Triple Queue Management Based Fuzzy Distributed Admission Control for High Performance Internet Routers

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Abstract

Internet protocols currently use packet-level mechanisms to detect and react to congestion. Although these controls are essential to ensure fair sharing of the available resource between multiple flows, in some cases they are insufficient to ensure overall network stability. It is also necessary to take account of higher-level concepts, such as connections, flows and sessions when controlling network congestion. In this paper, we introduce and study a new Queue Management framework through the use of connection level information already embedded in existing data traffic. Our goal is to improve the system performance and resource utilization at times of intense network congestion. Under this framework, data packets and connection establishment packets are queued separately and further, two different queues have been introduced to the data packets for low load and heavy load of networks. Different queuing and dropping policies can then be applied to the packets which facilitates the term Triple-Queue Management (TQM). This framework is stateless and does not require per-flow queueing or flow counting. Using examples of such policies, our simulation shows that this scheme can lead to much higher performance and network resource utilization during intense congestion. It also leads to more robust and scalable network design for low and heavy load of networks.
Keywords : AQM, Drop Tail, DSRED, EREM, TQM, TCP and UDP.

I. Introduction

Much of today's data traffic is *best-effort* based (e.g., TCP or UDP). Although best-effort does not provide any performance guarantee, most of the applications using best effort-service do require certain minimal performance to be of practical use. At times of high congestion, not only does the end user experience very poor performance, but a *lot of network resource is wasted due to retransmissions and aborted connections*.

The regulation of best-effort traffic and congestion control is largely left to Queue Management. FIFO drop-tail (DT) and Random Early Discard (RED) based queuing are widely deployed. There has been extensive research in Active Queue Management (AQM)[4],[5]. These methods are quite effective in reducing packet losses under certain level of congestion and these AQM Schemes unable to reduce packet loss at times of more congestion. Hence, it is required to propose new efficient Queue Management scheme to reduce the packet loss even at more congestion time.

A. Related Work

Distributed Admission Control through Dual Queue Management [2],[10] framework consists of separate queues for different types of *packets* (which may belong to the same flow) instead of separate queues for different types of *flows* (which may contain different types of packets). This does not require the router to keep any per-connection or per- flow states, nor does it interfere with functionalities of end-to- end protocols. Current router technologies on fast lookup can easily realize this scheme. Once we place connection establishment packets and data packets into separate queues different drop policies can be applied. By adopting a more aggressive policy to the connection establishment packets in the event of heavy congestion, e.g., delay or drop more connection establishment packets, we can maintain a small enough drop probability for data packets, so that existing connections can go through and complete rather quickly and release network resources. *This scheme can be seen as a generalized distributed admission control mechanism, as well as an enhanced AQM mechanism.*

Dongsook Kim *et al.,* [2] introduced two separate fixed *queue size* queues, where one for SYN and SYN/ACK packets and one for the rest. Admission control for TCP has been studied in the literature [3] and it was thoroughly discussed congestion collapse and inefficiency of the network mathematically, and this advocated the use of admission control for TCP connections in order to ensure a minimum acceptable throughput [9].

However, this Distributed Admission Control through Dual Queue Management mechanism has less throughput and *it will not support heavy load of networks* because it calculates packet dropping probability by using Gentle RED[1] (GRED)

To solve this problem, N K Sakthivel *et al.,*[1] proposed *An Efficient Scheduling Algorithm based Dual Active Queue Management Scheme for High Performance Internet Intelligent Routers* which will support for both low load and heavy load of networks. In this paper, DSRED [6] and EREM [7] have been combined together with the help of Adaptive Size Measurement Algorithm, which is explained in the Section III (B).

Bing Zheng *et al.,* [6] proposed DSRED Active Queue Management Scheme to achieve higher throughput than RED and N K Sakthivel *et al.,* [7] proposed EREM Active Queue Management Scheme to achieve higher throughput than REM. We have analyzed and revealed that, the DSRED achieves higher throughput only for low load of networks, EREM achieves higher throughput only for heavy load of networks hence, we have combined DSRED and EREM Active Queue Management Schemes in [1].

