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Inspiration from the Human Society to Design an Active Queue Management Scheme

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Abstract: Nowadays, multidisciplinary approaches have found extensive applications in many scientific research areas. At the time computer networking has adopted many multidisciplinary solutions such as nature-inspired algorithms and protocols. This paper proposes that the human society can also serve as a source of inspiration to design effective solutions for the computer networking. Toward this idea, the computer network is considered as a computer society in which the social theories are employed to develop effective algorithms and protocols. As the first step for this novel and promising branch, this paper employs a well-known work psychology theory, namely, ADAM's Equity theory to design a high-performance AQM scheme for the Internet. Extensive packet level simulations in ns-2 environment show that the proposed algorithm, called ET-RED exhibits an improved performance in comparison with the most common AQM algorithm of the Internet i.e. RED.

Keywords: computer, networking, AQM, RED, ET-RED

I. INTRODUCTION

Congestion control, as one of the critical issues in the Internet, has attracted a lot of attentions in recent years. The congestion control mechanisms in the Internet consist of the congestion window algorithms of TCP, running at end-systems, and active queue management (AQM) algorithms (e.g. [1]) at routers, seeking to obtain high network utilization, small amounts of queuing delay, and some degree of fairness among users. Recently some researchers have employed interdisciplinary approaches such as biologically-inspired computing and economically-inspired models to design more effective solutions for the Internet congestion control problem [2-4]. These interdisciplinary solutions try to bring achievements and advantages of other disciplines to the computer networking area. For example Jamali [2] uses principles of natural population control tactics to designs an efficient congestion control algorithm and in the other research Al-Manthari [3] employs economical theories to design a congestion control scheme for broadband wireless access network.

We believe that the human society and the theories developed for it have also good potentials to be employed for developing effective solutions for communication networks. According to this proposal a computer network can be redefined as a computer society which is governed by the social theories. As we know, social science uses various methods of empirical investigation and critical analysis to develop a body of knowledge about human social activity. For many sociologists the final goal is to develop policies that lead to an improved performance and welfare in the society. It can be found that this is much similar to the computer network society in which the major goal is to develop algorithms that lead to an improved performance in the network. This similarity motivates us to bring one of the well-known society theories, namely, Adams' Equity theory [5], to design a high performance active queue management algorithm. This theory says that in a society a fair distribution of resources within interpersonal relationships improves performance of both the individuals as well as the whole society. In a similar manner this paper proposes that a fair dropping policy in a queue management algorithm leads to improved performance of the network.

II. ADAMS' EQUITY THEORY

Adams' equity theory is named for John Stacey Adams, a workplace and behavioral psychologist, who developed this job motivation theory in 1963. The theory was built on the belief that employees become de-motivated, both in relation to their jobs and their employers, if they feel as though their inputs are greater than the outputs. Employees can be expected to respond to this in different ways, including de-motivation, effort reduction, disgruntlation, or in more extreme cases, perhaps even disruption. Adams called personal 'efforts and rewards' and other similar 'give and take' issues at work, 'inputs and outputs', respectively. An individual will consider that he is treated fairly if he perceives the ratio of his inputs to his outcomes to be equivalent to those around him.

III. INSPIRATION FROM EQUITY THEORY TO DESIGN A HIGH-PERFORMANCE AQM

As we saw, Adams' equity theory denotes that fairness in a society can improve performance of the society and its individuals. This paper borrows this theory from the society and proposes a novel framework to design an active queue management, in which, the performance arises from the fairness. In the other words, while by far fairness and performance have been considered as two different and independent features of congestion control schemes, in this paper fairness introduced as cornerstone of the network performance. Toward this idea the computer network is considered as a society in which TCP senders are employees and the AQM algorithm is their employer. Form the congestion control point of view the input (effort) of a TCP source to the society is the amount of its responsibility against the network congestion, which is inversely proportional to its sending rate. In other words, while all sources naturally desire to send packets as much as possible, any source that sends fewer packets to the network is tagged as responsible node and hence expects to get fewer dropped packets. Hence, for a given source its output (reward) is the number of its packets that are sent through network without being dropped.

