Proceedings of ITC18,2008

Real-time Video Streaming System for LHD Experiment Using IP Multicast

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In order to accomplish smooth cooperation research, remote participation plays an important role. For this purpose, the authors have been developing various applications for remote participation for the LHD (Large Helical Device) experiments [1], such as Web interface for visualization of acquired data [2]. The video streaming system is one of them [3]. It is useful to grasp the status of the ongoing experiment remotely, and we provide the video images displayed in the control room to the remote users. However, usual streaming servers cannot send video images without delay. The delay changes depending on how to send the images, but even a little delay might become critical if the researchers use the images to adjust the diagnostic devices. One of the main causes of delay is the procedure of compressing and decompressing the images. Furthermore, commonly used video compression method is lossy; it removes less important information to reduce the size. However, lossy images cannot be used for physical analysis because the original information is lost. Therefore, video images for remote participation should be sent without compression in order to minimize the delay and to supply high quality images durable for physical analysis. However, sending uncompressed video images requires large network bandwidth. For example, sending 5 frames of 16bit color SXGA images a second requires 100Mbps. Furthermore, the video images must be sent to several remote sites simultaneously. It is hard for a server PC to handle such a large data. To cope with this problem, the authors adopted IP multicast to send video images to several remote sites at once. Because IP multicast packets are sent only to the network on which the clients want the data; the load of the server does not depend on the number of clients and the network load is reduced. In this paper, the authors discuss the feasibility of high bandwidth video streaming system using IP multicast.

Keywords: remote participation, monitoring, streaming, IP multicast, SINET3

1. Introduction

Large scale experiment such as Large Helical Device (LHD) experiment in NIFS has been executed under the corporation of many researchers work at various places. Therefore, for such an experiment, a remote participation facility plays an import role to accomplish smooth cooperation. For example, motional image data is useful in that it can help researchers recognize not only the status of the experiment, but dynamic behaviors of plasma, including plasma-wall interactions and impurity transport at the plasma periphery. Commonly, video streaming over a limited network is sent in lossy compressed formats such as RealVideo, MPEG, QuickTime, and the like. For example, Shoji developed the Video on Demand system for LHD experiments to monitor plasma behavior [4]. That system provides MPEG1 or MPEG2 format images by the network. Using these formats, the video data can be shrunk to a tenth of its original size or smaller, whereas with the lossless compression algorithm, the data shrinks only tens of percents at the most. However, the disadvantage of using lossy compression is that information is lost when it is compressed. This does not matter if the image is used solely for monitoring, but it

Fig.1 Control room in NIFS

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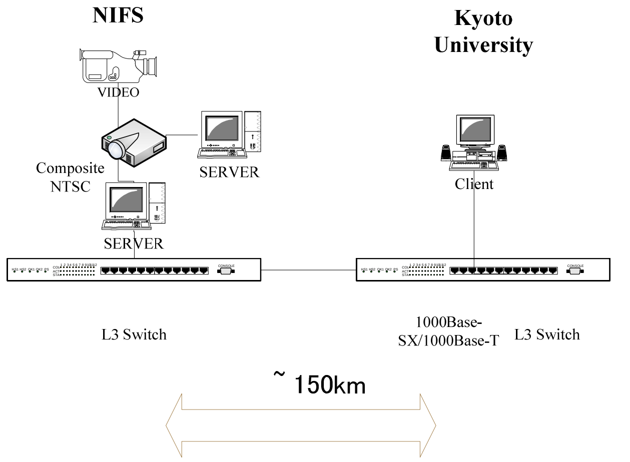

Fig 2. System overview

cannot be used for further scientific analysis. Another disadvantage is delay. Because these lossy compression uses motion compensation to reduce sizes; it detects the difference between consecutive frames and send only differences. However, because of this scheme, it needs to store the previous frames to determine the next images. Therefore, the delay is inevitable.

To solve this problem the authors has been developing the real-time monitoring system that send lossless images.

2. Real-time Monitoring System

In the control room of NIFS, there is a 150-inch projector to display the summary graph of the latest acquired data and the video image of the plasma to monitor the current going experiment (Fig.1). This information is helpful to the researchers in NIFS to monitor the ongoing experiment. Because the authors thought it was also helpful to the researchers at the remote sites, the authors have developed a system to send this image to the other universities. Fig 2 is the overview of this system. The network connecting NIFS and Kyoto University is Super SINET [5], an optical fiber based network. The server in NIFS sends the video images displayed by the projector to the client in Kyoto University. The source of the image is captured from the composite signal out from the video switcher using NTSC format. NTSC is widely used by video recorder and video capture in Japan, and is an easy format to handle. Although the output signal from the PC is RGB signal, it is converted into NTSC signals. The captured data is composed of VGA-size 24bit RGB images. The server and clients use two TCP/IP ports to communicate with each other; one for sending image data, the other for flow control.