However, we observed that in the scheme [1], at times of high congestion, not only do end users experience very poor performance, but a lot of network resource is wasted due to retransmissions of packets. Therefore, we have proposed an efficient technique to solve this problem. For this we have applied one of the soft computing techniques called Fuzzy logic.
The soft computing techniques now-a-days are used to improve the quality of service in TCP/IP networks. In 1965, Lotfi Zadesh first published a description and analysis of Fuzzy Logic. This is a true superset of Boolean Logic and permits the description of functions and processes with degree of vagueness or uncertainty. Since the various researchers in the field have extended the concept of Rule Based Fuzzy Systems to embrace Fuzzy Logic specially in the Congestion Control Algorithms.[11,12]
In this paper, we aim to use the reported strength of a Computational Intelligence technique **fuzzy logic** for controlling complex and highly nonlinear systems to address congestion control problems. In this **proposed Triple Queue Management Mechanism,** Computational Intelligence of this Fuzzy Logic Controller (FLC) based Fuzzy Systems used to identify the congestion. We draw from the vast experience, in both theoretical as well as practical terms, of Computational Intelligence Control (Fuzzy Control) in the design of the control algorithm [11]. Nowadays, we are faced with increasingly complex control problems, for which different Mathematical modeling representations may be difficult to obtain. This difficulty has stimulated the development of alternative modeling and control techniques, which include fuzzy logic, based ones. Therefore, we aim to exploit the well-known advantages of fuzzy logic control [11]:

- Ability to quickly express the control structure of a system using prior knowledge.
- Less dependence on the availability of a precise mathematical model.
- Easy handling of the inherent nonlinearities.
- Easy handling of multiple input signals.

The rest of the paper is organized as follows. We present the details of DQM in Section II along with discussions on the features and limitations of this scheme. In Section III and Section IV, we present proposed technique and simulation results respectively. We conclude with features of this proposed scheme in Section V.

B. Objectives of this Paper

From the above discussion, we observe that Sakthivel et al.'s[1] paper was suitable for low and heavy load of networks, even though, it has some limitations in terms of throughput, delay, utilization and dropping probability. Hence, it is important to introduce a new efficient mechanism to solve the above said limitations. The objective of this paper is to develop a *Triple Queue Management Scheme*, which will improve the throughput, utilization and delay characteristics.
In the *Triple Queue Management Scheme*, one queue called *connection level fuzzy queue* which is maintained by Fuzzy Linguistic Rules used for maintaining connections packets and another two active queues combined by efficient scheduler called Dual AQM (DSRED and EREM) used for maintaining data packets. The

main key feature of this TQM is to drop the more connection packets while severe congestion occurs which is not implemented in Dual AQM [1] and Dual Queue [2] Schemes. The DSRED and EREM have combined together by efficient scheduler because, DSRED will support for low load of networks and EREM will support for heavy volume of networks. We have combined the DSRED and EREM AQM in this paper for achieving high throughput in low and heavy load of networks because no single AQM Schemes are available to support both low and heavy load of networks with high throughput. The detailed explanation for this is given in section III.

The Fuzzy logic concept is used to design connection level queue because, with the help of Fuzzy Logic, we can *frame connection drop functions with* respect to *packets queues drop function*. That is, while more data packets are congested, more connections packets will be dropped and for less data packets in the queue, more connections packets will be admitted. With this scheme, we can minimize the number of retransmitting packets and it will support for low load and heavy load of networks with more throughputs, less delay and higher utilization.

II. Dual Queue Management Mechanism

The basic concept underlying this approach is to separate data packets and connection establishment packets into two separate queues as shown in Figure 1. More specifically, in the case of TCP, each router keeps one queue for SYN and SYN/ACK packets and another for normal data packets. The SYN and SYN/ACK packet queue is called the *connection queue* and the other data queue is called the *packet queue*. In this Dual Queue Management mechanism scheme introduces higher drop probability for

