DEVELOPMENT OF REMOTE EXPERIMENT SYSTEM

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Abstract

A remote experiment system has been long desired for synchrotron radiation facilities. For simultaneously ensuring radiation and physical safety; and operation and data security, a careful consideration of these issues is required. A beamline interlock system provides radiation safety with radiation shielding hutches. When synchrotron radiation is to be introduced into the hutch, the interlock system guarantees that no humans are present inside the hutch. Using the information obtained from the radiation safety interlock system, a physical safety system has been built. For ensureing operation and data security, we have developed a custom SSL server that requires interactive authentication. The server replays commands from a remote user's program to the experiment control computer. A client authentication certificate containing information about the remote user's experiment is transmitted to the SSL server, and the server accepts commands from the authorized user. The remote user can view samples and/or experimental equipment on a streaming video. The system latency is sufficiently small, and hence, remote users can perform their experiment as if they are located beside the beamline. The system is under trial, and it will be available to users in early fiscal year 2010.

INTRODUCTION

Many users visit large scale synchrotron radiation facilities from all over the world. For example, more than 10,000 users visit SPring-8, which has about 50 x-ray beamlines, and most of them stay two or three days. All the users except for “mail-in data-collection service” users are required to visit SPring-8 and the costs and time of travelling to and from SPring-8 are often very high for the users.

Using the “mail-in data collection service”, which is now available for performing protein crystallography and power diffraction experiments, users send their samples to SPring8 and the SPring-8 staffs measure the x-ray diffraction data[1]. The staffs measure a preliminary data set for sample screening and send it to the remote user data via the Internet. The remote user verifies the data set and decides which sample should be used for the experiment.

With the progress in the field of structural genomics, smaller and non-homogeneous protein crystals have to be measured. The qualitiy of the x-ray diffraction data depends on the position at which the crytal is x-ray irradiated. In the mail-in data collection service, however, the SPring-8 staff decide the x-ray irradiatiion position. Remote users prefer handling operate their samples themselves. Therefore, we have developed a remote experiment system.

Remote experiment systems have been implemented using tools such as using the virtual private network (VPN) and Windows' Remote Assistance [2]. Using these tools, a remote user's computer is virtually connected to the same network as that of the experimental station control system, and the remote user can access all the resources available at the experimental station. In the case of Remote Assistance, the remote user shares graphical user interface (GUI) panel with the station control system, however, the user cannot modify the sequence of measurements.

We have developed a remote experiment system with access control and flexibility for remote users as discussed below,

DESIGN CONCEPT

To develop a remote experiment system, we have to take account into the following issues.

1) Ensuring radiation safety
2) Ensuring human physical safety
3) Avoiding interference – Other users of on the beamline connected via th Internet should not affect the remote experiment.

About ensuring radiation safety of the experimental station, there are no need to make extra treatment for remote experiments.

"Ensuring human physical safety” implies avoiding following situation. If the remote user, who has no information about the experimental station, moves the experimetal station equipment while the SPring-8 staff are accessing the equipment, the staffs may get hurt. To avoid this situation, the experimental equipments are enclosed in a radiation shielding hutch and the beamline interlock system allows the introducing x-ray beam to enter the hutch only when there are no human present inside the hutch (i.e. the hutch is “clolsed normally”). Using the status of the hutch, the remote experiment system permits the user to perform the experiment only when the hutch normally closed.

“Interference” from the other beamline users connected via the Internet can be avoided by using access control with interactive authentication.

