◆研究論文◆

An Educational Development on Learning Paradigm of Region-wide IT Hands-on Workshop

情報技術に関する地域規模の演習ワークショップの実践を通した新たな教育展開に関する研究

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This paper presents an educational development that extends the boundary of traditional distance learning approach to incorporate computer laboratory for live IT hands-on lessons for learners in developing countries. The proposed approach contributes to widen the IT learning opportunities in Asia where shortage of local teaching resources is the restricted condition. The distance learning environment is designed to deliver high-quality lectures and support multi-point live conversations in a distributed classroom. Computer virtualization technology and large-scale computing laboratory are integrated to provide laboratory environments for region-wide learners. The proposed approach has been proven feasible and effective through the actual implementations and evaluations of Asia-wide workshops in 2006 and 2008.

本研究は、講義配信という従来の遠隔教育の枠を超え、情報技術の演習環境を構築し、発展途上国の学習者に対して新たな教育展開を行った。本手法は、教えるための資源が限られるアジア地域において、情報技術習得の機会拡大に貢献した。提案する遠隔講義環境は、高品質の講義映像を分散した複数教室で同時受信が可能であり、教室間のコミュニケーションも保障する。また、各参加者に仮想環境を用いた大規模演習環境を提供する。提案手法を2006年及び2008年にアジア規模ワークショップとして実践し、評価を通してその実現性と有用性を明らかにした。

Keywords: IT education, Workshop, Remote laboratory, Distance learning, Educational technology

1 Introduction

Educational development is a gradual process to achieve new approaches which improve existing education systems by addressing recent demands and circumstances. These developments are progressing throughout the world to educate human resources in different contexts and constraints. In developing regions, there is high demand of human resources in Information Technology (IT) since it has been involved in daily operations of almost all sectors, e.g. education, finance, industry and government. However, limited teaching resources including teachers, laboratory facilities, and budgets are still the restricted conditions. Educational development in this area is needed to widen learning opportunities and to produce skilled human resources to empower social and economic growth in the region.

In IT education, both theoretical and practical knowledge is essential to develop full comprehension on learning subjects. To provide practical knowledge in an IT education program, it requires experienced teachers and a laboratory system. In case of lacking these resources, learners have to obtain practical lessons elsewhere, either at domestic or foreign training locations, but travel costs could be another constraint.

Distance education is an ongoing work to support teaching and learning from distant locations by applying digital and communications technologies. For educating IT human resources in developing regions, it can deliver knowledge from experienced teachers at any locations to region-wide learners without incurring travels. However, distance learning systems are mostly designed to support lecture activities only. Therefore, further researches to develop a new scheme to include IT hands-on practices are necessary.

This paper presents an educational development to research for innovative approaches of region-wide hands-on IT education through the actual experiences of School on Internet Asia (SOI Asia)[1]. SOI Asia is a distance education project working on a collaborative model to globalize education in Asia region since 2001. With region-wide partner universities, autonomous operation is achieved by educating human resources to be able to maintain their local facilities. Annual IT hands-on workshops were held to train staff with theoretical and practical knowledge. With an increasing number of partner universities, the face-to-face workshop approach is not scalable due to the high overhead, as explained in Section 3. Therefore, a region-wide distance learning environment is designed to carry out activities in a face-to-face workshop to a distance learning workshop as explained in Section 4. To develop a computer laboratory platform for a distance learning environment, computer virtualization technology and large-scale computing laboratory are the two approaches which were researched for their feasibilities and effectiveness, as explained in Section 4.2.1 and 4.2.2 respectively. The different aspects of these approaches were analyzed with the data collected from actual implementations in Section 5.

2 Related Works

There are several distance learning development programs that focus on sharing educational content region-wide or world-wide, e.g. Global Development Learning Network (GDLN)[2], Association of Pacific Rim Universities (APRU)[3], ASEAN Virtual Institute of Science and Technology (AVIST)[4]. The established E-learning systems commonly support communications between a lecturer and learners in both synchronous and asynchronous style. Since they were designed for general lecture topics, they are not equipped with a computer laboratory system for hands-on IT lessons.

On the other hand, several researches were proposed to support remote hands-on IT environment. Remote console access technologies including VNC and Windows remote desktop were deployed[20], however the quality of remote access could be disturbed from the limited Internet conditions in some developing countries. Computer virtualization technology[21,22] was utilized for hands-on practices. These experiments are useful deployment works in different contexts and scales. More researches are needed to discover suitable and practical approaches for the conditions of a developing region.

