‘Global Academy’—Remote Network Applications Connecting Japan and Chile over GEMnet2 and R&E Networks

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Abstract

This article describes two demonstrations at the NTT Group Communication EXPO held at the Tokyo International Forum in December 2005. These showed visitors two of our trials on the feasibility of remotely operating instruments in Chile from Japan: an optical telescope and rock hammers in an underground copper mine. These applications use a relatively high bandwidth of around 100 Mbit/s and require short delay times for smooth interactive operation. To satisfy these requirements we used NTT’s experimental research network GEMnet2 in collaboration with partner R&E (research and education) networks in North and South America. The demonstrations showed that Internet-based networks can handle interactive network applications with sufficient quality between two sites separated by almost the maximum possible distance on the Earth as long as the bandwidth and the route are carefully managed.

1. Introduction

To commemorate the 20th anniversary of NTT’s privatization, the “NTT Group Communication EXPO 2005” was held from December 20th to 22nd, 2005 at the Tokyo International Forum. The aim of this exhibition was to show the future vision of the NTT Group and to raise public perception and awareness of the NTT Group. The event was aimed at the general public, especially children and younger people, so some of the exhibits were intended not only to show the technical superiority of NTT in communications technologies but also to provide some educational benefits.

Our assignment was to show a ‘Global Academy’, which was part of the “Learning” zone. The initial plan was to connect places of educational interest in Japan with the exhibition site using a high-speed Internet service to communicate with the people in distant places. However, since NTT Laboratories has a long history of international collaboration, connecting to sites abroad using the NTT Laboratories’ experimental network, GEMnet2 [1], was considered to be a better plan because showing international collaboration via high-speed communications was expected to be very attractive to visitors to the exhibition. By collaborating with GEMnet2’s partner research and education (R&E) networks, we were able to communicate with a wider selection of research institutes and universities around the world at a speed of over 100 Mbit/s, which is not possible using a commercial Internet service at the moment. Thus, the theme of ‘Global Academy’ was eventually chosen to be “see and feel the other side of the earth with optical high-speed networks”.

The candidate destinations included Chile, which is the furthest country from Japan, 20,000 km away. The days and nights there are almost exactly opposite to those in Japan and the seasons are also opposite. In addition the constellations in Chile’s southern sky are different from those observed in Japan. Furthermore, NTT has a long history of collaboration with the University of Chile [2] and has started a joint research project with CODELCO (Corporación Nacional del

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Cobre de Chile) in the last two years [3]. Considering this collaboration, two demonstrations were conceived: (1) showing the sky in Chile by remotely operating an astronomical telescope and (2) remotely operating rock hammers inside an underground copper mine by connecting the Chilean sites and the exhibition venue via GEMnet2 and partner R&E networks.

2. Remote network applications and connection between Japan and Chile

2.1 Overview of the demonstrations

The first demonstration (**Fig. 1**) involved remote operation of an astronomical telescope at the Cerro Calán Campus of the University of Chile using MPEG-2 video streaming from Cerro Calán to the EXPO venue and videoconferencing between Tokyo and the telescope control room in Cerro Calán. This utilized equipment set up for an ongoing joint experiment among NTT Laboratories, the University of Chile, and the National Astronomical Observatory of Japan (NAOJ). The second demonstration (**Fig. 2**) involved remote operation of rock-crushing hammers in CODELCO's Andina mine using MPEG-2 video streaming from the underground mine to the EXPO venue and video conferencing between Tokyo and CODELCO's Los Andes control room. This utilized equipment set up for a joint experiment between NTT Laboratories and CODELCO. The main goal of the demonstrations was to show the feasibility of using Internet-based networks for these demanding applications over very long distances. Through collaboration with other R&E networks, GEMnet2 was able to connect the exhibition site and the sites in Chile with a reasonably high bandwidth (about 100 Mbit/s).

2.2 GEMnet2

NTT Laboratories is operating an experimental network testbed called GEMnet2 (Global Enhanced Multifunctional Network) for research and development of various communications technologies within NTT Laboratories [1]. It started operating in 1998 to help verify new communications technologies in a real network environment by providing network and application researchers with a global network testbed [4].

GEMnet2 (**Fig. 3**) utilizes new technologies developed in NTT Laboratories, especially the latest photonic devices and transmission equipment utilizing them. In 2001, GEMnet2 deployed a full-mesh photonic network system (AWG-STAR) [5] together

