

Mediacommunication Based on Application–Layer Multicast

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INTRODUCTION

Collaborating and media-handling applications demand efficient and scalable methods for media streaming and group communication; however, such mechanisms have still not been deployed widely in the Internet. Network-level multicasting (in the Internet it is called IP-multicast) gives a bandwidth-saving solution for the one-to-many and many-to-many group communication, since it provides an efficient network mechanism through which senders can transmit their information to a large number of receivers without having to send multiple copies of the same data over a physical link (Hosszú, 2001). The IP-multicast has been realized for research purposes on multicast-capable networks (so-called multicast islands) within the Internet, but wide-scale deployment has not been reached due to some unresolved issues. That is why recent efforts are in the development of multicasting protocols at the application layer instead of the network layer. Most of these Application-Layer Multicast (ALM) protocols address the case of a single-source streaming media to a large number of receivers in applications such as video on demand or live broadcast. In the following sections, the main properties of the ALM protocols are overviewed, then some typical ALM solutions and a new approach are presented.

IP-MULTICAST

Group communication refers to one-to-many and many-to-many data communication between hosts on a network, such as is TV and radio broadcasting, where a relatively small number of sources transmit programs to potentially millions of subscribers. A smaller-scale multicast communication is used by multiparty conferencing or gaming systems, where data is required to be sent from any participants to all of the other participants.

The simplest solution to Internet group communication uses unicast, whereby the source sends a duplicate of each data packet to each receiver. However, the unicast communication method scales less efficiently for large groups or for high-bandwidth data typical of audio/video streams.

A more efficient communication way is multicast, which is a technique for efficient multiparty communication on the Internet, allowing multimedia streaming applications for large groups of users. It has two types, the network-level IP-multicast and the ALM.

IP-multicast currently offers the most efficient technique for group communication in IP networks by moving data packet replication from the hosts into routers to distribute data using multicast-routing protocols. In case of the IP-multicast, the routers multiply and forward the packets to each branches of the multicast distribution tree, called Spanning Tree (ST). IP-multicast uses the concept of multicast groups, where clients can join to disseminate data. Multicast groups are identified by a reserved subset of IP addresses (so-called Class-D) in the range of 224.0.0.0 to 239.255.255.255.

The major problems facing IP-multicast deployment are routing protocol scalability and the need for changes to router software at the infrastructural level (Chu, Rao, Seshan, & Zhang, 2001).

One of the serious barriers against the wide usage of IP-multicast is the transferring of traffic through the domain-borders of the Autonomous Systems (AS), which are the basic building elements of the Internet. For this purpose, specially designed inter-domain network-level routing protocols are used, but their application is difficult and not always supported by the administrators of the AS. Its reason is that one sender generates a multicast traffic and many receivers are interested in that content, and in such a way in their local AS a huge traffic is generated due to the multiplications in the network. Therefore, the multicast traffic leads to a not well-controllable load on the network of the various AS. This is why many administrators of the AS are averse to permit the IP-multicast.

Due to the reasons above, the IP-multicast has not been deployed in the global Internet, and therefore, application-layer solutions are developed, which are overviewed in the following paragraphs.

APPLICATION-LAYER MULTICAST

The ALM is the application-level solution of the group communication problem; its other names are host-multicast

or end-host multicast. Its basic idea is that the multicasting functionality is implemented in the application layer at the end hosts instead of the routers. In IP-multicast, data packets are replicated at routers inside the network; however, in ALM, data packets are multiplied at end hosts, where the nodes are responsible for the multicast delivery, not the routers as in the IP-multicast. Virtually, the end hosts form an overlay network, and the goal of ALM is to construct and maintain an efficient overlay for data delivery.

In the case of ALM, the hosts use unicast between the member-hosts, and the multiplication points of the multicast tree are the member-hosts, not the routers as in IP-multicast. The main advantage of ALM is that it utilizes the existing unicast routing protocols, which facilitates instant deployment without modifying the existing Internet infrastructure. This is why ALM can be easily deployed in the network. Figure 1 shows the differences among unicast, IP-multicast and ALM.

The special type of ALM is the hybrid approach, which installs a user-space program at end hosts and no support is required from routers; however, it can utilize the existing IP-multicast infrastructure where available.

Though the ALM technique is not as efficient as IP-multicast in terms of data duplication on links or in terms of delay, it reduces load on the server compared to the unicast scenario (as Figure 1a shows) without requiring any help from the network infrastructure.

The multicast efficiency of an ALM solution is determined by the overlay topology used. It can be constructed as a Peer-to-Peer (P2P) or proxy-based network. P2P applications allow the construction of overlays and multicast communication with other peers directly. However, the proxy-based ALM systems, composed of proxy servers, are placed around the Internet, to which local clients are connected to receive or send multicast data. The proxy servers construct a P2P overlay network. The overlay efficiency increases as more proxy servers are deployed (Chu et al., 2001).

Distributed and collaborative virtual environments have different properties that in turn necessitate various sets of requirements for ALM protocols. The ALM is widely used for distributed collaborative applications

and multi-sender teleconferencing. The current ALM architectures support large-scale single-source multicast or small-scale any-source communication.

QUALIFICATION OF ALM METHODS

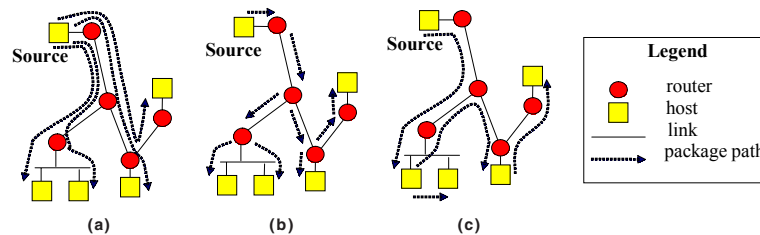
The ALM protocols organize the group members into two topologies: the control topology and the data topology (Banerjee, Kar, Bhattacharjee, & Khuller, 2003). Members periodically exchange refresh messages to maintain the control topology. The data topology is generally a subset of the control graph, and defines the data path for a multicast packet to be transmitted. The data topology is a Spanning Tree (ST), while the control graph (called mesh) has richer connectivity between members.

Depending on the sequence of construction of the data and control graphs, the various ALM approaches belong to the following classes: tree-first, mesh-first and implicit. Their main properties are shown in Table 1, displaying several ALM solutions, where some typical forms of them will be detailed in the following paragraphs.

The overlay nodes usually organize themselves into tree or mesh structures, mapping efficiently to the underlying network topology for the metric such as latency or bandwidth. The goal of ALM is to construct and maintain an efficient overlay for data transmission. Since ALM protocols must send identical packets over the same link, they are less efficient than native multicast. In general, ALM protocols can be evaluated along the following dimensions: *quality of the data delivery path*, *robustness of the overlay* and *control overhead* (Banerjee, Bhattacharjee, & Kommareddy, 2002).

The quality of the data delivery path is measured using the metrics *stress* and *stretch* (Chu, Rao, Seshan, & Zhang, 2000). The metric stress is defined per link and counts the number of identical packets sent by an ALM protocol over each underlying link in the network. For IP-multicast, there is no redundant packet replication and, hence, in its case, the stress metric is one at each link of the network. The metric stretch is defined per member and is the ratio of path length from the source to the member along the overlay to the length of the direct (optimal) unicast path.

Figure 1. Comparison of (a) unicast, (b) IP-multicast and (c) ALM



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