

Real-Time Lecture Delivery Connecting Distant Classrooms by Redundant Network Combining a High-Speed Satellite (WINDS) and a Terrestrial Line (JGN2plus)

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Abstract—This paper reports on the authors’ attempts for real-time lecture delivery between Japan, Thailand and Malaysia using a redundant network consisting of a high-speed internet satellite (WINDS) and a terrestrial line (JGN2plus). The feasibility of multi-site real-time distant lecture system has been confirmed in several lecture delivery experiments. Also, the robustness of system has been proved by near automatic switching of long-distance routes from satellite to ground and back. This enables to compensate for the weakness of the satellite link using the Ka band in case of heavy rainfall. Additionally, quality improvement of video and audio with a high definition teleconference system has been confirmed by questionnaire surveys.

I. INTRODUCTION

Distant learning can offer learning opportunities for more students regardless of their habitation by relatively lower cost. Therefore, it is helpful to aid the inequality of opportunities to receive education. Recent evolution of information and communication technologies enables more effective distant learning with high definition video and audio. However transmission of high definition video and audio requires wide band communications. Although wide band internet connection is offered in wide area of developed countries, there are many areas such as developing countries and geographically secluded area in which people cannot gain a privilege of wide band internet. Satellite internet is one of potent solution for digital divide.

In case of conventional distant learning by communication satellites, lectures of broadcasting style are easily performed. However those of collaborative style with tighter participation are difficult because the conventional communication satellites only offer asymmetric networks. For example, School on Internet ASIA project [1] delivering distant lectures for wide area in Asia, used relatively narrow band lines for transmission from students sites to the lecturer site. Space Collaboration

System [2] could transmit audio and video via mesh type network, however, the system needed a hub station to control the switching of lines for audio and video.

The authors’ group in University of Tsukuba have also tried an experiment of distant lectures by a commercial communication satellite, SUPERBIRD [3]. In this experiment, problems became obvious such as insufficient band width and communication delay.

The ultra-high speed internet satellite WINDS (Wideband InterNetworking test and Demonstration Satellite) has an on-board ATM switch, which enables high speed mesh type network without a control station. We have carried out several experiments of distant learning using WINDS and showed its efficiency [4]. However, the satellite network has a weak point that connections tend to be interrupted by heavy rain as it uses relatively high frequency radio waves (Ka-band); high frequency radio waves are attenuated by rain drops. To avoid complete service interruption of satellite internet in such cases, we propose to jointly use terrestrial lines as backup combined with the satellite network so that availability of whole network will be improved.

II. WIDEBAND INTERNETWORKING TEST AND DEMONSTRATION SATELLITE (WINDS)

The Wideband InterNetworking engineering test and Demonstration Satellite (WINDS), which is also called “Kizuna” was developed and launched by Japan Aerospace Exploration Agency (JAXA) and National Institute of Information and Communications Technology (NICT). WINDS aims to offer wide band internet service for users in Asia Pacific regions around Japan. Specifications of WINDS are shown in Table I. WINDS has Ka-band Multi-Beam Antennas (MBA), a Ka-band Active Phased Array Antenna (APAA) and an ATM

TABLE I
MAJOR SPECIFICATIONS OF WINDS

Launch Date	February 23, 2008
Carrier	H-IIA Launch Vehicle
Mission Life	5 years
Location	143 degree E
Dimension	3×2×8 m Span of Solar Paddles: 21.5 m
Mass	4,850 kg (lift off)
Electric Power	5,200 W/EOL, Summer Solstice
Attitude Control	Zero-momentum 3-Axis Control
Frequency	Uplink: 27.5-28.6 GHz Downlink: 17.7-18.8 GHz
Satellite G/T	18 dB/K (MBA) 7 dB/K (APAA)
Satellite EIRP	68 dBW (MBA) 55 dBW (APAA)
Onboard Processing	ATM Baseband Switch

switch on board, which enables construction of wide band mesh-type network with relatively low latency.

