Performance analysis of TCP in an IP network using fluid-flow models

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Abstract

There is a strong demand for Quality of Service (QoS) in the internet. One key element of QoS is traffic management during congestion. Congestion occurs when aggregate load exceeds the capacity on bottleneck link. In this paper, congestion is caused by heterogeneous traffic. A queue builds up in the router servicing the bottleneck link. We advocate RED (random early detection) as AQM (active queue management) policy to decrease the generated load when congestion detected and increase the load linearly in order to probe for available capacity when congestion subsides. The decrease and retransmission of packets due to drop persists decrease in TCP (transmission control protocol) performance. Large portion of the present work is to analyse and understanding of nature of CBR (constant bit rate) flows which are non-responsive to network traffic, on round trip time, TCP flows, packet losses, queue length. It is observed that CBR flows misuse cooperative nature of TCP flows. The unresponsiveness of CBR flows capture the bandwidth and make TCP starve without resources. The CBR flows benefit from their noncooperative behaviour and TCP flows suffer poor performance.

Index terms- TCP, CBR, Stochastic Differential equations, AQM, RED, queue length.

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1. INTRODUCTION

Information at various internet sites suggests that 85-90 % of current network traffic is based on TCP [1]. TCP provides an end-to-end service that ensures reliable in-order, and unduplicated delivery of bytes from a sender to a receiver. TCP support flow control which ensure that the sending application transport data at a rate not exceeding the rate at which the receiving application can process it. Congestion control ensures that sender data rate should not exceed the currently available transmission capacity along the network path. Experiments show that majority of data loss occurs because of finite capacity buffers overflow and arriving data is discarded at routing nodes in the Internet. TCP congestion control mechanism is successfully allowing the Internet to handle unanticipated traffic through window adjustment at the source avoiding the network collapse during congestion.TCP RENO reduce the congestion window to half the current size whenever notices the packet loss [2]. The other transport protocol for the Internet UDP (User Datagram Protocol), does not provide any mechanism for reliable data delivery or congestion control. Therefore, various proposals have made for monitoring and policing UDP flows to avoid congestion control [3]. Increase in bandwidth and computational power has encouraged the growth of multimedia applications. Multimedia applications rely on UDP. Constant Bit Rate (CBR) is an example of UDP application. All CBR flows have the same data rate. RED (Random early detection) is used as an AQM (Active queue management) policy at the router for congestion avoidance. The router detects the congestion by computing queue size and notifies the congestion to the sources by dropping the arriving packets. RED are designed to support TCP [4]. There has been an increased interest in developing protocols that respond to congestion differently from TCP and provide smoother bandwidth to end applications [5], [6].

2. LITERATURE REVIEW

RTT distribution for TCP traffic in the Internet is discussed [10] and distribution of RTT can dynamically affect the data rates. RED gateways for congestion avoidance in packet switching network is analysed [4] and the router detects the congestion by computing queue size and notifies the congestion to the sources by dropping the arriving packets. TCP flows decreases as the number of competing flows increases is Discussed in [11]. Interaction of TCP & RED using stochastic differential equation models [12] shows an excellent agreement with ns simulator for similar networks. Combined models of TCP/AQM dynamics with models of unresponsive traffic used to analyse the performance of AQM [13]. A scheme for estimating the proportion of incoming traffic that is not responding to congestion at a router is presented in [9]. A new traffic management scheme Multilevel ECN [14] that responds better to congestion by allowing the system to reach stability point faster which results better network performance. A time-delay control theory is applied to analyse the mechanism of packet dropping at a router [15] and window updating in TCP source for congestion control.

