Performance Analysis of AQM Schemes in Wired and Wireless Networks based on TCP flow

Abdullah Al Masud, Hossain Md. Shamim, Amina Akhter

***Abstract*— TCP is the main protocol that carried the traffic in a reliable way. IP based network always facing congestion because of increasing traffic. To control congestion and implement QOS in TCP we perform a comparative study between different active queue management techniques. Queue management is an important part to provide for better utilization of buffer. Our objective is to perform a comparative study of RED, DropTail, REM and PI in wired and wireless network based on the number of TCP flows and how they perform in congested link.**

***Index Terms*—AQM, DROPTAIL, PI, RED, REM, TCP.**

I. Introduction

QOS (Quality of Service) is now become very important part of networking. Now there is a demand of high bandwidth and low latency traffic from sender to receiver but to provide this kind of request is not always possible because of low bandwidth of the links that passes the packets. It becomes very important how we put different traffic in queue in different situation where some traffic needs to pass quickly and some needs greater bandwidth. When congestion occurs then main difficulty is to send big amount of packets from one end to the other end of a network.

FIFO (First In First Out system) was first used when buffer is full then all packet will be dropped. But active queue mechanism [1,2,3] drops or marks packet by some rules. It maintains one or more drop or mark probabilities for its operation. There are several queue management techniques that do not drop all incoming packets after congestion occur. One of most effective active queue management is Random Early Detection (RED) [4,5]. Other AQM algorithm are – Random Exponential Marking (REM) [6], Proportional Integral (PI) [7].

II. FIFO

FIFO is the basic queue management technique drops packets when buffer becomes full. So this is not the best solution because it drops important traffic too. Though it is a very simple method to avoid congestion and no state variables are required to perform its operation. It also called DropTail or Taildrop. End terminal has to perform the congestion control so if there is sufficient bandwidth with small queue will result less packet drops.

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Abdullah Al Masud, Department of Electronic and Telecommunications Engineering, International Islamic University Chittagong, Bangladesh, (iammasud@yahoo.com).
Hossain Md. Shamim, Network Product Department, Huawei Technologies Limited Bangladesh, (startanim@yahoo.com).
Amina Akhter, Department of Computer Science, Asian University for Women, Bangladesh, (amina.akhter@auw.edu.bd).

III. Active Queue Management

AQM differs from the FIFO that it does not drop all the incoming packets when the buffer become full. It can distinguish between propagation and persistent queuing delays.

A. *Random Early Detection*

The RED congestion control check the average queue size for each output queue, and using randomization, choose connections to notify of that congestion. Transient congestion is accommodated by a temporary increase in the queue. Longer-lived congestion is reflected by an increase in the computed average queue size, and results in randomized feedback to some of the connections to decrease their windows. The probability that a connection is notified of congestion is proportional to that connection's share of the throughput through the gateway.

provide both congestion recovery and congestion avoidance avoid global synchronization and biases against burst traffic maintain an upper bound of average queue size work with TCP and non-TCP transport-layer protocol monitor the average queue size for each output queue use randomization to choose to notify congestion accommodate both transient and longer-lived congestion probability to be notified is proportional to share..

B. *Random Exponential marking*

Congestion measure (price) is computed proportionally to the difference between input rate and output rate and current buffer occupancy at router. Source rate is computed inversely proportional to the congestion measure. It attempts to match user rates to network capacity while clearing buffers (or stabilize queues around a small target), regardless of the number of users. The end-to-end marking (or dropping) probability observed by a user depends in a simple and precise manner on the sum of link prices (congestion measures), summed over all the routers in the path of the user.

C. *Proportional Integral*

A PI controller consists of a proportional and an integral controller. PI controller regulates the queue size of the router properly when it operates around the target queue size. However, real network traffic load varies rapidly due to the burst nature, and sometimes can be much lighter than what is required to maintain the target queue size. Queue length slope determines packet drop probability and the queue are regulated to the desired queue length.