III. JAPAN GIGABIT NETWORK (JGN2PLUS)

The Japan Gigabit Network phase 2plus (JGN2plus) was a three-year (2008-2010) project for providing an open testbed network for R&D by the National Institute of Information and Communications Technology (NICT). JGN2plus consisted of layer 2 switches and layer 3 routers, and had 59 access points throughout Japan. The backbone networks connecting the major operation hubs consisted of networks having capacities of 1Gbps to 20Gbps. Other access points were connected by bandwidth such as 100Mbps. It promoted collaborative activities of Japanese researchers and also researchers outside of Japan, by providing 5 international circuits and access points at Hong Kong, Bangkok, Singapore, Busan, Los Angeles and Chicago. The JGN2plus project has ended in March 2011 and the JGN-X project has been started focusing on the development of new generation network technologies.

IV. LECTURE DELIVERY EXPERIMENTS

A. Experiment 1 : Distant lectures between three sites

1) *Configuration*: On 11th and 12th November 2010, we carried out a series of distant lectures. Three universities, namely Asian Institute of Technology (AIT) in Thailand, Multimedia University (MMU) in Malaysia and University of Tsukuba (UT) in Japan, participated in these lectures. Network configuration for these lectures is shown in Fig. 1. At MMU and UT, an earth station for WINDS was settled in each campus and connected directly to each local area network (LAN) via layer 3 switches. For AIT, an earth station was settled in National Electronics and Computer Technology Center (NECTEC), adjacent to AIT, and connected to LAN of AIT via dedicated lines and a layer 3 switch.

Each earth station consists of an antenna, an Outdoor Unit (ODU) and an Indoor Unit (IDU). Diameter of antennas is 1.2m that enables the earth stations 51Mbps transmission and 155Mbps reception. IDUs works as bridges, therefore WINDS and all earth stations belong to same subnet, 192.168.0.0/24. Each local area network of participating universities belongs to each different subnet.

As a terrestrial line, we connected several networks to provide a high-speed connection between Tsukuba, Japan and Bangkok, Thailand. The longest section was provided by JGN2plus, with local access paths provided by Tsukuba WAN on the Tsukuba side, and ThaiSarn on the Bangkok side.

The line was configured as transparent layer 2 network between UT and NECTEC including access lines to each nearest access points of JGN2plus by virtual LAN (VLAN). For MMU, there was no adequate candidate of terrestrial connection. Therefore, MMU site would be unconnected if the association of line by WINDS was lost at MMU earth station. However, the function of network would be maintained when one of the associations of line by WINDS was lost at either UT site or NECTEC site.

We adopted spanning tree protocol (STP) for dynamic routing with satellite line and terrestrial line. Priorities were configured as connections by satellite were used when both satellite and terrestrial lines were normal. Layer 3 switch used at UT was CentreCOM 9424T (Allied Telesis) and Catalyst 3560 (Cisco) were used at NECTEC and MMU.

We used software named MultiMedia Communicator (MMC) to distribute video and audio. MMC-Video encodes video and audio and transmits them in UDP packets. It also receives UDP packets and decodes video and audio. UDP packets are transmitted by UDP selector, which can send packets to multiple destinations simultaneously. To show presentation slides, we used MMC-PPT, which pages slides of prepared Microsoft PowerPoint files at distant sites same as the lecturer pages.

Each classroom of participating universities has two displays at least, one for video and another for slides. As an example, we show the layout of the classroom in UT in Figs. 4 and 5.

2) *Results*: To confirm redundancy of network, we simulated the disconnection of satellite line at UT by physical removing of the LAN cable between the IDU and the layer 3 switch. As a result, transmission from UT to AIT was maintained while transmission from AIT to UT was interrupted. At the same time, normality of the JGN2plus connection itself was confirmed by pinging between both layer 3 switches at UT and NECTEC.