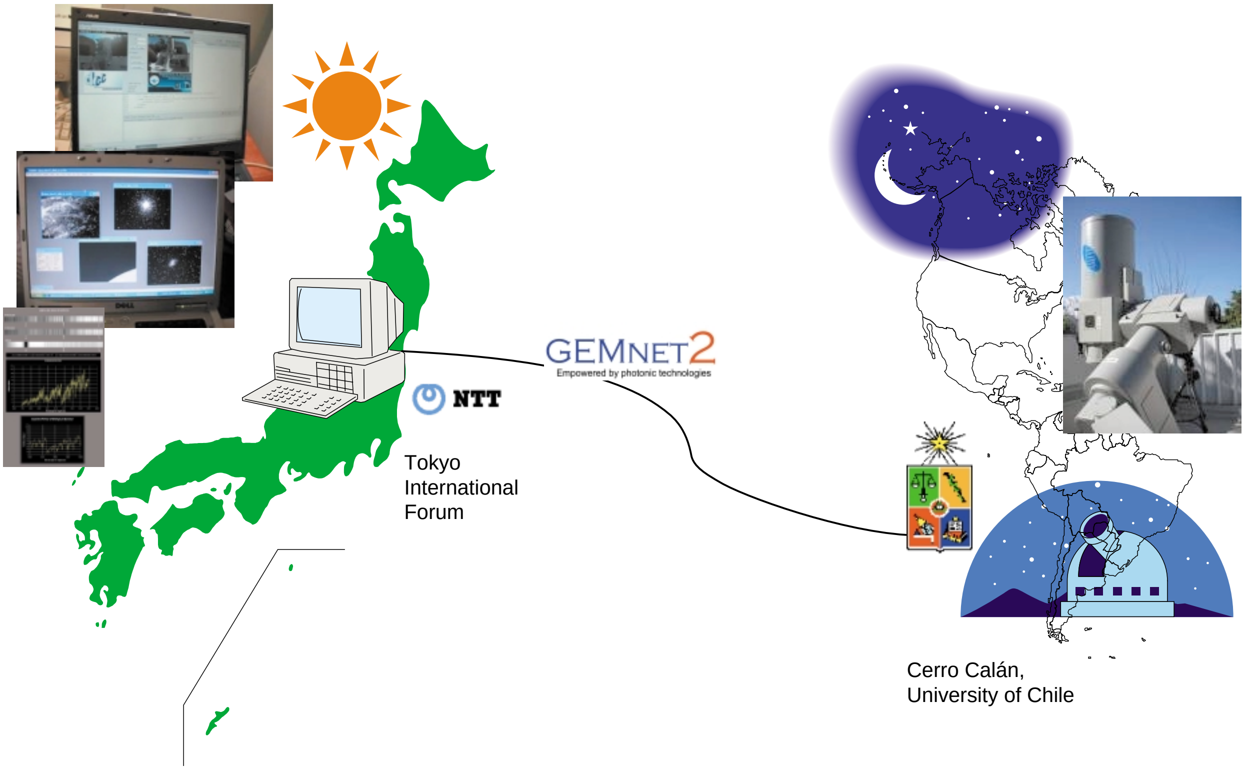

Fig. 1. Remote operation of astronomical telescope.

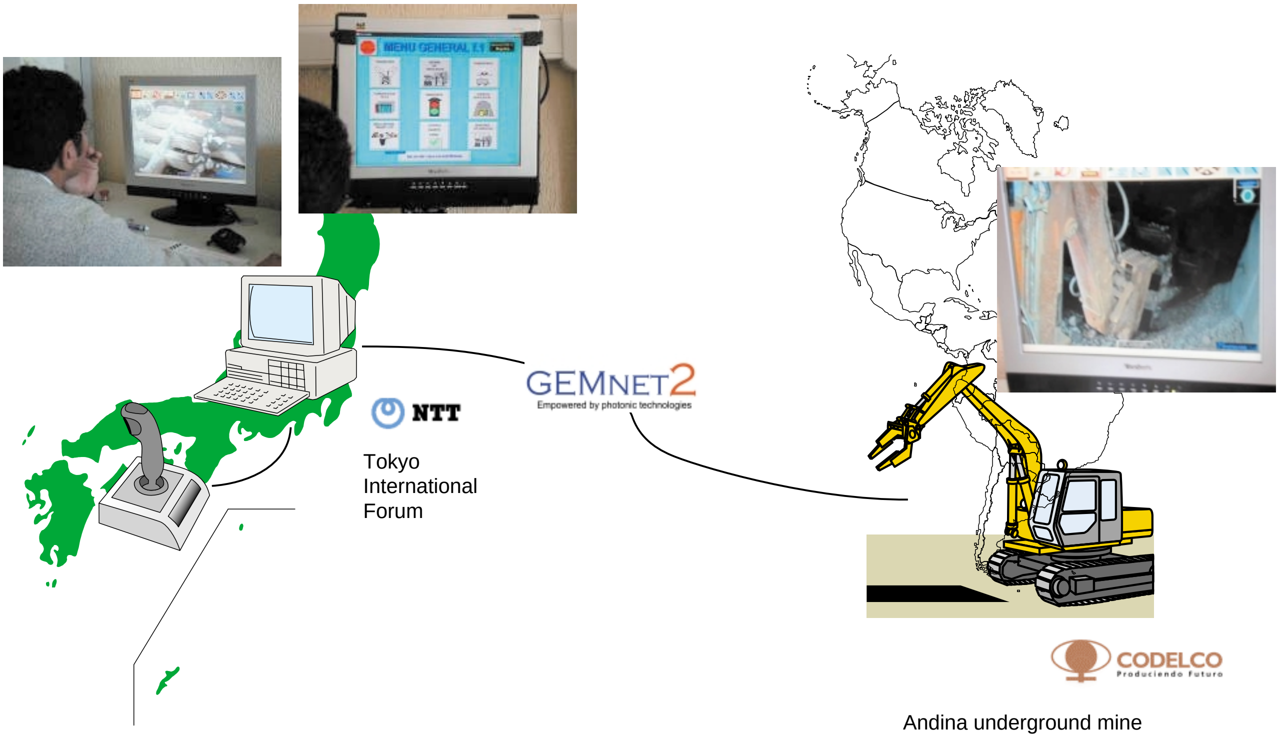

Fig. 2. Remote operation of copper mine hammers.

with dense wavelength division multiplexing (WDM) equipment in the GALAXY network [6]. AWG-STAR is a WDM filter using silica-based planar lightwave circuit technology developed by NTT Photonics Laboratories and it can multiplex/demultiplex several WDM signals simultaneously. GEMnet2 uses different wavelengths to separate traffic of a highly experimental nature from other traffic requiring stable connections to prevent unwanted interference between those two classes of traffic.

