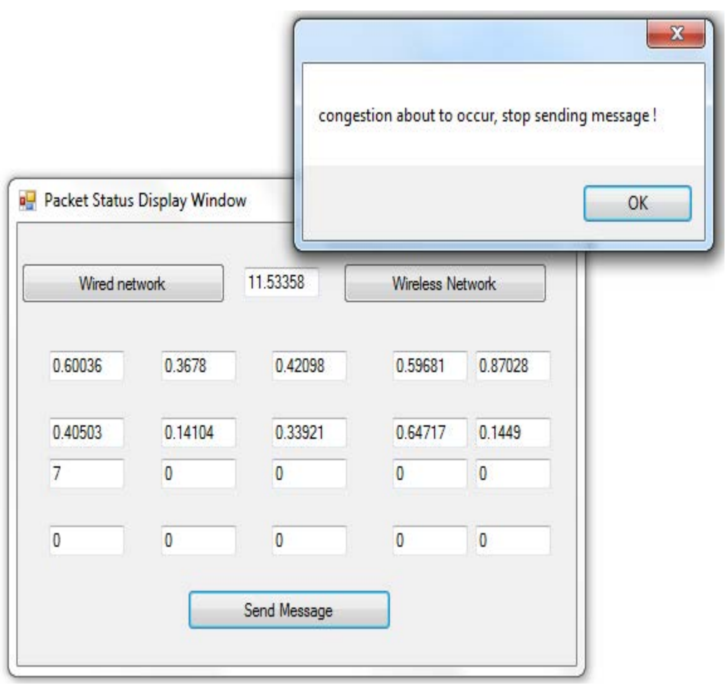

Fig. 5: Warning message for congestion about to occur

be sent to the desktop application designed to pop up the notification window for the user. Moreover, the result predicted by the model after training produced the predicted results from the model after input the data generated to test the validity of its performance. The sample input to test was generated from the training data to check whether the result will be correlated without using any target.

Simulated result: After setting the values for the hidden layer for getting the best result, the training was simulated. It generated the graphs in Fig. 6-8 which show the result of the best validation performance, the training regression and the gradient, respectively. To get the best validation performance grade, the mean square error was used and the epoch was set at 1000.

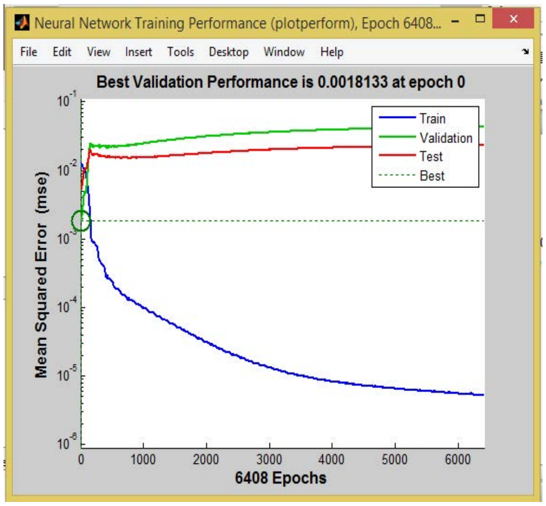

Fig. 6: The graphical result showing the best validation performance

Figure 6 shows the Performance plot with the epochs, the MSE (Mean Square Error) of the artificial neural network has decreased. A well-trained ANN would have a very low MSE at the end of the training phase which in this design equals 0.0018133 at epoch zero. The significance of MSE being very small (close to zero) is the expected outputs and the ANN's outputs for the training set have become very close to each other.

Figure 7 shows the neural network's regression models when test datasets differ from input_1, input_2, input_3 and input_4. Figure 8 is the graphical result of the gradient. These graphs visualize how well the predicted value fits the actual output data and outlines the influence of the increasing number of flows in predicting the number of dropped data packets. It can be observed that by increasing the intricacy of the network topologies, the accuracy of the neural network congestion control measures will justify implementing this artificial intelligence predictor technique.