B. Experiment 2 : Distant seminar between two sites

1) *Configuration*: On 23rd February 2011, we held another distant seminar. UT and Chulalongkorn University (CU) in Thailand participated in this seminar. Network configuration for this seminar is shown in Fig. 2. For CU, the earth station in NECTEC was connected to local area network of CU via VLAN and the layer 3 switch. As a terrestrial line, we used

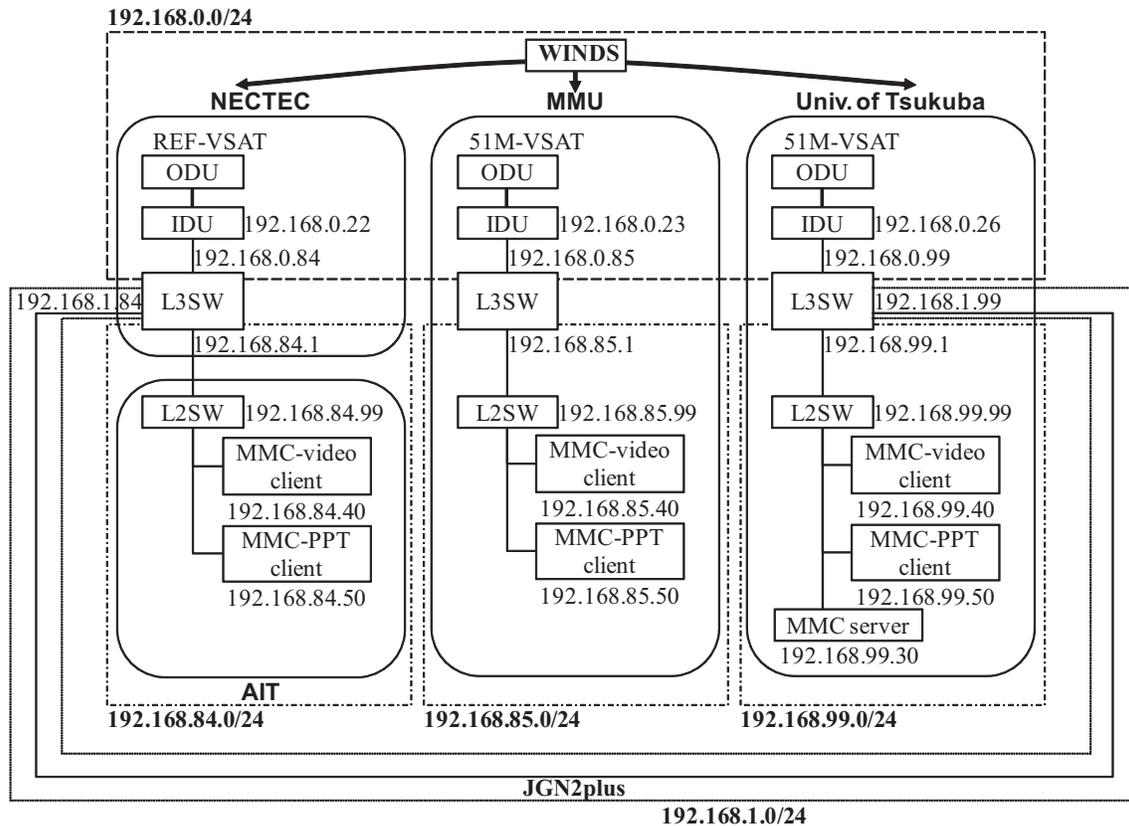


Fig. 1. Network configuration used in Exp. 1

JGN2plus again. Layer 2 VLAN was configured between UT and NECTEC.

We adopted open shortest path first (OSPF) for dynamic routing. Layer 3 switches used at both UT and NECTEC were Catalyst 3560.

We used Polycom HDX 8000 teleconference systems to distribute video, audio and materials. In case of Polycom, presentation materials are distributed also as video by capturing desktop images of PC connected to Polycom.

