Live Streaming Switch System for Wide-area, Low-cost, and High-quality Internet Broadcasting

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Abstract

Although there are high hopes for broadband stream broadcasting, there are many problems to be solved, such as how to increase the capacity of the delivery server and how to reduce the operation cost, before high-quality broadcasting can be provided on a large scale and at a low cost. This article reviews stream broadcasting technologies and introduces the Live Streaming Switch being developed in NTT Laboratories, which enables a low-cost, stable-delivery, automated streaming service.

1. Introduction

Broadband access to the Internet, such as by ADSL (asymmetric digital subscriber line), is spreading at an accelerating pace. The number of broadband service users exceeded 8.8 million in Japan at the end of August 2003. In parallel, streaming delivery over the Internet is gaining attention as a new means of adding value to portal sites. For example, at a product selling portal site, streaming delivery is used to introduce products, or Internet broadcasting is provided in combination with a chatting capability. Broadband streaming delivery enhances the value of IP (Internet protocol) streaming delivery, thereby increasing business opportunities (Fig. 1).

Although expectations are high for broadband streaming delivery, there are still many problems if high-quality Internet broadcasting is to be provided on a large scale. The following sections of this article review stream broadcasting technology and show how NTT Laboratories are solving the problems.

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2. Overview of stream broadcasting technology

Content can be delivered to an individual user when he/she requests it (on-demand streaming delivery) or it can be broadcast to many users simultaneously (stream broadcasting). The primary concerns in on-demand streaming delivery are request navigation, which involves locating servers that hold the file

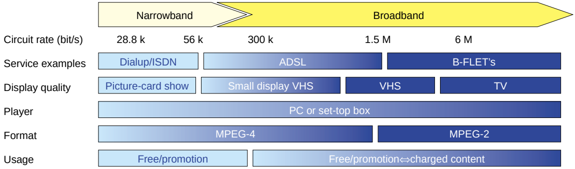

Fig. 1. Expansion of bandwidth used in stream broadcasting.

requested by a user and guiding the user to the nearest server, and mirroring (caching), which reduces the load on the central server by either copying or temporarily storing popular content files in other servers.

In stream broadcasting, content, such as a live concert program, is simultaneously viewed by a large number of users. Therefore, additional technologies are needed for simultaneous delivery and quality controlled delivery to maintain stable viewing quality throughout the broadcast.

Figure 2 compares three stream broadcasting schemes. When Internet broadcasting is provided on narrowband lines to a small number of viewers, the server copy scheme is commonly used. One advantage of this scheme is that the service is easy to implement and operate because the existing IP network can be used and because all servers are installed at a central site. However, if broadband content is to be delivered to a large number of users, the volume of traffic from the central site is so huge that the circuit and server costs can become prohibitive. For example, if an item of content is broadcast at 1 Mbit/s to 10,000 people, a bandwidth of 10 Gbit/s is needed, making it unrealistic to deliver the content from a single center.

To solve this problem, the splitter copy scheme has begun to be used. A proxy server (splitter) is installed at each site of the existing IP network, and stream broadcast data from the center is copied and broadcast at each site. Since request navigation can be used to guide the user to the nearest splitter, traffic can be confined to the Internet service provider (ISP) serving that user. However, since there is a splitter at each site, the cost of operating and maintaining the splitters is high. For example, to maintain a stable service, it would be necessary for each site to monitor video quality.

Instead of this unicast splitter-copy, IP multicast broadcasting is often tried. Although this scheme looks effective at first glance, it actually raises many problems in its application to a broadcasting service because of the intrinsic problems of the IP multicast service model. For example, since the basic IP multicast service model allows anyone to deliver content and anyone to receive content (the “any source–any client” model), some mechanism must be implemented separately to prevent unauthorized delivery or reception of content when the service is to be provided commercially. In addition, owing to the lack of a scalable multicast routing protocol covering multiple domains, a tremendous quantity of resources is required to manage the routing table at each multicast router in a large-scale, multi-channel broadcasting service [1]. In addition, delivery performance tends to decrease as the volume of routing tables increases. Because of these problems, IP multicasting has not been applied to a commercial service even though 15 years have passed since the emergence of the technology. J/Splash and numerous other multicast trials have been carried out, but they have ended. A technological breakthrough is needed for IP multicasting.