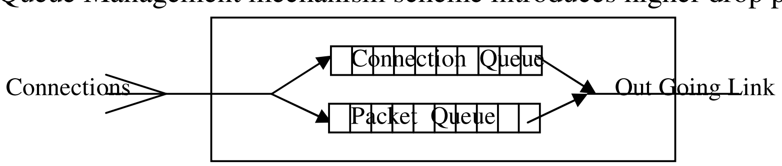
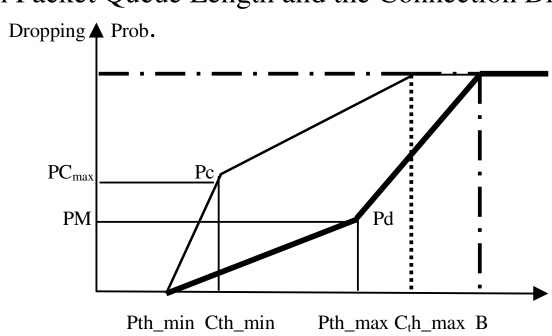


Figure 1 : Architecture of Dual Queue Management

drop probability for SYN packets in order to reduce the number of connections in the network at times of congestion. Thus a smaller number of connections will achieve higher throughput and hence the utilization of resources can be optimised. The linear relationship between Packet Queue Length and the Connection Dropping Probability is



Average Queue Length (x)
Figure 2 Design Parameters of DQM

as shown in the Figure 2. Here B is the packet queue size and P_d is the data packet drop probability. P_c is the connection drop probability, which is determined by two thresholds C_{th_min} and C_{th_max}. PC_{max} is the drop probability at the higher threshold. Here, x is the average queue length. The technique does not reflect the scheduling of two queues. Its current simulation studies the connection packets and data packets are transmitted on a FIFO basis. That is connection packets are only dropped but not delayed.

III. Proposed Triple Queue Management Mechanism

The proposed *Triple Queue Management (TQM) based Fuzzy Distributed Admission Control Mechanism* uses the same method of Dual Queue Management Mechanism for separation of connection establishment packets and data packets. And different marking probability technique has introduced in packet queue to achieve high throughput. That is, in the data packets' queue, the techniques of Efficient Packet Scheduling algorithm via Dual Active Queue Management [1] is introduced to achieve more throughput and low delay for both the low and heavy load of networks. This TQM mechanism achieves the high utilization, negligible loss and low delay with high throughput as compared with an efficient scheduling algorithm based Dual AQM mechanism. The basic architecture of TQM mechanism is as shown in Figure 3. This Triple Queue Management Mechanism consists of

- Efficient Scheduler based Dual AQM.
- Connection Establishment Level Fuzzy Queue and