3 Face-to-Face Approach

The traditional approach of an IT hands-on workshop is the face-to-face model which class members, including lecturers, teaching assistants (TAs) and learners are at the same location with laboratory facilities. With access to equipments, learners can obtain practical experiences of both logical operations on software and physical manipulations on hardware. However, overhead of the approach is high considering costs of travels, laboratory equipments and staff workload. In SOI Asia project, hands-on workshops were held annually in the traditional face-to-face approach from year 2002 until 2005. Lecturers and participants traveled from their countries to the same location for a 5-7 day training program. Laboratory equipments in proportion to the number of participants must be arranged by purchase, rental or loan from other sources. Laboratory administration tasks to prepare these equipments according to the given lab designs were carried out manually, thus human workload increased corresponding to the number of participants.

With increasing number of partner universities over years as shown in Figure 1, the number of workshop participants increased. From the point of view of workshop capacity planning to accommodate future expansion, the face-to-face workshop model

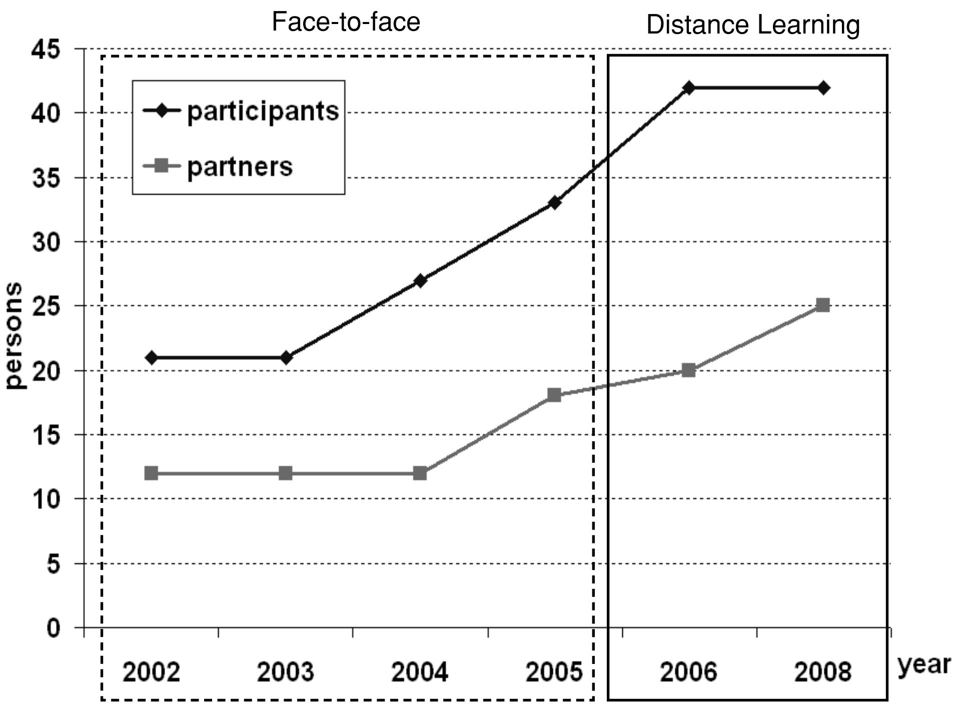

Figure 1 Workshop participants by years

is not scalable due to high travel overhead and high workload on manual administration of larger laboratory system. Therefore, the distance learning approach was designed and implemented in year 2006 and 2008 to research for innovative means that are able to deliver theoretical and practical IT knowledge with less resource required.

4 Distance Learning Approach

The proposed distance learning approach aims to create an environment that supports hands-on workshop activities to class members at distant locations. It consists of a technology model, which enables region-wide distance learning with a remote hands-on computer laboratory, and a supervision model which defines class structure and TAs training process to manage distributed class components. The distance learning environment, described in Section 4.1, provides an effective and scalable solution for high-quality region-wide live communications. Hands-on computer practices are accomplished by the two approaches of remote laboratory system in Section 4.2. The distributed class supervision model is described in Section 4.3. Implementation details from the SOI Asia project are also included respectively.

4.1 Asia-wide Distance Learning Environment

4.1.1 Network Infrastructure and Technologies

Asia is one of the regions where distance learning faces a known problem of inadequate Internet quality[8]. Therefore, the design focuses from network infrastructure and network technologies which are fundamentally important to the communications quality. As shown in Figure 2, a unidirectional broadcast satellite link, called the satellite UDL, covering Asia is selected as the infrastructure to deliver distance learning traffics to learner sites instead of relying on the existing Internet. Because of its broadcast characteristic, once a lecture is transmitted on the satellite UDL, all learners can share the lecture without repeating transmissions to each and every site. Therefore, it is a bandwidth-optimized and scalable medium for region-wide connectivity. Each learner site has a Receive-Only (RO) station to receive lectures and uses the local Internet connectivity to send back video, audio or text communications depending on the available bandwidth. It is a cost-effective solution since to be able to receive the same quality of lectures at any locations region-wide, investing in an RO satellite station is less costly and fast-setup compared to building a terrestrial infrastructure. A lecturer site can be at any locations provided that there is a high-speed Internet connectivity to the gateway site. The gateway site is located at the satellite hub station and is functioning as a bridge to relay lecture traffics onto the satellite UDL to all learners.