Besides the broadcasting schemes shown in Fig. 2, streaming broadcasting using the peer-to-peer (P2P) scheme has recently emerged. At present, this technology is mainly applied to narrowband content delivery because it is difficult to control the performance/circuit quality of the client. The application of the P2P scheme to broadband stream broadcasting is introduced in the next article: “Peer-to-peer-based,

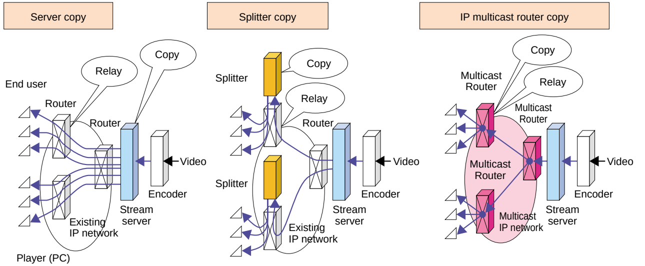

Fig. 2. Comparison of stream broadcasting schemes.

High-quality Live Video Delivery System for Business-to-business Applications".

3. Overview of Live Streaming Switch system

NTT Information Sharing Platform Laboratories is developing a Live Streaming Switch (LSS) for high-quality, large-scale, and low-cost Internet broadcasting [2]. LSS is a software program that runs on a general-purpose PC server. The software is installed in the central content servers and other sites in an existing IP network to provide Internet broadcasting on a large scale and at a low cost (Fig. 3). The LSS system consists of splitters (LSS-SPLs), which enable a single general-purpose PC server to achieve a delivery performance on the order of gigabits per second, and an integrated stream broadcasting management system (LSS-SMS), which enables centralized management to perform integrated monitoring/control of distributed splitters and stream servers. LSS is used in combination with an already commonly used off-the-shelf streaming system and requires no special software or plug-ins at client terminals. Thus, it enables an existing streaming system to be upgraded smoothly.

3.1 LSS-SPL system

In conventional stream servers, session control and delivery are usually not separated. In contrast, in LSS-SPL, they are separated (Fig. 4). This server architecture prevents the operating system socket processing load from becoming a processing bottleneck, as it does in conventional servers, and enables stream copying at the driver layer. With this architecture, even a general-purpose server can achieve broadcasting performance nearly equivalent to the performance of the gigabit Ethernet network interface card (GbE-NIC), which is more than ten times the performance of an existing server (Fig. 5).

In addition, LSS-SPL changes the streaming rate and controls packet retransmission based on the line

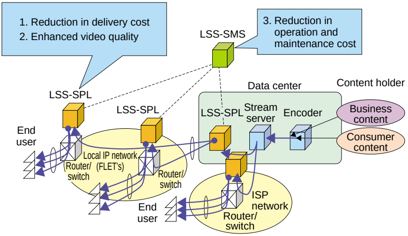

Fig. 3. Overview of Live Streaming Switch (LSS) system.

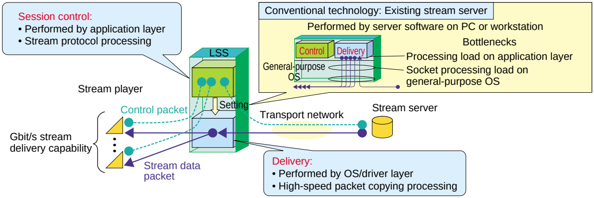

Fig. 4. LSS-SPL software architecture.

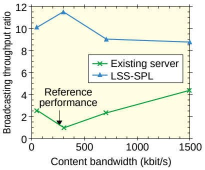

Fig. 5. Comparison of broadcasting throughput.

