Computer Communications 33 (2010) 1752–1766

Contents lists available at ScienceDirect

Computer Communications

journal homepage: www.elsevier.com/locate/comcom

An efficient networking technique for synchronous e-learning platforms in corporate environments

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ARTICLE INFO

Article history:
Available online 24 February 2010

Keywords:
Synchronous e-learning
Multimedia networking
Overlay multicast
Modeling and measurement
Network scalability

ABSTRACT

A synchronous e-learning platform constitutes an effective tool to implement training programs for human resources in large corporations. These organizations are usually widely dispersed in multiple sites, so the delivery of multimedia data over the whole corporation during an e-learning activity is a true challenge. Multimedia data is usually delivered using the RTP protocol. Although an RTP session can involve multiple participants and has no restriction on the underlying network, it is usually restricted to IP multicast scopes. However, IP multicast is rarely available throughout corporate networks. In this paper, an efficient delivery technique based on an overlay multicast network is proposed. The overlay is made up of multiple servers that operate at the RTP level and combine unicast and native multicast transport whenever possible. This technique has proved to be more efficient than a technique based exclusively on unicast delivery.

1. Introduction

This paper presents a technique for real-time delivery of multimedia data between several user groups making efficient use of the network bandwidth when IP multicast is not globally available.

The motivation for the development of this technique arises from the utilization of multimedia applications to support synchronous e-learning activities in geographically dispersed multinational corporations.

For security reasons, the employees of these corporations must always work within the corporate network. This network usually consists of several Local Area Networks (LANs), one in each site of the corporation, joined by the Internet.

The bandwidth contracted by the corporation with one or several Internet Service Providers (ISPs) to connect the LANs of the various sites is usually fitted to the daily necessities of the corporation, without considering the additional load generated by an e-learning activity.

Thus, any multimedia application operating with this kind of network must use the available bandwidth as efficiently as possible. Maximum efficiency is obtained when the multimedia information can be transmitted throughout the entire corporate network using IP multicast. However, the delivery of data using IP multicast reaching all the nodes of the network simultaneously is rarely feasible in world-wide corporate networks.

The corporation could request its ISP to provide a temporal multicast service during e-learning activities between the sites where participants are located. However, if the sites are connected by different ISPs, enabling and later disabling the multicast service is cumbersome and expensive.

In order to satisfy the training requirements of large corporations, we have developed a synchronous e-learning tool [1]. It provides the most common functionalities of this kind of tool, such as videoconference, instant messaging and presence control, shared whiteboard, annotation of slides and telepointers. Depending on the instructor's wishes, these features can be used with one-way broadcast delivery from the instructor to the learners, or in a collaborative way from any one participant to the rest. For example, the instructor may use his telepointer to point to a relevant element on the shared whiteboard, while a learner may activate his telepointer to inquire about a specific element on the whiteboard. A snapshot of the synchronous e-learning tool can be seen in Fig. 1.

All data must be delivered in real-time to enable instant interactions between participants, so the Real-time Transport Protocol (RTP) is used to transport all multimedia data. Separate RTP sessions are used to transmit each type of media, where each session represents an entity which is made up of all the participants. These sessions are not geographically or network scoped. That is, the RTP sessions are independent of the network layer. Ideally, IP multicast is available in the underlying network and every RTP session is associated to an IP multicast group, so participants must join the multicast groups in order to receive all the multimedia data.

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doi:10.1016/j.comcom.2010.02.020

