

◆研究論文◆

Sustainable Education Collaboration Architecture on Digital Infrastructure

インターネット環境を利用した
持続可能な教育協力アーキテクチャ

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This paper presents the first sustainable education collaboration architecture that interconnects universities to build multilateral learning environment to foster students to become cosmopolitans. The proposed approach is taken from technical and administrative aspect to enable effective and sustainable education collaborations among the universities. The distance education system enabled any contents provider or university to technically participate in the education collaboration. The collaboration guidelines enabled other distance education systems to interconnect with the proposed system as well as enabling official education collaboration among the partners within the proposed system. The operator development enabled the sustainability and autonomy of the proposed architecture. This research is unique that it pursues how to sustain the education collaboration region-wide by integrating the three aspects: distance education system, guideline development and operator development, while other work focuses on only one or two components. The six years of experience conducting the education collaborations proved the feasibility, sustainability, and effectiveness of the proposed architecture.

本研究は、真の世界市民たる学生を育成するため、国を超えた大学同士の連結を実現させ、大学同士の教育協力を持続的に行うアーキテクチャを提案した。遠隔教育システムでは、大学やコンテンツ提供者が技術的に教育協力に参加できる枠組みの構築を行った。協力ガイドラインでは、提案システム上での大学間の教育協力手法の提案に加え、他の遠隔教育システムとの連結も可能とした。オペレータ育成を通し、システムの持続的・自律的な運用を可能とした。本研究は、地域規模の教育協力を持続可能なものにするため多角的なアプローチを取り、遠隔教育システム・ガイドラインの作成・オペレータの育成を行った。他の研究ではこれら3つの要素が全て揃っておらず、持続性に欠ける。6年間の教育協力を通じた実証実験より、提案アーキテクチャの有用性及び持続可能性を証明した。

Keywords: Sustainable collaboration, Distance education, Tertiary education, Multilateral environment, Asia

1 Introduction

Why people learn? Yukichi Fukuzawa, the founder of Keio University, said in his essay “Encouragement of learning”^[1] that the God put no one above the others, and no one below the others, and the differences of people were caused by the fact that they study or not. He also mentioned that when people study, the results of the studies have to contribute to the society else there is no use of study. In order to create a place to pursue one’s study, Yukichi Fukuzawa established the oldest university in Japan. Since then, many students have learned and graduated from the university and worked to contribute to the society. The role of universities is to develop human resources who contribute to the society, and ultimately, develop them to build the future of the world. University is a place to share the knowledge people have accumulated from the past studies, and offers research laboratories as the place to apply the knowledge.

In many aspects, the world requires leaders with global point of view. With the expansion of global economy, big companies are placing their headquarters and factories regardless of the country borders. There are many problems that have to be solved with effort from multiple regions such as water pollution and global warming. The universities are one of the places to develop the human resources who will become the leading forces in many areas. We believe that these human resources have to be trained to be cosmopolitans who can respect their own cultures and view points at the same time respecting the cultures and view points of other nations. In order to develop these human resources, multilateral learning environment is indispensable. Through jointly learning with students from other countries and sharing ideas, students learn to respect each other’s point of view, and learn how to collaborate in multilateral environment.

This research proposes to create a multilateral

learning environment in multiple universities across borders by developing an education collaboration architecture that connects multiple universities in different countries on digital infrastructure. The proposed architecture is consisted of three modules: 1. a distance education system, 2. collaboration guidelines, and 3. operator development.

The distance education system is a real-time lecture-sharing environment among multiple universities across borders. The system achieved the following three results. It solved the Internet infrastructure gap among universities by using an additional Internet connectivity on satellite communication link. It enabled lecture sharing with multiple universities in a realtime manner by introducing multicast-capable applications and network. It enabled universities to maximize the utilization of the existing facilities for establishing the distance education system by introducing and clearly defining Relay Site, Primary Site, and Receiving Site, which are the concepts of the universities’ roles in this distance education system.

The collaboration guidelines clearly defined the university roles in the proposed distance education system so that each university can easily understand how to establish its site. The guidelines also set the administrative collaboration procedures to enable formal education collaborations among universities. In addition, the guidelines also defined the interfaces to collaborate with other distance education systems to share education resources across each distance education system.

In order to make the distance education system scalable and sustainable, it is mandatory to have skillful human resources at each site who operate and maintain the site autonomously. This research developed operators at each site, and proposed a region-wide realtime distributed hands-on workshop to enable human resource development programs with areas where there are limitation on 1) human

resources to teach, 2) educational materials to teach with, and 3) hands-on environment to teach on.

The architecture has been deployed in Asia for six years to evaluate its feasibility and sustainability. The simple requirements enabled many organizations to interconnect. The Receiving Site was installed at 23 organizations in 11 countries. The Primary Site was installed at 31 sites in 7 countries, and the Relay Site was placed at Keio University, Shonan Fujisawa Campus. The collaboration guidelines enabled autonomous education collaborations among the universities, where education collaboration can be forged even between two universities within this architecture. The operator development provided the skilled human resources for the daily implementations of the collaborations. 33 university level courses, with a total of 311 lectures, and 34 realtime sessions including conference broadcasting and faculty meetings were conducted on the environment. The results of this six years of education collaborations proved the sustainability of this architecture.

This research realized an effective and sustainable architecture that can achieve university-level education collaborations across borders to foster cosmopolitans who create the future of the world. This research result will contribute to the future creations of region-wide distance education environments, and development of world-wide education collaboration platform.

2 Related Work

There are several activities to develop region-wide or worldwide education collaboration environment.

APRU (Association of Pacific Rim Universities)^[2], started in 1997, aims to foster education, research and enterprise in order to contribute to the economic, scientific and cultural advancement in the Pacific Rim. APRU currently have 37 partner

universities in 16 countries. It is proposing to create distance education environment among the group universities, however, since the development of their distance education system is done on their existing environments, and universities without existing facilities of network/equipment cannot participate in the distance education activities. Therefore, the main activities of APRU are limited to the meetings of several levels, i.e., the presidents, doctoral students, researchers.

GDLN (Global Development Learning Network)^[3], started in 2000, is a network run by World Bank that supports distance communications such as lectures and meetings. GDLN have 120 locations for their network, and some of the locations include universities. However, their network is not targeted to the university-level education collaboration, and community building among the universities is out of their focus.

