On Application Layer Multicast

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Abstract

Application Layer Multicast (ALM) is a promising technology for constructing content delivery systems across the Internet with low cost and scalability. Unlike the conventional, well-known IP Multicast paradigm, ALM uses unicast to virtually realize multicast communications. In this article, we present a survey of state-of-the-art techniques for designing efficient ALM trees and the challenges we are facing.

Background

As opposed to IP Multicast (Fig. 1), in which routers play the role of data copying and forwarding at the network layer, ALM composes multicast trees at the application layer (Fig. 2). Basically, there are two types of nodes in ALM, namely, a parent node and a leaf node. Parent nodes are supposed to take the role of routers in IP Multicast. The greatest benefit of ALM is that users can easily design their own content delivery systems without the constraints of other layers. ALM leans on the fact that the bandwidth of networks and the processing speed of end nodes have increased tremendously in recent years, and this trend is sustainable in the foreseeable future.

In ALM, the content server is treated as the root and user nodes are considered as either parent nodes or leaf nodes depending on their locations. By making use of this tree-like structure, ALM allows users to share the contents in a multicast manner. ALM exhibits many attractive features such as scalability and simplicity of using only unicast, yet several issues need to be addressed. The first one is the accumulation of delay at the lower layers in ALM trees. The second is the degradation of QoS caused by frequent joining and seceding of nodes, especially the secession of nodes in the upper layers. The third, which impacts greatly whether quality video streaming can be achieved, is the diversity of networks between the content server and receivers (Fig. 3). These three issues have to be addressed in designing a content delivery system based on ALM.

Existing Proposals

Aiming at achieving high throughput and Quality of Service (QoS), several ideas have been proposed so far. From the view point of a tree structure, they can be classified into two categories, namely, the so called single-tree multicast and multi-tree multicast, respectively.

(1) Single-tree multicast (Fig.4)

In the single-tree multicast, the server sends streaming traffic via a singular tree. Yoid [1], SpreadIt [2], ALMI [3], HBM [4], NICE [5], ZIGZAG [6], and Scribe [7] are examples that fall into this category. Yoid [1] and SpreadIt [2] use the Shortest Path Tree to minimize the delay from the server to end nodes, whereas ALMI [3] and HBM [4] use the Minimum Spanning Tree to reduce the overall delay, both without the consideration of bandwidth constraints. As a whole, the objective of these four methods is to minimize the content streaming delivery delay. NICE [5] and ZIGZAG [6] construct the tree by clustering. The purposes of using clustering are to curtail signaling overhead and to speed up tree management. Scribe [7] first uses Pastry [8] to construct the search paths and then makes the delivery tree by tracing back the search paths. Scribe exhibits the merit of limiting the overhead of control messages, but without consideration of the available bandwidth of participating nodes.

(2) Multiple-tree multicast

The inability of single-tree multicast to facilitate node secession is its main drawback. Multiple-tree multicast has thus been proposed to overcome this problem. Multiple-tree multicast adopts Multiple Description Coding (*MDC*) [9],[10] to first divide the original stream into multiple descriptions, and then construct the single-tree multicast for each description, separately. The size of each description is, in general, much smaller than that of the original stream. Thus, playback is executable upon receiving any description of the original stream. The more the number of descriptions received, the better the stream quality. MDC is now being studied widely for practical deployments such as incorporating MDC in the video coding standard

H.264/AVC [11]-[13]. Multiple-tree multicast can also prevent nodes from suffering the interruption caused by the secession of nodes. CoopNet [14],[15], SplitStream [16], and THAG [17] are some representative methods that fall into the multiple-tree multicast category. In CoopNet, all trees are managed at the server. Therefore, overloading the server might be a concern. On the contrary, SplitStream [16] makes use of Scribe [7] to construct the trees. Trees in SplitStream are constructed in a distributed manner so that nodes can freely join a tree at any position. These two methods have addressed the available bandwidth issue, but they do not guarantee the node-disjoint property. Consequently, a node secession from the tree may result in simultaneous breakdown in multiple trees. Incidentally, as shown in Fig. 5, the node-disjoint structure allows a parent node in a certain tree to be a leaf node in the other trees. In THAG, the node-disjoint structure is implemented by the hierarchical Arrangement Graph (*AG*) [18], [19]. As a result, THAG is more robust in terms of node secession as compared to SplitStream or CoopNet. However, the main concern of THAG is that it does not take network heterogeneity into consideration.