2.3 Collaboration with other R&E networks

The original aim of GEMnet2 was to promote collaboration with research groups abroad as well as within Japan [4]. The significance of international cooperation is growing year by year and partnerships with other R&E networks play an important role in this respect. One example of NTT Laboratories' international collaboration already in progress is the joint research project on remote observation using a radio telescope with NAOJ and the University of Chile. In this project, astronomers at NAOJ's main campus in Tokyo can access their sub-millimeter radio telescope located in the Atacama desert in northern Chile via GEMnet2. To make this possible we are collaborating with a number of R&E networks, which provide transit services for our experiment.

GEMnet2 and partner R&E networks in the USA and other countries are connected with our OC-48 (2.488-Gbits/s) trans-Pacific link. The circuit is connected to the Pacific Wave [7], which is one of the main connecting hubs for R&E networks on the west coast of the USA. Pacific Wave is operated by the University of Washington and we have a peering agreement with R&E networks including the Pacific Northwest GigaPoP [7], CENIC [8], AARNET [9], TWAREN [10], and the Abilene network [11].

2.4 Routes and performance of international connection

The international connection for the experiment is shown in **Fig. 4**. There were two alternate routes to REUNA (Red Universitaria Nacional) [12], which is a Chilean R&E network with connectivity to the two experimental sites in Chile: one is through Europe via the GÉANT backbone network [13] funded by the EU and the other is a new route that started operations last year through RedCLARA [14], which runs along the west coast of the American continents. This new route greatly reduces the roundtrip transmission delay from 440 to 250 milliseconds.

Netperf [15] tests conducted between NTT Musashino R&D Center and the REUNA office in

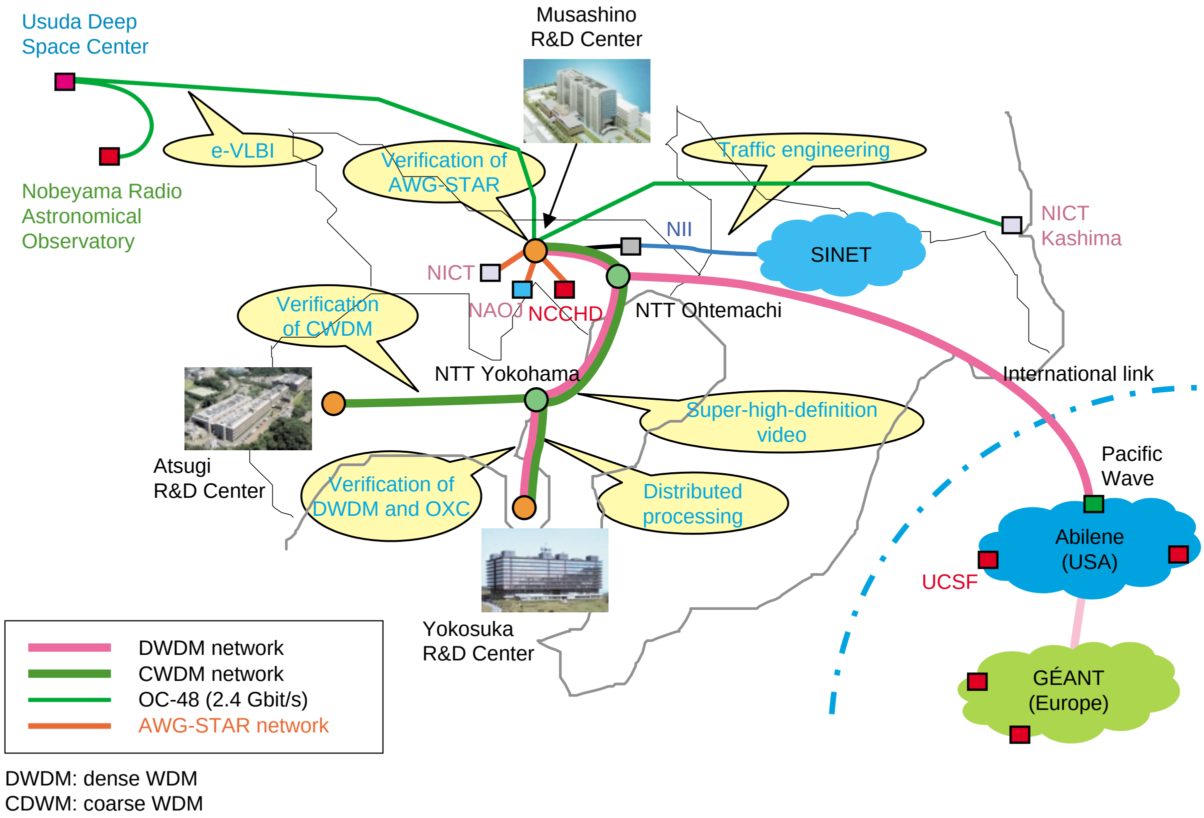

Fig. 3. Configuration and research topics of GEMnet2.

Santiago showed that the throughput was 70 Mbit/s for UDP (user datagram protocol) traffic and 1.7 Mbit/s for TCP (transmission control protocol) traffic, which is more than adequate for MPEG-2 video streaming, which requires about 6 Mbit/s or less. We found a bandwidth bottleneck in the range of 2–10 Mbit/s for the link between the DCC Beauchef Campus of the University of Chile and the Cerro Calán Campus where the astronomical telescope was. The link connecting REUNA and CODELCO's Los Andes office had a dedicated bandwidth of 100 Mbit/s and there was no bottleneck in this segment, allowing very stable MPEG-2 video streaming.