AVU (African Virtual University)^[4], started in 1997 is a Pan African Intergovernmental Organization whose aim is to increase access to quality higher education and training through the use of information communication technologies. The AVU has 72 Partner Institutions in 27 countries in Africa. The purpose of their activities does not focus on the education collaborations which enable any university to join the environment and transmit/receive lectures on the environment. The universities who can receive the lectures are many, but the universities who can transmit the lectures are limited in their environment.

Each development is done with aim on different purposes. In order to achieve a multilateral education collaboration environment that includes as many universities throughout the world, more integrated research approach that enables development of the distance education facilities, education collaboration scheme, and sustainable operation management is required.

3 Problem Definition and Architecture Proposal

In creating effective multilateral education collaboration architecture, several problems are to be addressed.

3.1 Problem Definition

3.1.1 Lack and inefficient use of university facilities

It is the case with many universities that the sufficient infrastructure and applications for sharing the education programs such as lectures are not yet developed. Therefore, it is often the case with cross-country distance education environments such as Space Collaboration System(SCS)^[5] led by National Institute of Multimedia Education since 1998 that they install the infrastructure and applications in order to conduct education collaborations. The infrastructure and application gap among the universities exists, and in order to develop effective education collaboration system, these gaps must be filled. Moreover, in order for each university to participate actively in the class and communicate with each other to support multilateral learning environment, lecture sharing must be done in a realtime manner.

Project based infrastructure and application installation will lead to inefficient use of the facilities. For example, Asian Institute of Technology(AIT), Thailand is participating in two distance education projects, namely, Distance Education of Graduate Programs via International Communication Satellite led by Tokyo Institute of Technology^[6], and the e-Learning pilot test^[7] led by Tsukuba University. Two satellite antennas are installed at AIT to receive lectures from each university. Since both the universities are located in Tokyo area, there might have been other ways to share the infrastructure to broadcast lectures to AIT. Similar cases are happening at other universities as well. Based on the hearing investigation, Hasanuddin University in Indonesia has installed three different infrastructures,

applications and classrooms to receive lectures from three different distance education programs. Installation of similar facilities for multiple times is clearly inefficient use of the facilities.

3.1.2 Inexperience of education collaboration in multilateral environment

Official education collaboration among universities over distance education environment requires administrative approach as well as the technical approach. However, since this is one of the first trials to develop the multilateral learning environment with collaboration of multiple universities across borders, the process standardization, administrative and operational guidelines are not yet prepared.

Several distance education activities are emerging currently such as GDLN^[3], JICA-Net^[8] and SEAMEO(Southeast Asian Ministries of Education Organization)^[32], each runs their own activities. By defining the procedure to enable education collaborations among each activity, the possibilities of conducting the collaborations will widen.

3.1.3 Limited number of operators

JICA-Net^[8] is an organization that also supports distance education since 2000. The 88 locations in 62 countries in the world are placed mostly in the JICA(Japan International Cooperation Agency) office, and the network and applications are operated by the technicians employed by JICA. It means when the project ends, all the operators will be relocated, and there will be no one to operate the environment. When building a university-level education collaboration architecture and developing a sustainable distance education environment in scalable manner, autonomous operation by local university staff from participating universities is indispensable. By applying this scheme, the knowledge of network and applications operation is

accumulated in each university, and the knowledge could be utilized for other distance education programs.

However, the number of technicians who can operate the network and applications for distance education environment is still limited in some regions. This is because the number of human resources who can teach the local staff to be operators is limited, teaching materials for cutting edge technologies are not prepared, and some universities lack the equipments to teach the local staff with.

3.2 Education Collaboration Architecture Proposal

This research proposes a university education collaboration architecture that enables multilateral learning environment for each university to foster cosmopolitans to lead the future of the world. The architecture is consisted of 3 modules, and each module solves the above mentioned problems. The modules are 1) distance education system, 2) collaboration guidelines, and 3) operator development as illustrated in Figure 1.

The distance education system realizes an environment that any university to technically able to participate in the distance education programs run on this system, filling the network and application gaps. It also enables each university to maximize the use of their existing network infrastructure and applications. The collaboration guidelines are consisted of 3 parts. First, the contents delivery guideline and contents reception guidelines are designed to enable the contents partner and the contents receiving universities to freely circulate the educational contents on the proposed distance education system. While the guidelines for other work often show only how to setup and manage the each work's system, our guidelines include the administrative perspective such as developing a new academic course, managing copyrights, agreement to realize official collaborations among different universities. Second, the bridging guideline is designed to enable the sharing of educational contents with other distance education systems such as GDLN, JICA-Net and SEAMEO. Normally, since each project focuses on the education collaborations within their

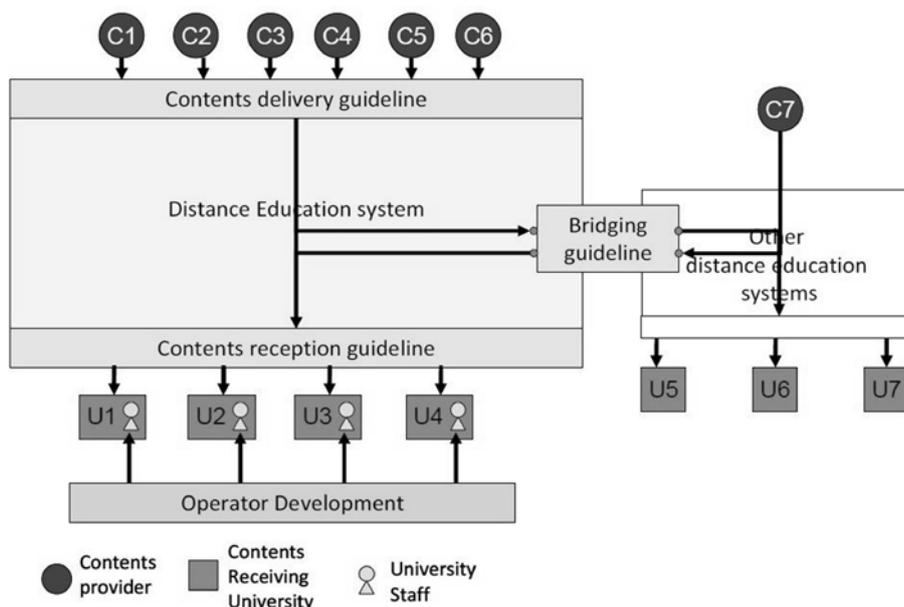


Figure 1 Education Collaboration Architecture Overview

systems, these kind of guidelines to collaborate with other distance education systems are not prepared to expand the collaborations beyond the proposed system. And third, the operator development solves the lack of technicians at each university by proposing human resource development programs, including region-wide distributed hands-on workshop.