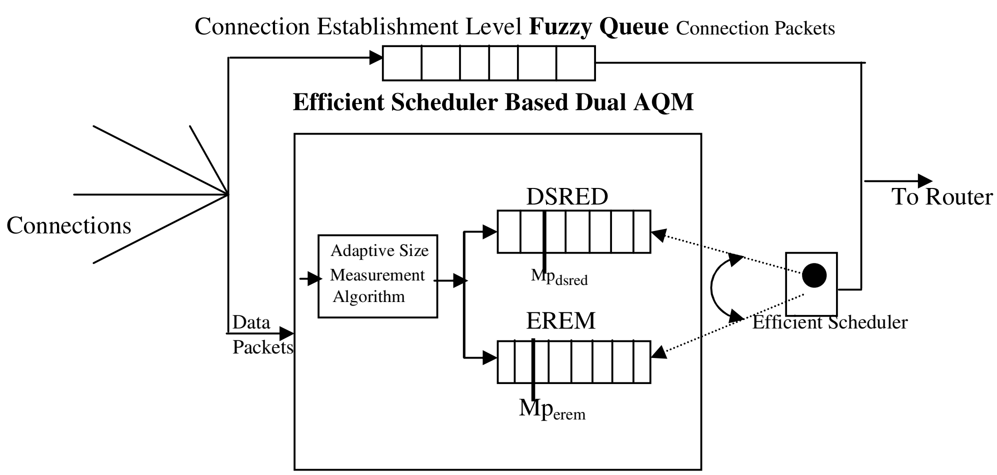


Figure 3 Architecture of TQM Mechanism

A. *Efficient Scheduler based Dual AQM*

This Efficient Scheduler based Dual AQM module consists of Adaptive Size Measurement Algorithm, DSRED, and EREM Active Queue Management Schemes. To achieve high throughput for both the low load and heavy load of networks, DSRED and EREM Active Queue Management Schemes combined together with the help of scheduler. We have combined DSRED and EREM because, from the simulation result, we have revealed that DSRED provide high throughput with less delay for low load of networks and EREM provide high throughput with less delay for heavy load of networks. In this Efficient Scheduler based Dual AQM, the network element is a processor sharing system with two input queues that map to DSRED and EREM Active Queue Management Schemes respectively. Each Queue is associated with a certain weight whose value is controlled by the Adaptive Size Measurement Algorithm [8]. Based on the weights, the Efficient Scheduler maps the AQM (either DSRED or EREM) to the Router for data transmission.

B. *Adaptive Size Measurement Algorithm*

This Adaptive Size Measurement Algorithm is used to measure the queue size of the DSRED / EREM. Depends upon the queue size, the Adaptive Size Measurement Algorithm will pass the arrival data packets either to DSRED or to EREM. It also sets the weight parameters to select the AQM by Scheduler.
In this Adaptive Size measurement algorithm, if the DSRED queue size is less than or equal to the marking probability of DSRED (Mp_{dsred}), all packets are sent to router through DSRED. If the DSRED queue size is greater than the marking probability of DSRED and less than that of EREM (Mp_{erem}), all packets are sent to router through EREM. If the queue size is greater than the marking probability of EREM, our algorithm informs to sender to decrease the sending rate and hence we can minimize the data packet-dropping rate. That is, this adaptive size measurement algorithm maps the data packets either to the DSRED or to the EREM Active Queue Management schemes to achieve high throughput for low load and heavy load of networks. The adaptive size measurement algorithm is as given below.

initialize the $qsize_{dsred}$ and $qsize_{erem}$ as 0
  Mp_{dsred} : Marking Probability of DSRED
  Mp_{erem} : Marking Probability of EREM
  while (true) {
    if ($qsize_{dsred} \leq Mp_{dsred}$) {
    set Weight parameter w = 1
      (if w = 1, Scheduler fetch the packets from DSRED)
    sent packets to DSRED }
    else if ($qsize_{dsred} > Mp_{dsred}$) {
    sent packets to EREM
    fetch all packets of DSRED
    set Weight parameter w = 2
      (if w = 2, Scheduler fetch the packets from EREM) }
    else if ($qsize_{erem} < Mp_{dsred}$) {
    sent packets to DSRED

fetch all packets of EREM
set Weight parameter w = 1
(if w = 1, Scheduler fetch the packets from DSRED) }
else if ($qsize_{erem}$ > Mp_{erem}) {
inform to sender to decrease the sending rate } }

Note : In our simulation study, it is clear that up to 470 packets, DSRED produce good throughput and hence we have fixed 470 as the dropping probability of DSRED and We have fixed 850^{th} packets level as dropping probability of EREM because up to 850 packets, EREM produce good throughput.

C. Connection Establishment Level Fuzzy Queue:

The idea of this *connection level Fuzzy queue* is to introduce higher drop probability for SYN packets in order to reduce the number of connections in the network at times of congestion. The Fuzzy rules and sets for connection level Fuzzy queue and Linguistic Rules for Connection Dropping Probability is given in the section III (D) and section III (E).

D. Fuzzy Rules and Sets for Connection Level Fuzzy Queue

We have established a rule based fuzzy approach to drop the *connection establishment packets* while severe congestion occurs and at the same time to increase the throughput. In this paper, *we have developed a new methodology called Connection Establishment Level Fuzzy Queue.* It *is used to drop the connection establishment packets while congestion becomes severe.* The Figure 4 shows the connection drop probability of TQM Mechanism, which is made based on Fuzzy Membership. *A*s shown in Figure 5, the linguistic classification is made as