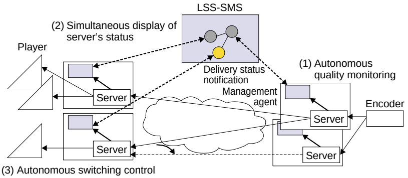

Fig. 6. Outline of LSS-SMS configuration.

condition and packet reception status of each client to keep the quality of stream broadcasting on an existing IP network. These capabilities minimize the degradation of viewing quality even when the IP network is congested or packets are lost. Moreover, when a stream server running on a general-purpose OS is used continuously for a long time, packet arrival fluctuation gradually happens, which degrades viewing quality [3]. To prevent this, LSS-SPL has a connection refreshing function, which monitors the quality at the streaming level. If it detects an unstable streaming session, the session is refreshed so that stream broadcasting service can be provided stably 24 hours a day.

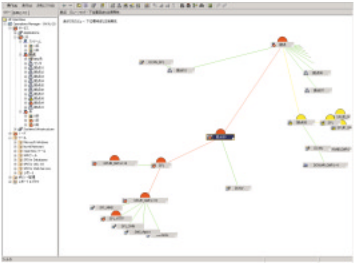

Fig. 7. LSS-SMS display window example.

3.2 LSS-SMS system

Since stream broadcasting requires the continuous stable delivery of programs, it has been necessary to monitor from an operations center as well as at every site to visually inspect the delivery status so that not only service interruptions or network failures but also degradation in video quality can be detected as soon as possible. That is to say, maintenance staff must not only monitor service status, traffic conditions, and the number of simultaneously operating stream connections, but also determine whether video and audio signals are being delivered satisfactorily throughout the live broadcast.

Our LSS-SMS system has a management agent built into each delivery server/splitter. The management agent monitors not only service status but also streaming delivery quality, and, if it detects any degradation in quality, it switches the delivery routes (Fig. 6). Specifically, the management agent monitors streaming delivery quality at the content level, and, based on this quality information, such as fluctuations in packet arrivals, switches the upstream servers without requiring human judgment or control by maintenance staff. This eliminates the need for constant visual inspection by maintenance staff, so reducing the operation cost dramatically.

LSS-SMS also allows centralized monitoring and can display the service status and stream flow status of each item of content at each site (Fig. 7). It also allows bulk control of deliveries based on our streaming expertise. This enables 24-hour-a-day operation of a stream broadcasting service. The time it takes to detect degradation in quality, analyze status, and restore quality has been reduced from over ten minutes in conventional systems to less than one minute (mainly for detecting quality degradation and buffering data at each client after failure recovery).

4. Examples of existing installations and future studies

LSS has been deployed by NTT operating companies in many trial and commercial services. For example, it was used to build, at a quite a low cost, a large live broadcasting network with widely distributed sites, which provides Japan's first and largest commercial live 1-Mbit/s delivery 24 hours a day. In addition, the application of connection refreshing technology has made it possible to provide a stable delivery of live broadband content 24 hours a day, something that was difficult to achieve with conventional systems.

LSS was also used to provide a late-night radio broadcasting service in combination with an existing P2P system. LSS provided a stable stream flow (packet flow) to the P2P system, and made it possible to operate and maintain the late-night broadcasts from a remote operating center managed by operators who are not skilled in streaming delivery.

We will continue to develop systems that will support the expansion of steam broadcasting business by NTT operating companies.

References

[1] I. Stoica, T. S. Eugene Ng, H. Zhang, "REUNITE: A Recursive Unicast Approach to Multicast," INFOCOM'00, Tel-Aviv, Israel, Mar. 2000.

[2] K. Yamada, T. Shiroshita, and S. Ushijima, "Large-capacity Content Delivery System for B-to-E and B-to-C: MDS-Dome/Megacast, LSS," NTT Technical Journal, Vol. 14, No. 4, pp. 46-49, 2002 (in Japanese).

[3] M. Tanikawa, T. Ikeda, and S. Ushijima, "Proposal and Evaluation of Large-scale Stream Broadcasting Management System Architecture," IEICE Technical Report IN2002-238, 2003 (in Japanese).

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