Trans-Pacific Demonstration of Visible Human (TPD-VH)

Reat Nozomu Nishinaga[a], Haruyuki Tatsumi[b], Michael Gill[c], Hirofumi Akashi[b], Hiroki Nogawa[b], Ivette egi[c]

[a] Communications Research Laboratory, I.A.I.
4-2-1 Nukui-Kita, Koganei, Tokyo 184-8795 Japan
Tel.: +81 42 327 6864; Fax: +81 42 327 6825
e-mail: nisinaga@crl.go.jp

[b] Information Center for Computer Communication, Sapporo Medical University
Minami 1 Nishi 17, Chuou-ku, Sapporo, Hokkaido 060-8556 Japan
Tel.: +81 11 612 2111 (2630); Fax: +81 11 640 3002
e-mail: tatsumi@sapmed.ac.jp, hakashi@sapmed.ac.jp, nogawa@cmc.osaka-u.ac.jp

[c] Lister Hill National Center for Biomedical Communications, National Library of Medicine 8600 Rockville Pike, Bethesda, Maryland 20894 USA
Tel.: +1 301 435 3212; Fax: +1 301 402 0341
e-mail: mike_gill@nlm.nih.gov, reategi@mail.nlm.nih.gov

Abstract

This paper describes the Visible Human (VH) part of the Trans-Pacific Demonstrations of the G7 Information Society-Global Interoperability for Broadband Network (GIBN) Projects. Aiming at a world-wide Visible Human Anatomical Co-laboratory, an application (VHP Viewer) was developed, which was used for data transmission testing (Trans-Pacific Demonstration of Visible Human) through broadband satellite links between the US and Japan. The demonstration includes (1) remote VH database access and (2) network multi-parallel computing access. It is shown that wide-area database access and high-speed multi-parallel computing could be effectively demonstrated via broadband satellite networks by circumventing a large time-delay by using the Mentat SkyX Gateway system and Personal File System (PFS). Elements of the demonstration verified here could be also applied to distance education and telemedicine as well as a postgenome project.

1. Introduction

The Trans-Pacific High Data Rate Satellite Communications Experiment phase II (a part of the G7 GIBN projects) was carried out from May to July 2000. The Visible Human (VH) demonstration was conducted during July 2000.

1.1 The background of TPD-VH: a G7 Information Society Project [1]

At the G7 Ministerial Conference of the Information Society, held in Brussels in February, 1995, Ministers agreed to core principles to guide the evolution of the global information society. The 11 pilot projects endorsed by G7 Ministers in Brussels were to demonstrate the potential benefits of the information society and stimulate its deployment. Their main objective was to promote joint R&D, demonstrations and pre-commercial trials of advanced high-speed services and applications. The Global Interoperability for Broadband Networks (GIBN) project is one of these pilot projects. Another is the Global Healthcare Application Project (GHAP) which includes the Multi-Language Anatomical Digital Database (subproject 8:SP8) proposed by the National Library of Medicine (NLM) in the United States. The developed applications and systems for the GHAP-SP8 were used for the GIBN-Trans-Pacific Demonstration of Visible Human (TPD-VH) [2].

1.2 Overview of this demonstration

The purpose of this demonstration was to prove the feasibility of wide-area database access and high-speed network parallel computing system access through long delay links. The delay here is caused by the use of geostationary satellites. TCP is the most commonly used reliable transport layer protocol supported by most operating systems. TCP allows flow control by a sliding window but no rate control function. The TCP slow-start mechanism is also introduced for congestion avoidance. It gradually increases the number of the packets that can be sent out at once. The number of packets to be sent out can be increased every time it receives an acknowledgement. When acknowledgement is not received, TCP lowers its sending rate. Using this mechanism, TCP can know the available bandwidth. However, the new packets cannot be sent unless the acknowledgement returns. Therefore, when the round trip time is large, even though there is bandwidth that can be used, enough data cannot be transmitted and the throughput is very low. RFC

1323 [3], to extend the sliding window size, is proposed to circumvent this problem. However, all operating systems (OSs) do not support this RFC. For example, the Mac OS X server (Ver. 1.1) which we used did not support RFC 1323. It is important to establish the technique for the broadband database access and high-speed network parallel-computing system access under the large delay time.

