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Enhancement of Performance of TCP Using Normalised Throughput Gradient in Wireless Networks

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Abstract. Transmission control protocol **(**TCP) is a dominant transport layer protocol for reliable data delivery in the internet. When packet loss occurs, TCP makes an implicit assumption that all packet loss is due to congestion. This results in unnecessary degradation in the TCP performance while traversing over a wireless link. In this paper, to improve the performance of TCP, we use NTG loss-predictor to distinguish congestion loss from transmission loss. Based on the prediction of type of loss, an appropriate algorithm is invoked by using NTG loss-prediction parameter β. Frequency of congestion loss and wireless loss predictions are analysed. Performance of TCP is improved further by discussing stability analysis over the system. A time-delay control theory is used and by constructing Hermit matrix, analysis is made for asymptotic stability of the system. Explicit conditions are derived for P_{max} (RED controller) and β (NTG loss controller) in terms of wireless network parameters. Using the characteristic equation of the matrix, convergence of the queue length at the bottleneck router is discussed. Analysis of convergence of queue length to a given target value is analysed. This establishes stability in the router performance. An approximate solution of queue length is derived. Our results provide better solutions for global stability and convergence conditions of the system.

Keywords: congestion-loss, convergence, immediate-recovery, loss-predictor, stability, transmission-loss, wireless-networks.

1. Introduction

Realistically, the existing Internet service uses the combination of wired and wireless media for communication, and is called as heterogeneous network. In wireless networks, packet losses are due to congestion and high bit error rate transmission over the wireless link. TCP, a widely used transport protocol, performs satisfactorily over wired networks and fails to perform well in the wireless networks because it is not be able to differentiate the loss caused by congestion or transmission. When a packet loss occurs during wireless transmission, TCP diagnoses it as a congestion event and reduce the flow rate. This policy will affect the performance of TCP and results in considerable degrade over wireless link [1], [2], [3], [20]. To improve the performance of TCP over wireless network, many techniques are proposed by the researchers. Some of them are, (i) I-TCP (Indirect TCP) - use two different links in the base station. One link is from base station to the mobile station and the other one is from wired host to the base station. Using wired link the base station receives data from the source and transmits the data to the mobile station using wireless link which feels like sending the data by using wired link [4]. (ii) M-TCP (Mobile TCP)-has the facility of keeping a retransmission timer in the base station. This timer is used by the sender TCP for checking the time-out period. For each receive of the data packet, base station sends an acknowledgement packet to the source before the timer period expires [5]. (iii) SNOOP is data link layer assisted protocol used to improve the performance of TCP in wireless networks (environment). The base station keeps track of all the packets transmitted from a source TCP. Base station keeps a copy of the packet in its buffer till it receives the acknowledgement. It removes the packet from its buffer after acknowledgement is received. When a packet loss occurs because of wireless transmission error, base station retransmits the lost packet. SOONP protocol does not answer for time-out event occurrence in mobile wireless transmission or the duplicate acknowledgements [6]. (iv) ELN (Explicit Loss Notification)-keeps the wireless loss information in the base station, and the base station sets the ELN bit to the duplicate acknowledgement. For the ELN-set duplicate acknowledgement, source TCP assumes that the packet loss is due to wireless transmission error and does not decrease its window size which results in congestion [7]. (v) W-TCP (Wireless-TCP)-is a rate-based wireless congestion control protocol. W-TCP assumes that the packet losses due to burst traffic as router congestion and random losses as the wireless transmission error. In each case, the receiver measures the time interval of the received packets and communicates the source to control the sending rate by using this time interval estimate. [8]. (vi) TCP Westwood- is a sender-side modification for wireless TCP. From the acknowledgement packet received, the sender estimates the current sending rate. For the congestion notification, the sender decides the congestion window size from the estimated sending rate. TCP Westwood has problem in time estimation and needs a fine-grained timer. In a dynamically changing network, the estimation cannot be accurate [9]. (vii) The ACK Pacing algorithm - can be used for black-out and hand-off delays. By sending ACK Pacing packets, burst data delivery is prevented from old path and the route update for new path [10]. (viii) JTCP (Jitter-based)-JTCP method is for heterogeneous wireless networks to adopt sending rates to the packet losses and jitter ratios [11]. (ix) ACK-Splitting-improves the TCP throughput over wired and wireless heterogeneous networks [12]. However, these schemes may not have good performance or fairness or it is too complex to deploy in wireless systems. To satisfy these challenges and for applying TCP over wireless link, we propose a model based scheme that can dynamically change the sending rate to the packet loss due to congestion and transmission. The model has integrated with the capability of distinguishing the packet losses due to congestion or transmission. If the loss is due to congestion, congestion control algorithm is invoked to reduce the network congestion and when the loss is due to transmission, immediate-recovery algorithm is invoked to recover from the decreased flow rate. One of the popular congestion avoidance schemes called RED (random early detection) and an accurate loss-predictor function called NTG loss-predictor which is designed based on CAT are used in the system model. Congestion avoidance technique (CAT) monitors the level of congestion in the network, and instructs the source that the sender window should be increased or decreased and vice versa. A TCP source understands that a particular packet has lost due to congestion or due to wireless transmission error and take appropriate action [18]. To enhance performance of TCP for further, we apply stability [13], [14], [22]. A time-delay control theory is used and hermit matrix method is applied to analyse the asymptotic stability. A relationship between RED parameter p_{max} and NTG loss-predictor parameter β is established. The stability boundaries are established in terms of wireless network parameters. The work is further enhanced by analysing the queue convergence at the ingress point of the bottleneck link. Using characteristic equation of the Hermite matrix, an approximate solution for the instantaneous queue length, q(t) is derived. The convergence boundaries of q_0, p_{max} and β are presented. Using these boundary values, convergence analysis of the queue length for a given target value is discussed. The helps in maintaining RED router stable. Using Matlab numerical results are given to validate the analytical results. The above illustrated characteristics collectively make TCP robust by minimising the packet losses and maximising throughput. Our results provide global stability and convergence conditions of the system.

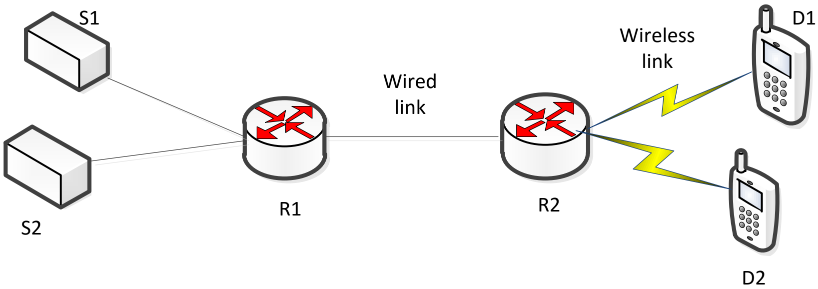

Fig.1: Network model.

2. System model for wireless networks

The The extended fluid model [15], [16], [17], [21] that describe the dynamics of the TCP congestion window size in wireless networks is,

$$dW(t) = \frac{dt}{RTT} - \alpha\, W(t)L_a(t) + \beta L_t(t) \tag{1}$$

TCP operates on AIMD congestion avoidance strategy. The factor α is decrease rate of source window which is normally 0.5, L_a (t) is the rate of arrival of packet losses due to congestion at time t and $L_a(t) =$