Unidirectional Link Routing (UDLR)[9] is used to emulate full bidirectional connectivity among the gateway site and learner sites to create an integrated network that supports upper-layer Internet Protocols (IP) effectively. IP version 6 (IPv6) Multicast extends the advantages of bandwidth optimization and scalability of the satellite UDL to the IP layer. IPv6 supports a greater number of addressable nodes, therefore more learner sites can be accommodated. Multicast delivers data packets to a number of destination hosts in a bandwidth-saving manner because no duplicate packet is sent on any shared paths. Therefore, applying IPv6 Multicast on the satellite UDL, a lecture stream can be shared by many learner sites in a bandwidth-optimized and scalable way[8].

The bandwidth requirement of the satellite UDL depends on the scale of a workshop because there are communications traffics from every learner site and remote lab access traffics of every learner. In case of the SOI Asia project, the

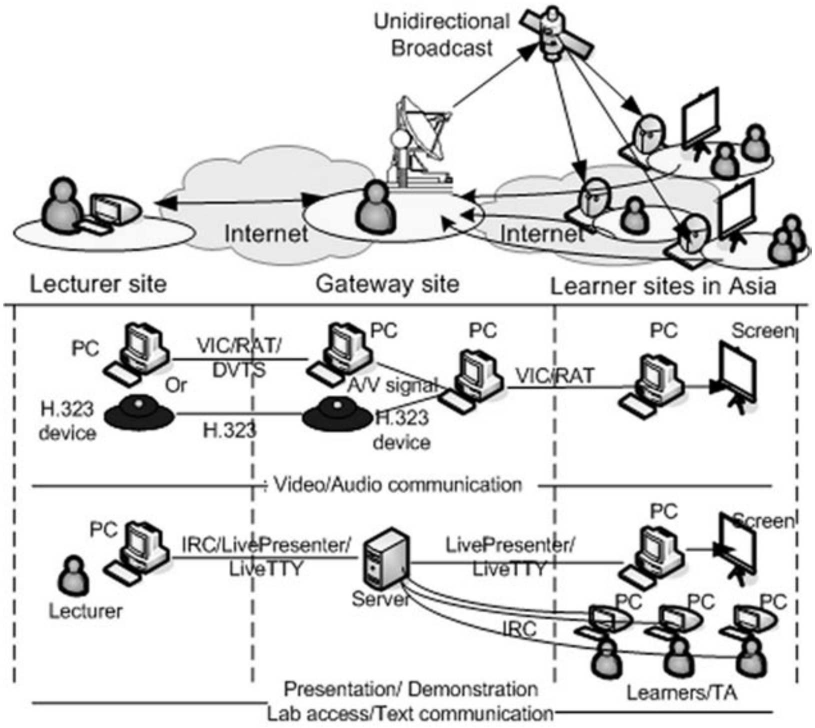

Figure 2 Asia-wide Distance Learning Environment

satellite UDL bandwidth capacity is 13-Mbps and was utilized 4-8 Mbps[19] during the workshop in year 2008 for 42 participants from 15 sites. The minimum outgoing bandwidth requirement from each learner site is 128kbps to be able to transmit video/audio streams, however it could be lower if learners only communicate back by text. For a lecturer site, the required bandwidth depends on the selected video/audio application with minimum of 256 kbps.

4.1.2 Class Communications

The proposed communications system supports conversation, presentation and demonstration activities among class members, as shown in Figure 3. The design keeps conversation environment to be close to the face-to-face approach by enabling live multi-site conversations in forms of video, audio and text. A Presentation of slides with animations and handwriting from a lecturer can be viewed at learner sites in real-time. A demonstration of a lecturer's lab work can also be observed lively by remote learners.

The proposed system for class communications is shown in Figure 2 which the design focuses on both functionality and practicality to deploy in the region. It intends to utilize available resources at lecturer and learner sites instead of demanding special hardware or software, therefore communications services are running on PCs with basic requirement of 1GHz CPU, 512MB RAM. Software are mostly open-source or self-developed operating on either Unix platform or Windows platform.

Video/Audio communications: Multi-site live video and audio communications for full interactivity among class members are required because of constant interactions during a hands-on workshop. Applications must support IPv6 Multicast streaming to save bandwidth on the satellite UDL. VIC/RAT applications[10,11] are used by learner sites in the implementation. A lecturer site may have different video/audio communications systems from learner sites. Therefore, the gateway site, as shown in Figure 2, is designed to be able to communicate with those systems at a lecturer site and relay the video/audio streams to the applications used at learner sites, and vice versa. In SOI Asia, it currently supports a lecturer site which uses VIC/RAT, DVTS[23], or H.323[24].