By realizing the proposed education collaboration architecture, universities will be able to build multilateral learning environment to connect their learning environment with other universities, where students can learn and communicate with students from other countries in realtime manner. The distance education system is operated autonomously by each university to sustain the environment, and it interconnects with other distance education systems to expand the education collaboration possibilities.

4 Distance Education System

4.1 Design

There are number of communication medium on which distance education can be conducted, such as telephone line, radio, satellite communication, and the Internet^[9]. The Internet infrastructure has advantages over other infrastructure as it can support data transfer such as lecture material and character based communications as well as sharing the video and audio. Also, the network infrastructure can be developed using different links such as fiber optic cables, power cables, telephone lines, wireless communication infrastructure such as satellite link or 802.11 equipments. Therefore, satellite Internet is used as the infrastructure for the proposed system.

In general, the lecture providing universities, which have accumulated research results and latest knowledge for certain topics, are located in the areas where broadband Internet infrastructure is already developed. These universities are already equipped with distance education systems on their campuses

as shown in the cases of distance lectures between Wisconsin University and Keio University^[13] and between University of California, Los Angeles and the Kyoto University^[14]. On the other hand, many universities still do not have sufficient Internet infrastructure to receive distance lectures. For example, when this research started in 2001, there was no Internet infrastructure at University of Computer Studies, Yangon in Myanmar, and Hasanuddin University in Indonesia was utilizing 28.8kbps cable modem telephone line for the network connection. The Internet infrastructure gap exists among the universities. This research aims to solve the heterogeneous network situation of the lecture-providing university and lecture-receiving university to encourage lecture circulations among universities worldwide.

This research defines the functions and procedures each university should refer to when participating in the proposed distance education system. The idea is to apply a relay site between the lecture providing university and lecture receiving university to adapt the heterogeneity of networks and applications among the participating universities. The categorization of the functions is as the following.

- Student Site
 - > Receiving lectures
- Primary Site
 - > Providing lectures, receiving lectures
 - > Coordinating the lectures including a moderator of lectures
- Relay Site
 - > Providing lectures, receiving lectures and relaying lectures
 - > Realtime translation such as Japanese to English
 - > Format conversion, lecture archival and redistribution
 - > Network monitoring

By introducing the categorization of each site and defining their functions, any education collaboration can be described as the circulation of educational resources among these sites. Each site design can be applied to any university in the world. Figure 2 shows some examples of the educational resource circulation. Since there is a Relay Site between the Primary Site and the Student Site, the Primary Site is required to have sufficient Internet infrastructure and applications to conduct the distance education only to the Relay Site. The Student Site is also required to have sufficient Internet infrastructure and applications to the Relay Site. Based on this proposal, a more flexible distance lecture can be conducted on this system.

As stated in subsection 3.1, the design of this distance education system aims to solve the problem of infrastructure gap and inefficient use of the facilities. In addition, as this research proposes to create a multilateral learning environment for students, it is important to share lectures on this system in realtime manner. These 1) filling the infrastructure gap, 2) increasing the number of

lecture sharing universities, and 3) efficient use of facilities, are the three objectives of the proposed distance education system.

4.1.1 Filling the infrastructure gap

The past researches^{[15][16]} show that at least 1Mbps network connection is required from the Primary Site to the Student Site to conduct distance lectures, but the backward network connection can vary as long as the Students Site can give some feedback to the Primary Site. In the age of the information, almost all of the universities are equipped with some kind of Internet connection. Therefore, this research proposes to utilize the existing Internet infrastructure for the feedback mean from the Student Site to the Primary Site, and install an additional link to receive the lectures from the Primary Site to the Student Site.

Since the proposed distance education system should have wide coverage area as much as possible, and the universities could be located anywhere from the remote island to the mountain top, the wired network is difficult to be applied.

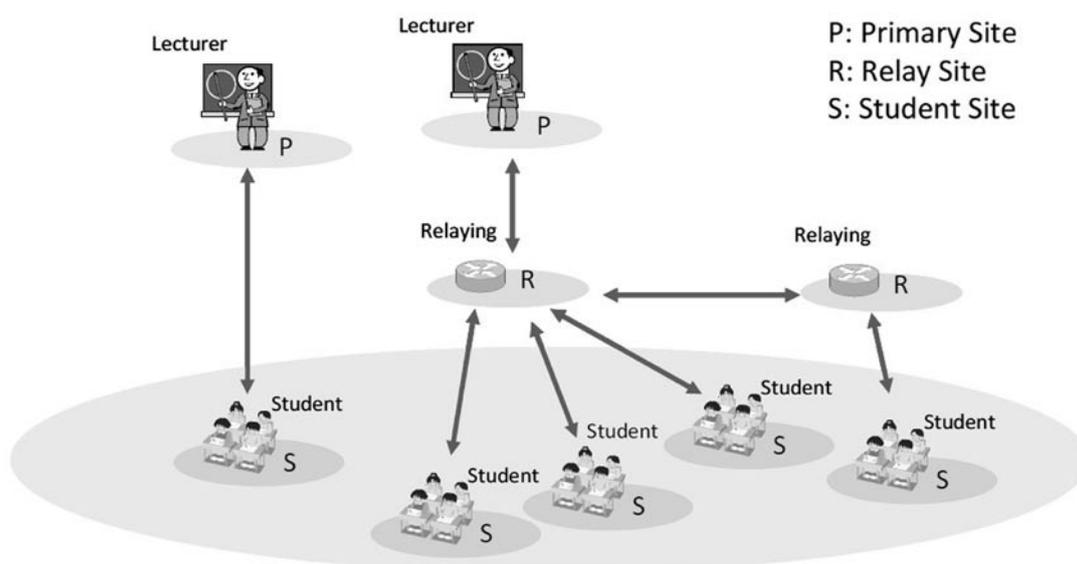


Figure 2 Design Concept

Wireless communication system such using the communication satellite is appropriate to be applied because 1) a single satellite can cover as much as 1/3 part of the world, 2) as satellite communication utilizes fixed frequency and bandwidth allocation, the network bandwidth that is applied on the infrastructure can be guaranteed on the link, and 3) the path from the source to destination can be developed with just single hop despite of the geographical distance. Therefore, this research adopts the satellite link as its Internet infrastructure.