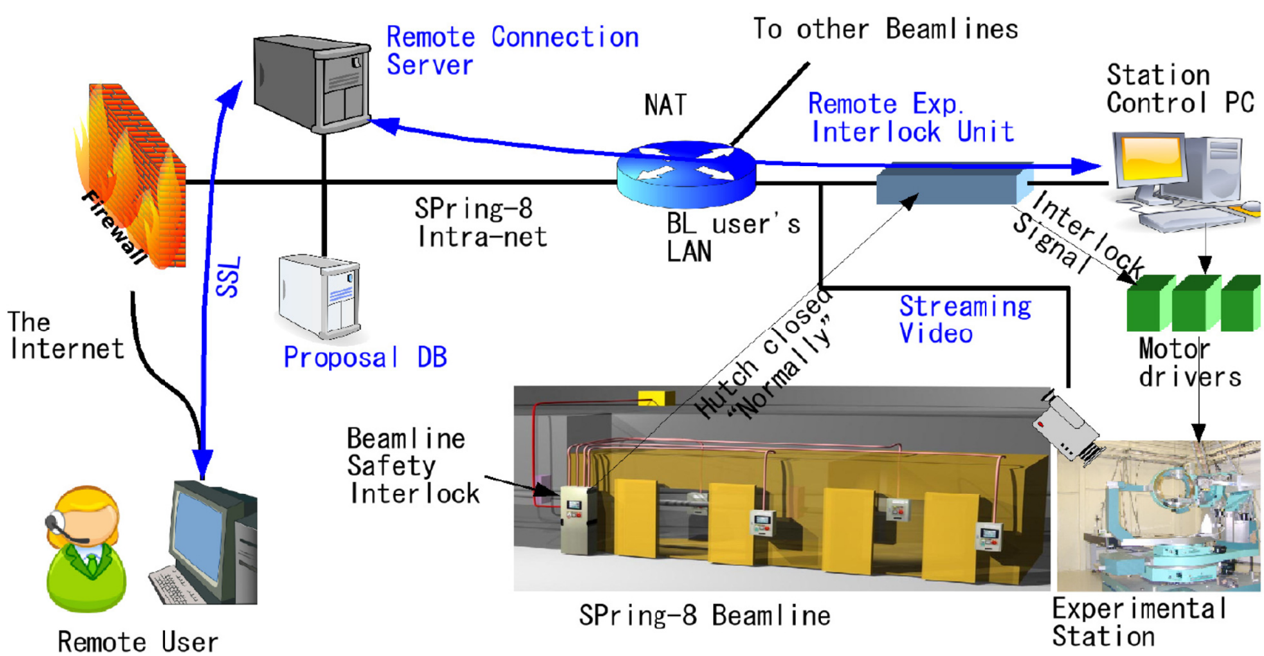

Figure 1:An overview of the remote experiment system.

As a remote control tools, we choosed message exchanging between remote cusers and the experimental station control system. Message exchanging has many advantages: (A) remote user can create their own control sequences using simple scripting languages, (B) the remote experiment system at SPring-8 can filter messages and transmit messages related only to the experimental station, and (C) the remote control system can connect seamlessly connect to the SPring-8 control system "MADOCA", because the MADOCA control system is also based on message exchanging [3].

A video streaming system is also introduced for monitoring the experimental equipment and samples.

OVERVIEW OF THE REMOTE EXPERIMENT SYSTEM

Figure 1 shows an overview of the remote experiment system. The experimental station control networks (BL-USER-LAN) are separated from the SPring-8 intra-net using a 1:N network address translation system and the station networks are inaccessible to each other or the SPring-8 intra-net.

The remote user connect to the "connection server" on the SPring-8 intra-net using the Secure Socket Layer (SSL) that requires interactive authentication. A signed authentication certificate is generated for the user by the SPring-8 remote control system. The connection server accept the signed authentication certificate (details will be described in the next section) and filters the message from the remote user. The connection server performs two functions: avoiding interference and filtering messages. The certification file includes information t corresponding to the beam time stored in the "proposal database (proposal DB)."

The interlock unit in the Fig.1 performs two functions: ensuring physical safety and controlloing network packet flow.Whe the hutch is closed normally, the interlock unit receives a signal from the radiation safety interlock system (the beamline interlock system) and ensures the physical safety of the staffs. A key switch is used to indicate the experiment status, i.e. "local" and "remote". When the switch is "remote" and the hutch is closed normally, the interlock system allows the remote user to move the experimental equipment.

DETAILS OF THE SYSTEM

Connection Server

As mentioned above, the connection server accepts the SSL connection from the remote users' computer after interactive authentication. For each beam time, an authentication certificate is created and signed at Spring-8, which includes an experiment identifier called the "proposal-ID." If the ID is altered, the SSL server detects it and rejects the connection request. The SSL server accepts only requests with signed authentication certificate generated by the remote experiment system.

The authentication certificate, which is a text file with a size of few kilobytes, is sent by e-mail to the user: however, the file is protected by a randomly generated password and the password is sent by physical mail. Thus even if the authentication certificate is wiretapped, the remote experiment system cannot be accessed without the password.