Text-based communications: Beside verbal communications, a text-based communications system is required to exchange text information in hands-on exercises. It is also important as a backup system when video/audio communications are unclear. IRC[12] is used in the implementation. Each class member uses an IRC client on his/her PC to connect to the IRC server at the gateway site, as shown in Figure 2.

Web-based live presentation: In a distance environment, it is desirable that learners can easily access and have synchronized presentation with the lecturer. LivePresenter is an application developed by SOI Asia to assist a lecturer to share synchronized views of slides with animations and handwriting to learners through the flash plug-in of web browsers. A raw presentation in several formats, e.g. PDF, PowerPoint, is converted to flash media before the lecture starts. The web-based approach eases learners' accessibility.

Web-based live Unix terminal display: In Unix-based hands-on workshop, lecturers often demonstrate some work examples on lab computers to explain the given assignments. To support the demonstration in a distance class, LiveTTY is a tool developed by SOI Asia based on TTYPlayer[13] to display a lecturer's terminal to learner sites in real-

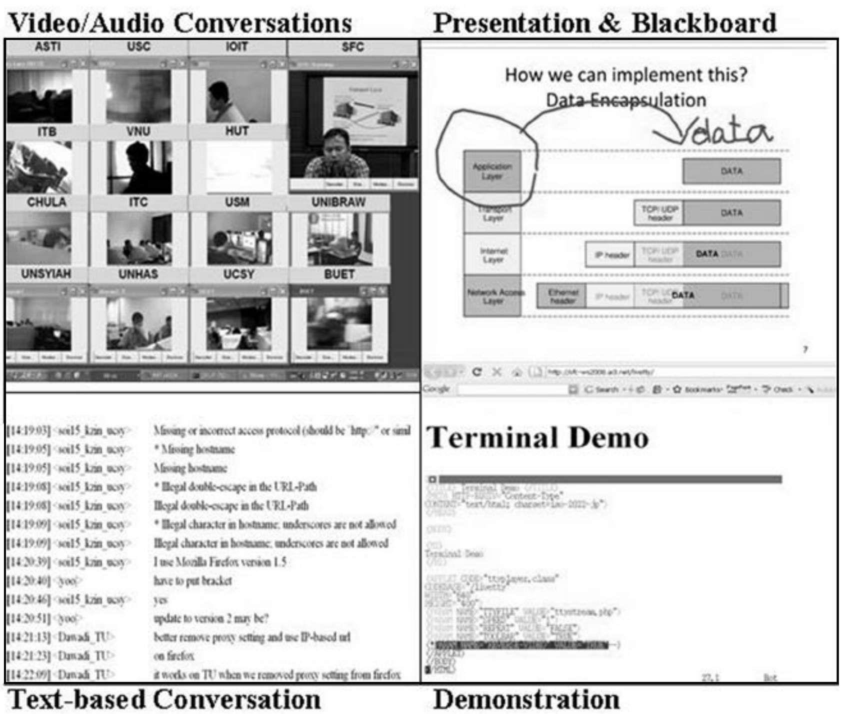

Figure 3 Class Communications

Table 1 Workshop content and lab scenarios

Lab No.	OS	Network Topology	Content of hands-on practices
1	FreeBSD6.1 (2006) FreeBSD6.2 (2008)	1-2	Router configuration: Basic - IPv6 network - IPv6 Unicast routing - IPv6 Multicast routing
2	FreeBSD6.1 (2006) FreeBSD6.2 (2008)	1	Router configuration: SOI Asia specific setup
3	FedoraCore4 (2006) FedoraCore6 (2008)	1	Server configuration - Web/ Web cache/ DHCP/ DNS/ Video and audio streaming services - SOI Asia file distribution service

time through the java applet on a web browser. The content transmissions of both LivePresenter and LiveTTY to clients at lecturer and learner sites are connected through the server at the gateway site.

4.2 Remote Computer Laboratory

Computer laboratory platform for distance learning is an important development which will realize an IT hands-on distance education model and open new opportunities to mobilize practical IT knowledge to more region-wide learners. The platform design focuses on two main qualities: its functionality to support live hands-on work from distant locations and its scalability to accommodate larger laboratory with less human workload in which the integrity of laboratory configurations is high. In term of functionality, system must support lecturers' lab designs including hardware specifications, operating systems (OS), software compatibilities and network topologies. The system must support remote hands-on work from learners, remote monitoring and troubleshooting from lecturers and TAs, and remote laboratory administration. The scalability of the platform targets on effective management of larger laboratory rather than reduced number of equipments if it affects the teaching quality.