However, the Internet connection assumes bi-directional network links, and this approach that utilizes asymmetric links of existing Internet infrastructure at each university and the link over the communication satellite infrastructure does not work as it is. Therefore, UDLR (Uni-Directional Link Routing) technology^[17] is utilized to emulate the bi-directional link

4.1.2 Increasing the number of lecture sharing universities

In order to share single lecture among multiple universities in realtime manner, applications with

multicast capabilities are used. They are VIC and RAT (Video Conferencing Tool and Robust Audio Tool)^{[18][19]} and VideoLAN^[20]. The former application is a video conferencing application, and the latter is a video streaming application. The policy of designing the applications is to use open source software as much as possible, as to minimize the cost for installation. Windows Media Technologies^[21] did have same functions with VideoLAN. However, since it requires a Windows Server Professional to operate the application, the application was considered to lack the system generality. Since the VIC and RAT enable all the participating sites to transmit their video and audio unlike the video streaming applications, the VIC and RAT is introduced as the primary distance education application in the proposed system.

For material sharing, a software dedicatedly developed for this system, called the LivePresenter is used. The function of the LivePresenter is to synchronize the slide change timing in a Flash file converted from a PowerPoint file. It can show and share the pointer and characters written on the slide as shown in Figure 3.

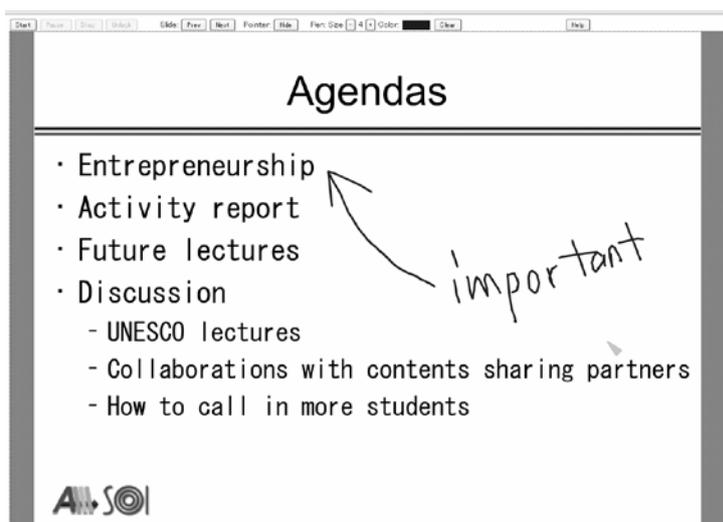


Figure 3 LivePresenter Overview

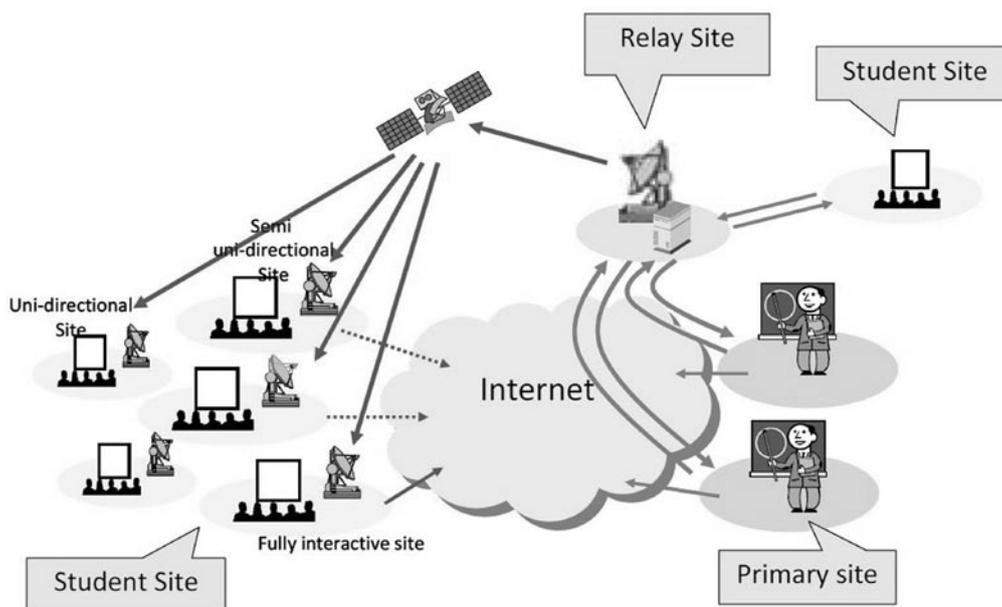


Figure 4 Design overview

4.1.3 Efficient use of facilities

The Relay Site acts as a proxy to deliver the lecture from the Primary Site to the Student Site. The connection between the Primary Site and the Student Site is made using unicast, and then the lecture will be broadcasted to all Student Sites using multicast. Any Primary Sites who have more than 1Mbps connections to the Relay Site can have the advantage of Relay Site. The Primary Site and Student Site are designed to have several types so that each university can choose most preferable design based on their Internet connection and the application they have. Figure 4 shows the overview of the proposed distance education system design.

The Primary Site can be any location that has sufficient Internet connection to the Relay Site utilizing the existing Internet infrastructure. Based on their connectivity, the Primary site can choose their video communication applications to use DVTS^[22] (30Mbps one way), Polycom^[23] or Sony PCS^[24] (512kbps-2Mbps one way) and VIC/RAT (1.5Mbps one way). The staff communication is done

using Internet relay chat (IRC)^[19], and the material sharing is done using the LivePresenter.

