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IDFC: A new approach to control bifurcation in TCP/RED

Maziar Ahmad Sharbafi [a,*], Mohammad Javad Yazdanpanah [b]

[a] ECE Department, Islamic Azad University of Qazvin, Qazvin, P.O. Box 14395/515, Tehran, Iran
[b] Control and Intelligent Process Center of Excellence (CIPCE), School of ECE, University of Tehran, Tehran, Iran

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ABSTRACT

The main objective of this research is to analyze the bifurcation phenomenon in Internet congestion model for Transmission Control Protocol (TCP) with Random Early Detection (RED). This problem can be divided to many categories considering different viewpoints. Different approaches of modeling (continuous and discrete models) and various system structures (control in end node or routers) are some of these categories. The most significant method in control of such systems is Delayed Feedback Controller (DFC). In this paper, a discrete model is considered and a new algorithm Integral DFC (IDFC) is presented that has many preferences over similar algorithms, which are illustrated by simulation results and analytical discussions.

1. Introduction

Analyzing the nonlinearity of systems resulting in unpredictable behavior is the main subject of many studies in the nonlinear control field. Bifurcation and chaos make two significant categories in such challenging problems. Many attitudes toward control engineering are related to bifurcation, which has recently made a vast field of research (Chen et al., 2004; Kang, 1998; Ma et al., 2008; Zhang et al., 2007). Studying bifurcation includes many branches from solving control problems to stability analysis and control of systems containing bifurcation via nonlinear tools (Ghosh et al., 2008; Ma et al., 2008; Zhang et al., 2007).

Delayed systems make one of the largest groups of systems, resulting in bifurcation and complex situation in control. In other words, system delay is one of the most important reasons of bifurcation occurrence, which are studied a lot in the literature (Ding and Li, 2007; Ghosh et al., 2008; Ma et al., 2008; Xiao and Cao, 2007). One of the state-of-the-art research case studies in problems with such characteristics is Internet congestion control (Chen et al., 2004; Liu et al., 2005; Ranjan and Abed, 2002).

The congestion occurs when a low speed link wants to serve to two high-speed links and control is applicable in end nodes or middle points (routers). Many approaches have been introduced to solve the problem in an optimum manner; however, it is still an interesting open problem. Tahoe, Reno and SACK (which are compared with each other in Fall and Floyd (1996)) are some of the suggested methods to control the window size (*cwnd*) in the end system that react to the acknowledgment (ACK) received via the sender by changing *cwnd*. On the other hand, RED, REM and PI are instances of control, which tune the probability of packet loss in routers (Yaghubi, 2005). The whole Internet congestion avoidance operation is a combination of the end-to-end Transmission Control Protocol (TCP) congestion control mechanism (Jacobson, 1988) and queue management mechanism at the router (Yaghubi, 2005).

Many researchers have developed different techniques to postpone (in terms of values of corresponding parameters) the occurrence of bifurcation (Ranjan and Abed, 2002; Chen et al., 2004). The main approach is the delayed feedback control (DFC) in which the difference between the state and its delayed ones multiplied by a coefficient is utilized as the controller (Ranjan and Abed, 2002; Xiao and Cao, 2007). This paper is started with a discrete model presented in Liu et al. (2005) and then the possibility of the bifurcation phenomenon is investigated. Next, with respect to the DFC approach, a new controller, Integral DFC (IDFC), is introduced in order to cope with difficulties of the problem. This controller is implemented in end nodes and its desirable performance is illustrated by simulation results and mathematical proof. Another point in this research is to elevate the control quality with respect to different factors considered as bifurcation parameters.

2. Bifurcation and period doubling

Analyzing dynamic systems and investigating their behaviors are popular fields of study in nonlinear systems. Recently, bifurcation

* Corresponding author. Tel.: +98 21 66937246.
E-mail address: sharbafi@ut.ac.ir (M. Ahmad Sharbafi).

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