2) *Results*: To confirm redundancy of network, we simulated the disconnection of satellite line at UT by dissociation of the satellite line.

As a result, bilateral transmission at layer 2 (IP) level between UT and CU was maintained. Confirmation of transmission was done by pinging between both user terminal belonging each "local" networks (192.168.84.0/24 and 192.168.99.0/24). To check which route was actually used, we examined the transmission delay of ping and the result of traceroute. These results are shown in Fig. 6. These results show that switching of lines from the satellite line to the terrestrial line had been done at 45 seconds after the dissociation of the satellite line. The results also show that switching of lines from the terrestrial line to the satellite line had been done almost immediately after the reassociation of the satellite line.

At layer 7 (application) level, teleconference session was held while the switching of the lines was carried out. However,

the session terminated a few seconds after the dissociation of the satellite line.

C. Experiment 3 : Subjective evaluation of audio and video quality

1) *Configuration*: On 28th October 2011, we held one more distant lecture. UT and MMU participated in this lecture. Network configuration for this lecture is shown in Fig. 3. In this case we used only the satellite line because of network circumstances of MMU.

We used Polycom HDX 8000 teleconference systems to distribute video, audio and materials. Maximum video resolution of Polycom (1280 x 720) is higher than that of MMC (640 x 480).

2) *Results*: We have evaluated subjective quality of video and audio by questionnaire. Comparison of subjective video quality between MMC and Polycom is shown in Fig. 7. Mean opinion score (MOS) of video by MMC is 3.78, on the other hand MOS of video by Polycom is 4.30. This means a considerable improvement in subjective video quality by the enhancement of resolution.

Comparison of subjective audio quality between MMC and Polycom is also shown in Fig. 8. MOS of audio by MMC is 3.61, meanwhile MOS of audio by Polycom is 3.88. There is also some improvement in subjective audio quality, however extent of improvement is rather small.