2. Materials, Application & System

2.1. Visible Human Project Dataset [4, 5]

The Visible Human Project is a historic project started in 1986 by the U.S. National Library of Medicine, which set about to build a digital image library of volumetric data representing a complete, normal adult male and female. The VH image dataset amounts to about 15 GB for the male cadaver and 40 GB for the female cadaver. The 1,871 axial images in the male dataset were created via anatomical cryosectioning at 1 mm intervals and then CCD scanning at 2048 x 1216 x 24 bits. The female dataset is the same except the cryosectioned images are at 0.33 mm intervals resulting in 5189 cross-sections. We used the male dataset for this demonstration.

2.2. VHP Viewer

Aiming at a world-wide Visible Human anatomical Co-laboratory [6], a viewer of the Visible Human data (VHP Viewer) was developed for observing arbitrary sections of interest with the scroll bars of TransView, SagitView and LongView (Fig 1). The viewer shows small reduced-size images (Fig.2) and large original–size images (Fig. 2). To get reconstructed images from serial transverse images, we have developed a powerful processing engine (network multi-parallel computing system). The viewer has a switch for Gserver, which is a control part of the network multi-parallel computing system (described below). For the case where the Gserver switch is on, the viewer uses the system via the network to reconstruct the image. Otherwise, (Gserver-off) it uses the ready-made images on the local hard disk. Therefore the viewer has a hard disk mode (but including NFS or PFS mounted disk) and a Gserver mode.

2.3. Network Multi-Parallel Computing System

A network multi-parallel computing system [7] consists of 35-50 Mac OS X server machines (Gservers) and a Linux machine (Gboss) (Fig. 3). The Gboss is accessed from the VHP Viewer using TCP sockets when the Gserver switch is on, as mentioned above. The Gboss at Sapporo Medical University (SMU) in Japan, (1) receives a request from a remote client (VHP Viewer) at the NLM in the USA, (2) makes a control command for each Gserver according to the request, (3) sends the command to each Gserver, (4) gathers computed data from each Gserver, (5) reconstructs an image, and (6) sends the image back to the remote client, which displays the image.

3. Network configuration

Two geostationary satellites and multiple high-performance research networks: NORTH [8], IMnet [9], APAN [10], TransPac [11], CA*net [12], STARTAP [13], NREN [14] and ATDnet [15] were employed (Fig.4). The transportable earth stations located at SMU and Kashima Space Research Center (KSRC) Japan were linked via the Japanese domestic satellite N-STAR Ka-band transponders. Also linked by satellite (via Intelsat 802) was KSRC and the Lake Cowichan earth station (LCW) operated by Teleglobe Canada. The bandwidths of both satellite links were 44.5Mbps (DS-3), which is considered to be a bottleneck as the LANs are 100Mbps. Use of this special communication path enabled higher quality of service than use of the general or commodity Internet. A photograph of the Ka-band transportable earth station located at SMU is shown in Fig. 5. A 20Mbps leased line was used for the terrestrial link between LCW and the Canadian CA*net 3 research network. CA*net 3 was linked to the NASA research network in Chicago and both NLM and NASA were connected via the ATDnet, an advanced research network located in the metropolitan Washington DC area. The terrestrial link in the United States was available 24 hours a day, but the operation time of the satellite link was only 18 hours per day from 18:00 to 12:00 JST, creating challenges in staffing the sites in Japan.

Since all packets were sent through two geostationary satellite links and extensive fiber optic terrestrial links, it was necessary for the system in this demonstration to work with a Round Trip Time (RTT) exceeding one thousand milliseconds. Therefore the SkyX Gateway (XH45), produced by Mentat Inc. [16], was used as a “link enhancer” to overcome the effects of this large time-delay. Two SkyX gateways were used, one at SMU and one at NASA’s Goddard Space Flight Center, the closest NASA location to NLM. The SkyX Gateway works by intercepting the TCP connection and converting the data to the SkyX protocol for transmission over the satellite. The SkyX Gateway at the other end of the link converts from the SkyX protocol back into TCP. Therefore, large throughputs can be obtained even if not using an operating system supporting a counter-measure for long-fat-pipes like RFC 1323. Since this enhancement is only valid with TCP, there is no gain using the network file system implemented running over the UDP like NFS version 2. The protocol stack of this demonstration is shown in Fig. 6.