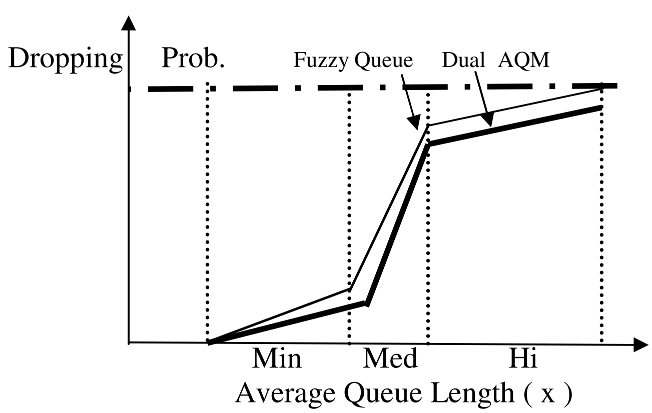


Figure 4 Design Parameters of TQM Mechanism

Minimum *Min*, Medium *Med* and High *Hi.* The Figure 5 illustrates that, if the connection_queue size is less than or equal to *a*, then there is no need to drop the connection establishment packets. If the connection_queue size is in between *a* and *b*, then the connection establishment packets dropping rate is Minimum. If the connection_queue size is in between *b* and *c*, then the connection establishment packets dropping rate is Medium. If the connection_queue size is in between *c* and *d*, then the connection establishment packets dropping rate is High and if the connection_queue size exceeds *d,* then the connection establishment packets dropping rate made to 100%.

$$M_{dc}(x) = \begin{cases} 0 & \text{for } x \le a \\ \frac{x-a}{b-a} Tb & \text{for } a < x \le b \\ Tb + \frac{x-b}{c-b}(Tc - Tb) & \text{for } b < x \le c \\ Tc + \frac{x-c}{d-c}(Td - Tc) & \text{for } c < x \le d \\ 1 & \text{for } x > d \end{cases} \quad \text{-------- (1)}$$

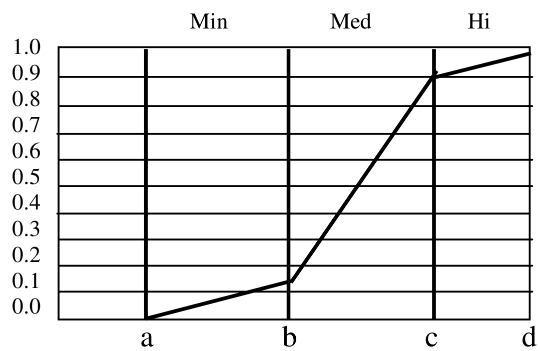


Figure 5 Dropping Probability of Connection Establishment Level **Fuzzy Queue**

To reduce the data packets dropping rate, the Fuzzy Queue has been introduced. The membership function for connection dropping probability, which is used in Fuzzy queue is given in equation "1" where, d = N (connection_queue size), x is the *average queue length* and T_b, T_c and T_d are the tolerance limits of b, c and d respectively. The linguistic rules can be framed according to the dropping membership function.

E. Linguistic Rules for Connection Dropping Probability

Let us consider **Q**ueue **C**apacity is $\mathbf{Q_c}$, **Q**ueue **S**ize is $\mathbf{Q_s}$, **D**ropping **P**robability $\mathbf{D_p}$

if Q_c is Empty and Q_s is Decreasing then D_p is Low;
if Q_c is Empty and Q_s is Zero then D_p is Low;
if Q_c is Empty and Q_s is Increasing then D_p is Medium;
if Q_c is Medium and Q_s is Decreasing then D_p is Low;
if Q_c is Medium and Q_s is Zero then D_p is Low;
if Q_c is Medium and Q_s is Increasing then D_p is High;
if Q_c is Full and Q_s is Decreasing then D_p is Medium;
if Q_c is Full and Q_s is Zero then D_p is Medium;
if Q_c is Full and Q_s is Increasing then D_p is High;

F. Features of TQM Mechanism

The main feature of this mechanism is decouples congestion measure from performance measure and results in much higher resource utilization and lower packet losses. That is, this mechanism has two main aspects. They are

- Efficient Scheduler based Dual AQM provide high throughput and low delay for low load and heavy load of networks.