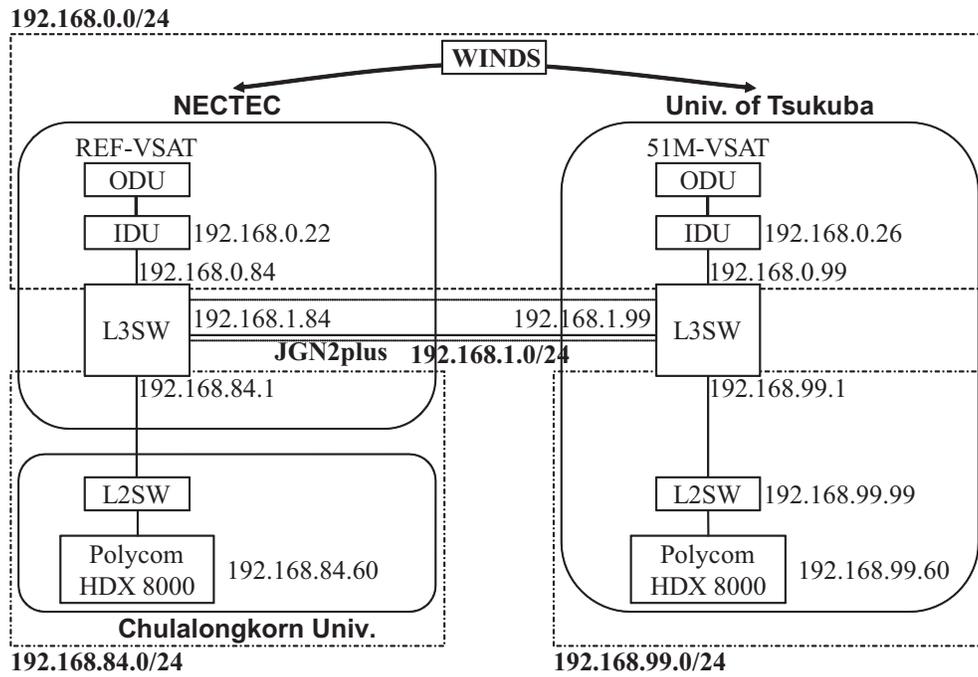


Fig. 2. Network configuration used in Exp. 2

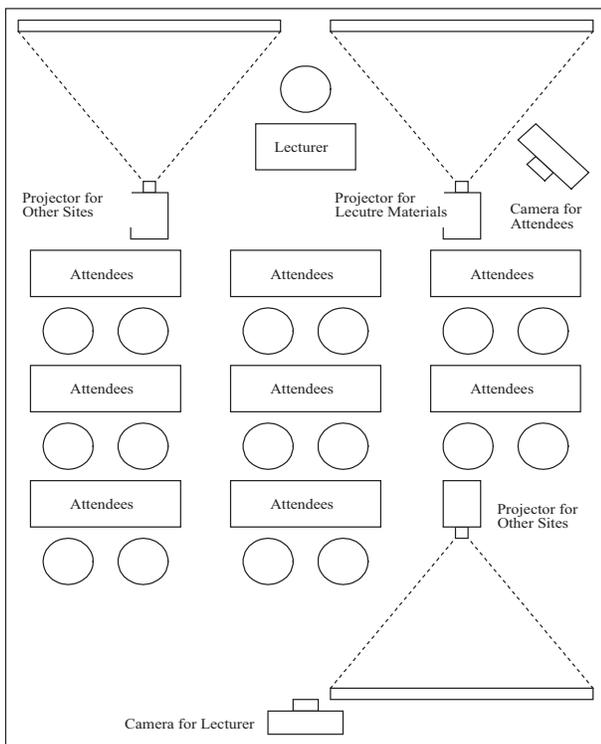


Fig. 4. Layout of the classroom used for the lecture delivery at University of Tsukuba. Note the triple display, one for the lecture material and the other two for showing the remote classrooms.

V. DISCUSSION

In Exp. 1, the switching between satellite and terrestrial lines was incomplete, and only one way of the bilateral



Fig. 5. Scene from the lecture delivered from University of Tsukuba.

connection was maintained. To use WINDS, IDUs must have static ARP (address resolution protocol) table for network interfaces at distant sites for a reason of its technical specifications. Therefore the IDU at NECTEC had a static ARP entry for the layer 3 switch at UT. This may have caused the layer 3 switch at NECTEC to be unable to detect the disconnection of the satellite line.

In the experiment of two-sites distant seminar, the dynamic routing protocol OSPF adopted uses "hello packets" to check connectivity of possible routes. Therefore the layer 3 switches could detect the actual condition of the lines. As the first step, we applied the default settings for OSPF hello packets in this experiment. The interval of hello packets was 10 seconds. When four hello packets are unreachable, the line is considered "dead" by the layer 3 switch. This interval of 40 seconds (10×4) corresponds the time lag of the switching of the lines from the satellite line to the terrestrial line. We