The Student Site is required to have 1Mbps Internet connection from the Relay Site. The site with sufficient Internet infrastructure can connect directly to the Relay Site, and the site without sufficient Internet infrastructure have to install the receive-only satellite antenna as the Internet link to receive the lecture video and audio from the Relay Site. The applications for broadcasting the lectures are the VIC/RAT and VideoLAN, and the each site chooses the application, namely VIC/RAT, IRC or Bulletin Board, to send the feedback to the Primary Site based on their Internet connection.

The Relay Site is equipped with a satellite transmitter to guarantee a sufficient communication path to the Student Site. It converts the application format from DVTS, Polycom and SonyPCS to VIC and RAT and VideoLAN to be broadcasted to the Student Site, and converts the format in opposite way to relay the feedback from the Student Site to the Primary Site.

The network and application designs to achieve the efficient use of facilities are described at table 1.

4.2 System Development

An experimental deployment has been conducted to show the feasibility of the proposed distance education system in Asia^[25]. The satellite link used in this experiment is JCSAT-3, which covers Asia. The Primary Site was developed in 31 locations in 7 countries, and the Student Site was

developed in 23 locations in 11 countries in Thailand, Vietnam, Indonesia, Laos, Philippines, Bangladesh, Cambodia, Nepal, Myanmar, Malaysia and Mongolia as shown in Figure 5. The Relay Site was developed in Keio University, Japan with collaboration with AI3 Project^[26]. Since the distance education system was developed experimentally in Asia, the Relay Site is developed in Japan. However, the same architecture can be applied to other regions like Europe or Africa, and in that case, the Relay Site will be developed

Table 1 Network and applications at each site

	Primary	Relay	Student
Network	- Sufficient network to Relay Site using the existing Internet infrastructure	- Link over Bi-Directional Satellite antenna - Link to the world's network backbone	- 1Mbps to Relay Site over the satellite link
Video/Audio Application	- DVTS (30Mbps) - Polycom (512kbps - 2Mbps) - SonyPCS(512kbps - 2Mbps) - VIC/RAT (1.5Mbps) - Live Presenter	- Converts the applications of Primary Site to the Student Site applications	- VIC/RAT (256kbps -1.5Mbps) - VideoLAN (256kbps -1.5Mbps)
Staff communication	- IRC - BBS		

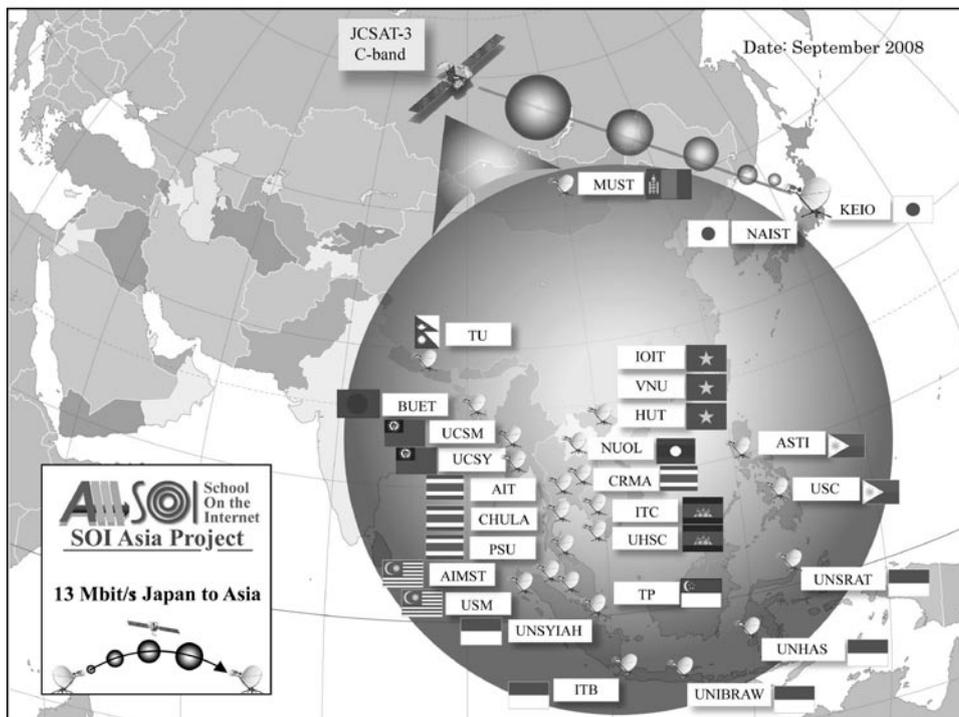


Figure 5 Student Site Coverage in Asia

in other sites that have both sufficient Internet connection to the world's network backbone, and can build satellite earth station that can cover the region. The Relay Site can be installed at multiple places to meet the requirements of the Primary Sites and the Student Sites. By connecting these Relay Sites in the future, an education collaboration environment that covers entire world can be developed.

4.3 System Evaluation

4.3.1 Filling the Infrastructure Gap

By introducing a receive-only satellite link as an additional link to the existing Internet infrastructure at each university, any university regardless of their existing Internet infrastructures could establish the sites^[16]. When we conducted the lecture streaming testing in May-June 2006 targeting 10 universities in 8 countries, 3 universities could not receive the lecture streaming, and other 4 universities could not receive the streaming video in sufficient quality. After the installation of our environment, all the sites could receive the lecture streaming in sufficient quality. The details of the improved quality are shown in the previous research^[15]. University of San Carlos in Philippines, 5 universities in Indonesia established the Student Site regardless of their locations in remote islands. The Tribhuvan University in Nepal established the Student Site in spite of the 3hours and 15minutes time differences from the Relay Site in Japan. All the established 23 Student Sites in 11 countries can receive good quality video and audio from the Primary site, and the introducing of the satellite communication link as the Internet infrastructure met the requirement of filling the infrastructure gap.