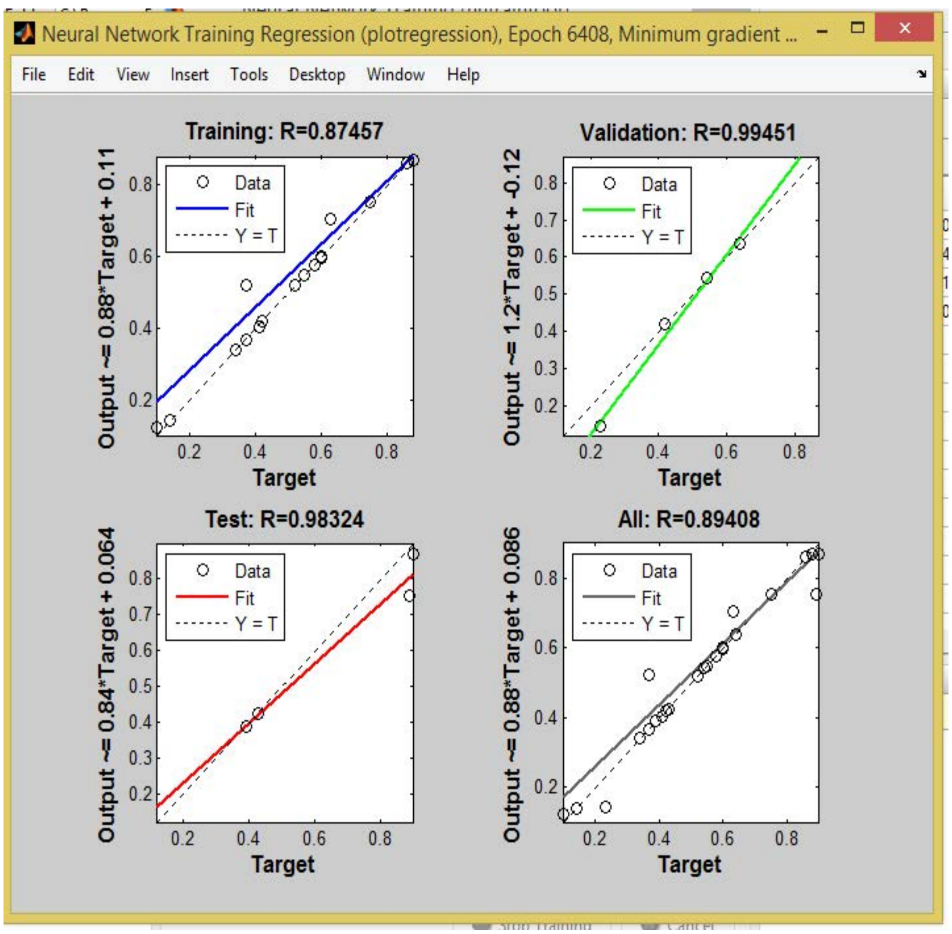

Fig. 7: The graphical result showing the regression

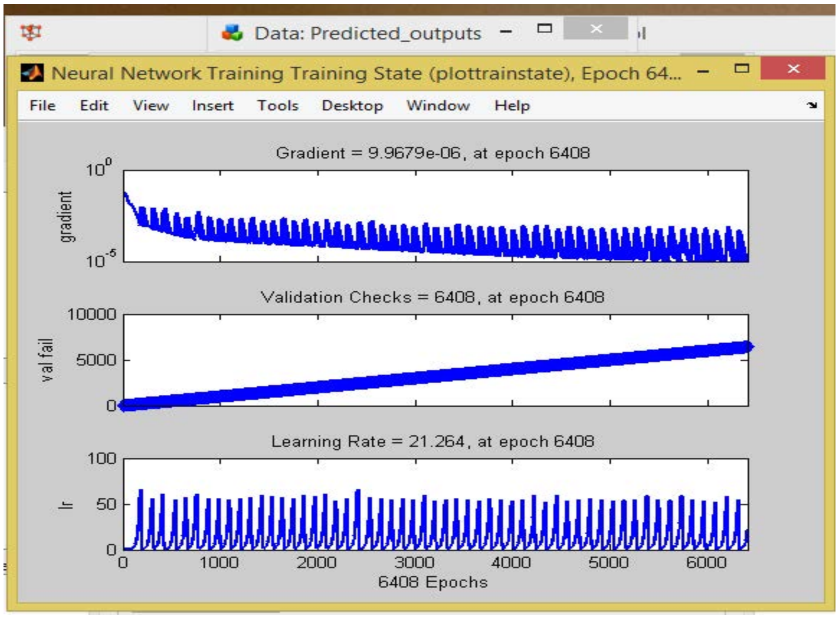

Fig. 8: The graphical result showing the gradient

CONCLUSION

Effective congestion control in packet-switched data of wired and wireless networks is an essential quality expected in today's network technology for fast and accurate timing for the free flow of packets in a communication network.