4. Results & Discussions

This demonstration included (1) a remote VH database access and (2) a network multi-parallel computing access.

4.1. Remote VH Database Access Demonstration

In this demonstration, we used the male dataset (15GB). For prompt reference, researchers at SMU accessed the small-size compressed VH images (around 100KB) stored in a mirror server via a local area network with the VHP Viewer running on a Mac G3s (Mac OS X server Ver. 1.1). When wanting to see original high-definition images, the researchers could access a file server (Sun Solaris 8) located at NLM in the USA. In fact, this access to the VH data server was done through a UNIX file system. These image files on the NLM data server were mounted on to a local file system in the client machine using a network file system (NFS).

We used a mounted disk using NFS version 2 for the VHP Viewer, before inserting a satellite link in the communication system path. Using the satellite links took too much time to get the VH images. Therefore the Personal File System (PFS) [17], developed by Mr. Tateoka at the University of Electro-Communications, was utilized. This is a portable network file sharing system designed for mobile computers. It is constructed from file servers on stationary hosts and mobile clients. It has cache storage on the client, and dynamically adapts to a variety of network speeds, bandwidths and disconnections. Since the PFS is implemented over the TCP, the SkyX gateway can accelerate the throughput. All of the PFS system is implemented on UNIX, and communicates with client kernels with traditional NFS. So PFS can run on variety of UNIX variants.

The PFS performance was compared with NFS version 2 (Tables 1 and 2). The RTT between SMU and NLM was measured by UNIX ping command. The RTT were 1124.825 ms via satellite link and 191.746 ms via the TransPAC respectively. We measured throughputs via the TransPAC and via the satellite link with NFS version 2. We used an image file of 7,471,284 bytes for the throughput measurement. Since the NFS version 2 uses the UDP, there is no benefit to using the SkyX Gateway. For calculating the throughput, we use the elapsed time for copying a file from a remote file system to a local file system with the UNIX copy command. The result is shown in Table 1. For the case using the TransPAC (cable), we did the measurement 51 times; the minimum throughput was 158 kbps, the maximum throughput was 592 kbps and the average throughput was 438 kbps. For the case using the satellite link, 144 kbps (minimum), 292 kbps (maximum) and 208 kbps (average) throughputs were obtained, with measurements made 27 times. The NFS version 2 is the network file system developed for the LAN and it is difficult to apply to long-fat-pipes like broadband satellite links. We measured the PFS throughput in the same way. The result is shown in Table 2. Using the TransPAC path, 787 kbps (minimum), 933 kbps (maximum) and 879 kbps (average) throughputs were obtained, with measurements made 17 times. Using the satellite link, we obtained 1,928 kbps (minimum), 8,414 kbps (maximum) and 4,980 kbps (average) throughput, with measurements made 96 times. We also measured the PFS throughput via the satellite path for the case of a larger image file (11,538,432 bytes). The results are also shown in Table 2. For measurements made 6 times, we obtained 3,296 kbps (minimum), 8,391 kbps (maximum) and 5,429 kbps (average) throughput. Since the satellite link was about 1.1 seconds RTT, several seconds elapsed in carrying out TCP handshaking. If supposing an ideal simple file system existed supporting only the reading operation, the throughput becomes 14.5Mbps (for 7MB-sized file) and 16.1Mbps (for 11MB-sized file) respectively. There is room for improving the throughput. From these results, we can construct a wide area data base access network by combining the SkyX Gateway system and PFS.

4.2. Network Multi-parallel Computing Access Demonstration

To reconstruct an image of a new section from the serial transverse section data, it takes about 2000 seconds with one machine (Mac G3). Using the network multi-parallel computing system consisting of 35 Mac G3 clusters, it takes about 2-3 seconds to generate the new image data [7]. Due to the overhead of the program and local drawing performance, it really takes about 6-7 seconds to display the image on the terminal. That is quite tolerable for researchers, as compared to 2000 seconds.

The network multi-parallel computing system located at SMU was used from the VHP Viewer running on a Mac G3 (Mac OS X server Ver.1.1) at NLM via a terrestrial (Table 3) and satellite (Table 4) lines. For the case of the terrestrial line, the file transfer rate was 0.2-0.4 Mbps and sometimes 0.6 Mbps. For the satellite line, the rate was 0.1-0.2 without SkyX gateway system and 4-7 Mbps with this system (Table 5). As mentioned above, TCP socket data transfer was much influenced by a large time-delay, but SkyX improved the transfer rate from 0.1-0.2 Mbps to 4-7 Mbps.