While the authors were testing this system, several problems were found. First, the system uses NTCS video signals while the output signal from PC is RGB digital signal. The number of scan lines of NTSC is 525 while

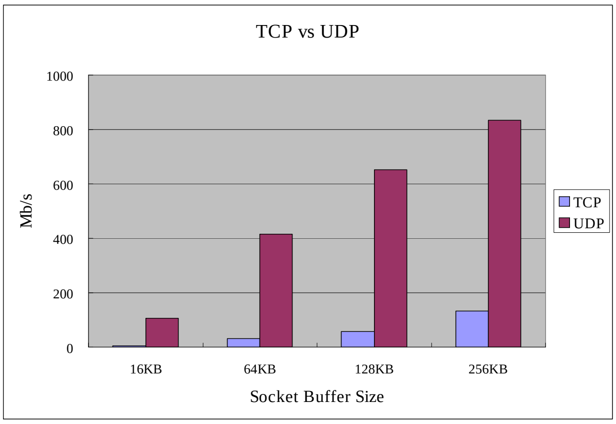

Fig. 3 Network speed between NIFS and Kyoto University using Super SINET

the vertical resolution of the PC signal is 1024. Thefore, the image is deteriorated and it is hard to read the small text in the summary graph.

The second problem is transfer ratio. The system uses TCP connection to send video images. Using TCP, the sender must confirm that the client receives the packet before it will send the next packet. Therefore, if there is a large latency between the sender and receiver, the total transfer ratio decreases. For example, the total TCP transfer ratio between NIFS and Kyoto University becomes 6 ~ 130 M bit/sec depending on socket buffer size while they are connected by 1Gbits/sec capability network (Fig. 3) [6]. On the other hand, the maximum transfer ratio of UDP reaches more than 800 Mb/sec.

The third problem is its scalability. Because the server must send images to each client one by one, the server's CPU and network load increase proportional to the number of clients. Judging from the current network bandwidth (less than 1Gbps), one server can handle only a few clients

3. New System

To solve the problems of the previous system, the author has been developing a new monitoring system. First, the new system uses VGA capture device to capture video signal out from PC directly. Second, in order to solve large latency problem, the new system uses IP multicast that uses UDP instead of TCP. When the sender uses UDP, it doesn't have to wait for the client's reply, and

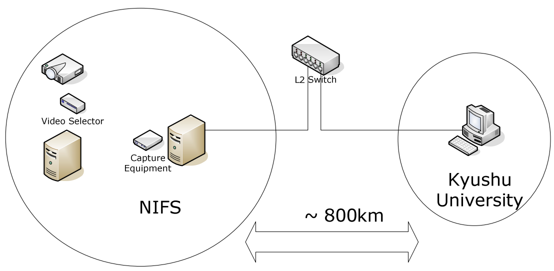

Fig.4 New system

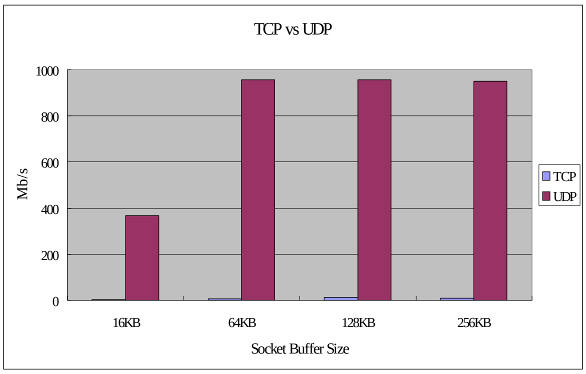

Fig. 5 Network Speed between NIFS and Kyoto University using SINET3

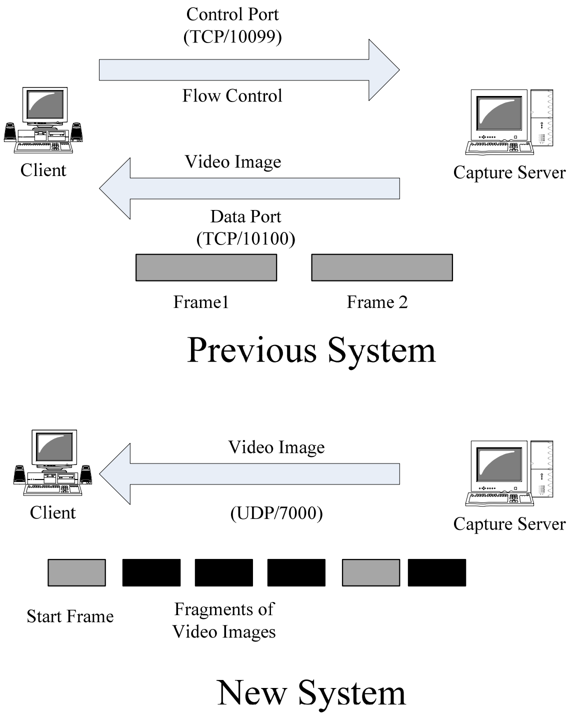

Fig. 6 Protocols of the video streaming system.

