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Discrete bandwidth allocation considering fairness and transmission load in multicast networks

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Abstract

As a promising solution to tackle the network heterogeneity in multicasting, layered multicast protocols such as receiver-driven layered multicast (RLM) and layered video multicast with retransmission (LVMR) have been proposed. This paper considers fairness as well as transmission load in the layered multicasting. Lexicographically fair bandwidth allocation among multicast receivers is considered under the constraint of minimum bandwidth requirement and the link capacity of the network. The problem of transmission load in the layer multicasting due to various user requirements is also examined by minimizing the number of layers.

The bandwidth allocation is formulated as a nonlinear integer programming problem. A dual-objective tabu search is proposed to solve the fairness and transmission load problem in multicast networks. Outstanding performance is obtained by the proposed tabu search. When the fairness objective is considered, the solution gap from the optimal solution is less than 2% in problems with 50 virtual sessions. The complexity of the dual objective largely depends on the weighting factor of the two objectives. Even in tough cases the proposed tabu search provides excellent solution, whose gap is within 6% from the optimal solution.

Keywords: Multicast network; Fairness; Layered transmission; Bandwidth allocation; Tabu search

1. Introduction

Multicasting provides an efficient way of transmitting data from a sender to a group of receivers. Instead of sending a separate copy of the data to each individual group member, a source node sends one stream of messages to any one segment of the network on which there is a subscriber. An underlying

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routing algorithm determines a multicast tree connecting the source and group members. Data generated by the source flow through the multicast tree, traversing each tree edge exactly once. As a result, multicast is more resource-efficient and is well suited to applications such as teleconferencing, video-on-demand (VOD) service, electronic newspapers, cyber education and medical images.

In a multicast network multiple sessions each with different group members share network resources simultaneously. Thus, it is ideal to provide a fair share of bandwidth to each session. This issue of inter-session fairness has been extensively studied in unicast networks. In case of multicast, the other notion of fairness, i.e., intra-session fairness, has to be considered because of the network heterogeneity that is due to various networks connected to the Internet. Users having high bandwidth connectivity would prefer to receive a higher rate and higher quality service, while users with low bandwidth connectivity would be satisfied with a low rate service. Thus, multirate multicast technology is necessary for transmission in heterogeneous networks. Receiver-driven layered multicast (RLM) [1] and Layered video multicast with retransmission (LVMR) [2] are well-known protocols for a layered multicast that satisfies the multirate multicast. The source signal is encoded and presented to the network as a set of bit streams, called layers. Layers are organized such that the quality of reception is proportional to the number of layers received. The first layer provides basic information, and every other layer improves data quality.

In layered multicast, a multicast session requires more and more layers to transmit as each receiver in the multicast group requires different bandwidth due to the network heterogeneity. Here, increased number of layers in a session results in high overheads for sender encoding, multicast address allocation and receiver decoding. To prevent the high overheads required for layered multicast a source needs to set the number of layers to transmit and assign bandwidth to each layer by organizing requirement by receivers [3].

In this paper, we are interested in multicast transmission that satisfies fair bandwidth allocation with a lower overhead. The number of layers employed for receivers in each session needs to be minimized, while satisfying fairness among receivers.

The paper is organized as follows: Section 2 discusses fairness and transmission load in multicast networks. A nonlinear integer programming model is presented in Section 3 for the bandwidth allocation problem. A dual-objective tabu search is developed to solve the fairness and transmission load problem in Section 4. An optimal solution for the bandwidth allocation is discussed in Section 5. Computational results and conclusion are presented in Sections 6 and 7, respectively.

2. The issue of fairness and transmission load in multicast network

When a network has profound heterogeneity, the fairness must include the characteristics of a multirate multicast network. Each source of multicast session transmits data to all of its receivers at a different rate. One of the frequently used definitions of fairness in multi-rate multicast networks is lexicographically optimal fairness [4,5]. Different from the well-known max–min [6–9] fairness, the lexicographically optimal fair allocation always exists in a discrete case [4]. A bandwidth allocation vector is lexicographically optimal, if its smallest component is the largest among the smallest components of all feasible bandwidth allocation vectors. Subject to this, it has largest second smallest component, and so on.

As an example, consider the network in Fig. 1. In the figure a virtual session is defined as a source and receiver pair of a session. Each virtual session may have different data quality even if the original content is the same as other virtual sessions. Session 1 consists of virtual session 1 (path 1–3–4) and