3. Remote astronomical observation

Ever since the mid 1980s, it has been possible to control small astronomic telescopes from a computer. The movement of the telescope is controlled by commands sent from a computer, and the images are captured by CCD (charge coupled device) cameras as digital data and stored on a computer. Remote astronomical observation over the Internet is becoming popular these days and such observation systems are sometimes called "Internet telescopes" [16], [17]. The Gunma Astronomical Observatory in Japan, a 65-cm telescope, can be operated remotely for educational purposes using a web browser and streaming video over an ISDN (integrated services digital network) connection [18], [19]. However, these examples are mainly aimed at educational use by elementary or junior high schools.

3.1 Optical telescope in University of Chile

The telescope we used at the Cerro Calán Observatory in Santiago, which belongs to the Department of Astronomy of the University of Chile, is a 45-cm Cassegrain (reflecting) telescope made by GOTO Inc. (**Fig. 5**, **Table 1**). This telescope was designed for use by researchers, but it is mainly used for training astronomy students and teaching students of other departments. The telescope is controlled by four computers: one is dedicated to telescope movement (GOTO CATS3), the second handles the CCD, the third provides a web service for the telescope on a web server, and the fourth contains application software that provides a friendly user interface to the user, using the web service. CATS3 is hidden from

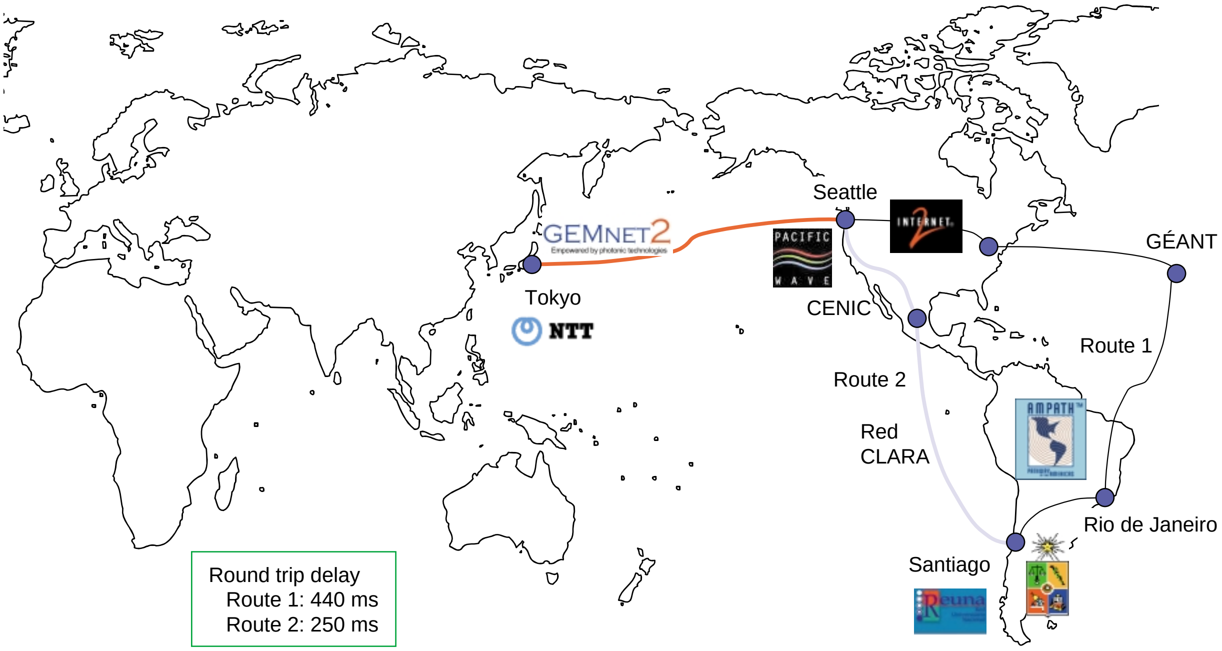

Fig. 4. International connection through collaboration with R&E networks.

Fig. 5. Telescope in University of Chile.

the Internet by the web server for security reasons. We set up a personal computer (PC) with the user interface application in Japan and controlled the telescope remotely from Japan.

3.2 Application software

The application software for the user interface and web service interface were developed by the University of Chile. The university is developing applications for use in remote observation from schools. The user interface application is written in the Java language and uses the Java 3D library. The web service interface is provided using the Apache web server and Axis software. With these programs, we can control everything on the telescope, such as the direction and exposure time. The images captured by the CCD are transferred from the remote control computer to this application on the local computer. The user interface software works roughly as follows.

1) It receives telescope pointing data when there is a change in pointing status to update the 3D image of the telescope.
2) On the user interface software, a target object is selected by name, which is sent to GOTO CATS3 either directly or after being interpreted to a position. CATS3 moves the telescope to the object.
3) When an exposure command is sent by the user interface software, the CCD is exposed to the object, and the resulting data is transmitted from the CCD to the server.
4) Then dark exposure* is done and the data is transmitted to the server. For brighter objects, dark exposure may be omitted. Using this data, dark calibration is done in the server.
5) Image data is transferred from the server to the client PC. This takes about 1–3 minutes

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* Dark exposure: CCD exposure in complete darkness. This creates a dark image frame representing the noise pattern of the CCD, which is then subtracted from images.