4.3.2 Increasing the number of lecture sharing universities

Every year, the number of participating partner sites increased as shown in Table 2. Each site

Table 2 Increasing number of the partner site

Year	Number of partner sites
2002	10
2003	10
2004	11
2005	18
2006	20
2007	23
2008	23

is equipped with satellite antenna and network equipment to participate in the lecture shared on the proposed environment. The proposed environment enables all the 23 Student Sites to join a single lecture simultaneously. There is no limitation of the number of the participating site, and more Student Sites can participate in the proposed system in the future. Thus, multilateral learning environment across borders is established with the proposed system.

4.3.3 Efficient use of facilities

Introducing of the Relay site enabled the Primary Site to be established regardless of the location as long as the site has sufficient Internet connection to the Relay Site. By utilizing this design, 31 Primary Site were established in 7 countries including Indonesia, Malaysia, Thailand, Myanmar, Laos, the United States, and Japan. A total of 33 university-level courses including 311 lectures as shown in Table 3,

Table 3 Number and Topics of Shared Lectures

Year	# of lectures	Topics
2002	39	IT, Marine Science and Technology
2003	6	Engineering, Marine Science and Technology
2004	26	Marine Science and Technology
2005	65	IT, Agriculture, Disaster Management, Engineering, Marine Science and Technology
2006	60	IT, Agriculture, Disaster Management
2007	88	Disaster Management, IT, Biotechnology, Renewable Energy, Marine Science and Technology
2008	37	IT, Agriculture

and 34 realtime sessions were broadcasted utilizing this system^[31]. Lecture topics include biotechnology, marine science and technology, information technology, disaster management, law, agriculture and renewable energy. More than 250 professors gave lectures or speeches on the proposed system and throughout these lecture broadcasting, the Student Site did not have to change any configuration to receive different topics by different organizations.

The first module, distance education system solved the lack of university facilities for the distance education mentioned in subsection 3.1.1 by introducing the additional Internet infrastructure over the satellite link. It also solved the inefficient use of university facilities mentioned in subsection 3.1.1 by defining three sites, Primary Site, Student Site, and Relay Site, to maximize the facility use of each site. Introduction of this model enabled any education collaboration to be the circulations of educational resources among these three sites. The contents providers can maximize the use of existing infrastructure to publish their lectures, and universities can receive different topic lectures from different organizations without changing their lecture receiving facilities. The system that enable multilateral learning environment was created by this research.

5 Collaboration Guidelines

5.1 Proposed Guidelines

In order to operate the proposed multilateral education collaboration environment effectively, a formal agreement on the administrative level of the university is required as well as the technical guidelines. The contents providers can be not just universities, but other organizations who handle educational matters such as NGOs and international organizations, and research laboratory divisions in companies. By having a collaboration framework, the contents providers and universities have sign on

an agreement only once to conduct the education collaborations utilizing the proposed education collaboration architecture. They do not have to sign and agree on the way of collaborations every time a new partner participates in the architecture.

In this research, three types of guidelines are prepared to enable the education collaboration among the partner organizations.

Contents delivery guideline

- MoU (Memorandum of Understanding) to agree on the delivery of lectures through the Internet, and be archived online, to form a collaboration scheme for delivering the lecture in the future
- Copyright Form to clear the copyright issue
- Primary Site setup guide including network and application configuration

Contents reception guideline

- MoU to agree on the contents usage policy (to use the delivered contents for educational purpose only), form steering committee, academic committee, operator committee in each Student Site to smooth contents sharing
- Student Site setup guideline including network and application configuration

Bridging guideline

- MoU to agree on the contents usage policy (to use the delivered contents for educational purpose only)
- Network and applications setup manual to enable the contents sharing

5.2 Guideline Evaluation

The site development and education collaborations were done based on the guidelines.

The content providing site was developed in 31 places in 7 countries, and content provider such as JICA (Japan International Cooperation Agency), UNESCO (United Nations Educational, Scientific and Cultural Organization) were also able to provide their

contents utilizing our environment.

The contents receiving site was developed in 23 educational organizations in 11 countries. 33 university-level courses including 311 lectures and 34 realtime sessions such as conference broadcasting and faculty meetings were conducted following the guideline.

Lecture sharing with other distance education systems such as APAN (Asia Pacific Advanced Network)^[10], UniNET (Thailand Inter University Network)^[11], and INHERENT (Indonesia Higher Education Network)^[12] was achieved following the guideline.

The second module, collaboration guidelines solved the inexperience of education collaboration in multilateral environment mentioned in subsection 3.1.2. By following the collaboration guidelines, contents provider, contents receiving site and other distance education systems are able to participate in the education collaboration conducted on the proposed distance education system. The uniqueness of this research is to support the education collaborations to be conducted from technical and administrative perspectives. Based on the development of each site and educational resource sharing following the proposed guidelines, the guidelines were evaluated as feasible, universities are able to conduct education collaborations following the guidelines prepared by this research.

6 Operator Development

Local operators are indispensable to develop the education collaboration environment in sustainable yet scalable manner. However, as stated in subsection 3.1.3, the number of operators is limited in each university due to 1) inadequate number of lecturers who can tech, 2) lack of education materials, and 3) lack of teaching equipments.

In order to develop the local operators at each site, various activities such as annual operator

workshops^[27], monthly operator meeting, internship programs and e-mail based daily communications were conducted. The purpose of these training is to foster the human resources to be able to develop other operators. The operators require at least 2-3 years of experiences to be the trainer for other operators, based on the 6 years of experiences of training the operators. However, the evolution of Internet technology is fast, and spending that much time for developing the trainers is not realistic. The operators have to be trained more intensively in shorter time.

This research proposes a mechanism to organize a distributed realtime workshop where the lecturer and participants are located at each local university. In this way, the lack of teaching human resources will be solved with the remote lecturer and local teaching assistants. The lack of educational materials will be solved with already developed materials at the areas where the accumulated knowledge and operation experiences of network infrastructures are available. The lack of educational environment can be solved by placing the minimum required equipments at Student Site and placing rich hands-on environment at Primary Site.

The contents of the workshop include basic UNIX operation, introduction to TCP/IP, router installation, lecture archival server construction, distance education application operation, and satellite receiver box operation. Even though the workshop for the proposed environment is designed for the distance education program operators, most of the contents of the workshop could be used to develop general network operators.

Based on the past face to face operator's workshop experiences, the following components have to be prepared to train the operators with hands-on exercises.