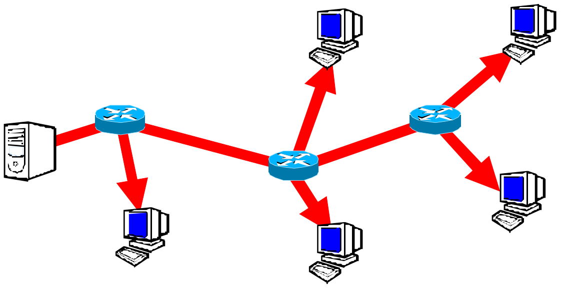

Fig. 1. IP multicast

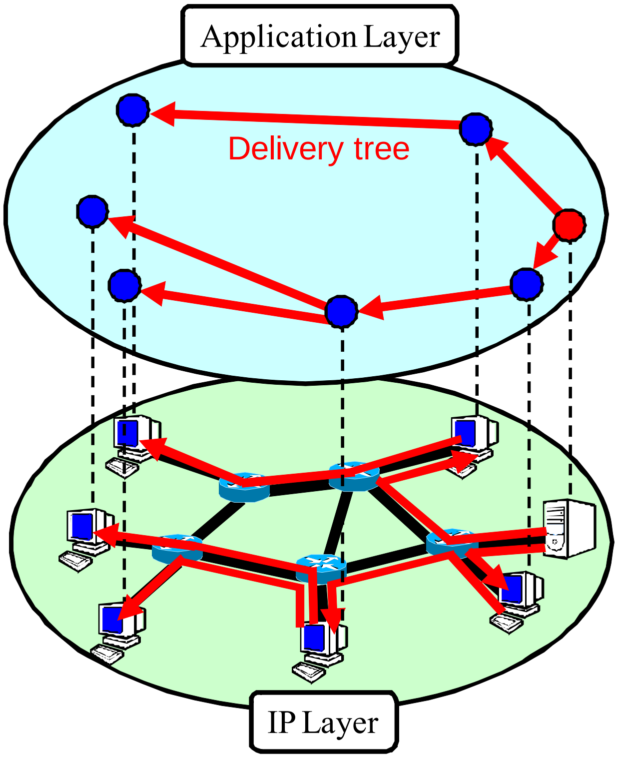

Fig. 2. Application layer multicast

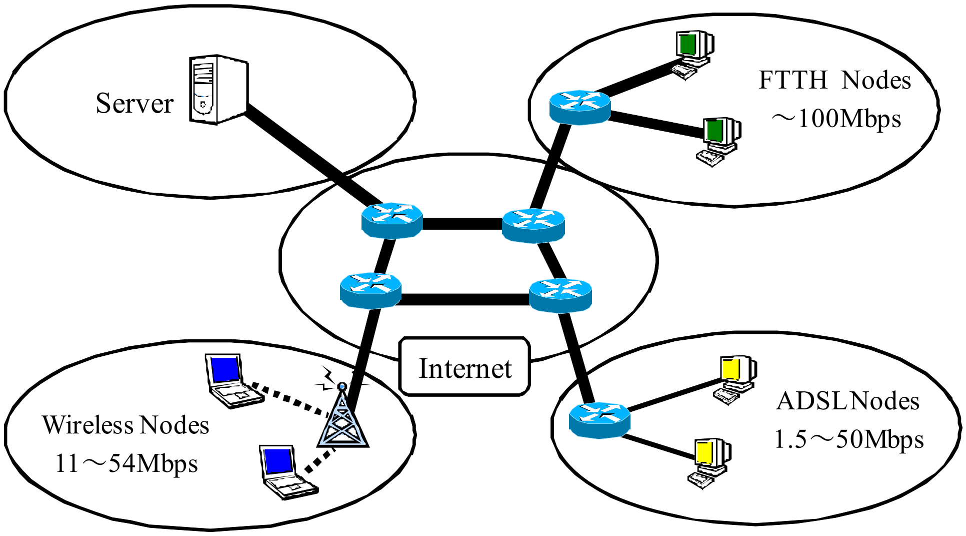

Fig. 3. Heterogeneous network environment where the server and receivers are located.