Table 1. Telescope specifications.

Telescope GOTO

Components	Description
Primary mirror	Effective opening: 450 mm (parabolic surface) Focal distance: 1800 mm (F/4) Aluminized and recovered with a layer of silicon monoxide
Secondary mirror	Effective opening: 150 mm (parabolic surface) Focal distance total of the Cassegrain system: 5400 mm (F/12) Aluminized and recovered with a layer of silicon monoxide
Finder	Effective opening: 100 mm Focal distance: 1800 mm (F/4) Achromatic objective lens
Eyepiece	K 60 mm, Er. 28, XL 40, XL 14, XL 5.2
Mount	German equatorial type
Weight	Approx. 1400 kg

Camera SBIG ST8

Components	Description
CCD for images	1530 × 1020 pixels
CCD for guide	656 × 495 pixels
Filters	U, B, V, I, G, G, B, H-alpha

Data from webpage of the Department of Astronomy of the University of Chile

depending on the network throughput.

6) The image is displayed on the computer's monitor.

3.3 Configuration of the demonstration system

For the EXPO demonstration, we supplemented the telescope system described in sections 3.1–3.2 with (1) a video camera and MPEG-2 encoder and decoder to view the telescope's movement or the sky and (2) an H.323 videoconferencing system to communicate between Japan and Chile (**Fig. 6**), i.e., between the client side and the remote observatory staff. Since the MPEG-2 encoder can be remotely controlled, we could change the MPEG-2 output (encoding) rate on demand, which is convenient when the bandwidth is limited. The client side at the demonstration in Tokyo is shown in **Fig. 7**.

3.4 EXPO demonstration results

Remote astronomical observation was scheduled in the daytime (11am–3pm) on December 20–22, 2005 in Japan, which was 11pm–3am on December 19–21 in Chile. The weather was fine for the first day, but it was cloudy over almost half the area of the sky on the second day, and it was very cloudy on the third day. We obtained two days of observation and took several pictures of stars. **Figure 8** shows a photograph of the Tarantula Nebula (NGC2070) in the large Magellanic cloud, which cannot be seen from Tokyo (exposure time: 150 seconds) and **Fig. 9** shows a photograph of Saturn (exposure time: 0.1 second).

Data transmission between the client PC and web server does not need a realtime connection, so we were able to control the telescope remotely and took pictures of the stars despite the long distance between Japan and Chile. This demonstration showed the following:

- Communication between the local and remote sites is necessary. The videoconferencing system was good for this purpose. To use a telescope remotely, we need to communicate with technicians at the remote observatory. We need to be prepared for actions such as focusing and tracking and emergency measures in the event of rain, etc. When observing, we need to know which direction is clear and which stars are observable.
- Remote viewing using a video camera and MPEG-2 encoder/decoder is useful. Remote tasks such as finding a clear direction were done by technicians at the observatory this time, but they could be done remotely if a camera is set up appropriately.

Visitors were impressed with the clarity of the images and the easy control of the telescope.

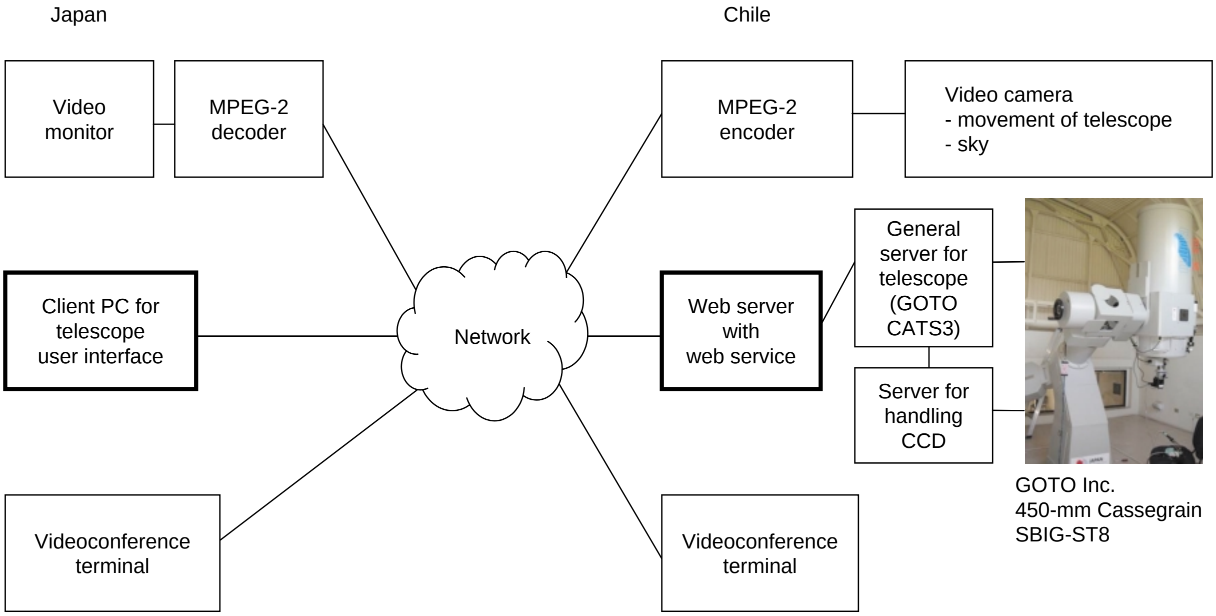

Fig. 6. System diagram of the remote telescope operation.