the system can take full advantage of the network capability. On the other hand, there is a drawback of UDP; it is not reliable because the sender doesn't confirm whether client receives the packets or not, therefore, packets may be lost. If the system send the experimental data by UDP, this drawback becomes critical even if the number of lost packets is few. However, for sending video images for monitoring, it is not critical because the user can still identify the images if the number of lost packets is few. Using IP multicast also solve the scalability problem because multicast packets are sent only to the sub-nets on which the clients want the data, and the load of the server does not depend on the number of clients.

Fig 4 shows the overview of this system. The newly developed system uses a signal duplicator to duplicate the signal input to the projector. It is RGB signal of 1280 x 1024 pixels and its frame ratio is 60 frames / sec, and the NTSC signals from the VTR is converted to RGB signal. To capture the signal, the system uses a video capture device, Epiphan system's VGA2USB LR [7]. It is a USB device and connected to the server. The operating system of the server is Linux, and the image is captured using Video4Linux API.

The network connecting NIFS and Kyushu University is SINET3 [5], the latest inter-university network integrating the former Super SINET and SINET. The server and the client are connected by L2 switches, and they don't send packets via routers or L3 switches. Fig.5 shows the TCP and UDP transfer ratio. Same as the previous system, TCP transfer ratio is not good considering it is 1Gbp network. However, that of UDP reaches 950 Mb/sec, and it is almost upper limit of the network speed.

While the server of the previous system sent each frame one by one using TCP protocol, the new system sends fragment of a frame using IP Multicast, i.e. UDP protocol. (Fig.6)

4. Results

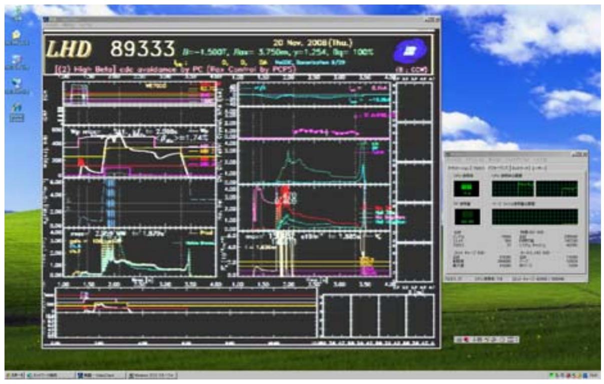

Fig.7. Client Program

Fig.7 shows the display of the client PC. The center window shows the same image displayed in the control room in NIFS. The actual frame ratio sent from the server is 23 frames /sec, and the total transfer ratio becomes 420 Mb/s.

The captured image is divided into pieces, and the server sends each piece as a multicast packet. Therefore, if

	Server	Client
OS	Fedora 9 (i386)	Windows XP
CPU	Intel Core 2 Duo E6550 (2.33GHz)	Intel Core 2 Duo T8100 (2.1GHz)
Memory	2GB	2GB

Table 1. Specification of the server and client PC

the client doesn't catch up with the packet flow, it will drop packets and area of the images corresponding to the dropped packets are missing. Seeing the images of the client PC, no packet loss is observed. However, the CPU load becomes almost 80% during this test. Therefore, computers less powerful than this PC might drop the packets. The specification used for this system is listed in table. 1.

It is difficult to measure the exact delay of the video images between NIFS and Kyushu University, but it is estimated 220 msec. This estimation is the sum of 200 msec, which is the delay of images measured between two PCs located at the local LAN, and 20 msec, which is the time to send IP packets from NIFS to Kyushu University.

5. Discussion & Conclusion

The authors demonstrated the feasibility of real-time monitoring system using IP multicast. Judging from the frame ratio of 23 frames / sec and the delay of 220 msec, the system may not be used for real-time control, but can be used for monitoring. However, the authors experienced the excessive increase of CPU load of the L3 switch while the system was tested using local area network; the CPU load of the network switch increased to 100%, and it became an obstacle to other functions. This is probably because the multicast function of this switch is implemented by software and consumed CPU power. On the other hand, the excessive CPU load increase was not observed for NIFS-Kyushu University network. One of the reason of this is it is L2 connection, and it doesn’t relay L3-level transportation. From this fact, the multicasting high quality video images needs enough power, and the multicast function should be implemented as wired logic.

Acknowledgements

This work was partly supported by Cyber Science Infrastructure (CSI) development project of the National Institute of Informatics.

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