Multicast Address Management and Connection Control Based on Hierarchical Autonomous Structure

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Abstract Multicast capability, including multicast address and multicast routing mechanisms, at the network layer is necessary in order to reduce the bandwidth requirements of multiparty, multicast applications. Based on hierarchical autonomous structure in accordance with the self-organization topologies of Internet, the paper puts forward a multicast address management scheme that is shown to be robust and scalable. Connection control hierarchy (CCH) based on master/slave relationship and a simple efficient building algorithm of multi-point connection is also built. The paper also describes the normal operations of multicast address management and multi-point connection controller. Through simulation experiment, HAM, CM and DDM of Multicast Address Allocation are compared. HAM integrates the merits of CM and DDM, which is efficient as a whole, robust and scalable. CCH raises the efficiency of connection control, and is highly robust, flexible and scalable.

Keywords hierarchical autonomous structure (HAS), multicast address management, multi-point connection control

1 Introduction

Multicast capability at the network layer is necessary in order to reduce the bandwidth requirements of multiparty, multicast applications. Integral to such a capability are multicast address (i.e. a set of network addresses that designate a group of recipients), and multicast routing mechanisms. Applications that make use of multicasting have to address four main issues: (1) multicast addresses management, (2) connection control, (3) call management, and (4) data transport.

Multicast group address must be assigned to multiparty session\(^1\). In contrast to conventional network addresses that are administratively allocated to unique hosts, multicast addresses have to be freely available. Multicast addresses have to be dynamically allocated to multi-point applications, and returned to the network when no longer needed. That is to say, conventional network addresses are host-oriented, while multicast addresses are session-oriented. Furthermore, the same address must not be assigned to concurrent sessions, as this will lead to interference or 'cross-talk'. In the IP environment, there is currently no such robust and scalable dynamic allocation mechanism, and users have to exchange beforehand all relevant communication parameters to establish a session, using conventional means. These limitations hinder further development and deployment of multi-party applications, and unnecessarily move the burden of network management operations to the users. The expected growth in the number of multicast applications will demonstrate the need for an effective and dynamic management scheme of address.

Although there have been a number of proposals for multicast transport protocols, such as XTP, ST-II, MTP, RTP, etc., they all assume that there exists some outside authority for allocating and managing multicast addresses. Braudes\(^2\) has proposed an actual architecture for multicast address management, although not in sufficient detail. In this architectural
outline, a Multicast Group Authority (MGA) hierarchy manages the addresses, with a centralized controller as the root of an administrative tree. One significant drawback of this approach is that nodes closer to the root of the tree have to be able to sustain very high levels of control traffic. In addition, if any of the intermediate nodes or links in the MGA hierarchy breaks down, nodes below and above cannot exchange free multicast addresses. Eleftheriadis advanced an MAMCC protocol (named as DDM in the paper), a distributed mechanism for multicast address allocation and connection management. MAMCC is a domain-based allocation scheme, but it does not take advantage of the inter-domain structures and relationships to address the tradeoff between the blocking probability and the session setup delay, and to facilitate building multi-point connection. Besides, its multicast address space-partitioning scheme is incomplete.

A broadcast application that can potentially involve a large number of users (possibly thousands) can dispense with connection control due to the computational and bandwidth overhead associated with any distributed algorithm of such scale. This specific style of multiparty session will be referred to as “open-style”, due to the loose coupling among participants. Similarly, “closed-style” will refer to highly interactive applications in which both address allocation and connection controls are effected. These will typically involve a limited number of users, due to inherent limitations in human interaction. An address management scheme should accommodate the need to support such diverse conferencing models. Connection control is necessary in order to manage effectively the multi-point connections in real-time.

The paper is organized as follows. Section 2 details Hierarchical Autonomous Concept and domain structure on which the paper will be based to build the multicast address-allocation scheme. Section 3 puts forward the schemes of multicast address allocation based on Hierarchical Autonomous Structure (HAS). Multi-point connection control and the ‘time-out’ mechanism are described in Section 4. Section 5 describes a simple building algorithm for multi-point connection. Section 6 introduces the fault recovery scheme and analyzes the performance of the address management protocol, including scaling characteristics and robustness in the cases of failures. With simulation experiment, HAM, CM and DDM of Multicast Address Allocation are compared in Section 7. Finally, in Section 8, we provide a summary.

2 Hierarchical Autonomous Concept and Domain Structure

Internet is a global network comprising many sub-networks distributed around the world. Thus, it may also be regarded as being made up of hierarchical autonomous domains. For example, CERNNet comprises eight region network centers each of which connects several universities and colleges in its area. On the other hand, the CERNET is connected with Internet by international lines. Therefore, we regard CERNET as an autonomous domain, and eight region network centers are its autonomous sub-domain each consisting of several campus networks as sub-sub-domain.

An autonomous domain is an integral, and in order to contact inside host from outside, domain interface is necessary, but the knowledge about inside structure is not needed. An autonomous domain consists of an IP Address Manager (IPAM), a Multicast Address Manager (MAM), some Connection Controller (CC), an Inter-Domain Connection Manager (ICM), and several routing nodes which connect all sub-domains and other domains. IPAM keeps the range of IP address in this domain, and checks whether a destination host is in the domain. MAM takes charge of managing multicast addresses. ICM mainly manages the connections with other domains, including connections with super-domains, sub-domains and other domains.