IV. Transmission Control Protocol

Transmission Control Protocol (TCP) [8,9,10] processes big groups of data from an application and breaks them into segments. It maintains number and sequence for each segment so that the destination's TCP stack can put the segments back into the order the application intended. TCP at the transmitting host waits for an acknowledgment of the receiving end's TCP after these segments are sent, again retransmit those that aren't acknowledged. The sender's TCP stack contacts the destination's TCP stack to establish a connection after a transmitting host sends segments down the model this process is known as a virtual circuit. It also defined as connection-oriented communication. Initial handshake, the two TCP layers also agree on the amount of data that's going to be sent before the recipient's TCP sends back an acknowledgment. After all steps completed then the path is paved for reliable communication to take place. It provides full-duplex, connection-oriented, reliable, and accurate communication, but maintaining all these steps and conditions, on the other hand error checking is a very complex and big task. So it often becomes costly in terms of load in the network.

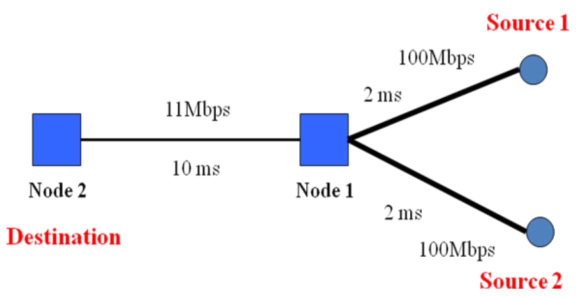

Figure 1. Experimental Setup for Wired Network scenario.

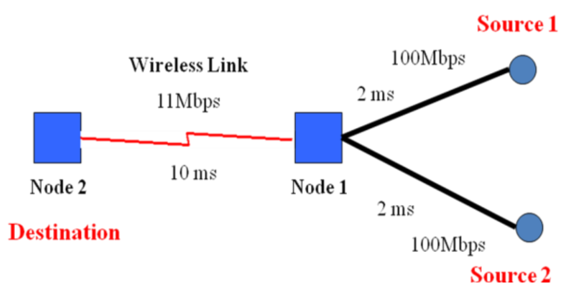

Figure 2. Experimental Setup for Wireless Network scenario.

V. Experimental Model

We have created two scenarios in our study, first one is wired network and the another for wireless network to compare the performance of RED [4,5], Drop Tail, REM [6] and PI [7] by using Network Simulator (NS2). In both scenarios we used two senders and one receiver. In wired case there are two router and bandwidth of the link is 11 Mbps and latency is 10 ms and from sender to router bandwidth of the link is 100 Mbps and latency is 2 ms. Wireless case there is a base station and a mobile station and bandwidth of the link is 11 Mbps and latency is 10 ms from sender to base station bandwidth of the link is 100 Mbps and latency is 2 ms. For both wired and wireless cases we varied the number of TCP flows with fixed queue size of 30 for each of the protocols and analyze the performance. The setup is given below. Here started with number of TCP flows from 3 to 30 steps of 3. Simulation duration is 200 ms. For both wired and wireless cases we varied the number of TCP flow for each of the protocols and analyze the performance. The setup is given in Fig. 1 and Fig. 2.

VI. Data Collection

We run some AWK scripts for data analysis from the trace file generated by the NS-2. We calculated Throughput, Packet drop and Jitter. We also drawn graphs from the data that we collected from the script.

VII. Calculation

Here we perform the correlation matrix which computes the correlation coefficients of the columns of a matrix. Here matrix is the data found in the simulation. That is, row i and column j of the correlation matrix is the correlation between column i and column j of the original matrix. The diagonal elements of the correlation matrix will be 1 since they are the correlation of a column with itself. The correlation matrix is also symmetric since the correlation of column i with column j is the same as the correlation of column j with column i.

Parameters that are used in NS-2 Trace file are:

$1 = Action;
$2 = Time;
$3 = Node 1;
$4 = Node 2;
$5 = Source;
$8 = Flow Id;
$9 = Node 1 Address;
$10 = Node 2 Address;
$11 = Sequence No;
$12 = Packet Id;

VIII. Result & Analysis

To compare between different AQM schemes: RED, DropTail, REM and PI, for both wired and wireless scenario we have developed some graph using MS Excel regarding throughput, packet drop and jitter.

A. Throughput versus number of TCP flows of different AQM schemes for wireless scenario

From Fig. 3 and Table I we see that the throughput of different AQM schemes for wireless scenario.

