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An Enhanced Queue Management Scheme for Eradicating Congestion of TFRC over Wired Environment

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ABSTRACT

To accomplish increasing real time requirements, user applications have to send different kinds of data with different speeds over the internet. To effectuate the aims of the computer networks, several protocols have been added to TCP/IP protocol suite. Transport layer has to implement emerging techniques to transfer huge amount of data like multimedia streaming. To transmit multimedia applications, one of the suitable congestion control mechanisms in transport layer is TCP Friendly Rate Control Protocol (TFRC). It controls congestion based on its equation. To get more smoothed throughput, intermediate nodes (like Routers. etc.) have to use suitable procedures in all real time situations. To eradicate the level of congestion in the network, we introduce enhanced Holt-Winters equations to RED queue management algorithm and applied to TFRC. The simulation results have shown that this strategy reduces packet loss and increases throughput.

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1. INTRODUCTION

Computer network has grown from its origin ARPANET to worldwide autonomous interconnected networks. To transfer data with quality of service (QoS) from one computer to another computer, TCP/IP protocol suite was designed. Some protocols have been added to each layer in TCP/IP protocol suite to accomplish real time complex scenarios.

One of the important layers in Internet protocol suite is Transport layer, to support end to end communication between the two hosts in the network. QoS is one of the primary issues in transport protocols. Nowadays billions of computers are connected to the internet and thousands of terabytes of data are being transmitted per hour through the internet. When too many packets arrive at one place, network will be unable to handle the packets; this situation leads to congestion in the network. Congestion may occur when the load on the network is greater than the capacity of the network.

Different applications require different data transmission rates over internet. These applications transmit with high data rate which leads to congestion in the network. Congestion control is a primary concern in a computer network. Many congestion control protocols have been used to avoid or reduce congestion in the network.

Internet Engineering Task Force (IETF) standards concerning end-to-end congestion control focus either on specific protocols [1] [2] or on the syntax and semantics of communications between the end nodes [3]. Various congestion control mechanisms are developed at transport layer level. TCP is used in connection-oriented environment, and it is reliable for end-to-end mechanism. TCP is designed to fit into a layered hierarchy of different protocols which support multi-network applications. TCP is used to provide reliable inter-process communication between pairs of processes in host computers which are attached to distinct but interconnected computer communication networks.

TCP [4] is not only a reliable protocol but also controls congestion which has preserved the stability of the Internet. Congestion affects the network efficiency, which was successfully addressed by TCP. Key essentials of TCP for stability of the network are its mechanisms of congestion control and reliability.

The trend has changed and majority of the streaming and real-time applications are starting to use UDP, where TCP is suitable for the task. UDP doesn't control congestion and is unreliable protocol [5]. However, there is a rapid increase of multimedia applications over the internet for which TCP and UDP are not well suited. Hence we require protocols which have congestion control mechanism which competes with TCP and UDP without compromising QoS. This is the primary motivation to design a new protocol named TFRC. TFRC is proposed [6] which adjust its sending rate based on TCP Reno Equation (1).

$$X = \frac{S}{RTT\sqrt{\frac{2bp}{3}} + 3 * RTO\sqrt{\frac{3bp}{8}}\, p(1 + 32p^2)} \qquad (1)$$

Where X is the expected sending rate in bytes per second, S is the packet size in bytes, *RTT* is the round-trip time, *b* is the number of packets that are acknowledged by one ACK, *p* is the loss event rate, and *RTO* is the retransmit timeout value. This equation maintains a steady state sending rate to network to avoid the abrupt fluctuations. TFRC sending rate X is a function of packet size which is represented as Equation (2).

$$X = \frac{S}{RTT\sqrt{\frac{2p}{3}} + 12 * RTT\sqrt{\frac{3p}{8}}\, p(1 + 32p^2)} \qquad (2)$$

Based on the above equation, TFRC congestion control mechanism works as follows. At first step, the loss event rate will be measured by receiver and pass this information to sender. Sender measures round trip time based on received information. Sender measures its sending rate as a function of loss event rate and round-trip time. Sender maintains its sending rate based on its calculated rate from the equation. TFRC sending rate is primarily a function of loss event rate and round trip time. This paper is organized as follows. Section 2 describes related work on TFRC. Section 3 presents the proposed methodology for enhancing the queue management. In Section 4, Simulation environment is described, Metrics are presented and results are discussed. Section 5 presents the conclusion.