The connection server fetches data regarding the beam time and beamline corresponding to the proposal-ID, which is included in the authentication certificate from the proposal DB. Before or after the beam time, the connection server sends back only error messages to the remote user's computer. During the beam time, the connection server filters messages and sends only permitted message to the station control system.

The SPring-8 staffs can access the proposal DB using a Web interface, register proposal-IDs, beam times, user names, etc. They can monitor the status of the remote connection using the Web interface.

The Interlock Unit

The interlock unit receives the hutch status from the radiation safety interlock system of the beamline. The interlock unit has a two-state key switch, and when the key switch is in the “remote” state and the hutch is closed normally, the unit enables experimental station control.

An ARM based embedded Linux controller with two Ethernet port, Armadillo-220 [4] is installed in the interlock unit, and the controller controls the network packet flow using a Linux Security Module (LSM) which provides an infrastructure of the SELinux. The Linux kernel calls the socket_sendmsg() or socket_recvmsg() function every time it sends or receives network packets, and if the functions return a negative value, the packets are dropped. The functions are modified to check the status of the key switch via a general purpose input/output port (GPIO) of the ARM processor, and if the key status is “local,” all the packets from the remote connection server are dropped. By setting the key switch to the “local” state, the SPring-8 staffs can operate the experimental equipment without interference from the remote user.

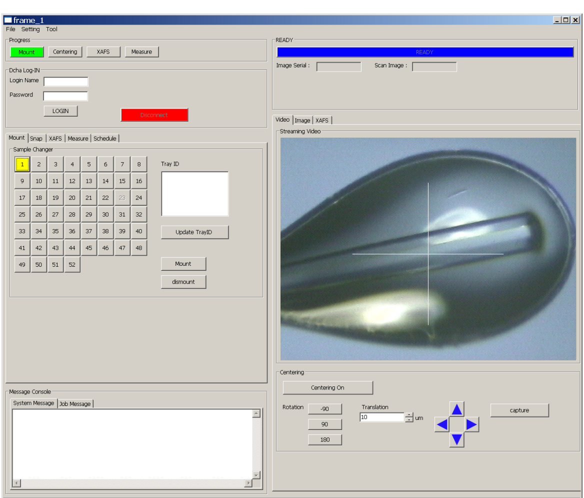

Figure 2: The remote GUI for protein crystallography experiment. On the right center, a sample image is shown via the streaming video.

Streaming Video

Using an open source video streaming software package, “ffmpeg/ffserver”[5], we have developed a simple video streaming system for monitoring the experimental station and samples. A computer is set up beside the experimental station for capturing videos and running the ffmpeg program for video compression. The ffserver program runs on the connection server and relays the streaming video data. Currently, we can sending 15 fps VGA-size movies at a transfer rate of 700 kbps.

By connecting to the video streaming port of the connection server, the remote user can monitor the experimental station or samples.

REMOTE PROTEIN CRYSTALLOGRAPHY EXPERIMENT

As the first setp toward the application of the remote experiment system, we are currently developing a remote protein crystallography experiment system. Remote users can directly change the poistion of the sample by viewing the sample in the streaming video. By clicking on the video running on the GUI on the remote user's computer, she/he can indicate the x-ray irradiation position (see Fig.2). This procedure is called “centering.”

The total response time from indicating the irradiation position to moving the crystal on the remote user's screen is less than 1 s, which is short enough for the experiment. Most of the response time is spent in video compression. The video latency and compression ratio show a trade-off relation. We have selected a high compression ratio to maintain the quality of the video for a narrow network bandwidth. The message response time is less than 100 ms, but the actual response time depends on the network condition between the remote user and SPring-8 site.

The protein crystallography experiment system is currently under trial, and it will be made available to users next April.

SUMMARY

We have developed a remote experiment system for synchrotron radiation facilites. The system provieds a safe and flexible means for performing experiments remotely.

As an application, we are developing a remote protein crystallography experiment system and it will be available to users next April.

REFERENCES

[1] N,Okazaki, et.al., J. Synchrotron Rad. **15** (2008) 288.

[2] H.Sawa, “"Collaboratory" in Photon Factory”, International Symposium on Frontier in Materials Design, Synthesis and Measurements, Hyogo, JAPAN, 2005/3.

[3] R. Tanaka, et. al., Proc. of ICALEPCS'97, Beijing, China, (1997) p.1

[4] http://armadillo.atmark-techno.com/armadillo-230

[5] http://ffmpeg.org/