Hence, AQM must drop packets fairly. A source is treated fairly if the ratio of its dropped packets count to its sent packets count is to be equivalent to other flows. Since sending rate of any flow is inversely proportional to its RTT, hence we define a Fair Dropping Index (FDI), defined as (1), for flow i. To realize fairness should FDI of various flows should be kept at the same level. According to this index, a source whose RTT is lower than average of RTTs and hence utilizes more than their fair share of bandwidth, encounters more drops compared with a source whose RTT is longer than the average.

$$FDI_i = Drop_i\left(\frac{RTT_i}{RTT_{avg}}\right) \quad for\ i = 1,2,\ldots,n \qquad (1)$$

Dropi is drop probability of dropping packet i which calculates with the AQM. Note that [6 and 7] have proposed a way to estimate RTT in the routers.

IV. PACKET LEVEL SIMULATION RESULTS

In order to evaluate the proposed AQM algorithm, we implement it in NS-2 [8] environment by some modifications on its RED module. The network topology used in this simulation is the reference dumbbell topology shown in Fig. 1. In this network five long lived FTP connections share a bottleneck link whose bandwidth is 10 Mbps; the bottleneck router buffer size is set to 100 packets, packet size is 500 bytes and the basic parameters of RED are set as min_{th}=15, max_{th}=75, max_p=0.01 and w_q = 0.002.

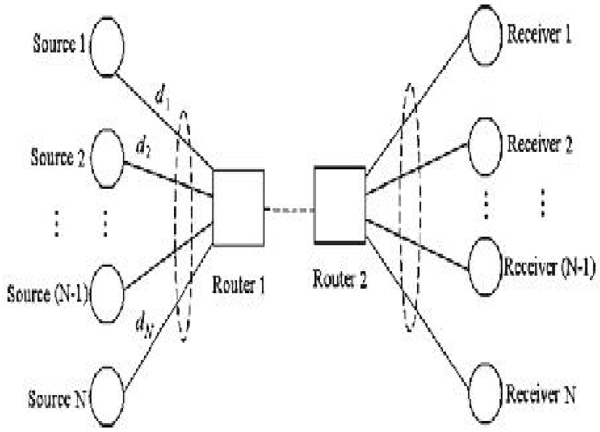


Figure. 1 The network topology

We simulate this network once under RED algorithm and then under ET-RED algorithm. For each algorithm we present two series of simulation results. In the first simulation, we study the network with homogeneous RTT of 100 ms and in the second simulation flows are considered with heterogeneous RTTs of 20 ms, 40 ms, 60 ms, 80 ms and 100 ms.

Fig. 2-4 shows the simulation results for the first scenario with identical RTTs. As can be found in Fig. 2, ET-RED converges more rapidly to its steady-state in which the bottleneck is fully utilized. Fig. 3 shows the address for the effects of RED and ET-RED algorithms on behavior of various sources. According to this figure when queue is managed by ET-RED various sources behave more similarly, their window sizes are roughly equal and their throughputs average is larger than the case that queue is managed by RED. Fig. 4 shows that regardless of router's buffer size ET-RED drops fewer packets in comparison with RED. According to discussion above, fair dropping leads to high performance for all TCPs and prevents them from de-motivation. According to unfair treatment of RED, flows that experience more drops are de-motivated and their throughputs are reduced to lower levels.