2. RELATED WORKS

Queue management is a primary aspect in transport layer protocol. Sally Floyd, Van Jacobson [7] proposed an efficient active queue management algorithm named RED, for congestion avoidance in packet-switched networks. RED algorithm calculates an average queue length based on exponential weighted moving average (EWMA) procedure and it lies between two control thresholds called min_{th} and max_{th}. RED algorithm avoids congestion by dropping or marking some packets by calculating dropping probability function in terms of average queue size.

Sally Floyd [8] applied Holt-Winters procedure to RED algorithm and identified its behavior, when queue size varies due to traffic. Holt-Winters procedure calculates the average slope *sl* of average queue size as well as the average queue size *ave* itself. Results had shown that Holt-Winters procedure is more efficient than EWMA when there is a sudden large increase in queue size. However, existing Holt-Winters procedure is not an essential improvement to EWMA procedure. Van Jacobson [9] proposed some algorithms and ideas for congestion avoidance and control over the network.

In recent years, RED had undergone a number of changes with effect of dynamic requirements. Sally Floyd et al [10] proposed Adaptive RED which is an extension of RED, in which RED parameter sensitivity is reduced. Feng et al. [11] proposed a suitable varying mechanism for RED parameter named maximum marking probability (max_p) which significantly reduce packet loss over congested links. In this study, by changing max_p parameter according to the observed traffic by constant factor α and β depending on which threshold it crosses better results are obtained. Analyzed how about active queue management along with ECN to effectively reduce packet loss over congested networks.] J. Aweya et al [12] proposed dynamically changing the threshold to enhance the effectiveness of RED under different system loads.

Ahmed E kamal, Manzoor Murshed [13] proposed dynamic threshold adjustment to RED, to maximize throughput and minimize packet dropping and delay. Alpaben K. Patel, Jyothi Divecha [14] introduced modified exponential weighted moving average, which is very effective in detecting small and abrupt shifts in monitoring process mean. Usman Ahmed et al [15] compared many network congestion control techniques to solve the problems in different network environments. In this paper authors compared TCP variants like TCP CUBIC, TCP compound, TCP Reno and HS-TCP in terms of inter and intra protocol fairness. Authors suggested that congestion control techniques still need more improvement for the utilization of available link bandwidth in high bandwidth long RTT networks and other network resources.

Several attempts were made to analyze and enhance the performance of TFRC. S. Lee and K. Chung [16] suggested a new slow start mechanism and bandwidth estimation methods to improve the performance of TFRC in terms of better RTT fairness and reduced burst packet losses. B. H Oh, J. Han, K. Kim, J. Lee [17] proposed a new receiver based retransmission scheme for TFRC to improve the effective retransmission ratio according to the forward path delay variance. This scheme is more suitable for fluctuating networks. N.Ramanjaneya Reddy, P. Chenna Reddy, et al [18] modified some fixed parameters in the TFRC throughput equation to improve its performance. They proposed an enhanced TFRC by synchronous increment of parameters namely number of packets that are acknowledged by one ACK (b) and retransmission time out (RTO) in TFRC throughput equation. S. Lee, H. Roh, H. Lee, K. Chung [19] proposed an enhanced TFRC for high quality video streaming over high bandwidth delay product networks. This scheme reduces the packet losses of slow-start, and provides RTT-fairness. Z. Song, Y. Zhang, M. Zhou [20] proposed an enhanced TFRC control algorithm called NSTC is proposed which estimates the available bandwidth and adjusts the sending rate appropriately.

