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Interfaces with Other Disciplines

Fair allocation using a fast smart market auction

Chu-Fen Li [a,*], Jung-Shian Li [b]

[a] *Department of Finance, National Formosa University, 64 Wun-Hua Road, Huwei, Yunlin 632, Taiwan, ROC*
[b] *Department of Electrical Engineering, Institute of Computer and Communication Engineering,*
National Cheng Kung University, Taiwan, ROC

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Abstract

Allocation of network resources may be formulated as an optimization problem seeking to maximize the sum of the utility function of each flow. Individual flows collectively achieve social welfare with a constraint that global fairness must be provided by a congestion control scheme using congestion indication feedback signals. However, in the reality, non-cooperative flows without employing any congestion control scheme do not respond to congestion indication feedback signals. In this paper, we analyze fairness of congestion control with cooperative and non-cooperative flows for communication networks. Furthermore, we propose a fast smart-market auction (FSMA) approach to achieve social welfare in the environment that cooperative and non-cooperative flows coexist. Through detailed simulations, the proposed approach is proven to be effective in providing fairness.

Keywords: Congestion control; Efficiency; Fairness; Fast auction; Smart market; Social welfare

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1. Introduction

When a communication network becomes congested, two actions may be taken. First, end users might stop sending packets. Then, congestion should be cut down since the generated traffic decreases. Second, routers in the network might drop packets. Congestion can also be alleviated with less transmission packets. Regardless whether dropping packets in the routers or suppressing packets in the sources is adopted, fairness should be provided. These issues are important for the future e-business on the Internet. Traffic generated by applications that are able to modify their data transfer rates according to the available

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[*] Corresponding author. Tel.: +886 5 6315756; fax: +886 5 6331950.
E-mail address: cfli@nfu.edu.tw (C.-F. Li).

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bandwidth within the networks is termed *cooperative*. Kelly [13] has shown that the aggregate utility is maximized according to a weighted proportional fairness if users' utilities are concave functions of their attained throughput. He has also shown that a weighted proportionally fair allocation could be achieved by simple rate control algorithms using additive increase and multiplicative decrease rules like Transmission Control Protocol (TCP) [14,15,17]. The prescribed researches assume cooperation of applications. The social welfare and fairness can be achieved if all the applications are cooperative. However, more and more non-cooperative real-time applications use non-adaptive algorithms similar to User Datagram Protocol (UDP). Here, we want to discuss how the available bandwidth within the networks could be shared between competing streams of *cooperative* and *non-cooperative* flows. The smart market approach has been proposed by MacKie-Mason and Varian [16]. The approach is employed to allocate resources in a network, where a price is set for each packet depending upon the level of demand. In this paper, we present that the benefits of a smart market may be achieved by a very simple proposed mechanism when cooperative and non-cooperative flows coexist. The proposed scheme, called Fast Smart-Market Auction (FSMA), can provide both social welfare and fairness for cooperative and non-cooperative flows.

The success of the Internet lies in keeping the router simple and distributing the complexity to the end-hosts. In the proposed FSMA scheme, the router maintains only a zombie list, by which a threshold cutoff is calculated. When congestion occurs, the router drops packets by comparing the mark of each packet with the threshold cutoff. The marking of packets is performed in each end-host and remarking in the router is not necessary for FSMA, contrary to Core-Stateless Fair Queueing (CSFQ) [9].

The rest of the paper is structured as follows. Section 2 describes our proposed rate-marking algorithm and discusses the difference of cooperative and non-cooperative flows in nature. In Section 3, the methods for marking the price in packets for cooperative and non-cooperative flows are presented. Furthermore, the fast auction algorithm is described. Section 4 shows the simulation results of our proposed scheme compared with CSFQ [9] and Fair Random Early Detection (FRED) [5], which have similar complexity. Finally, we describe our conclusion in Section 5.

2. Rate-marking algorithms

On the Internet, packet loss may occur as a result of transmission errors, but also, and most commonly, as a result of congestion. TCP end-to-end congestion control mechanism reacts to packet loss by reducing the number of outstanding unacknowledged data segments allowed in the network. TCP flows that share a common bottleneck reduce their rates so that the available bandwidth will be, in the ideal case, distributed equally among them.

Not all Internet applications employ TCP congestion control and therefore, the available bandwidth may not be allocated fairly among flows. Unfairness is not obvious if most of the applications use TCP-friendly congestion control schemes, such as HTTP, SMTP, or FTP. However, the amount of audio/video streaming applications such as Internet audio players, IP-telephony, video conferencing and similar types of real-time applications is constantly growing and the percentage of non-TCP traffic increases tremendously. Since these applications do not integrate TCP-compatible congestion control mechanisms, they treat competing TCP flows in an unfair manner: upon encountering congestion, all contending TCP flows reduce their data rates in an attempt to dissolve the congestion, while non-TCP flows continue to send packets at their original rate. This unfair situation can lead to starvation of TCP traffic, or even to a *congestion collapse* [2], which describes the undesirable situation where the available bandwidth in a network is almost exclusively occupied by packets that belong to flows without equipping any congestion control mechanisms [10].

A handful of approaches to dealing with congestion in the router have been proposed. Some of these are Source Quench, Random Drop, Congestion Indication, Selective Feedback Congestion Indication, Fair