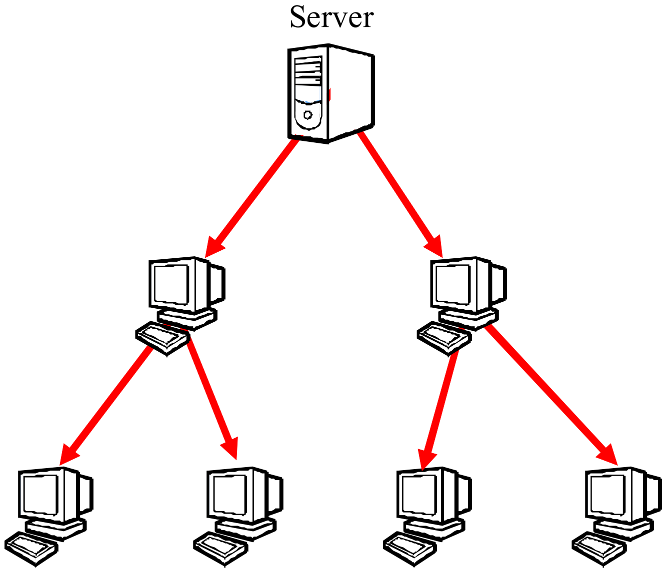

Fig. 4. Single-tree multicast

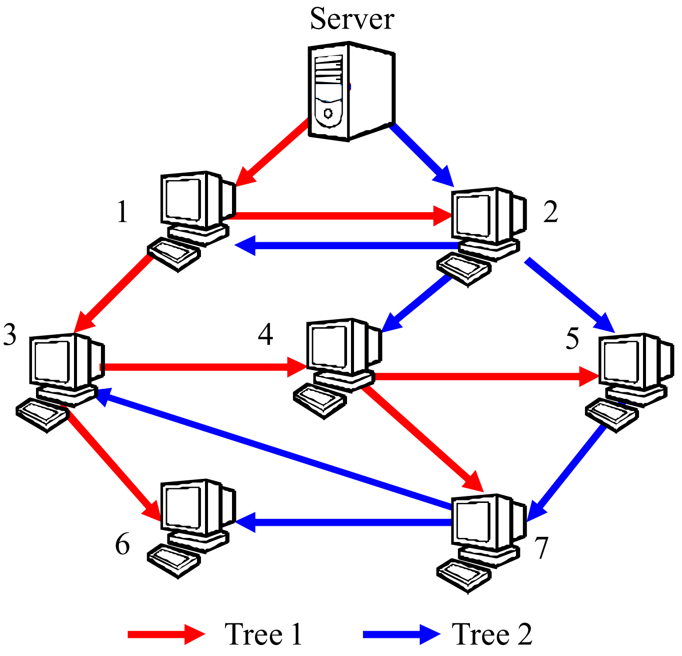

Fig. 5 Multiple-tree multicast in which each node may be assigned as both parent and leaf node.

On Realizing an Efficient ALM for Heterogeneous Networks

Kobayashi *et al.* [20] proposed a novel idea referred to as Network-aware Hierarchical Arrangement Graph (*NHAG*) to construct efficient ALM trees in heterogeneous networks. In NHAG, the size of AG is dynamically changed and adapted to meet various bandwidth requests from nodes. NHAG is scalable, and simulation results have demonstrated that NHAG outperforms other existing methods, especially in heterogeneous networks. We believe that NHAG is a promising approach to further advance the ALM technology.

Summary and Open Issues

We have briefly presented the state of the art of ALM for establishing a robust content delivery system. Although ALM is deemed powerful for constructing the flexible P2P networks over the Internet, it is still at the embryonic stage; besides efficiency, more studies in terms of security and incentive strategies for nodes to participate in the relay are imperative in ultimately commercializing the ALM technology.

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