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A multiobjective fuzzy bandwidth partitioning model for self-sizing networks

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Abstract

The ability to cope with dynamic bandwidth demands is a special feature for Quality of Service provisioning in networks carrying bandwidth hungry applications. This paper introduces a novel approach based on multiobjective fuzzy optimization for dynamic bandwidth allocation. This new approach deals with uncertain bandwidth demands more efficiently than approaches based on Classical Optimization Theory and yet supports Quality of Service commitments.

Keywords: Fuzzy optimization; Quality of service; Network simulation; Bandwidth allocation

1. Introduction

Although resource over-provisioning is currently a common practice among communication service providers (Barkat et al., 2002), such a design choice is increasingly recognized as less desirable, given economic trends in the telecommunications business (Macian et al., 2003). Moreover, the development of broadband access technologies will allow end-users to consume bandwidth hungry services, pushing providers to satisfy higher demands of bandwidth with stringent quality of service requirements.

Furthermore, the increasing use of such services by the end-users will result in highly dynamic bandwidth demands, making the capacities of rapid and efficient bandwidth provisioning a key issue.

"Self-sizing" networks (Nakagawa et al., 1996) are capable of automatically allocating bandwidth and switching capacity according to instantaneous demands. Such allocation calls for evaluating the bandwidth demand on-line as well as re-routing traffic to meet quality of service expectations. Fig. 1 illustrates the benefits of a self-sizing approach by plotting the loss rates both in traditional (non-self-sizing) and in self-sizing networks. While in traditional networks the bandwidth allocated and path taken by the traffic are static, in self-sizing networks they are dynamic, leading to a higher degree of adaptation and, consequently, lower loss rates (further details about the derivation of this figure are given in Section 4).

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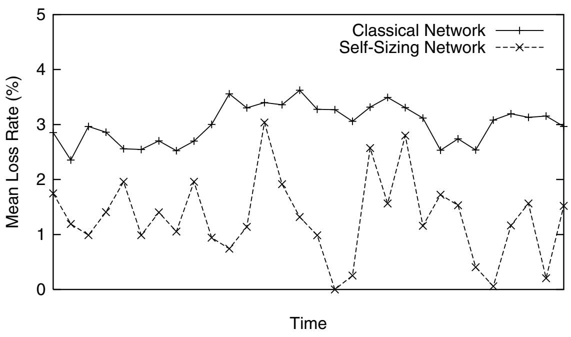

Fig. 1. Mean loss rate in classical and self-sizing network.

Self-sizing is one of the aspects of Autonomic Computing systems which can manage themselves given high-level objectives defined by administrators (Kephart and Chess, 2003). The four aspects of self-management in autonomic computing are: self-configuration, self-optimization, self-healing and self-protection.

Self-sizing frameworks for globally controlled networks, such as, ATM networks were proposed in the past (Nalatwad et al., 2004; Hao et al., 2000; Yan, 1998; Nakagawa et al., 1996). However, the self-sizing concept can be extended to current routing/switching technologies such as MPLS/GMPLS networks (Shen and Devetsikiotis, 2002). The traffic engineering approach used in self-sizing networks divides the network bandwidth into virtual ''bands'', with each band dedicated to a different type of traffic. Flows of a specific media with the same source–destination pair are grouped in the same band and the widths of these bands are dynamically adapted according to the varying demands. This adaptation of the width of virtual bands is performed periodically and the demand estimated via measurement procedures. An agent (or ''bandwidth broker'') uses these estimates to decide the width of each band. The decision should minimize costs and avoid resource wastage.

Fig. 2 illustrates the self-sizing process which is conducted by taking four steps. First traffic measurements are collected so that information can be used to estimate the demanded bandwidth. Knowing the bandwidth demands, an optimal partition of the available bandwidth can be sought for reconfiguring network resources and the routing of flows.

Two key steps are the evaluation of the bandwidth demand of each virtual band and the decision making process for bandwidth partitioning. The accuracy of the bandwidth demand estimation influences the optimality of the band partitioning. Moreover, this accuracy depends on the measurement procedures and tools adopted.

The frequency of the bandwidth allocation decisions should be on the same time scale as the bandwidth demand fluctuations, in order to render effective Quality of Service provisioning. Moreover, the accuracy of bandwidth estimation depends on the sample sizes (Jain and Dovrolis, 2004).

The uncertainty about the precision of bandwidth estimation as well as about the ideal frequency of the bandwidth allocation calls for procedures which incorporates these uncertainties in the design process.

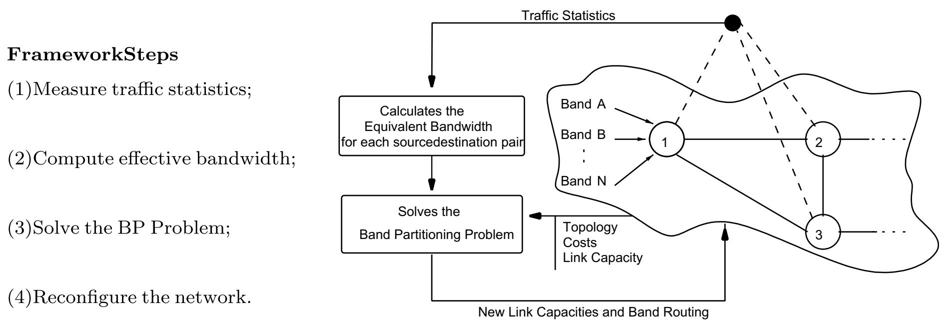

Fig. 2. Self-sizing networks framework.