ArjunaSathiaseelan, GorryFairhurst, [21] proposed the introduction of congestion control for multimedia traffic to ensure the stability of the next generation Internet. TFRC algorithm was first specified in RFC 3448 [22]. S. Floyd, E. Kohler [23] proposed TFRC-SP (Small-Packet TFRC) a variant of TFRC which supports fixed sending rate by using variable sized small packets. The design goal for TFRC-SP is to achieve the same bandwidth in bps as a TCP flow using packets of up to 1500 bytes. Pedro ReviriegoVasallo [24] proposed an extension to the TFRC protocol in order to support variable packet size flows. In this paper, numerator of TFRC equation has changed to MTU, so that it is suitable for variable packet size flows. Mohammad A. Talaat, Gamal M. Attiya, and Magdi A. Koutb [25] predicted that Video traffic is booming over Internet and to be the prevailing traffic type in the coming few years. TFRC is the most promising candidate congestion control algorithm over Internet that handles such type of traffic appropriately satisfying its QoS requirements. Agnieszka Chodorek and Robert R. Chodorek [26] suggest that although TFRC protocol is suitable for multimedia transmission it can be improved. They proposed to substitute the original TFRC throughput equation with a linear throughput equation. Results allow us to believe that the proposed linear equation is more suitable for multimedia transmission than the equation originally included in the RFC 3448.

3. PROPOSED SYSTEM

One of the popular active queue management algorithm is RED. This algorithm is based on some parameters (min_{th}, max_{th}, avg, max_{p}...etc.) to identify whether the packets are in the queue or dropped based on its average queue length measured by EWMA and its probability metrics. RED algorithm uses EWMA principle to calculate its average queue length. The average queue length formula in RED is represented as Equation (3)

$$avg_i = (1-w_q)avg_{i-1} + w_q\, q_i \qquad (3)$$

Variables:
w_q is queue weight, $w_q \in (o,1]$
avg represents average queue size
q represents current queue size.

Many researchers tuned the parameters of RED to increase its efficiency, but less work has been done on finding effective average queue length with unpredictable network traffic and sudden changes in the intervals. EWMA can perform well to detect small interval changes based on its traffic, but it can’t react to detect large shifts. Holt-Winters equations are an alternative procedure for EWMA to find average queue length. It calculates average queue length based on its trend, seasonality and its smoothed factors and is more appropriate than EWMA for dynamic traffic changes. The advantage of Holt-Winters model is, it can capture the history of network traffic variations and predict the future traffic.

3.1. Enhanced Holt-Winters Equations

We proposed an enhanced Holt-Winters scheme to detect sudden large changes. Moving towards in this direction, we applied an enhanced Holt-Winters scheme for finding average queue length in RED algorithm. This enhanced Holt-Winters formula is a simple way to detect both small and large traffic interval changes than earlier. Enhanced Holt-Winters resolves the issues when it is designed to detect all the changes and can predict the network traffic in future. Holt-Winters equations are represented with equation (4)

$$\left.\begin{aligned} &avg_{old} = avg \\ &avg_i = (1-W_q)*(avg_{i-1}+sl) + w_q * q_i \\ &sl = (1-\frac{Wq}{2}) * sl + (\frac{Wq}{2}) * (avg - avg_{old}) \end{aligned}\right\} \quad (4)$$

An enhanced Holt-Winters equation (5) is as follows.

$$\left.\begin{aligned} &avg_{old} = avg \\ &avg_i = (1-W_q)*(avg+sl) + w_q * q_i + (qi - q_{i-1}) \\ &sl = (1-\frac{Wq}{2}) * sl + (\frac{Wq}{2}) * (avg - avg_{old}) \end{aligned}\right\} \quad (5)$$

This enhanced Hot-Winters scheme can predict the average queue length due to sudden large changes. The term ($qi - q_{i-1}$) considers the present average queued value and previous average queued value, which can more adapt to the changes in traffic dynamically. Also auto tuned $min_{th}$and max_{th} formulas are newly added based on increase in average queue size as shown in Equations (6).