The SOI Asia workshop content and hands-on lab scenarios are shown in Table 1, a learner practices to configure PC-based router and server with required services. Network topologies which connect lab computers change according to lessons. The equipments required for the workshop are a number of PCs and network switches. The PCs for practicing routers require two network interfaces.

In this study, SOI Asia has researched on computer virtualization technology and large-scale computing laboratory to create a hands-on education platform for distance learning in year 2006 and 2008 respectively. The computer virtualization model is explained in Section 4.2.1. The large-scale computing testbed model is explained in Section 4.2.2.

4.2.1 Computer Virtualization Technology

Computer virtualization is a technology that allows a physical machine with virtualization software, called a virtualization server, to create a number of virtual machines (VM) with desired specifications, e.g. CPU, RAM, harddisk, network interfaces. Network connectivity among these VMs can also be created according to the given configurations. The virtual network can connect to Internet and allows communications between VMs and external networks. Each VM can perform functions like a physical machine, e.g. hosts an OS, configures system and network, runs software services and communicates with other VMs or real hosts.

Applying computer virtualization technology to accommodate the SOI Asia hands-on workshop 2006[5,6], a laboratory environment according to Table 1 was created by VMware[18] for 42 participants at 16 sites. Six virtualization servers with minimum performance of a single CPU Celeron Dual-Core 3.0 GHz, 1GB Memory, were placed at the satellite hub station. Each server hosted 6-12 VMs depending on its performance. Each learner is assigned a VM to execute hands-on tasks and requires a PC to be an access terminal to the assigned VM. Remote access was provided by serial console redirection through SSH[15] as shown in Figure 4. The basic performance requirement of a terminal PC is Pentium 800Mhz, 256MB RAM. An alternative method for remote access was the VMware server console application which requires higher bandwidth for the connection. Therefore only lecturers and TAs who had good connectivity to servers used it to monitor learners' activities on VMs.

Laboratory administration in the computer virtualization environment is convenient comparing to manual administration of the same number of lab computers. It is because the number of actual physical machines to be administered is reduced and the management of VMs can be operated through VMware software. Lab preparation is done by creating a master copy of a VM with required specification and reproducing identical VMs for the rest. The computer virtualization technology requires less human workload to create a laboratory environment and to ensure its integrity.

4.2.2 Large-Scale Computing Laboratory

StarBED[14] is a large-scale computing testbed consisted of 680 high-performance computers and network switch clusters to interconnect those

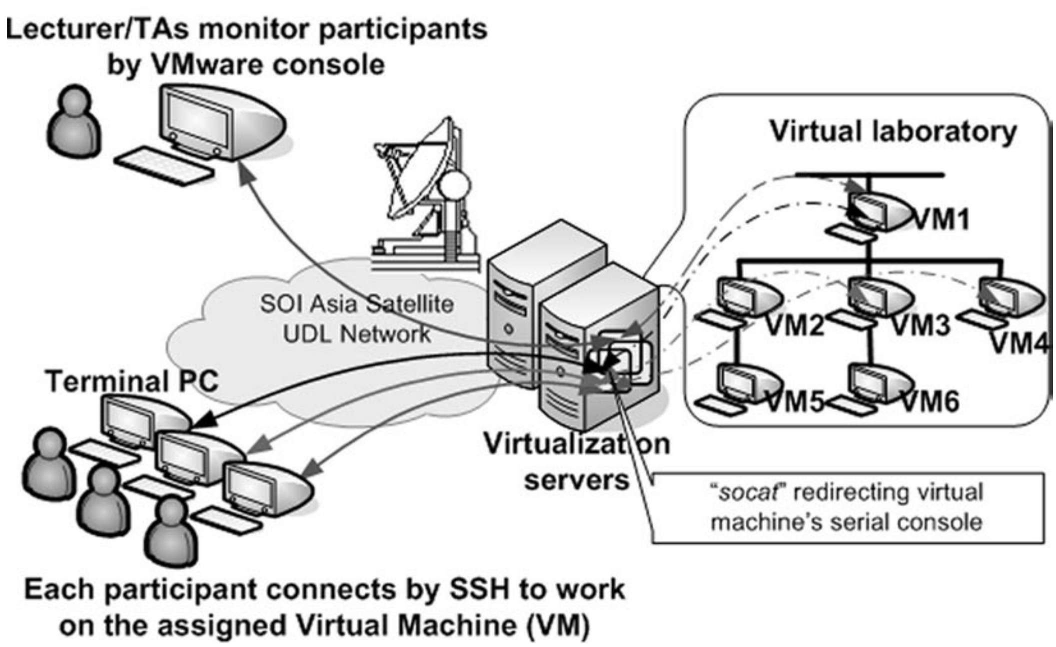

Figure 4 Computer virtualization in distance learning

computers for desired topologies. StarBED provides a realistic computer and network environment to support research and education usage which requires a large-scale system with flexible management. StarBED was deployed to create a laboratory environment according to Table 1 in year 2008 for 42 participants from 15 sites. A cluster of high-performance StarBED nodes (Pentium4 3.2GHz, 8GB RAM) were allocated. Since they are physical machines, hardware compatibility test for the given lab designs is required beforehand, however the identical hardware set reduces the number of test cases. Each assigned StarBED node has 4 network interfaces. One which is connected to the management network is for remote access and control. A learner connects to the assigned StarBED node by SSH through the StarBED's gateway as shown in Figure 5. Lecturers and TAs also use the same method to access StarBED nodes to monitor learners' work.