It shows that

TABLE I. CORRELATION MATRIX FOR THROUGHPUT OF DIFFERENT AQM SCHEMES FOR WIRELESS SCENARIO

	TCP Flow	RED	DROPTAIL	REM	PI
TCP Flow	1				
RED	0.75176821	1			
DROPTAIL	0.691504837	0.961190873	1		
REM	0.916243042	0.749869757	0.706505431	1	
PI	0.597692632	0.770013675	0.735880623	0.673337289	1

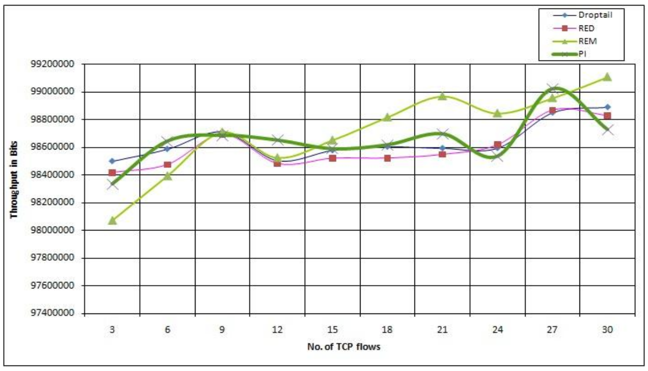

Figure 3. Throughput of AQM schemes for wireless scenario.

the throughput of REM is better than others and PI has the lowest throughput compared to others. We also find that all the schemes have almost the same performance regarding throughput when the TCP flow increases. Here we see from the correlation matrix the correlation coefficient between TCP Flow and others; REM has the highest coefficient which means with the increase of TCP flow REM has the highest performance and PI has the lowest. Correlation matrix also represents inter queue relation and how they are similar or related to each others.

B. Packet drop versus number of TCP flows of different AQM schemes for wireless scenario

From Fig. 4 and Table II we see that the packet drop of different AQM schemes for wireless scenario. It shows that the packet drop of RED is better than others and PI has the highest packet drop compared to others. We also find that all the schemes have almost the same performance regarding packet drop when the TCP flow increases. Here we see from the correlation matrix the correlation coefficient between TCP Flow and others; PI has the highest coefficient which means with the increase of TCP flow PI has the highest packet drop and RED has the lowest. Correlation matrix also represents inter queue relation and how they are similar or related to each others. All the AQM schemes almost have the same performance till twenty.

TABLE II. CORRELATION MATRIX FOR PACKET DROP OF DIFFERENT AQM SCHEMES FOR WIRELESS SCENARIO

	TCP Flow	RED	DROPTAIL	REM	PI
TCP Flow	1				
RED	0.9927415	1			
DROPTAIL	0.996494171	0.99882515	1		
REM	0.994418143	0.998845255	0.998610102	1	
PI	0.997179021	0.996466953	0.998004577	0.99722251	1

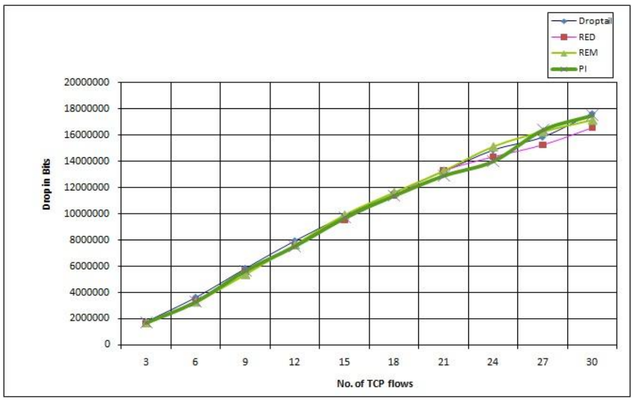

Figure 4. Packet drops in AQM schemes for wireless scenario.

TABLE III. CORRELATION MATRIX FOR JITTER OF DIFFERENT AQM SCHEMES FOR WIRELESS SCENARIO

	TCP Flow	RED	DROPTAIL	REM	PI
TCP Flow	1				
RED	-0.344762352	1			
DROPTAIL	0.356366521	-0.18905677	1		
REM	-0.090742162	0.044232684	0.00451035	1	
PI	-0.426871683	0.632364516	-0.299481543	-0.039960602	1

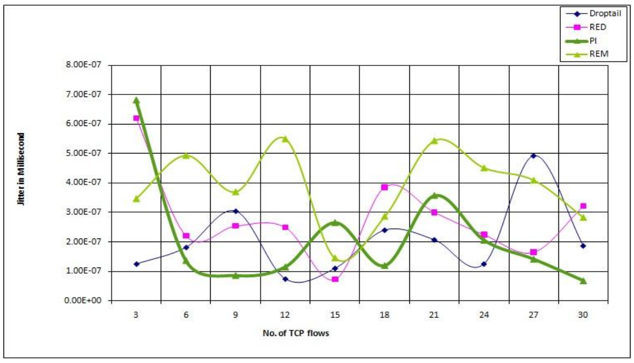

Figure 5. Jitter of different AQM schemes for wireless scenario.