$$\left.\begin{aligned} &If\ ((max_{th}-min_{th}) < (avg_i - avg_{i-1})) \\ &\qquad begin \\ &min_{th} = min_{th} + (q_i - q_{i-1}) + \alpha \\ &max_{th} = min_{th}*3; \\ &end \end{aligned}\right\} \quad (6)$$

Variables:
w_q is queue weight, w_q ϵ(o,1]
avg represents average queue size
min_{th} represents minimum threshold
max_{th} represents maximum threshold

Application of all modifications to RED algorithm is depicted in Figure (1):

```
Initialization of variables
Avg=0; count=-1;
Calculate average queue length for each packet
arrival based on modified Holt-Winters equations
If (!queue empty)
avg_old =avg
avg= (1-W_q)*(avg+sl) + w_q *q_i + ( q_i – q_i-1)
sl = (1-Wq/2 ) * sl + ( Wq/2 ) * (avg – avg_old)
m=f(time-q_time)
avg= (1-w_q)^m avg
if((max_th-min_th)<(avg_i – avg_i-1 ))
begin
min_th= min_th + (q_i – q_i-1)+ α
max_th = min_th*3;
end
ifmin_th<=avg<max_th
count++;
Compute probabilities with following info
Every interval seconds
If(avg>target and max_p<=0.5)
max_p = max_p + α
else
if(avg<target and max_p>=0.01)
max_p = max_p *β;
p_b =max_p(avg-min_th)/ (max_th–min_th)
p_a = p_b /(1-count*p_b)
mark the arriving the packet with probability p_a
count=0;
else if max_th<avg
mark the arriving packet; count=0;
else
count=-1;
when queue is empty
q_time=time;

Variable description:
min_th: minimum threshold for queue
max_th: maximum threshold for queue
max_p: maximum value  for p_b
avg: average queue size
time: current time
p_a: current packet marking probability
w_q: queue weight
q_time: start of the queue idle time
count: Number of packets marked
q: current queue size
```

Figure 1. Enhanced Pseudo code for RED algorithm

4. PERFORMANCE EVALUATION

4.1. Simulation Environment

Network simulator NS2.35 is one of the popular simulation tools which used to understand and predict the protocols behavior in networks. Dumbbell topology with multiple bottle neck links consisting of 10 nodes with different bandwidths like 5Mbps, 4Mbps, 10Mbps, and 2 Mbps with transmission delay 10ms is used. For both cases, TFRC packet size is fixed at 1000 bytes and total simulation time is 150 sec. NS2.35

is used as network simulator. Network topology having 10 nodes is used for performance evaluation as shown in Figure 2.

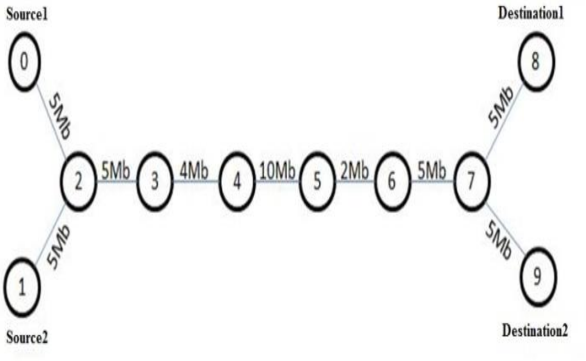

Figure 2. Dumbbell topology

4.2. Performance Metrics

Throughput:

Throughput is the rate at which a network sends or receives data. It is rated in terms of bits per second (bit/sec).

Packet Loss Rate:

Packet loss rate is the ratio between number of packets dropped or lost and number of packets sent through the network.

End-to-End delay:

The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

4.3. Results and Analysis

In this, we compare performance of TFRC with EWMA and EHW schemes via throughput and packet loss rate.

