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Multicast tree rearrangement to recover node failures in overlay multicast networks

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Abstract

Overlay multicast makes use of the Internet as a low level infrastructure to provide multicast service to end hosts. The strategy of overlay multicast slides over most of the basic deployment issues associated with IP multicast, such as end-to-end reliability, flow and congestion control, and assignment of an unique address for each multicasting group.

Since each multicast member is responsible for forwarding multicast packets, overlay multicast protocols suffer from multicast node failures. To cope with node failures in the overlay multicast networks, the employment of multicast service nodes (MSNs) is considered which allows relatively high processing performance to cover the disconnected nodes. We are interested in minimizing the cost of both the MSNs and additional links when a node failure occurs.

Overlay multicast tree rearrangement to connect multicast members is discussed and formulated as a binary integer programming problem. The tree rearrangement problem is solved by a heuristic based on the Lagrangian relaxation. The performance of the proposed algorithm is investigated by carrying out experiments in 50 and 100 node problems. The employment of MSNs is illustrated to be dependent on the end-to-end delay bound in overlay networks and the degree constraint of member nodes.

Keywords: IP multicast; Overlay; Node failure; Lagrangean relaxation

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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 identical messages simultaneously to multiple destination nodes. An underlying multicast routing algorithm determines a multicast tree connecting the source and group members. Data generated by the source flows 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. However, despite the conceptual simplicity of IP multicast and its obvious benefits, its deployment is difficult due to the complexity of IP multicast technology and lack of applications.

To cope with the increasing traffic of multimedia contents, the study on multicasting will become more active. Recent efforts to provide multicast delivery have thus shifted to overlay multicast that builds a transport-layer overlay network among members of a multicast group. Recent topics related to overlay multicast includes [1–9] as an alternative to IP multicast. Overlay multicast uses the Internet as a low level infrastructure to provide multicast service to end hosts. Many basic deployment issues such as end-to-end reliability, congestion control, and assignment of an unique address for each multicasting group that are associated with IP multicast can be solved with overlay multicast.

Current overlay multicast projects can be classified into two catalogs according to the structure: end-to-end overlay [1,3,5] and proxy-based overlay [2,4]. In end-to-end overlay, every member in the multicasting group shares the responsibility to forward data to other members. End hosts organize themselves into a multicasting tree. We call these end hosts multicast nodes in the end-to-end overlay case. Scattercast [2] and Overcast [4] are typical examples of proxy-based overlay structure that form a hierarchical structure compared to end-to-end overlay. The multicasting service is performed with the help of proxy nodes, which can duplicate data and forward them to end hosts with predefined routing algorithm. In proxy-based overlay, proxy is the multicast node and end hosts just receive the multicast data from the corresponding proxies.

Representative research [7] on overlay multicast protocol includes Scattercast, Overcast, Narda [3] and ALMI [5]. Each protocol has different design objectives, which leads to different properties. Narda and Scattercast intend to minimize the delay from a multicast source to each member. ALMI strives to minimize the multicast tree cost, where the cost of each link is defined as the round-trip delay between group members. Overcast, on the other hand, maximizes available bandwidth for each member. In the tree construction process, Narda and Scattercast use a mesh-first approach. That is, group members are first connected into a mesh and then the multicast tree is built on top of it. On the other hand, Overcast and ALMI use a direct approach. The step to build the mesh is bypassed and the multicast tree is formed directly.

In overlay multicast, since multicast members are responsible for forwarding multicast packets, they suffer from multicast node failures. When a multicast node fails, rapid multicast tree recovery is essential to distribute multicast data to disconnected nodes. However, many researchers have focused their attention mainly on constructing the initial overlay multicast tree [1–6,8,9]. In this paper, we are interested in solving the tree rearrangement problem by establishing new connections for the multicast members when a multicast node failure occurs.