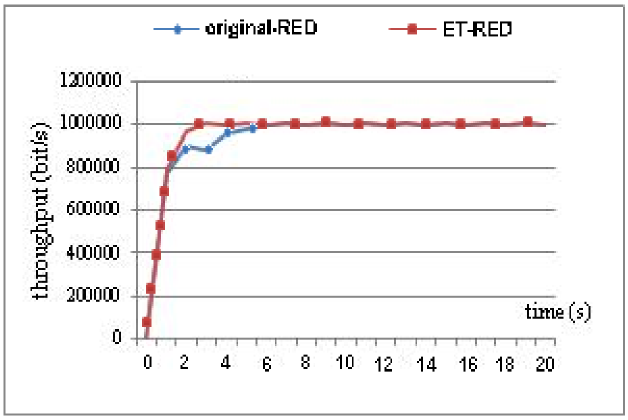
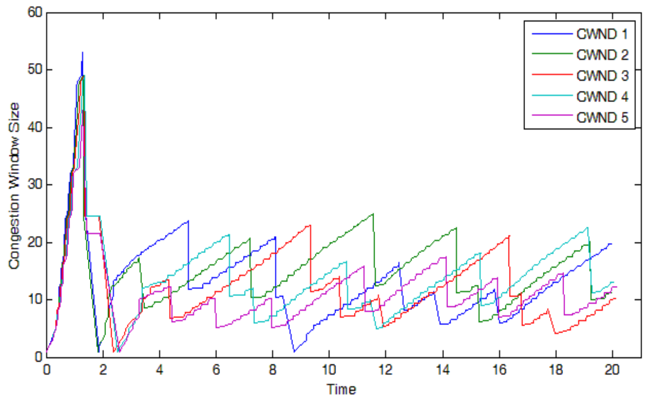


Figure. 2 Scenario 1: the congested router's throughput.



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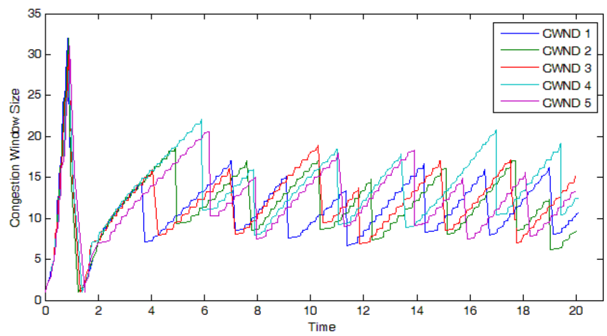

b

Figure. 3 Scenario 1: Congestion window size in the sources.

a unfair congestion window size by original RED.

b fair congestion window size by ET-RED.

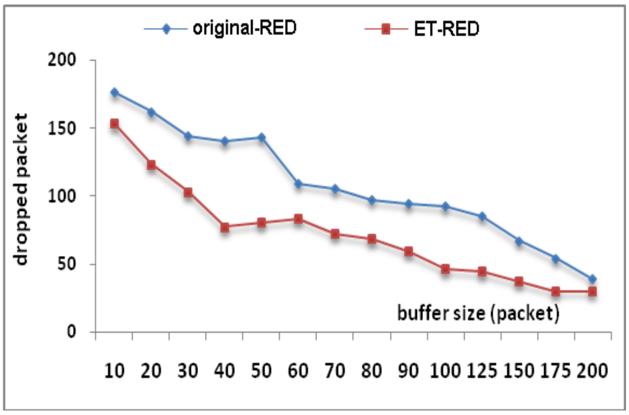

Figure. 4 Scenario 1: Dropped packet versus buffer size.

Simulation results of the second scenario with heterogeneous RTTs have been given in Table 1 and Table 2. It shows that ET-RED is fairer than RED and exhibits better performance in term of flows throughput and bottleneck utilization. In order to fairness comparison, we have used Jain's fairness index (FI) [9] as shown in (2).

$$FI = \frac{\left(\sum_{i=1}^{n} x_i\right)^2}{n * \sum_{i=1}^{n} x_i^2} \qquad (2)$$

Table 1: Scenario 2: throughput of various flows

	RTT (ms)	Original-RED (bps)	ET-RED (bps)
Flow0	20	295936	306304
Flow1	40	202840	212128
Flow2	60	161800	189232
Flow3	80	244528	168496
Flow4	100	89224	124496

Table 2: Scenario 2: fairness and performance study

	Original-RED	ET-RED
Average flows' Throughput	198865 bps	200131 bps
Bottleneck Throughput	994328 bps	1000656 bps
FI	**0.888**	**0.901**

V. CONCLUSION

In this paper we considered the computer network as a human society and proposed that society theories can be employed to solve the computer networking problems. Toward this idea this paper inspired from Adams Equity theory to design a novel active queue management algorithm. Simulation experiments showed that in the proposed algorithm fair dropping leads to improved performance of the network and its sending nodes.

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