4.3 Switching between satellite and terrestrial lines during the experiment

The Border Gateway Protocol (BGP-4) was used for the IP (Internet Protocol) layer routing protocol between Japan and North America. The BGP-4 router at SMU also worked as a routing switch between the satellite and terrestrial links because SMU could be connected via terrestrial IMnet and TransPAC to NLM when the N-STAR satellite link was not available.

5. Conclusion

In this paper we described the Visible Human Demonstration part of the Trans-Pacific Demonstrations. We showed that a wide-area database access network could be effectively established using a hybrid satellite/fiber optic network and that the network multi-parallel computing system can be accessed through the satellite with high speeds. The techniques verified here can be applied to the fields of distance education, telemedicine, and postgenome projects.

In fact, the BGP4 routing experiences based on this demonstration accelerated the deployment of the protocol to establish a regional Internet eXchange (IX) (Fig. 7) between the networks of NORTH (Network Organization for Research and Technology in Hokkaido) and OCN (Open Computer Network run by NTT Communications Inc.) for advanced medical networks in Hokkaido [18], which was supported by the Hokkaido Development Agency in Japan. In addition, the network multi-parallel computing system, developed for the GHAP-SP8, was used not only for this demonstration but also for the postgenome project [19], elucidating the function of the gene of P53. For good research environments, a well-established and well-integrated robust commodity Internet is essential as a Next Generation Internet benefiting the prosperity, welfare and health of the world.

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Table 1: NFS throughput

Route	Size(Byte)	Throughput (Kbps)			Time (sec.)		
		minimun	average	maximum	mimimum	average	maximum
Terrestrial	7471104	158	438	592	101	137	379
Satellite	7471104	144	208	292	205	286	416

Table 2: PFS throughput

Route	Size(Byte)	Throughput (Kbps)			Time (sec.)		
		minimun	average	maximum	mimimum	average	maximum
Terrestrial	7471104	787	879	933	64	68	76
Satellite	7471104	1928	4980	8414	7	12	31
	11538432	3297	5429	8392	11	17	28

Table 3: Routing from SMU to NLM via terrestrial line

x.sapmed.ac.jp	0.716 ms	SMU
x.north.ad.jp	0.914 ms	NORTH
x1.spnoc.imnet.ad.jp	6.766 ms	IMnet
x2.spnoc.imnet.ad.jp	6.163 ms	
x3.enoc.imnet.ad.jp	23.103 ms	
x4.cnoc.imnet.ad.jp	25.99 ms	
x.x.x	26.404 ms	
x.jp.apan.net	27.258 ms	APAN
x.jp.apan.net	172.507 ms	TransPac
x.startap.net	173.947 ms	STARTAP
x.nren.nasa.gov	189.229 ms	NREN
x.nren.nasa.gov	191.746 ms	NLM

Table 4: Routing from SMU to NLM via satellite link

x.sapmed.ac.jp	0.282 ms	SMU
x.north.ad.jp	0.380 ms	NORTH
Nstar-Intersat	1059.675 ms	N-Star,INTELSAT
x1.canet3.net	1059.142 ms	Ca*net3
x2.canet3.net	1071.573 ms	
x3.canet3.net	1080.794 ms	
x4.canet3.net	1087.966 ms	
x5.canet3.net	1105.354 ms	
x.x.x	1106.983 ms	
x.nren.nasa.gov	1121.560 ms	NASA
x.x.x	1122.156 ms	
x1.nasa.atd.net	1122.674 ms	ATDnet
x1.nlm.nih.gov	1122.394 ms	NLM
x2.nlm.nih.gov	1122.864 ms	
x3.nlm.nih.gov	1124.824 ms	
TPD.nlm.nih.gov	1124.825 ms	TPD-VH

Table 5 Rates for Visible Human Image Downloads

Image Size(Byte)	Route	Throughput (kbps)			Time(sec.)		
		minimum	average	maximum	minimum	average	maximum
TransView 7471104	Terrestrial	183	350	980	61	171	325
	Satellite	161	3320	7471	8	18	98
SagiView 6850994	Terrestrial	177	237	564	106	231	309
	Satellite	161	2610	6851	8	21	340
LongView 11538432	Terrestrial	188	235	310	298	392	490
	Satellite	2001	4013	7692	12	23	47