Other network interfaces of the StarBED node are connected to a switch cluster that can be programmed to create network topologies interconnecting StarBED nodes or to external networks. Different lab topologies for hands-on exercises are created on this experiment network by VLAN configurations without physical topology intervention, thus it simplifies lab administration tasks to manage network topologies for a large number of nodes. Lab preparation can be carried out in a similar way to the computer virtualization by creating a master disk image of a lab machine and duplicating it to other machines. With automated processes, it requires less human workload to create a laboratory environment and to ensure its integrity compared to manual installation.

Since StarBED environment is located at a different site from class members, it is helpful for teachers and TAs to be able to remotely perform preliminary administration tasks which usually require physical attendance, e.g. to access a node's console to fix boot failure caused by a learner's

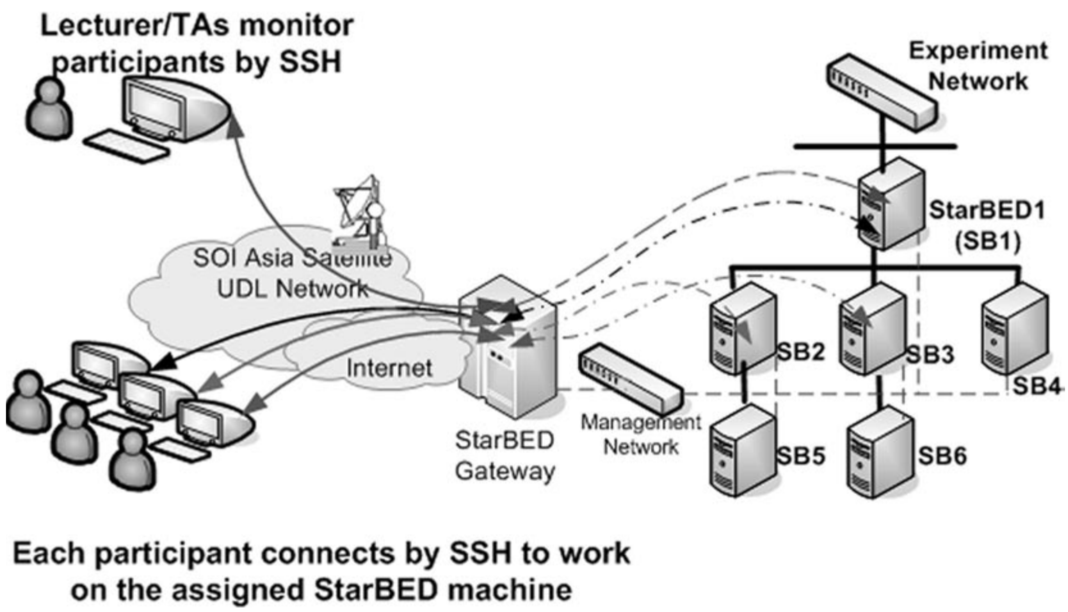

Figure 5 StarBED deployment in distance learning

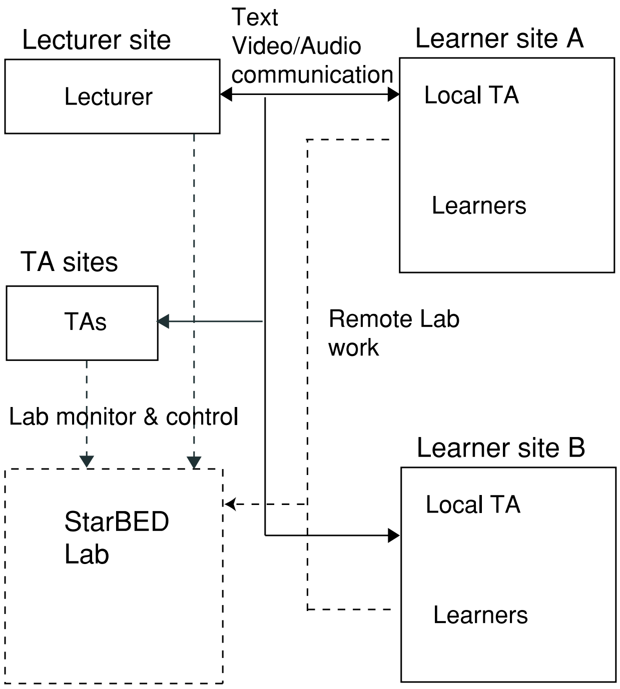

Figure 6 A remote class supervision model

misconfigurations. StarBED provides remote console access and power management by KVM-over-IP[16] and IPMI techniques[17] respectively.