- The **connection establishment level Fuzzy Queue** having dropping connections if more congestion occurs in the networks. It typically is far from sufficient to provide good per-connection performance where there are a large amount of incoming connections. The idea of connection establishment queue scheme is to introduce higher drop probability for SYN packets in order to reduce the number of connections in the network at times of congestion. Thus a smaller number of connections will achieve higher individual throughput and lower latency at the expense of a higher blocking probability. By doing so existing connections release resources sooner, and the utilization of resources can be improved.

IV. Simulation Results

A performance of a set of simulation using OMNET++ simulator tool [13]. The simulation configuration is shown in the Figure 6. On measuring the performance metrics of this proposed scheme in terms of dropping probability, throughput, delay, average number of admitted connections, and the number of retransmitted packet. To investigate these, the proposed scheme as tested under Low Load and Heavy Load of networks with DSRED, EREM , Dual Queue and Dual AQM schemes. For this simulation, We have assigned an average flow size as 40 packets and propagation delay is 50 ms over a simulation duration of 1000 seconds. We will vary the offered load on the system, denoted by $\rho = \lambda / \mu$, where, λ is the data packets arrival rate of TCP flows at the data packets buffer in packets / second (processed by Adaptive Size Measurement Algorithm) and μ is the data packet processing rate at the data packets buffer in packet/second.

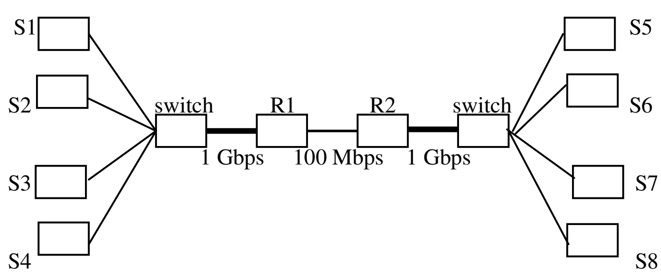


Figure 6 Network Configuration for Simulation

A. Dropping Probability, Throughput Performance and Comparison of Retransmitted Packets of Proposed Technique

The dropping probability, throughput performance and Comparison of Retransmitted Packets and Average number of admitted flows in the link of this newly proposed technique have been studied thoroughly. It is as shown in the Figure 7, Figure 8 and Figure 9 , Figure 10, Figure 11and Figure 12.

From the Figure 7, it is clear that, the proposed TQM technique has much less dropping probability than Dual Queue for low load and heavy load of networks. We also observed that the Dual Queue fails to withstand for heavy load of networks. Figure 8, we observed that the proposed Scheme has much less dropping probability for Low Load and Heavy Load of Networks than that of DSRED and EREM. From the Figure 9, we have observed that the Fuzzy Logic Controller (FLC) based proposed TQM technique has much less dropping probability for Low Load and Heavy Load of Networks than that of Dual AQM, because, FLC drops the established connections earlier than Dual AQM while severe congestion occurs.

From the Figure 10, it is clear that this proposed scheme gives higher throughput than that of Dual AQM Mechanism. We observed from the Figure 11, that the number of retransmitted packets are less as compared with Dual AQM. From the Figure 12, we see that the number of connections are restricted while traffic becomes more congested. This is possible because of the presence of the Fuzzy queue. That is, the Fuzzy Queue through Fuzzy membership function, restricts the connections to transfer the data packets while severe congestion occurs. Hence, the data packet-dropping rate decreases, which reduced the packet retransmissions. This is the main advantage of this proposed scheme. This technique is not included in Dual AQM and hence it admits more connections even though intense congestion Occurs. In general, our proposed technique has higher normalized throughput with less delay and less retransmitted packets, for low load and heavy load of networks as compared with DSRED, EREM , Dual Queue and Dual AQM Scheme.