Figures and Legends

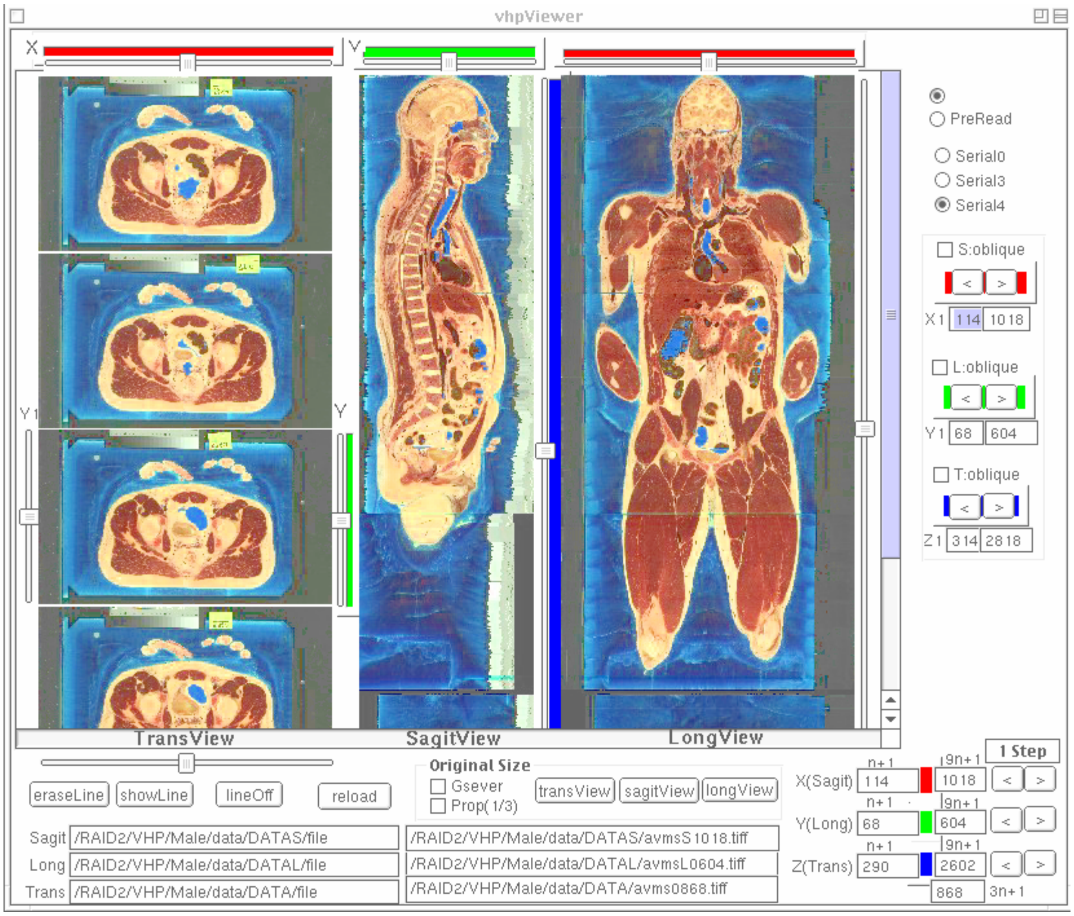

Fig.1. Screenshot of VHP Viewer

Local hard disk (includes NFS and PFS mount) mode or network multi-parallel computing mode are selected with Gserver switch.