4.3 Distributed Class Supervision Model

The technologies proposed in Section 4.1 and 4.2 enable distributed locations of class members and a computer laboratory by giving communications, access and controls over Internet. However, in the distributed environment, it is difficult for a lecturer to supervise class and lab activities without a well-defined class structure and qualified TAs. Therefore, a distributed class supervision model is proposed by defining a distributed TAs structure and a class progress tracking system.

At every learner site, as shown in Figure 6, local TAs are required to oversee local class activities and to assist learners in their studies. In a region-wide learning which the language used to conduct a class is not native in some learning sites, it is desirable that learners can consult their TAs in local language. When problems or questions cannot be answered by local TAs, they can be forwarded to the lecturer or TAs at remote sites. The TAs at remote sites are experienced TAs who support lecturers in lab preparation and have control of laboratory administration. Both lecturer and TAs can check problems on learners' lab nodes and troubleshoot accordingly.

With this structure, the quality of a hands-on workshop depends on local TAs, therefore it must be assured that local TAs have adequate knowledge and experiences on the training subjects and hands-on exercises. In the SOI Asia workshop, the required qualifications of a local TA are either those who participated in previous related trainings or those who have experiences in daily operation. If necessary, a TA training session prior to the workshop must be held to train for qualified TAs.

To instruct hands-on exercises, it is very important for lecturers to know learners' work progress to determine the pace of teaching, especially in the region-wide case in which learners' backgrounds and skills vary. In 2006, manual progress tracking by asking through the provided communications system was found not effective to deal with many learners and many hands-on exercises. Therefore, a web-based progress tracking system was introduced in 2008 as shown in Figure 7. A set of checkpoints on hands-on tasks is inputted into the proposed system by lecturers prior to the workshop. During the class, a learner reports his/her progress by filling in the work status of each checkpoint in a web-based form. Local TAs check that the learner has completed the reported steps and approve the reported status in a web-based approval form. The lecturer can view the whole class status in the progress report web page in a matrix format of learner names and checkpoints, then determines the pace of teaching accordingly. The local TA approval capability assists lecturer to examine learners' works.

5 Analysis and Evaluations

Towards the future direction of educational development to widen learning opportunities by utilizing emerging technologies, new approaches of region-wide IT hands-on workshop are presented in this paper. The proposed distance learning model which incorporates a remote computer laboratory by computer virtualization technology and large-scale computing platform has been proven its feasibility through the actual implementations of SOI Asia workshops year 2006 and 2008. The face-to-face and the distance learning approach yield different overhead and possess their own advantages. The analysis is made based on the data collected from implementations of SOI Asia workshops, questionnaires and comments from lecturers, TAs, participants and organizers.

