Two Problems of TCP AIMD Congestion Control [*]

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Abstract

AIMD (additive increase and multiplicative decrease) algorithm has been used in many congestion control protocols, including TCP in the Internet. In this paper, we compared AIMD and MAIMD (multiplicative additive increase and multiplicative decrease). We found that the convergence speeds to fair states of AIMD and MAIMD are close to each other. However, we observe that MAIMD has some advantages. For example, its speed to use network available bandwidth can be much faster than AIMD. We also investigated AIMD behaviors under a more realistic asynchronous system model. We found that under this model, AIMD system can have more than one attractor, and therefore can be another contributor to the fairness problem of TCP.

1 Introduction

In a shared network, such as the Internet, end systems should react to congestion by adapting their transmission rates to avoid congestion collapse and keep network utilization high [3]. The robustness of the current Internet is due in large part to the end-to-end congestion control mechanisms of TCP [5]. In particular, TCP uses an *additive increase multiplicative decrease* (AIMD) algorithm [2]; the TCP sending rate in congestion avoidance state is controlled by a congestion window which is halved for every window of data containing a packet drop, and increased by one packet per window of data acknowledged. Recently, many new congestion control protocols were proposed and investigated [4, 6, 13, 11, 1, 14, 7, 10, 12, 8, 15]. The objective of these new congestion protocols is to address the needs of new multimedia applications. We notice that, like TCP, many of these proposals are also based on the AIMD principle. Further, there is even a common belief that AIMD is optimal and is a necessary condition for a congestion control mechanism to be stable [9].

AIMD congestion control was first studied by Chiu and Jain [2]. Figure 1 shows the system model they used to analyze a congestion control system.

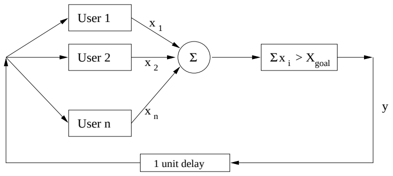

Figure 1: Chiu/Jain congestion system model

In this model, x_i denotes the load generated by user i. The congestion status of the network at time t is measured by $X(t) = \sum x_i(t)$. When $X(t) > X_{goal}$, the network is considered to be congested and the network sends a signal $y = 1$ to ask all users to slow down; otherwise, the network indicates no congestion by sending $y = 0$. In this case, all users increase their load.

Formally, the dynamics of the system can be specified as:

$$\begin{aligned} X(t) &= \sum x_i(t) \\ y(t) &= \begin{cases} 0 & \text{if } X(t) \leq X_{goal} \\ 1 & \text{otherwise} \end{cases} \\ x_i(t+1) &= \begin{cases} a_I + b_I x_i(t) & \text{if y(t) = 0} \\ a_D + b_D x_i(t) & \text{otherwise} \end{cases} \end{aligned} \tag{1}$$

It is important to notice that Equation (1) assumes homogeneous delay for all users, with a unit delay on each feedback link. In other words, what the authors have analyzed is a synchronous system.

Denote $\mathbf{x}$ as a vector of all users load x_i. Define a fairness index function $F(\mathbf{x})$ as:

$$F(\mathbf{x}) = \frac{(\sum x_i)^2}{n(\sum x_i^2)} \tag{2}$$

With the above system model in Equation (1) and the definition for fairness index function F in Equation (2), the authors derived the following results:

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