1. Lecture and hands-on environment

- > Lecture from the lecturer to the participants
- > Distribution of hands-on materials
- > Projection of lecture materials and lecturer's display on screens
- > Hands-on practice using a computer allocated for each participant

2. Communication among the lecturer, TA and participants

- > Question and answers among the lecturer and participants
- > Supervision of hands-on status for each participant

3. Preparation

- > Fulfilling the prerequisite to participate in the workshop

Following requirements have to be met to realize the workshop in distributed manner.

1. Projection of lecture materials on the screen

Effective ways to show the lecturer's hands-on status as well as the PowerPoint lecture material is required.

2. Minimized requirement for equipment at local site

This workshop aims to utilize the existing environment at local sites as much as possible. However, the equipments and network infrastructure situations differ from site to site. A mechanism to absorb the computer specification differences and network bandwidth differences at each site is required.

3. Reviewing scheme of hands-on process

Mechanism to peek the hands-on process of each participant from the lecturer is required.

4. Supervision mechanism for the lecture

A scheme to answer the participants' questions in timely manner is required.

The requirements are considered well, implemented and evaluated utilizing the proposed distance education system inviting 42 participants from 19 organizations in 10 countries from August 22 - August 26, 2006, and 42 participants from 16 organizations in 10 countries from March 31 - April 4, 2008^{[28][29][30]}. Figure 6 shows one of the workshop environment in a local university.

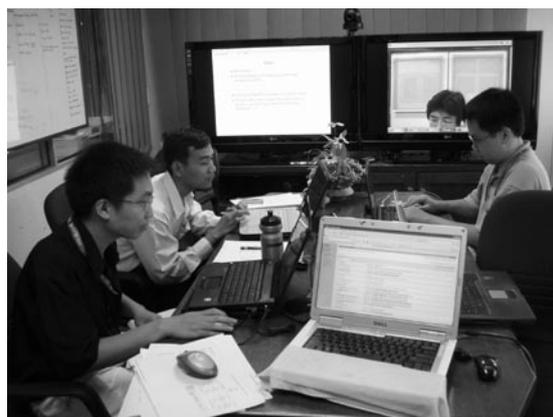


Figure 6 Workshop Environment

The third module, operator development, solved the problem of limited number of operators mentioned in section 3.1.3 by introducing the distributed realtime hands-on operator workshop that fosters the trainers for other operators. The proposed model of operator workshop enabled more frequent human resource development programs in locations where they lack 1) the human resources to teach, 2) educational resources to teach with, and 3) hands-on equipments to practice on. The contents of the proposed workshop can be used for general IT human resource development programs to conduct remote hands-on programs in locations where Internet infrastructure is not yet developed.

7 Conclusion

This research proposed sustainable education collaboration architecture in order to realize

multilateral learning environments in each university. With the introduction of the Internet, real education collaboration which connects university to university has made possible. In the age of globalization, the university's role has changed from developing human resources that could contribute to the local society to developing cosmopolitans who can lead the future of the world. In order to realize the environment, universities have to interconnect with each other across borders to realize multilateral learning environment where students can learn and communicate each other to become a real cosmopolitan. This research proposed three modules to realize the education collaboration architecture among universities.

The first module, distance education system was designed to meet following three requirements; 1) filling the infrastructure gap, 2) increasing the number of lecture sharing universities, 3) efficient use of the facilities. The design of the distance education system was to define the functions of universities, namely Primary Site, Relay Site and Student Site, and model any type of education collaboration to be the circulation of educational resources among these sites. Filling the infrastructure gap was solved by introducing the receive-only satellite link as the Internet infrastructure. With the established environment, 7 out of 10 sites, which could not receive the lecture video and audio in good quality, become able to receive them without problem. Increasing the number of lecture sharing universities was solved by introducing the multicast capable application, and 23 Student Sites developed in 11 countries in Asia become able to share a single lecture simultaneously in realtime. Efficient use of facilities was solved by introducing the Relay Site, and as result, 31 Primary Sites were developed in 7 countries, and 1 Relay Site was developed in Keio University. Altogether, 33 university-level courses including 311 lectures and 34 realtime sessions

were broadcasted utilizing this system. The topics shared on this system include law, biotechnology, marine science and technology, information technology, agriculture, and renewable energy each from different organizations from different locations. Student Site did not have to change any configuration while receiving these lectures.

The second module, the collaboration guidelines, defined the procedure for education collaboration for contents providers (contents delivery guideline), contents receiving universities (contents reception guideline), and other distance education systems (bridging guideline). By defining the guidelines, each party could conduct education collaborations autonomously on the proposed distance education system. The 311 lecture sharing on 6 fields was enabled based on the contents delivery and contents reception guidelines. By following the bridging guidelines, collaborations with other distance education systems such as JICA-Net (1 course, 5 lectures), UniNET(Connected, but not shared lectures yet), SEAMOLEC(3 courses, 27 lectures) were realized as well as sharing lectures especially designed for the proposed distance education system.

The third module, operator development, addressed the problems of lack of human resources to teach, educational resources to teach with, and hands-on environment to teach on. In the 2006 workshop, 98% participants were satisfied with the hands-on environment, 83% participants were satisfied with the distance supervision environment, and 93% participants were satisfied with the local-tutoring environment. 95% participants were satisfied with the overall distributed hands-on type workshop quality, and therefore, we evaluated the proposed workshop model was feasible. By proposing distributed realtime hands-on workshop, more frequent IT human resource development program can be conducted in the Internet developing areas. The proposed workshop contributed to the

sustainability of the proposed distance education system.

This research differentiates itself from other works in that it actually develops the distance education system that interconnects universities and contents providers to autonomously collaborate maximizing the use of their existing facilities. It also develops education collaboration procedure on multilateral learning environment. It develops human resources in universities to operate the system rather than hiring professionals to enable autonomous and sustainable operation of the proposed architecture. Table 4 shows the comparison of the proposed architecture with other works. “X” shows the components that are introduced in each work, and “-” shows the components that are not introduced in each work.