3. MODEL OF HETEROGENEOUS TRAFFIC

Focus on this section is the selection of dynamical model of heterogeneous traffic on a congested link in the network [9, 12, 13] that is well suited for estimation of effect of CBR flows on TCP flows.

$$\dot{W}_S(t) = \frac{1}{R(q(t))} - \frac{W_S(t)W_S(t-R(q(t)))}{2R(q(t))}\, p(t-R(q(t))) \qquad (1)$$

$$\dot{X}u = 0 \qquad (2)$$

$$R(t) = \frac{q(t)}{C} + T_p \qquad (3)$$

$$\dot{q}(t) = \frac{N_S W_S(t)}{R(q(t))} + N_u X_u - C \qquad (4)$$

$$p(t) = 0 \text{ if, } 0 \le q(t) < t_{min}$$

$$p(t) = \frac{q(t) - t_{min}}{t_{max} - t_{min}}\, p_{max} \text{ if, } t_{min} \le q(t) \le t_{max}$$

$$p(t) = 1 \text{ if, } t_{max} < q(t) \qquad (5)$$

Equation (1) describes TCP window dynamics having the behaviour additive increase and multiplicative decrease. Equation (2) & (3) demonstrates the CBR (constant bit rate) flow and RTT where T_p is the propagation delay and C is the link capacity. Equation (4) describes the queue length at the router. N_s and N_u are number of TCP and CBR flows respectively. Equations (5) describe RED with t_{mim} and t_{max} are minimum and maximum threshold values of queue buffer.

$$Z(t) = N_S W_S(t)$$

$$D = N_u X_u \qquad (6)$$

$$\dot{Z}(t) = \frac{N_S}{R(t)} - \frac{Z(t)Z(t-R(t))}{2N_S R(t)} p(t) \qquad (7)$$

$$\dot{q}(t) = \frac{z(t)+D}{R(t)} - C \qquad (8)$$

$$\psi = 1 - \frac{Z(t)}{D+Z(t)} \qquad (9)$$

Equations (6) and (7) give Nu number of CBR flows and Ns number of TCP flows respectively. (8) Describe queue length for Nu and Ns number of CBR and TCP flows measured at the ingress point of a router. (9) Indicates the CBR load in the network.

4. IMPLEMENTATION AND RESULT

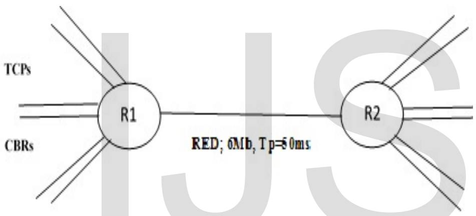

Figure 1

R1& R2 are the routers. Congestion control parameters are measured at the ingress point of the router. Simulation was carried out with C=750 packets, P_{max}=0.04, t_{min} = 50 and t_{max} = 150 packets,t_p= 50 ms, Ns= 40, CBR flow= 240KB and packet size=1000 bytes.

RTT in presence of in the absence of CBR flows varies over the range of 0.0391 – 0.2465s, with an average value of 0.244022s. RTT in presence of CBR flows varies over the range 0.0551 – 0.2423s with an average of 0.244093s. Network under discussion is a single hop network, average value of variation is 0.0000705s. Lower the RTT value higher the end to end TCP performance. If the value of the new RTT sample is much lower than current RTT value, the network ignores the value of the new RTT sample for some times, if the same value continues, network factors this value into the current RTT value using multiplicative decrease. An effective RTT value can be used as a metrics to load balance network traffic.