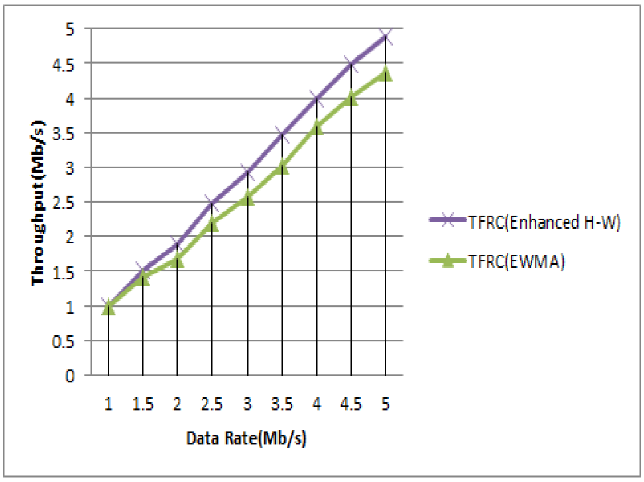

Figure 3. Comparison of throughput

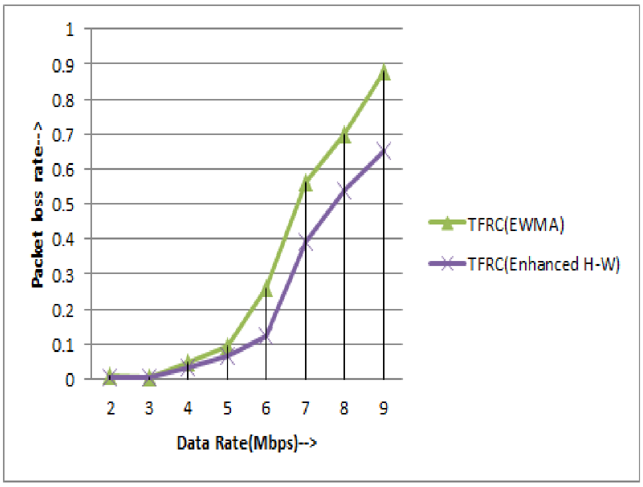

Figure 4. Comparison of packet loss ratio

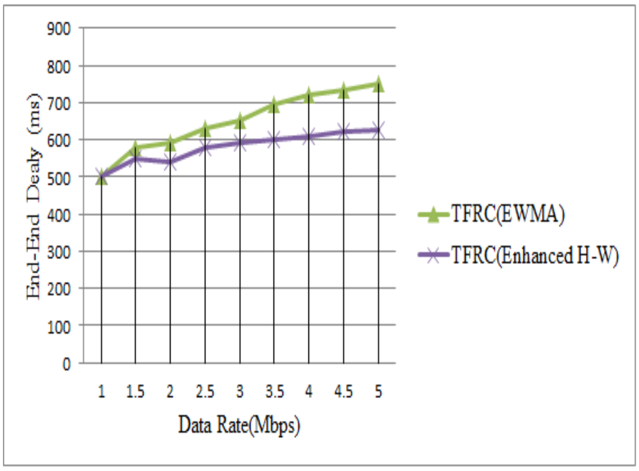

Figure 5. Comparison of end to end delay

Figure 3 depicts that throughput efficiency of TFRC with enhanced H-W queue management. With increasing data rate, TFRC with enhanced Holt-Winters gave good throughput than TFRC with EWMA. TFRC with Enhanced H-W performs 18% more throughput than TFRC with EWMA. Figure 4 illustrates that comparison of packet loss ratio with TFRC (EWMA) and TFRC (Enhanced H-W). With increasing data rate, TFRC with enhanced queue management (EHW) gives 15% low packet loss ratio than TFRC with EWMA. Figure 5 illustrates that comparison of end to end delay with TFRC (EWMA) and TFRC (Enhanced H-W). With creasing data rate, TFRC with enhance queue management (EHW) gives 15% less average end to end delay than TFRC with EWMA

5. CONCLUSION

This paper presents an enhanced Holt-Winters procedure for finding average queue length in RED algorithm and is applied to TFRC to alleviate the problems of congestion control and avoidance. This enhanced scheme helps to improve the performance of RED algorithm and simulation results have shown that the TFRC with EH-W produces increased throughput with less packet loss rate than TFRC with EWMA. In future work we have planned to measure and increase throughput of TFRC in adversities like, measuring round trip time during dynamically changing bandwidth.

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