C. Jitter versus number of TCP flows of different AQM schemes for wireless scenario

From Fig. 5 and Table III we see that the jitter of different AQM schemes for wireless scenario. It shows that the jitter of PI is better than others and DropTail has the highest jitter compared to others. We also find that all the schemes have different performance regarding jitter when the TCP flow increases. Here we see from the correlation matrix the correlation coefficient between TCP Flow and others; DropTail has the highest coefficient which means with the increase of TCP flow DropTail has the highest jitter and PI has the lowest. Correlation matrix also represents inter queue relation and how they are similar or related to each others. From the figure we also see that all AQM scheme jitter curve show fluctuation for increase of the number of TCP flows. When TCP flows are between twelve to eighteen then all AQM has lower jitter with comparing to other value.

D. Throughput versus number of TCP flows of different AQM schemes for wired scenario

From Fig. 6 and Table IV we see that the throughput of different AQM schemes for wired scenario. It shows that the throughput of DropTail is better than others but the correlation coefficient show that RED has the highest

TABLE IV. CORRELATION MATRIX FOR THROUGHPUT OF DIFFERENT AQM SCHEMES FOR WIRED SCENARIO

	TCP Flow	RED	DROPTAIL	REM	PI
TCP Flow	1				
RED	0.909317428	1			
DROPTAIL	0.112236221	-0.03853967	1		
REM	0.438071785	0.341182153	0.506175867	1	
PI	0.589847908	0.636949462	0.338591461	0.877366838	1

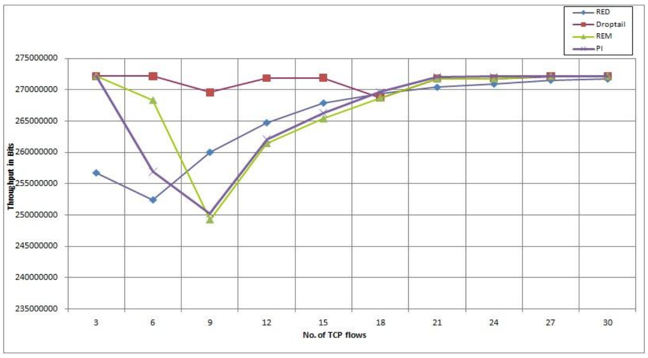

Figure 6. Throughput of AQM schemes for wired scenario.

performance compared to others. We also find that all the schemes have different performance till the number TCP flow reached to eighteen. Here we see from the correlation matrix the correlation coefficient between TCP Flow and others; RED has the highest coefficient which means with the increase of TCP flow RED has the highest throughput and DropTail has the lowest performance. Correlation matrix also represents inter queue relation and how they are similar or related to each others. From the figure we also see that DropTail has almost steady throughput from three to thirty TCP flows.

E. Packet drop versus number of TCP flows of different AQM schemes for wired scenario

From Fig. 7 and Table V we see that the packet drop of different AQM schemes for wired scenario. It shows that the packet drop of RED is the highest than others and REM has the lowest packet drop compared to others. We also find that all the schemes have almost the same performance regarding packet drop when the TCP flow increases. Here we see from the correlation matrix the correlation coefficient between TCP Flow and others; RED has the highest coefficient which means with the increase of TCP flow RED has the highest packet drop and REM has the lowest. Correlation matrix also represents inter queue relation and how they are similar or related to each others. RED has the exponentially increasing curve with the increase of the number of TCP flow. Here PI, DropTail and REM has almost same curve except for REM when the number of TCP flows are more than twenty then REM has higher packet drop compared to DropTail and PI.