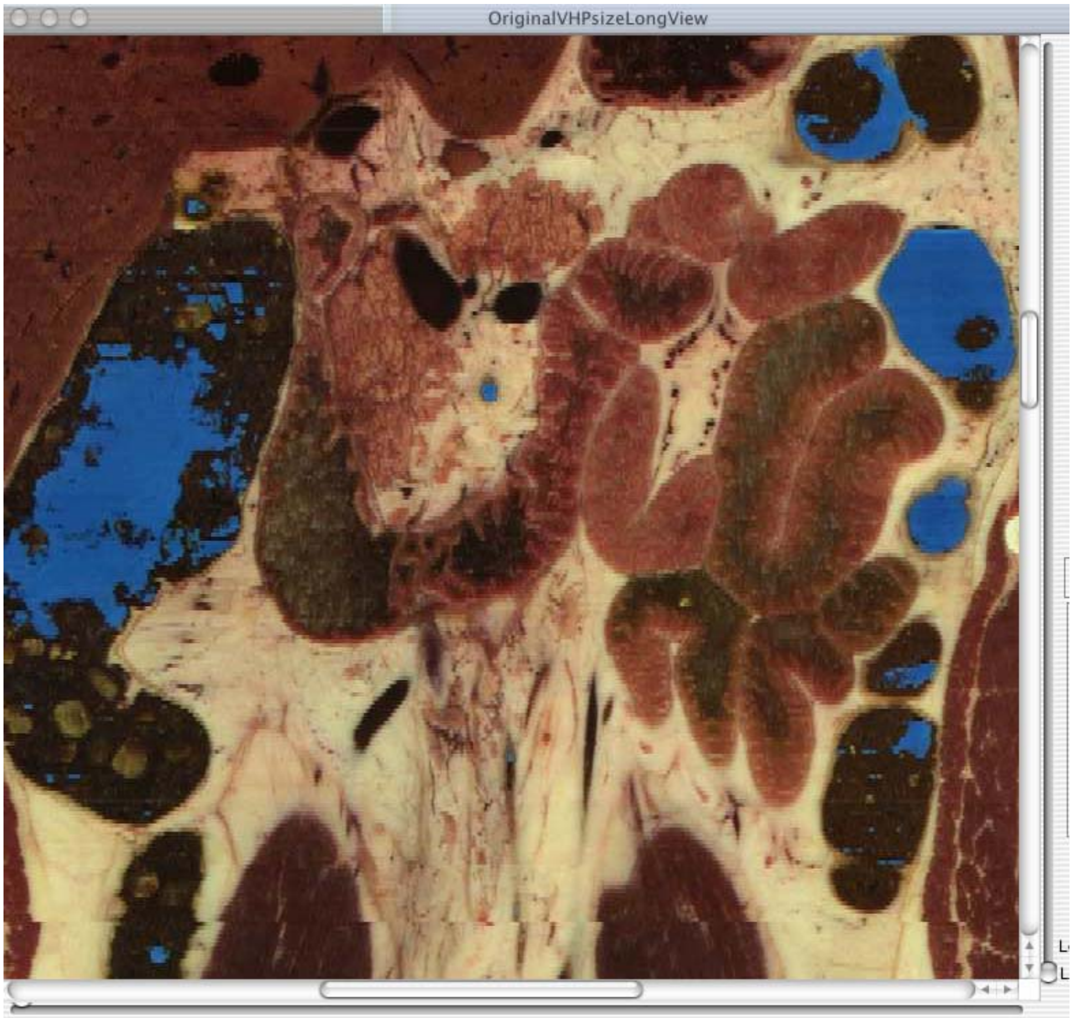

Fig.2. Reconstructed longitudinal image from serial transverse sections

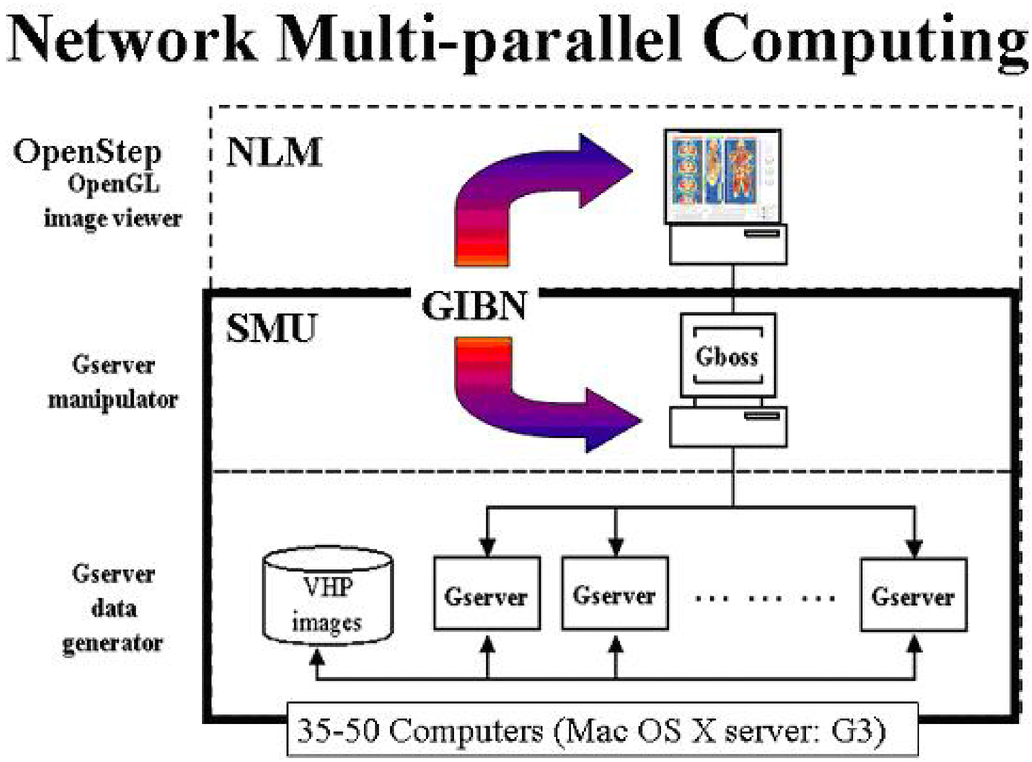