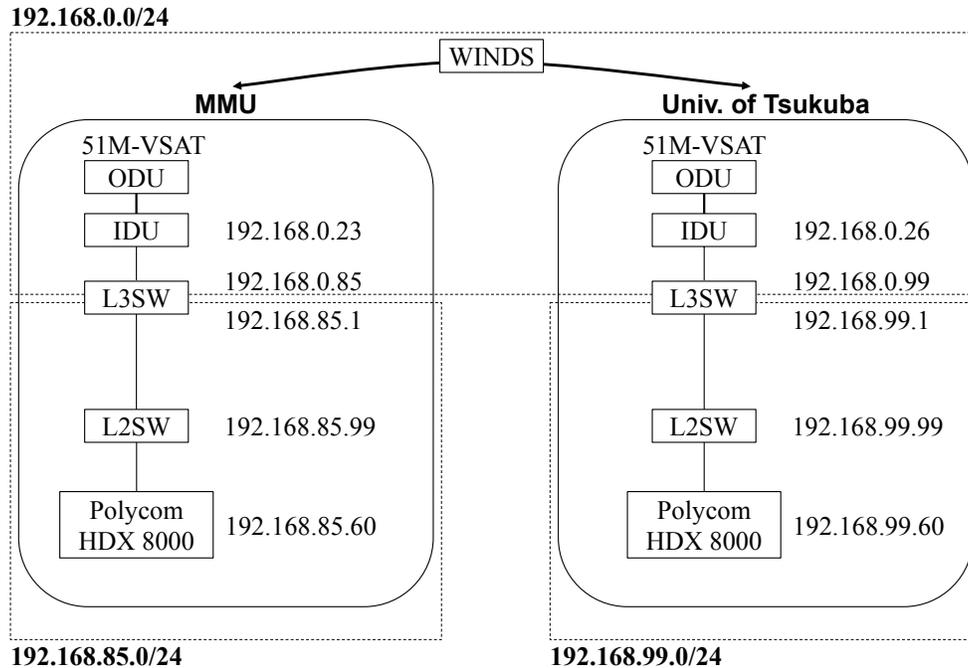


Fig. 3. Network configuration used in Exp. 3

should adjust the interval of hello packets so that time lag of the switching of the lines becomes shorter. Sessions of teleconference may be uninterrupted if we make time lag of switching short comparable to the time-out period of the teleconference system.

VI. CONCLUSION

We carried out distant learning experiments by redundant combined network of both ultra-high speed satellite internet and terrestrial network. We were able to confirm the switching of lines based on dynamic routing configuration using OSPF. These results will contribute for improvement in availability of satellite internet in case of adverse condition such as heavy rain.

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[winds@localhost ~]$ ping 192.168.99.10
PING 192.168.99.10 (192.168.99.10) 56(84) bytes of data.
64 bytes from 192.168.99.10: icmp_seq=1 ttl=62 time=726 ms
64 bytes from 192.168.99.10: icmp_seq=2 ttl=62 time=767 ms
64 bytes from 192.168.99.10: icmp_seq=3 ttl=62 time=728 ms
:(snip)
64 bytes from 192.168.99.10: icmp_seq=17 ttl=62 time=742 ms
64 bytes from 192.168.99.10: icmp_seq=18 ttl=62 time=703 ms
64 bytes from 192.168.99.10: icmp_seq=19 ttl=62 time=741 ms
64 bytes from 192.168.99.10: icmp_seq=20 ttl=62 time=701 ms
64 bytes from 192.168.99.10: icmp_seq=65 ttl=62 time=106 ms
64 bytes from 192.168.99.10: icmp_seq=66 ttl=62 time=106 ms
64 bytes from 192.168.99.10: icmp_seq=67 ttl=62 time=106 ms
64 bytes from 192.168.99.10: icmp_seq=68 ttl=62 time=106 ms
:(snip)
64 bytes from 192.168.99.10: icmp_seq=131 ttl=62 time=106 ms
64 bytes from 192.168.99.10: icmp_seq=132 ttl=62 time=106 ms
64 bytes from 192.168.99.10: icmp_seq=133 ttl=62 time=106 ms
64 bytes from 192.168.99.10: icmp_seq=134 ttl=62 time=777 ms
64 bytes from 192.168.99.10: icmp_seq=135 ttl=62 time=737 ms
64 bytes from 192.168.99.10: icmp_seq=136 ttl=62 time=777 ms
:

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← Satellite line was dissociated at UT

← Satellite line was reassociated at UT

(a) Result of ping while simulating the satellite line disconnection.