TABLE V. CORRELATION MATRIX FOR PACKET DROP OF DIFFERENT AQM SCHEMES FOR WIRED SCENARIO

	TCP Flow	RED	DROPTAIL	REM	PI
TCP Flow	1				
RED	0.998761388	1			
DROPTAIL	0.996602053	0.997490901	1		
REM	0.996500363	0.995874597	0.998527883	1	
PI	0.99827079	0.998776935	0.999412329	0.998799211	1

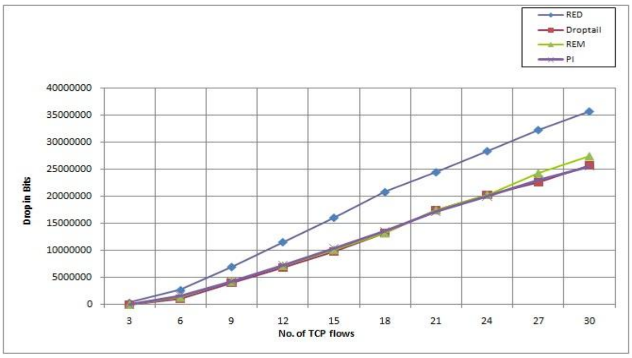

Figure 7. Jitter of different AQM schemes for wired scenario.

TABLE VI. CORRELATION MATRIX FOR JITTER OF DIFFERENT AQM SCHEMES FOR WIRED SCENARIO

	TCP Flow	RED	DROPTAIL	REM	PI
TCP Flow	1				
RED	-0.604506461	1			
DROPTAIL	0.666240054	-0.333843046	1		
REM	-0.468413083	0.460061903	-0.138545607	1	
PI	0.51306552	-0.283938576	0.294452055	-0.427906584	1

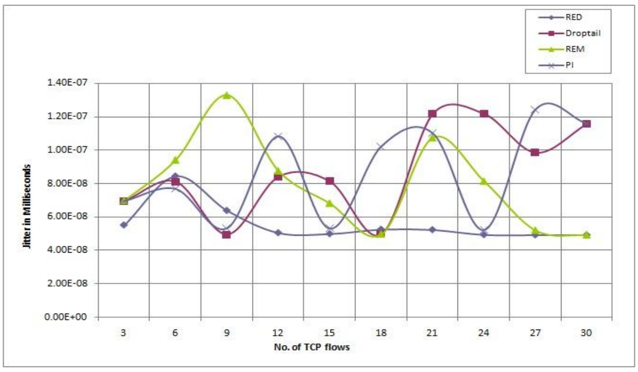

Figure 8. Jitter of different AQM schemes for wired scenario.

F. Jitter versus number of TCP flows of different AQM schemes for wired scenario

From Fig. 8 and Table VI we see that the jitter of different AQM schemes for wireless scenario. It shows that the jitter of RED is better than others and DropTail has the highest jitter compared to others. We also find that all the schemes have different performance regarding jitter when the TCP flow increases. Here we see from the correlation matrix the correlation coefficient between TCP Flow and others; DropTail has the highest coefficient which means with the increase of TCP flow DropTail has the highest jitter and RED has the lowest. Correlation matrix also represents inter queue relation and how they are similar or related to each others. From the figure we also see that all AQM scheme jitter curve show fluctuation for increase of the number of TCP flows. When TCP flows are between twelve to eighteen then all AQM has lower jitter with comparing to other value. PI, DropTail and REM are higher jitter than RED. With the increases number of TCP flows, jitter of

DropTail, PI and REM increases. We can see RED has steady jitter from twelve to thirty TCP flows, but rest three schemes shows fluctuation in their result.

IX. CONCLUSION

In wireless link, we find that throughput of RED and DropTail has almost similar result but for the number of TCP flows greater than twelve REM has slightly higher throughput than RED and DropTail. In wireless scenario, packet drop is almost same for all AQM schemes. For jitter in wireless PI performs better than the other three, but for lower number of TCP flows DropTail has lower jitter. On the other hand, in case of wired scenario, DropTail has steady throughput for increase of the number of TCP flows. RED has the higher packet drop than rest three schemes. Results of jitter in wired case, we see that RED has steady jitter from twelve to thirty TCP flows. So, for wireless link, RED and REM perform better than DropTail and PI, but for wired link DropTail and RED have better performance. Therefore we may conclude that for both wireless and wired link, performance of the link are vary on the number of TCP flows and queue types.

For future work we will implement the experiment with more nodes and also in multiple wired and wireless hop to check the performance of AQM schemes.

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