Fig. 3. The system of network multi-parallel computing

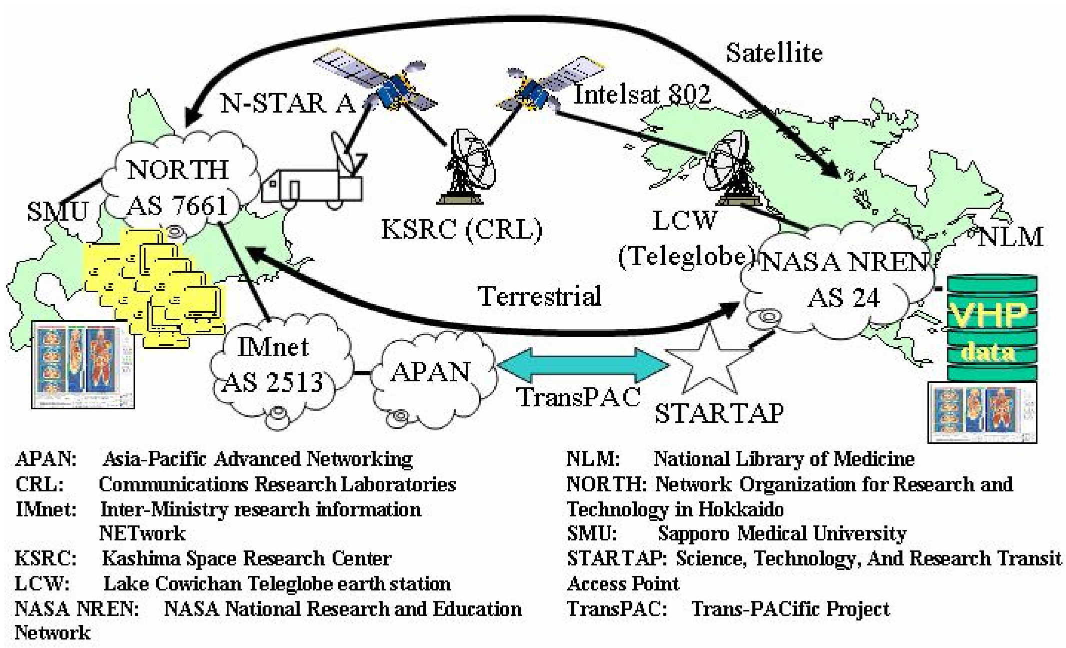

Fig.4. Network Configuration

Fig.5. Transportable Earth Station at SMU

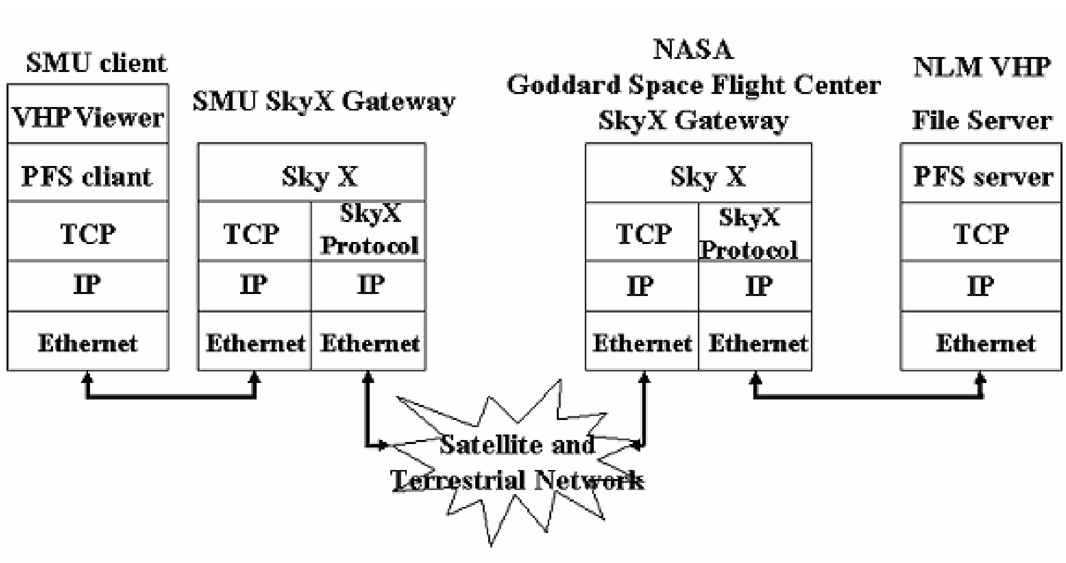

