ABSTRACT

This paper introduces and analyzes a class of non-linear congestion control algorithms called polynomial congestion control algorithms. They generalize the Additive Increase and Multiplicative Decrease (AIMD) algorithms used for Transmission Control Protocol (TCP) connections. These algorithms provide additive increase using a polynomial of the inverse of the current window size and provide multiplicative decrease using the polynomial of the current window size. There are infinite numbers of TCP-compatible polynomial algorithms by assuming a polynomial of a different order. This paper analyzes the interaction between the two models (Multiplicative Increase and Multiplicative Decrease/MIMD-Poly and Polynomial Increase and Polynomial Decrease/PIPD-Poly) of these generalized algorithms, for wired (with unicast and multicast) and wireless TCP networks. TCP compatibility of these algorithms is evaluated using the simulations of the implementations of the proposed two models. Simulations are done using ns2, a discrete event simulator. The model MIMD-Poly is proved to be TCP compatible. The results of the simulation are compared with TCP variants, such as TCP/Tahoe, TCP/Reno, TCP/New Reno and TCP/Vegas. The comparison shows that both algorithms perform better in terms of throughput.

Keywords: AIMD; congestion control; mobile ad hoc networks; multicast; non-linear algorithms; ns2; TCP

INTRODUCTION

During the last decade, computer networks have been growing tremendously. A large number of computers get connected to both private and public networks. In most of these networks, the protocol stack used is TCP/Internet Protocol (IP). In spite of the rapid growth and explosive increase in traffic demand on computer networks in general, the Internet in particular is still working without collapse.

In addition, the growth of the Internet has sparked the demand of several applications that require the stability of the Internet.
For achieving such success and to have the stability of the Internet, mechanisms are developed to reduce transmission errors, provide better bandwidth sharing of sources that use common bottleneck links, reduce round-trip time (RTT) and, mainly to provide congestion control by the transport layer protocol (i.e., TCP). TCP’s end-to-end congestion control mechanism reacts to packet loss by adjusting the number of outstanding unacknowledged data segments allowed in the network (Van Jacobson, 1988; Widmer, Denda, & Mauve, 2001). Such algorithms are implemented in its protocol, TCP. (Comer, 1991; Stevens, 1994; Allman, & Paxson, 1999). In the existing algorithms, increasing the congestion window linearly with time increases the bandwidth of the TCP connection, and when the congestion is detected, the window size is multiplicatively reduced by a factor of two (Yang & Lam, 2000).

TCP is not well suited for several emerging applications, including streaming and real-time audio and video, because it increases end-to-end delay and delay variations (Jin, Guo, Matta, & Bestavros, 2001).

This paper analyzes a new class of nonlinear congestion control algorithms for Internet Transport Protocols and applications. It seeks to develop a family of algorithms for applications, such as Internet audio and video, which do not react well to rate reductions, because the rate reduction technique used for these applications will result in degradation in user-perceived quality (Allman et al., 1999; Floyd & Fall, 1999). This analysis results in a good understanding of TCP-compatible congestion control algorithms by generalizing the AIMD algorithms. We analyze the proposed algorithms in a simulated wired TCP network.

One of the current challenges of the Internet is to allow universal access to multimedia transmissions, even for receivers located within networks of different bandwidth and other characteristics. Multicast allows one single transmission to be delivered to a large number of receivers over a network (Seada, Gupta, & Helmy, 2002). Congestion control is a major requirement for multicast to be deployed in the current Internet. This paper analyzes the performance of the proposed congestion control algorithms in a wired network that employs multicast routing strategies.

With the proliferation of mobile computing devices, the demand for continuous network connectivity regardless of physical location has created greater interest in the use of mobile ad hoc networks (Sundaresan, Anantharaman, Hsieh, & Sivakumar, 2003; Holland & Vaidya, 1999). This paper also analyzes the performance of the proposed algorithms in mobile ad hoc networks that use TCP and compares the performance of the two proposed models with the standard AIMD algorithms implemented for TCP networks.

In all simulations, the proposed two models are named MIMD-Poly and PIPD-Poly. They are compared with TCP variants such as TCP/Tahoe (called TCP), TCP/Reno, TCP/New Reno, TCP/Vegas and the comparisons are simulated in ns-2, the discrete event-driven simulator used by most network researchers.

This paper is structured as follows: First, we briefly describe the basic AIMD congestion control rules and existing TCP congestion control algorithms. Next, we discuss the proposed generalized congestion control algorithms, called Polynomial algorithms, and the two models MIMD-Poly and PIPD-Poly. Then, we analyze the proposed algorithms, and MIMD-Poly is
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