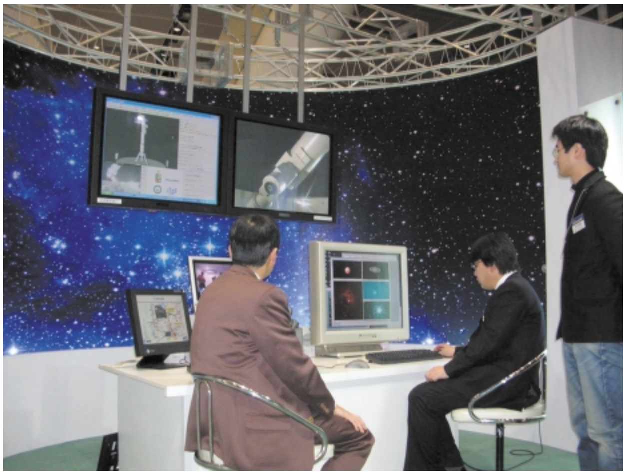

Fig. 7. Client system at the event site.

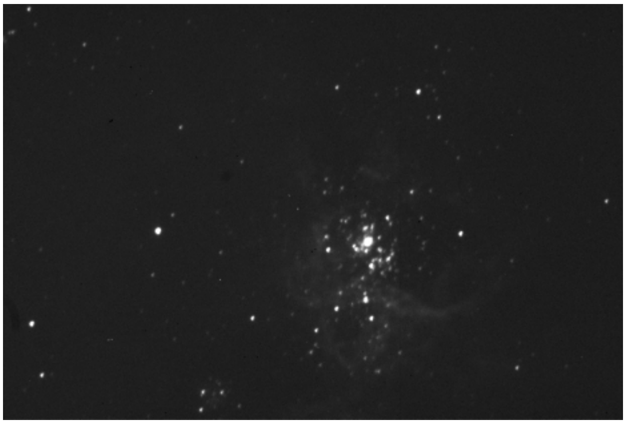

Fig. 8. Observed image: The Tarantula Nebula (NGC2070).

Fig. 9. Observed image: Saturn.

4. Remote rock hammer control demonstration

4.1 AWG-STAR network and its application to remote mining system

CODELCO and NTT Photonics Laboratories carried out a field trial of a remote mining system in CODELCO's Andina underground mine from April to October 2005 [3]. The mine is located in the Andes Mountains at a height of 3000 m above sea level and galleries extend hundreds of kilometers into the middle of the mountain. It runs 24 hours a day and the operators work in three eight-hour shifts.

In the trial, the AWG-STAR network was used as

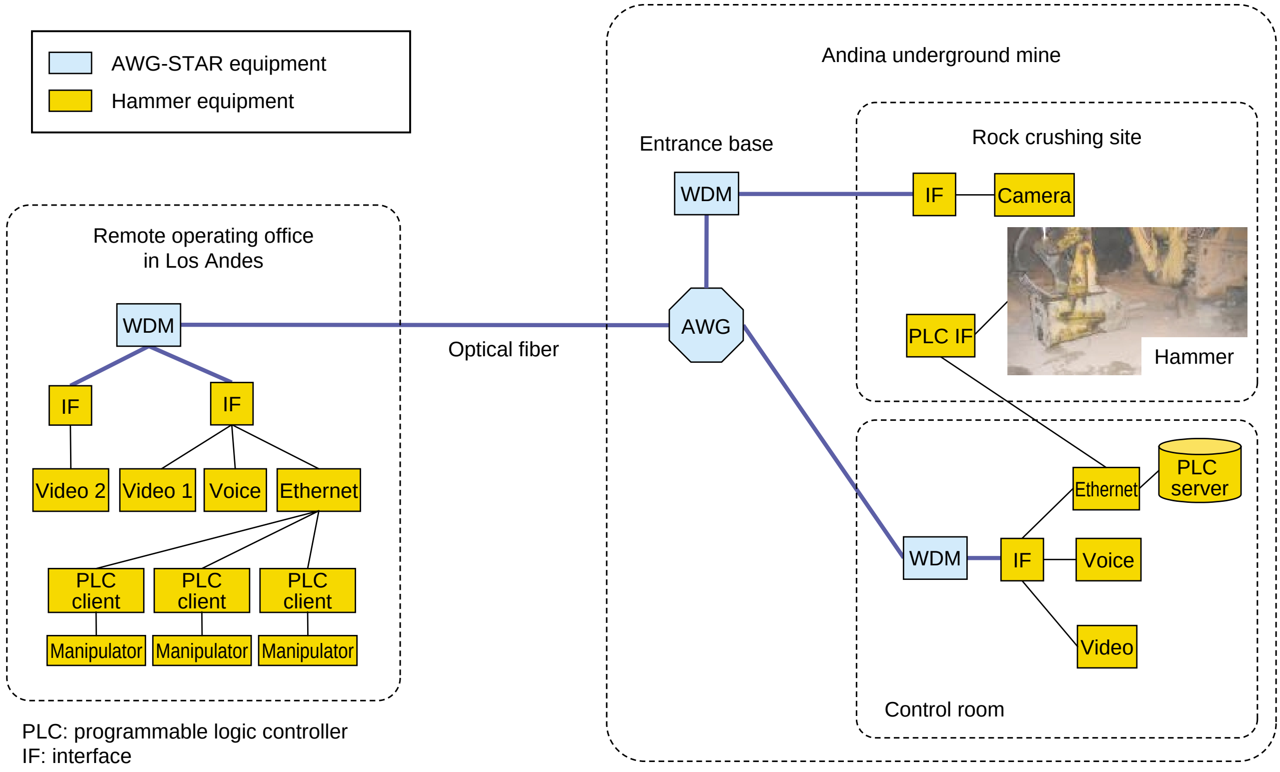

Fig. 10. Remote mining system based on AWG-STAR network.