Fig. 6. Protocol stack of Remote Database Access Demonstration

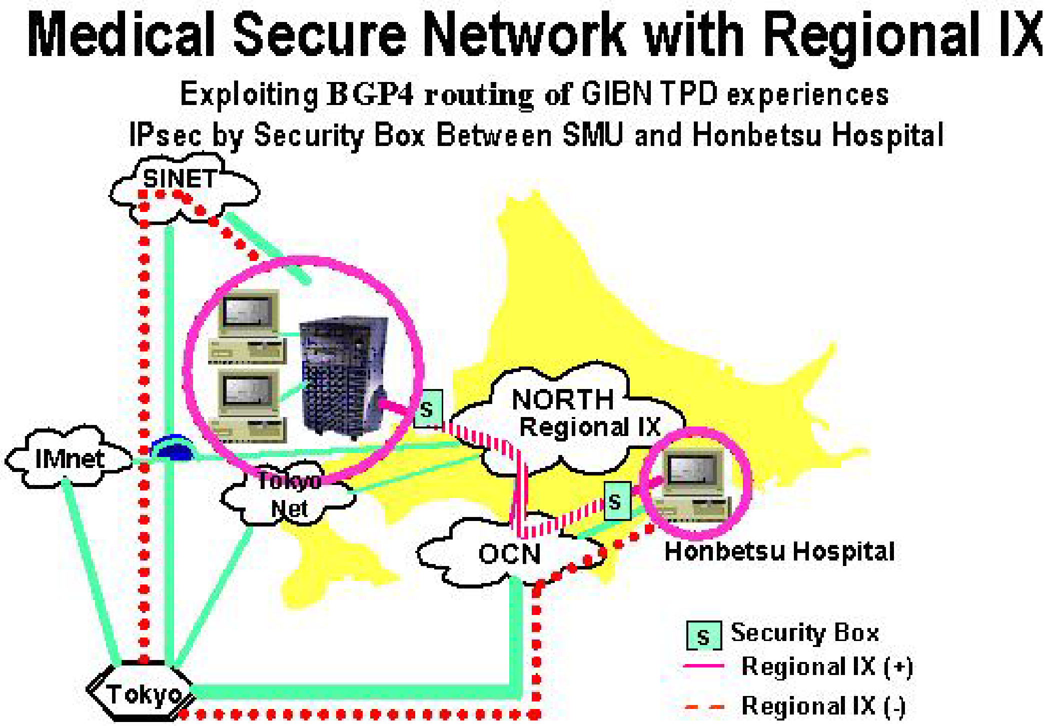

Fig.7. Advanced Medical Network utilizing GIBN-TPD experiences