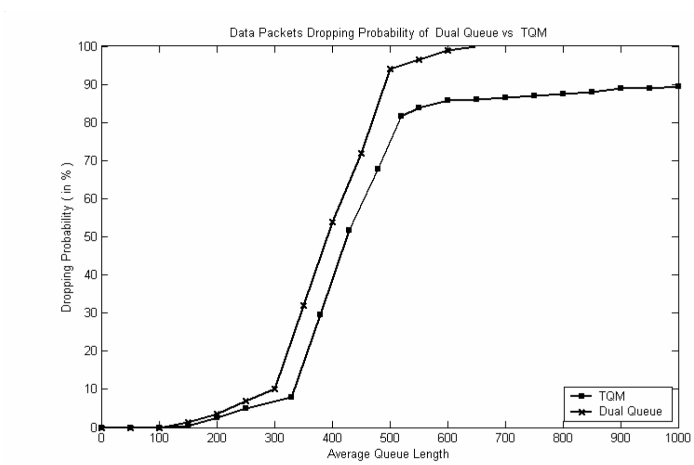


Figure 7 Data Packets Dropping probability of Dual Queue and TQM

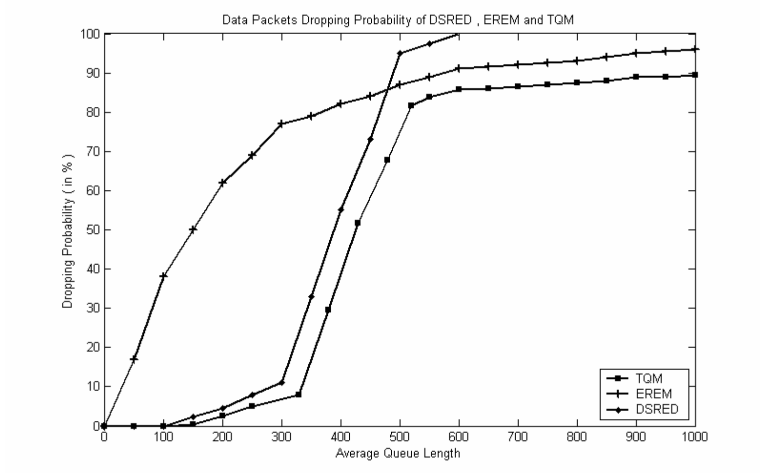


Figure 8 Data Packets Dropping probability of DSRED , EREM and TQM

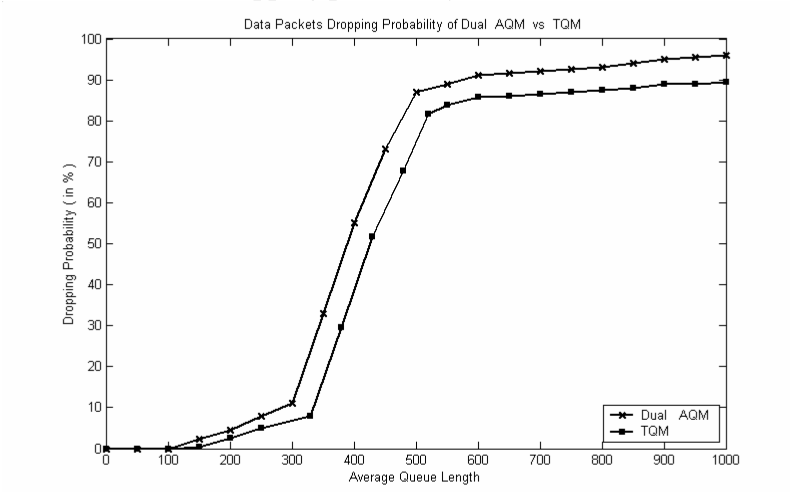


Figure 9 Data Packets Dropping probability of Dual AQM and TQM

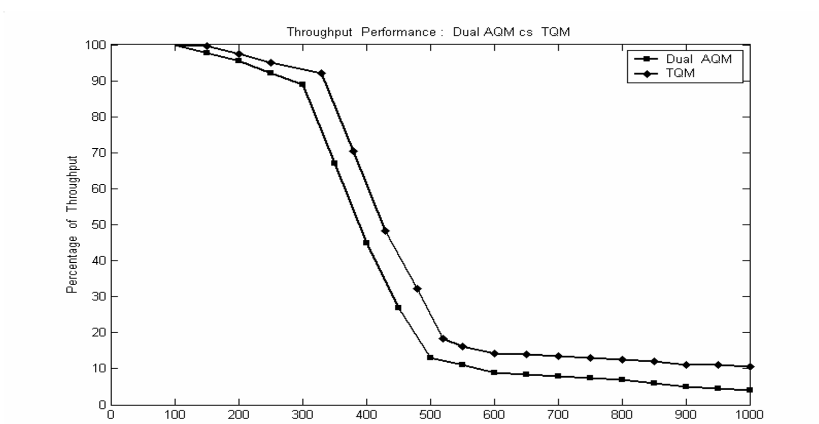


Figure 10 Performance analysis of Dual AQM and TQM

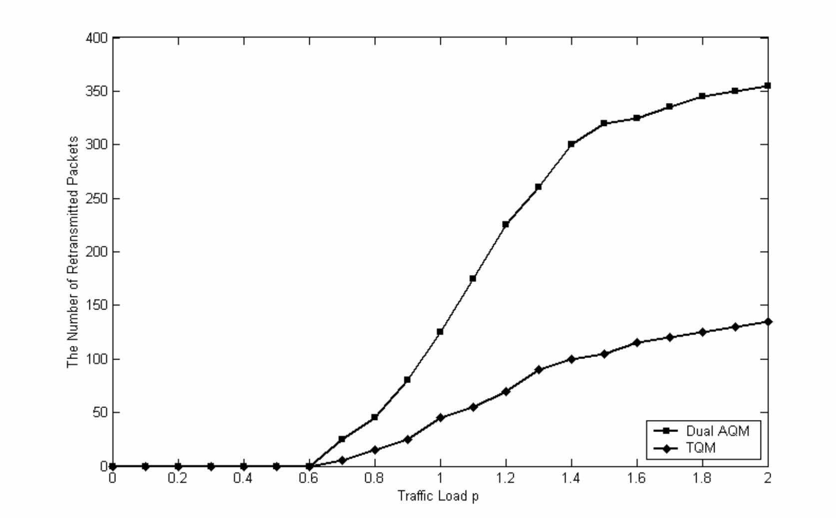


Figure 11 The number of Retransmitted Packets

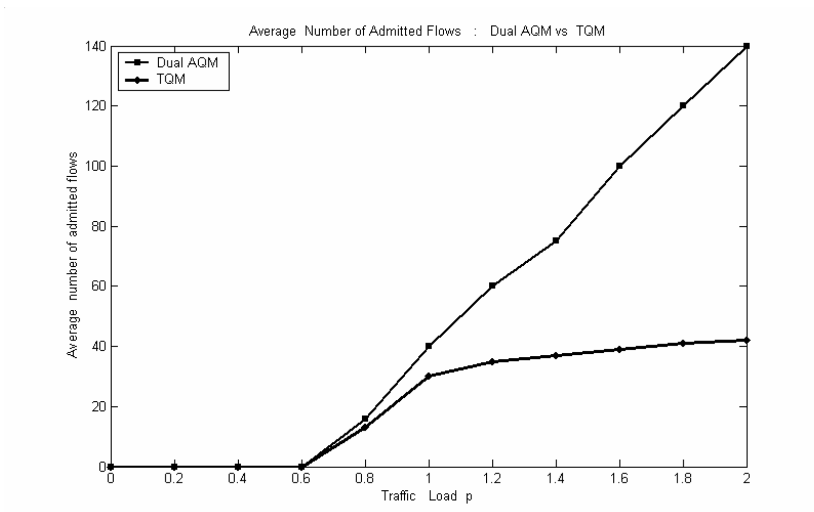


Figure 12 Average number of admitted flows in the link

V. Conclusion

In this paper, we have proposed and studied the new *Triple Queue Management Based Fuzzy Distributed Admission Control for High Performance Internet Routers.* For analyzing output, the proposed scheme performed quite well when compared with DSRED, EREM, Dual Queue. Our proposed scheme is compared with Dual AQM Scheme in terms of *Throughput, Retransmitting Packets and Delay* for low load and heavy load of networks and it has a much reduced number of retransmissions. Hence the utilization of the network becomes high. This proposed technique will improve the performance of Internet Routers for all network conditions such as dynamic arrival of low and high volume of data packets.

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