Modelling the Effect of a Rate-Smoothing Component on TCP Congestion Control Behavior

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TCP congestion control is the de-facto standard for transmission over the Internet, and it can be viewed as a nonlinear feedback control system that dynamically adjusts its transmission rate according to network congestion state. A significant amount of research work has been done on this system. For example, Jain and Chiu have proved that multiple TCPs converge to fair bandwidth-share by analyzing TCP's additive-increase and multiplicative-decrease (AIMD) algorithm. Padhye, et al., have derived equations for TCP's average throughput assuming that the TCP's feedback delay (round-trip-time) and packet loss rate are known.

Rate smoothing has been introduced into TCP in several contexts. Pacing within each round-trip-time was proposed to improve TCP's performance by Partridge, et al. Parallel to the TCP pacing work, several TCP-friendly congestion control mechanisms have been designed to provide smoothed rate for streaming multimedia. They control the transmission rate according to TCP's throughput equations or carefully choose the AIMD algorithm's parameters. These works have shown sophisticated bandwidth sharing behaviors. For example, Aggarwal, et al. showed some counter-intuitive results of TCP pacing, and other experiments on a tail-drop queue show that a TCP-friendly flow (according to the throughput equation) doesn't necessarily share bandwidth equally with other TCP flows.

The focus of our work is to understand the effect of rate smoothing on TCP congestion control behavior. We view both TCP pacing and TCP-friendly congestion control as forms of TCP rate smoothing. We have built a particular rate smoother that keeps average throughput equal to the throughput of standard TCP and can adjust inter-packet intervals independently of TCP's round-trip-time, enabling us to study the behavior of various smoothing strategies. We have also developed a feedback control model for TCP congestion control in the presence of rate smoothing.

In this demo, we will describe how our rate smoother works, and we will demonstrate our models of rate smoother and TCP congestion control in Matlab Simulink. We believe smoothing changes the dynamic behavior of bandwidth sharing among TCPs, which is related to the loss distributions among competing flows. To investigate this smoothing impact, we construct a phase plot to show the system's dynamic behavior. A phase plot visualizes the trajectory of a system's state along the time. The state variables that we choose to represent the system state include the transmission rates of all competing TCPs and the network buffer fill-levels.

To this end, our simulations show that bandwidth sharing behavior is closely related to the loss distribution at various points on the phase plot. When we assume a unified packet loss distribution, the system trajectory converges to equal bandwidth-share, but the shape varies as the parameters of the rate smoother vary. However, with a loss distribution related to the competing flow rates, the system trajectory is not guaranteed to reach equal bandwidth-share. We plan to study how the system state trajectory is related to packet losses as the next step of our research.