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[winds@localhost ~]$ traceroute 192.168.99.10
traceroute to 192.168.99.10 (192.168.99.10), 30 hops max, 40 byte packets
 1 (192.168.84.1)  9.857 ms  9.766 ms  9.846 ms
 2 (192.168.0.99) 735.031 ms 735.002 ms 734.980 ms
 3 (192.168.99.10) 734.853 ms 734.859 ms 734.829 ms
[winds@localhost ~]$

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(b) Result of tracetoure when the network was normal.

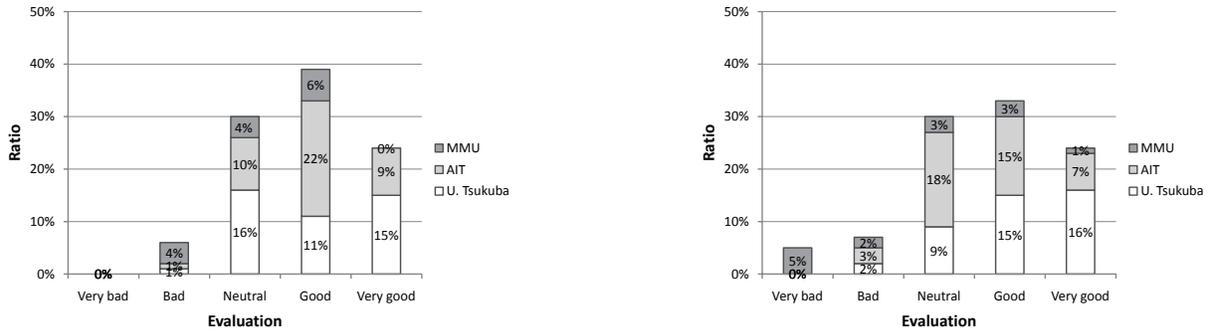
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[winds@localhost ~]$ traceroute 192.168.99.10
traceroute to 192.168.99.10 (192.168.99.10), 30 hops max, 40 byte packets
 1 (192.168.84.1)  4.288 ms  4.372 ms  4.522 ms
 2 (192.168.1.99) 106.831 ms 107.164 ms 107.384 ms
 3 (192.168.99.10) 106.671 ms 106.662 ms 106.631 ms
[winds@localhost ~]$

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(c) Result of tracetoure when the satellite line was disconnected.

Fig. 6. Results of line switching test. Average round trip time (RTT) of packets were 712 ms for the satellite line and 107 ms for the terrestrial line. Both RTT were measured with static routing configuration.



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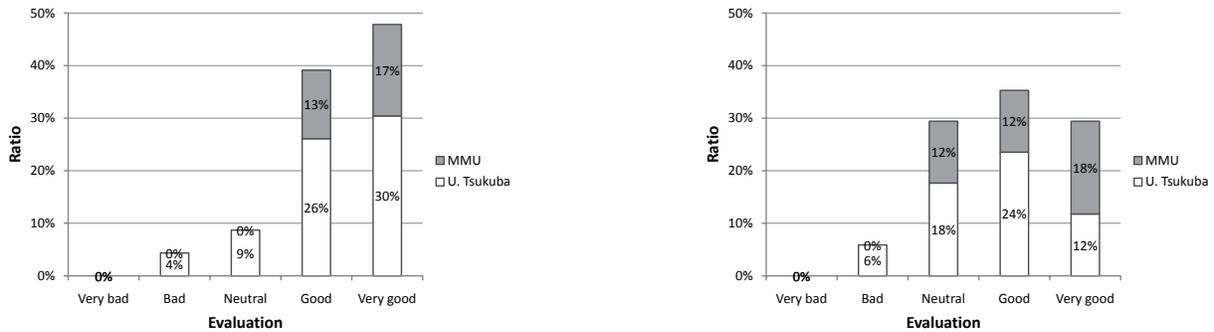


Fig. 7. Subjective evaluations of video. Upper: Video by MMC. Lower: Video by Polycom.

Fig. 8. Subjective evaluations of audio. Upper: Audio by MMC. Lower: Audio by Polycom.