the optical transmission system. The network was developed by NTT and consists of an arrayed-waveguide grating (AWG) router at its center, surrounded by WDM nodes connected with optical fibers in a star topology [5]. In this system, WDM optical signals from each node are wavelength-routed to the AWG-router, that is, demultiplexed and routed to the destination node according to their wavelengths. The AWG-STAR network provides both high capacity and immunity to inductive noise, which are inherent characteristics of optical fiber communication systems. Furthermore, since it can handle different types of signals simultaneously and has little signal delay and since the galleries in the underground mine have been dug in a star configuration, this system is highly suitable both technologically and physically for telecommunications use in underground mines.

The configuration of the remote mining system is shown in **Fig. 10**. An AWG-router and WDM equipment are installed in the machine room at the base located at the mine entrance. The other WDM equipment is installed in the control room in the gallery and in the remote control office in the city of Los Andes, which is about 100 km away from the mine. These three sites are linked by WDM optical signals (STM-16/OC-48, 2.488 Gbit/s) and are connected to the video, audio, and data communication equipment. The trial showed that voice and video signals from the mine were transmitted clearly and the rock-crushing hammers in the mine could be controlled from the remote office smoothly with little delay. It confirmed that the whole system worked stably despite the heavy snowfalls in the Andes during the Chilean winter season.

After the field trial ended successfully in October 2005, the whole system was retained by CODELCO and is now in regular use. The remote mining system provides benefits for both CODELCO and its workers: the company benefits because the system's nonstop operation eliminates the need to bring operators to the mine and workers benefit because they are saved from having to work in the dusty and dangerous environment in the galleries and take the two-hour commute from Los Andes to the mine along a precipitous mountain road.

4.2 Network configuration for demonstration

For the demonstration at the EXPO, a control chair with a programmable logic controller (PLC) client for the hammer was shipped to Tokyo so that remote control of the mining system could be extended from Los Andes to Tokyo. **Figures 11** and **12** show the

Fig. 11. Node distribution in Chile.

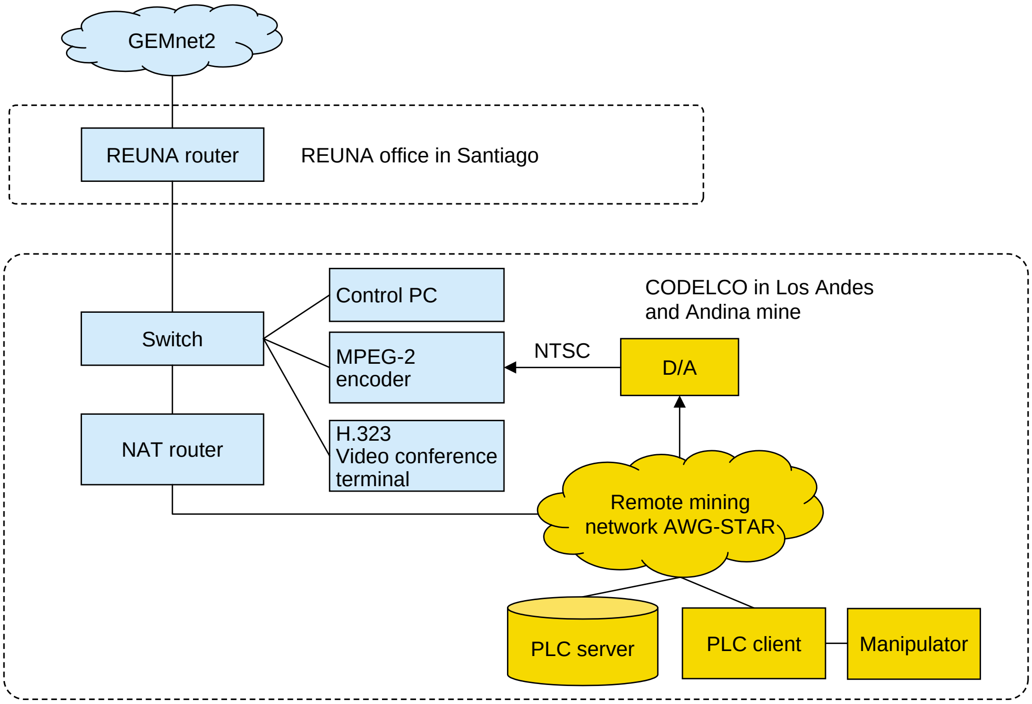

Fig. 12. Network configuration for remote hammer control.

node distribution in Chile and the network configuration for the demonstration at the EXPO, respectively. A 100-Mbit/s link was prepared between the remote operating office in Los Andes and the REUNA office in Santiago. REUNA provided a port-based virtual local area network (VLAN) in their routers for the operating network and GEMnet2 link was extended to CODELCO's office in Los Andes.

For the demonstration, an MPEG-2 encoder (NEL RU-1000E), an H.323 video conference terminal, and a network address translation (NAT) router were connected to the VLAN. An NTSC (national television standards committee) video signal was transmitted from the hammer site in the gallery over the AWG-STAR network to the encoder. The analog signal was converted to an MPEG-2 8-Mbit/s digital signal and sent to the decoder (NEL RU-1000D) in Tokyo. The videoconferencing equipment was used to enable conversation between Los Andes and Japan. Since the link capacity was stable and large enough, the signal was set to the maximum rate of 1920 kbit/s. The NAT router was installed between the REUNA VLAN and CODELCO's LAN to connect the PLC client in Tokyo with the PLC server in the underground mine.