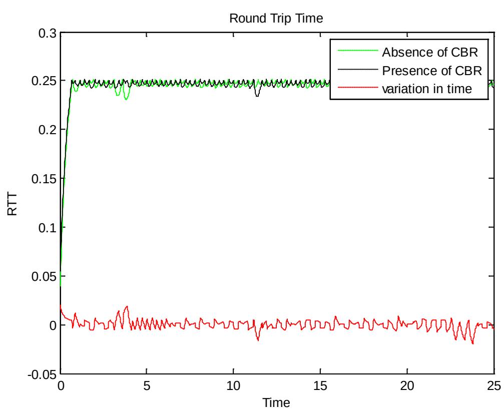

Figure 2

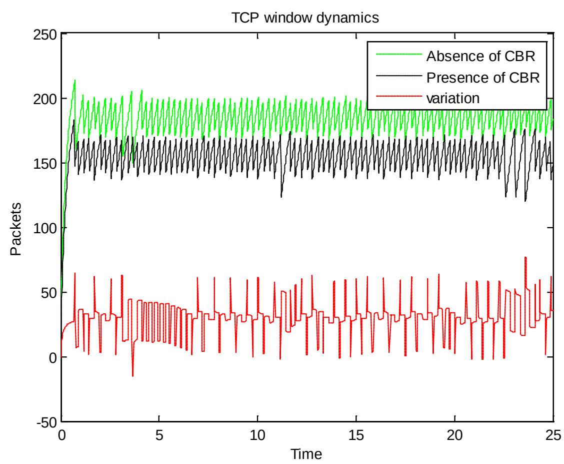

Figure 3

The TCP windows size is calculated in terms of packets. We assume packet size as 1000 bytes. TCP in absence of CBR flows varies over the range 17 – 213 with an average of 183 packets and in presence of CBR flows TCP varies in the range 17 – 182 with an average of 153 packets. Variation is in the range of 0 – 64 with an average of 30 packets. A TCP flow is inversely proportional to its RTT. TCP model (1) is a rate based model where rate is an average quantity of number of bits transferred over some interval of time and packets are visualised as fluid of bits on the wire. Figure (3) shows the rate of behaviour of TCP, i.e the exponential rate increase in slow start mode and saw tooth behaviour caused by packet drop in congestion avoidance mode.

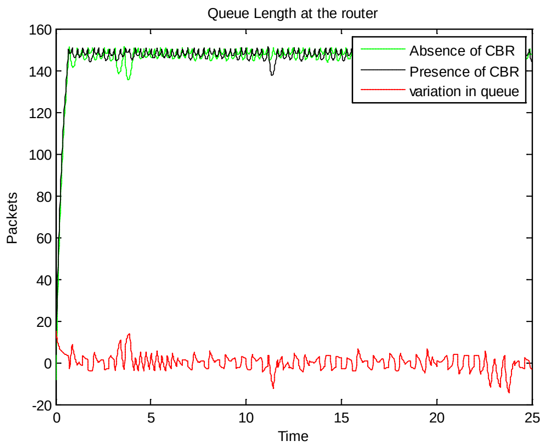

Figure 4

Both in Absence and presence of CBR flows queue length varies between 1 – 150 packets because maximum threshold value is 150 with an average variation of 0.0525. When the queue length is large RTT value in the network increases. Keeping queue length small, through put can be increased. In our work RED routers use packet dropping algorithm when queue exceeds the minimum threshold value of 50 packets and the TCP connections decrease their window size at the same time. It is very useful to keep queue size low to accommodate bursty traffic to avoid packet losses.