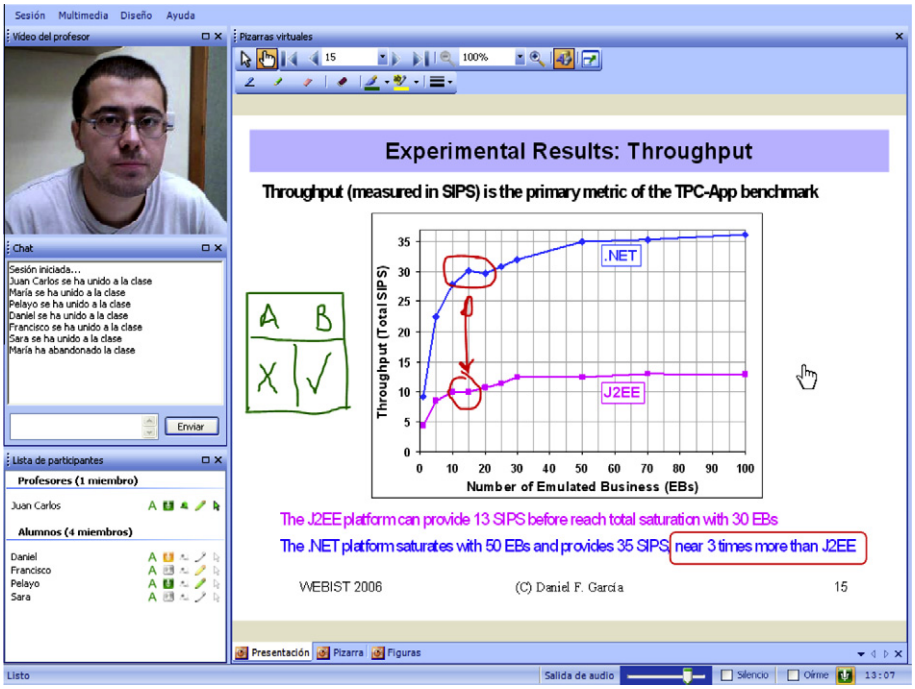

Fig. 1. Snapshot of a synchronous e-learning tool.

However, this is not always possible, as IP multicast is not available world-wide.

The solution proposed assumes that IP multicast delivery can be easily enabled in the LAN of each site of the corporation. In this case, multiple servers can be deployed as proxies to emulate the behavior of a multicast network between participants located in different sites. Nevertheless, the path of data packets between two participants must traverse as few servers as possible to minimalize latency. Therefore, the proposed platform emulates the behavior of a global multicast network between the LANs using an overlay network tailored to the specific requirements of synchronous e-learning applications.

On rare occasions participants who do not have IP multicast connectivity, or who join from outside the corporate network, participate in e-learning activities. Those from outside the corporate network join the network through VPN tunnels. The servers must forward traffic from the RTP sessions to these participants and vice versa.

The remainder of this paper is organized as follows. Technological background about multimedia data delivery using RTP is presented in Section 2. In Section 3, related work on existing techniques for group communication is discussed. The proposed architectural design of the networking platform is addressed in Section 4. In Section 5, the design and operation of the RTP relay used in the proposed networking platform are explained. The theoretical model of the traffic supported by the relays in the platform is presented in Section 6. In Section 7, the validation of the theoretical model and the performance evaluation of the platform are presented. Finally, Section 8 contains the concluding remarks and outlines future work.

2. Technological background

Delivery of audio and video data from instructor to learners, as well as the interchange of multimedia data, such as instant messages and shared whiteboard information, are common functions in synchronous e-learning activities. Audio and video streams stand out as being the most bandwidth-consuming data, imposing the most restrictive requirements on the underlying network.

The audio stream from the instructor carries his speech, while the video stream is useful to reinforce the learners' sense of the presence of the instructor, as it usually carries his talking head. Whenever possible, learners should be able to participate orally in the e-learning activity by delivering their own audio streams to the rest of the participants. In this way, learners can easily raise questions about those aspects of the class that might remain unclear.

RTP [2] is considered the de facto standard for delivering continuous media such as audio and video over IP networks, but it can also be used to transport other time-dependant data. RTP is an application-layer transport protocol running over UDP/IP. Thus, IP multicast may be used at the network level if available.

The participants in a synchronous e-learning activity must join an RTP session to receive multimedia streams from the rest of the participants. Each type of media is carried in a single RTP session. Thus, there is an RTP session for video, another one for audio, and so on. The RTP session represents an association of participants interchanging data, which is not limited to a specific geographical location or a network scope. In the developed platform, each RTP session involves all the participants in the e-learning activity.

The RTP specification defines intermediate systems at the RTP level. RTP mixers can be used to combine multiple data streams into a single stream, in order to reduce bandwidth requirements. RTP translators forward packets between two or more network scopes. Specifically, an RTP relay is an RTP translator which interconnects multiple network domains without modifying data [3]. Using an RTP relay, it is possible for participants in an IP multicast domain to communicate with others in a non-multicast-capable network. The RTP relay must forward packets between both network domains.

In addition to the transport protocol, RTP defines a complementary control protocol, the Real-time Control Transport Protocol (RTCP). All participants in an RTP session transmit periodic RTCP packets. This provides feedback on the quality of the data delivery and allows participants to maintain a list of all the participants in