4.3 Performance at the demonstration

The operation room in Los Andes is shown in **Fig. 13**. The control chairs with built-in manipulators and switches on both arms are connected with PLC clients, monitors are mounted on the walls, and telephones are set on the desks. During their normal working hours, the operators cooperated with our demonstration by videoconferencing and assisting with the remote operation from Tokyo.

The EXPO exhibition site and a video display of the rock-crushing hammer transmitted from inside the mine are shown in **Figs. 14(a)** and **(b)**, respectively. An operator's control chair was placed in the booth and the PLC client was connected to GEMnet2. The left display in Fig. 14(a) shows the decoded video signal of the hammer in the mine, and the right one shows the videoconferencing image of the operating room in Los Andes. By monitoring the movement on the left display, a visitor in Tokyo could control the rock-crushing hammer in the mine smoothly using the manipulators and buttons on the chair.

The round trip delay time for IP (Internet protocol) packets between Tokyo and Los Andes was 260 milliseconds, which is small enough to control the hammer from over 20,000 km away and allow smooth videoconferencing. The large bandwidth of the network made it possible to transmit clear MPEG-2 video signals from the mine.

During the three days of the event, the remote mining system worked without any problem. This showed the high reliability of the AWG-STAR network even in the severe, dusty environment of an

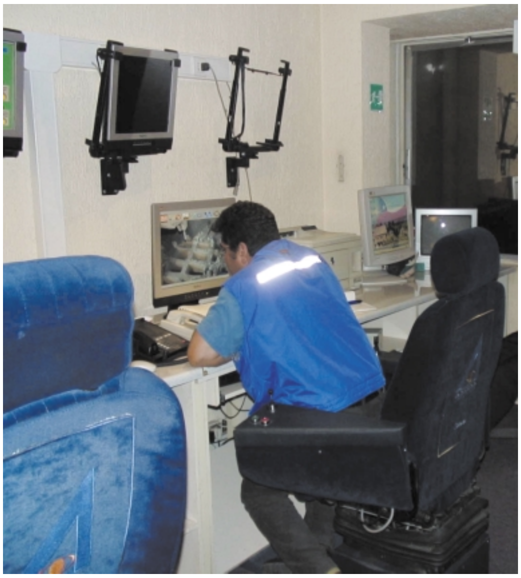

Fig. 13. Remote operating room in Los Andes.

(a) Expo site

(b) Received video signal of hammer

Fig. 14. Expo site and received video signal.

underground mine in a high-altitude location. This confirms that the AWG-STAR network is a promising platform for an efficient mining system. The success of this remote mining demonstration after fruitful cooperation provided a further boost to the good relationship between CODELCO and NTT.

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References

[1] H. Uose, M. Yamaguchi, and J. Kishigami, "GEMnet2: New Network Testbed for Global R&D," NTT Technical Review, Vol. 1, No. 5, pp. 31-37, 2003.
[2] N. Yamauchi, E. S. Vera, H. Yamamoto, and H. Uose, "Progress of Network Experiments in Research Collaboration between NTT Laboratories and the University of Chile: AccessNova," NTT Review, Vol. 14, No. 2, pp. 53-58, 2002.
[3] K. Nozawa, K. Noguchi, M. Shoji, H. Uehara, and R. Ohmoto, "International Joint Feasibility Experiment with a Copper-mining Company in Chile," NTT Technical Review, Vol. 4, No. 1, pp. 44-49, 2006.
[4] K. Okada, J. Kishigami, M. Yamaguchi, N. Miyaho, and N. Yamauchi, "Current Status and Future Direction of NTT's Global Networks for Experiments, GEMnet," NTT Review, Vol. 14, No. 2, pp. 26-33, 2002.
[5] K. Noguchi, Y. Koike, H. Tanobe, K. Harada, and M. Matsuoka, "Field Trial of Full-Mesh WDM Network (AWG-STAR) in Metropolitan/Local Area," IEEE J. Lightwave Technol., Vol. 22, No. 2, pp. 329-336, Feb. 2004.
[6] H. Uose, "Application of Ultrahigh-speed Network to Advanced Science," NTT Technical Review, Vol. 1, No. 5, pp. 39-47, 2003.
[7] http://www.pacificwave.net/
[8] http://www.cenic.org/
[9] http://www.aarnet.edu.au/
[10] http://www.twaren.net/
[11] http://abilene.internet2.edu/
[12] http://www.reuna.cl/ (in Spanish).
[13] http://www.geant.net/
[14] http://www.redclara.net/en/index.htm
[15] http://www.freebsd.org/projects/netperf/index.html
[16] T. Sato, K. Maeda, Y. Tsubota, N. Matsumoto, Y. Sakakibara, and Y. Yamazaki, "New Movement of the Internet Astronomical Observatory: Starry Night to Classroom from the Other Side of the Earth," The Astronomical Herald. Vol. 96, 565-571, 2003.
[17] http://rika.educ.kumamoto-u.ac.jp/ASOB-i/ (in Japanese).
[18] K. Kinugasa, H. Kawakita, T. Kurabayashi, and H. Taguchi, "Remote Telescope at Gumma Astronomical Observatory," The Astronomical Herald, Vol. 96, 585-591, 2003.
[19] http://www.astron.pref.gunma.jp/e/index.html

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