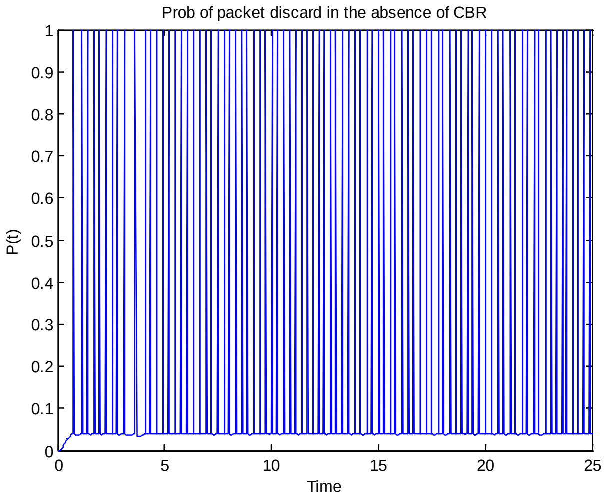

Figure 5

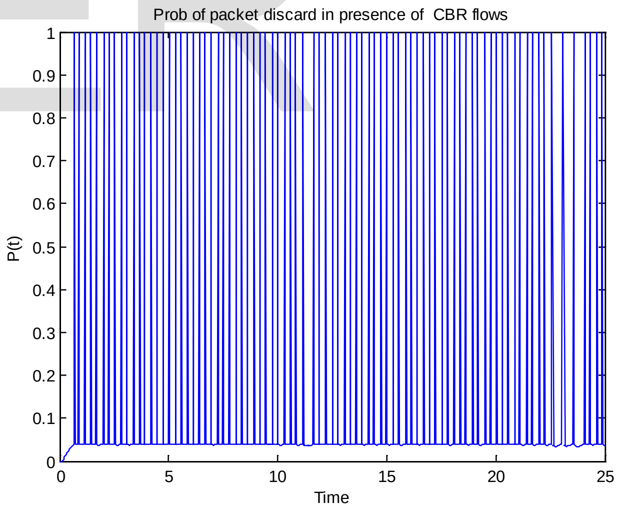

Figure 6

Figures (5) and (6) are packet discarding probabilities in the absence of CBR flows and in the presence of CBR flows respectively. Packet discarding is because of RED algorithm. Large number of P(t) values varies over the range 0.0024 – 0.0396 with an average value of 0.1065. When the queue length reaches a maximum threshold value of 150 packets, P(t)=1 and all the incoming TCP packets are discarded.

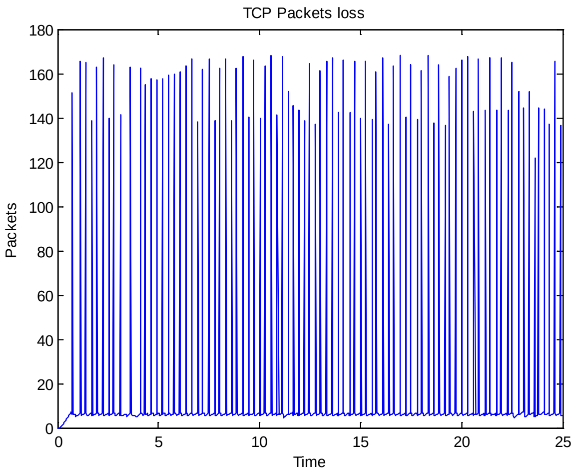

Figure 7

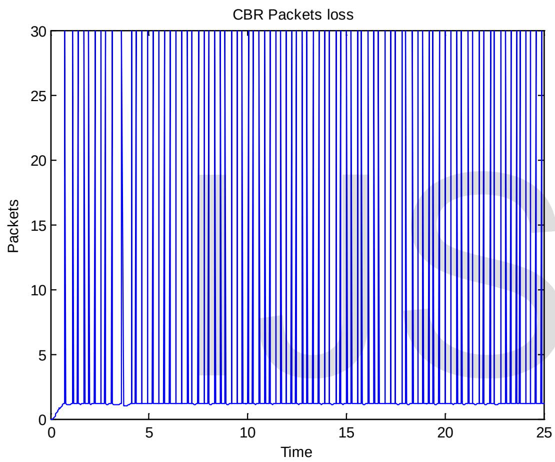

Figure 8

From figures 7 & 8 TCP packet loss varies between 0 – 7 with an average of 16 packets and CBR packet loss varies between 0 – 2 packets with an average of 2 packets. When queue length exceeds its threshold value 121 TCP packets and 30 packets of CBR lost.