Table 4 Comparison of the proposed architecture with other works

	Distance Education System	Education Collaboration Environment	Operator Development
APRU	—	X	—
GDLN	X	—	—
AVU	X	X	—
Proposed Architecture	X	X	X

No other work focus on all of the components that are necessary to sustain the region-wide education collaboration. Each component is designed to accomplish the sustainability of the education collaboration. Distance education system is designed to absorb the heterogeneous network and application situation in each area and to be developed in a short time and low cost. The proposed system could be applied to anywhere on earth where is facing the network and application differences. The guideline development accomplished to propose administrative collaboration procedure as well as the technical

collaboration. These guidelines could be utilized to collaborate with other distance education systems that are proposed by other researches, as well as to collaborate within the proposed system. The operator development accomplished to develop number of operators at each local site by reducing the cost for running the human resource development program. With these approaches, we developed the first region-wide successful sustainable education collaboration scheme.

The result of six years of experiment of running the system and conducting education collaborations showed the sustainability and effectiveness of the architecture. With more pedagogical studies, expansion of the contents partners and contents receiving partners, and connections with other distance education systems, we wish to connect the universities all over the world to create real multilateral environment for students to become real cosmopolitans.

References

- [1] Y. Fukuzawa, "Encouragement of learning : the first essay", 1872 / by Yukichi Fukuzawa ; translated by Eiichi Kiyooka, *Keio University*, 1957.
- [2] K. Allen and W. Poh-Kam, "Technology Spin-Offs from Pacific Rim Universities: Entrepreneurial Context and Economic Impact", *Proc. 23rd Annual Entrepreneurship Research Conf.*, Boston, MA. 2003.
- [3] GDLN, <http://www.gdln.org/>
- [4] M. N. Amutabi and M. O. Oketchb, "Experimenting in distance education: the African Virtual University (AVU) and the paradox of the World Bank in Kenya", *International Journal of Educational Development*, Volume 23, Issue 1, pp.57-73, 2003.
- [5] T. Ojima, K. Igarashi, M. Kawamura, et al, "Satellite communication experiments in the POST-PARTNERS project", *AIAA International Communications Satellite Systems Conference and Exhibit*, 17th, Yokohama, Japan, pp.356-361, 1998.
- [6] Distance Education of Graduate Programs via International Communication Satellite, <http://www.cradle.titech.ac.jp/asia/index.html>
- [7] The e-Learning pilot test held among universities in three Asian countries, <http://ispacejaja.jp/news/20050307e.htm>
- [8] JICA-Net, <http://www.jica-net.com/>
- [9] M. G. Moore and G. Kearsley, "Distance Education", Wadsworth Pub Co, 1995.
- [10] APAN, <http://www.apan.net/>
- [11] UniNET, <http://www.uni.net.th/>
- [12] INHERENT, <http://www.inherent-dikti.net/>
- [13] K. Okawa, A. Kato, G. Gast et al, "Global collaboration for the joint University course on the next generation Internet", *INET2000*, 2000.
- [14] Yagi, K. Kameda, Y. Nakamura, M. Minoh, et al, "A Nobel Distance Learning System for the TIDE Project", *ICCE2000*, Vol.2, pp.1166-1169, 2000.
- [15] S. Mikawa, P. Basu, Y. Tsuchimoto, K. Okawa & J. Murai, "Multilateral Distance Lecture Environment on the Internet for Asian Universities", *The Journal of Information and Systems in Education*, Vol. 5, pp.84-93, 2006.
- [16] P. Basu, A.H. Thamrin, S. Mikawa, et al, "Internet Technologies and Infrastructure for Asia-Wide Distance Education", *International Symposium on Applications and the Internet*, Hiroshima, Japan. p.3, 2007.
- [17] E. Duros, W. Dabbous, H. Izumiyama, et al, "A Link Layer Tunneling Mechanism for Unidirectional Links", *RFC 3077*, 2001. <http://www.ietf.org/rfc/rfc3077.txt>
- [18] S. McCanne and V. Jacobson, "vic: A Flexible Framework Framework for Packet Video", *Proc. ACM Multimedia '95*, San Francisco, CA. pp.511-522, 1995.
- [19] J. Oikarinen and D. Reed, Internet Relay Chat Protocol, *RFC 1459*, 1993. <http://www.ietf.org/rfc/rfc1459.txt>
- [20] VideoLAN, <http://www.videolan.org/>
- [21] Windows Media Technology, <http://www.windowsmedia.com/mediaguide/>
- [22] A. Ogawa, K. Kobayashi, K. Sugiura, et al. "Design and implementation of DV stream over Internet", In *Internet Workshop, 1999. IWS 99*, pp.255-260, 1999.
- [23] Polycom. <http://www.polycom.com/>
- [24] SONY PCS. <http://www.sony.jp/products/Professional/VIDEOCONF/>
- [25] SOI Asia Project, <http://www.soi.wide.ad.jp/soi-asia/>
- [26] Shunsuke Fujieda, Haruhito Watanabe, Kotaro Kataoka, et al, "Communication Backbone in Asia and Satellite Internet", *IPSI Magazine*, Vol. 46, No.8, pp.872-878, 2005.
- [27] Yasuo Tsuchimoto, Shoko Mikawa and Keiko Okawa, "The deployment of UDL network on satellite circuit with training workshop", In *Proceedings of the 2003 Symposium on Applications and the Internet Workshops*, pp.14-17, 2003.
- [28] S. Mikawa, P. Basu, K. Okawa, et al, "An Asia-Wide Realtime Distributed Hands-On Workshop", *International Symposium on Applications and the Internet Workshops (SAINTW'07)*, p.41, 2007.
- [29] A. Basuki, A. H. Thamrin, K. Okawa, et al, "A Remote Hands-on Exercise Environment for an Asia-Wide Real-Time Workshop", *International Symposium on Applications and the Internet Workshops*, p.38, Japan, 2007.
- [30] P. Basu, S. Mikawa, A. Basuki, A.H. Thamrin, et al, "Combination of Online Virtual Computer Laboratory and Region-wide Distance Learning for IT Education in Asia", *Proc. World Conference on Educational Multimedia, Hypermedia and Telecommunications*, pp.1261-1269, 2007.
- [31] Lecture List, <http://www.soi.wide.ad.jp/soi-asia/lecture.html>
- [32] Southeast Asian Ministers of Education Organization (SEAMEO), <http://www.seameo.org/>

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