Therefore, the crucial problem of congestion control of packet-switched data on the wired and wireless network is considered. The artificial intelligent technique was the main strategy used in this research to control congestion in a computer network. This research achieved some high-level training and prediction values for packet-switched data on the wired and wireless network. This work's approach accelerates congestion avoidance and can make a dramatic decrease in the rate of packet drops and possibly saves the time of retransmission. A neural network technique was used to realize the goal of determining at what level congestion of packets can occur.

In the two scenarios (both on the wired and wireless network), the model's interface was used to test the packet's congestion level using the predicted value and the error message was received successfully. Therefore, the simulation result shows that this method is efficient and effective in controlling congestion in applied performance congestion. The future work in this research will be looking into how an emergency message can be detected and give priority in an emergency scenario.

REFERENCES

01. Pablo, M., 2002. Circuit switching in the internet. Ph.D. Thesis, Stanford University, London, England, UK.
02. Ellis, H., 1994. ATM User-Network Interface (UNI) Signaling Specification. Prentice-Hall Inc., Upper Saddle River, New Jersey, USA.,.
03. Olasoji, B.O., O.M. Olanrewaju and I.O. Adebayo, 2016. Transmission control protocol and congestion control: A review of TCP variants. Int. J. Comput. Sci. Inf. Secur.,` 14: 127-135.
04. Lee, K.Y., N. Chung and S. Hwang, 2016. Application of an Artificial Neural Network (ANN) model for predicting mosquito abundances in urban areas. Ecol. Inf., 36: 172-180.
05. More, R., A. Mugal, S. Rajgure, R.B. Adhao and V.K. Pachghare, 2016. Road traffic prediction and congestion control using artificial neural networks. Proceedings of the 2016 International Conference on Computing, Analytics and Security Trends (CAST), December 19-21, 2016, IEEE, Pune, India, pp: 52-57.
06. Huang, S., 2019. Cross-layer congestion control with deep neural network in cellular network. M.Sc. Thesis, School of Electrical Engineering and Computer Science, Sweden.
07. Deivanai, P. and K. Sudha, 2015. Privacy-preserving and priority based congestion control for VANET. Int. J. Comput. Appl., 1: 8-12.

08. Deivanai, P., K. Sudha and K. Radha, 2015. Efficient authentication and congestion control for vehicular ad hoc network. Int. J. Innovative Res. Sci. Eng. Technol., 4: 219-223.
09. Sepulcre, M., J. Gozalvez, J. Harri and H. Hartenstein, 2010. Application-based congestion control policy for the communication channel in VANETs. IEEE. Commun. Lett., 14: 951-953.
10. Ogbimi, E.F., A.O. Oluwatope and G.A. Aderounmu, 2013. The improved feedback model for reducing congestion in packet switched wide area networks. Int. J. Networks Commun., 3: 118-129.
11. Al-Bahadili, H., 2012. Simulation in Computer Network Design and Modeling: use and Analysis. IGI Global, Pennsylvania,.
12. Aun, H., 2004. Improved congestion control for packet switched data networks and the internet. Ph.D. Thesis, University of Canterbury, Christchurch, New Zealand.
13. Lam, S. and Y. Lien, 1981. Congestion control of packet communication networks by input buffer limits? A simulation study. IEEE. Ann. Hist. Comput., 30: 733-742.
14. Papadopoulos, C., G. Parulkar and G. Varghese, 1998. An error control scheme for large-scale multicast applications. Proceedings of the IEEE Conference on Computer Communications and Seventeenth Annual Joint Conference of the IEEE Computer and Communications Societies Gateway to the 21st Century (Cat. No. 98&INFOCOM'98, Vol. 3, March 29-April 2, 1998, IEEE, San Francisco, California, pp: 1188-1196.
15. Socrates, C., P.M. Devamalar and R.K. Sridharan, 2014. Congestion control for packet switched networks: A survey. Int. J. Sci. Res. Publ., 4: 1-6.
16. Ojedayo, B. and E. Oyinloye, 2015. Evaluation of end to end delay and packet loss probability in congestion control system. Int. J. Sci. Eng. Res., 6: 427-437.
17. Houcque, D., 2005. Introduction to MATLAB for engineering students. Version 1.2., Northwestern University, Evanston, Illinois.