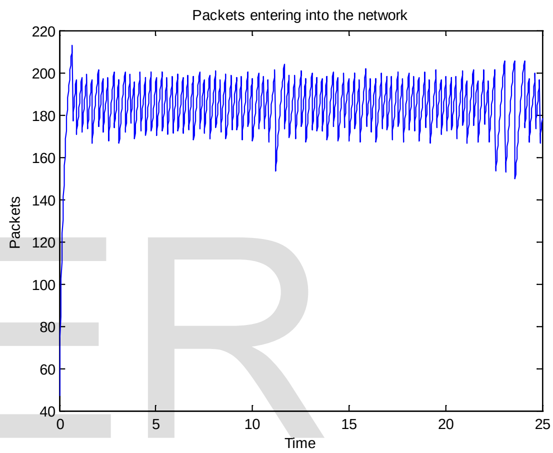

Figure 9

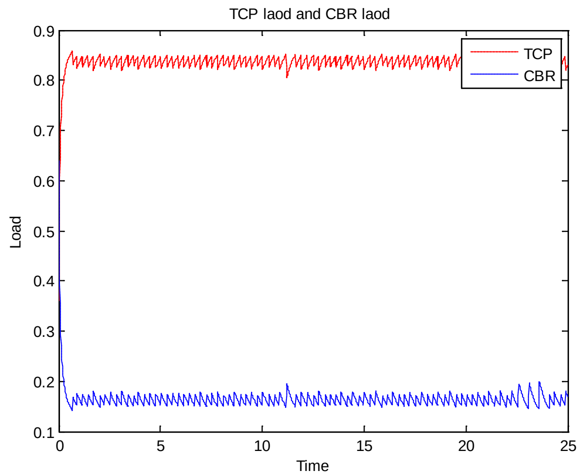

Figure 10

From figure 9, Packets entering into the network vary over the tang of 47 – 212 with an average of 184 packets. Figure 10, TCP load is an average of

0.8355 and CBR load is an average of 0.165 of the total bandwidth.

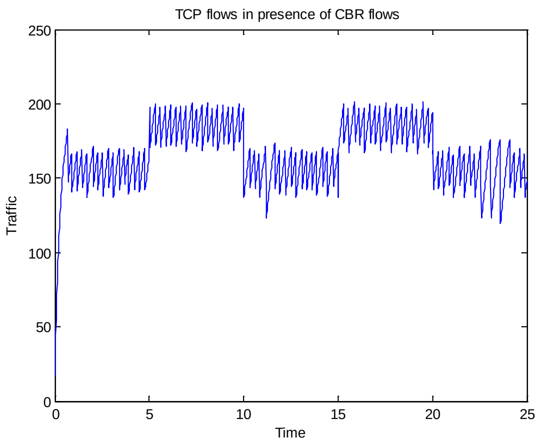

Figure 11

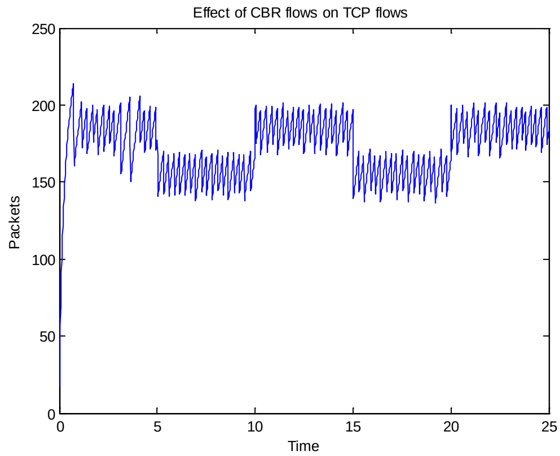

Figure 12

In figure 11 and 12, depicts the TCP flows in presence of CBR flows and effect of CBR flows on TCP flows respectively. 40 TCP flows were introduced at time t=1s, the flows quickly stabilise to an average value of 183s packets and are able to share the full capacity of the link. 240KB CBR traffic introduced at time t=6s and deactivated at t=10s. The TCP flows decreases by an average to 153s packets incurring a loss of 17% while the CBR traffic is present. The CBR sources benefit from their nonresponsive behaviour while TCP flows suffers poor performance.

5. CONCLUSION

Most of the internet applications are built using either responsive or nonresponsive protocols. Therefore it is necessary that the application designers to develop a mechanism for CBR flow to be TCP friendly and responsive to the network traffic.

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