The proposed distance learning approach is

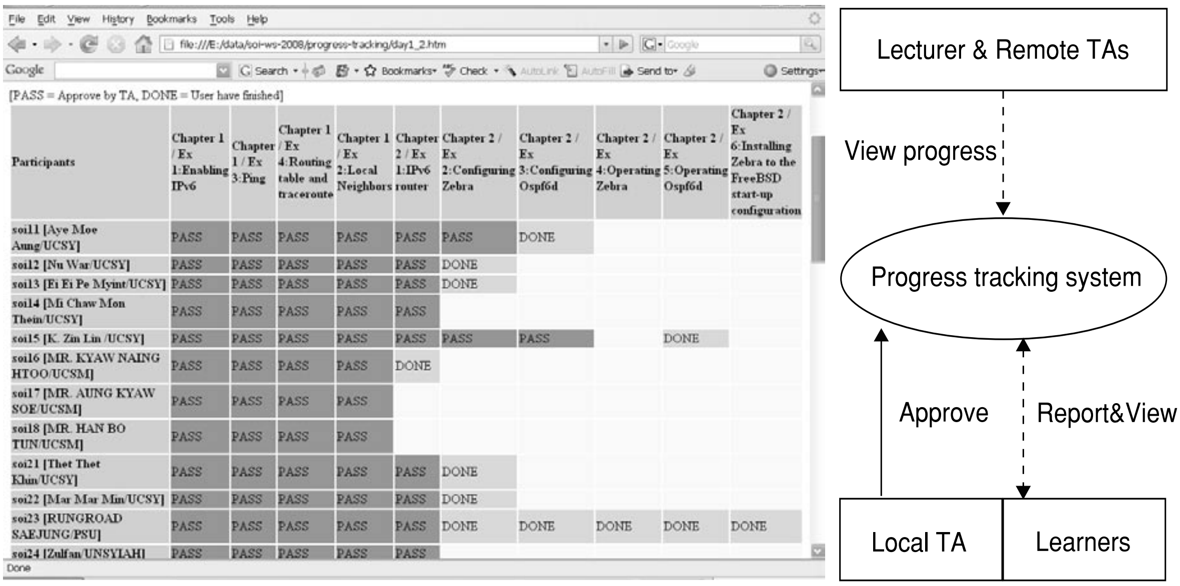

Figure 7 A web-based progress tracking system

Table 2　Outcomes of different workshop approaches

Year	2005	2006	2008
Approach	Face-to-Face + local computer laboratory	Distance learning + Virtualization laboratory	Distance learning + StarBED laboratory
#participants	33	42	42
#participant sites	1	16	15
#lecturers	3	4	6
#remote lecture sites	0	1	5
#TAs	8 local	23 local 8 remote	24 local 5 remote
#Total travels	37 international 0 domestic	3 International 5 domestic	0 International 3 domestic

evaluated by a comparative study from the outcomes of SOI Asia project annual operator workshops in year 2005, 2006 and 2008 as shown in Table 2. With the distance learning approach in year 2006 and 2008, the number of travels significantly reduced while the number of participants and lecturers increased. It demonstrated that more learning opportunities can be delivered to learners without teaching resources at local. The increased number of lecturer sites reveals that there are more possibilities to obtain teaching resources because the environment is designed to support flexible locations of lecturers and a laboratory. With increasing number of partner universities in recent years, the distance learning approach can scale to train more participants as shown in Figure 1.

On the other hand, the required overhead at each learner site are the local TAs, a PC terminal per participant and a local distance learning system. At least one TA per 3 participants is required in the implementation and since the environment is highly distributed as there were 16 and 15 learning sites in 2006 and 2008 respectively, more TAs were involved. In the cases that the local distance learning system is not ready or there is no qualified TA, travels are still required either for participants to attend the workshop at nearby locations or a qualified TA from other sites is requested to come. Those were the cases of travels in year 2006 and 2008.

Components of the proposed approach, including the technology model and distributed class supervision model, are analyzed in the subsequent sections.

5.1 Asia-wide Distance Learning Environment

The proposed distance learning environment focuses from network layer design to support a region-wide distance learning platform which delivers high-quality lectures' video/audio streams. The proposed network design was evaluated[8] to deliver better quality streams with stable rate, high correlation, low data loss and jitter compared to the existing Internet at learner sites. With IPv6 Multicast network service, the bandwidth consumed for video/audio streams was significantly reduced[19] from 48 Mbps in normal IPv4 Unicast case to 3Mbps in 2008. Therefore, the proposed network infrastructure and network technologies is scalable and support better communications, access and controls for a hands-on workshop compared to the existing Internet.

To evaluate from the participants' points of view, a questionnaire with 1-5 rating choices were replied from 24 out of 42 participants in 2008 and 40 out of 42 in 2006. The 1, 2 rating are interpreted as negative feedback, 3 is fair and 4, 5 are interpreted as positive. The results in Table 3 shows that the qualities of communications in the class including video/audio/text, synchronized live presentation and live demonstration are satisfactory from the relatively positive feedbacks in both years.

5.2 Remote Computer Laboratory

The computer virtualization and large-scale computing platform can achieve higher scalability because of their efficient laboratory management systems compared to the manual administration in the face-to-face approach. Since they use automated processes to construct laboratory scenarios according to lecturers' specifications, the deployment time is shorter and the integrity is higher. The deployment time of each approach is analyzed as shown in Table 4. With manual laboratory administration, the total deployment time is N times of the time used to prepare one laboratory machine. In virtualization and StarBED cases, the deployment time is the time used to prepare one master lab machine and the time for an automated process to duplicate the master machine's image to the remaining VMs or PCs. The preparation of the master machine was estimated as 1-4 hours in the SOI Asia workshop. The deployment of FreeBSD6.1 to 56 VMs in 2006 consumed less than 600 seconds[6] and the deployment of FreeBSD6.2 to 67 StarBED nodes in 2008 was measured 2,552 seconds[19]. On the other hand, the estimated time used to prepare 40 laboratory PCs in the face-to-face approach year 2005 was 120 man-hours[7]. It demonstrated that an efficient laboratory administration system can reduce much workload and time consumed to prepare a hands-on laboratory, hence both remote laboratory approaches can scale to support a larger hands-on environment.

The computer virtualization platform reduces the equipment costs compared to other two approaches because a physical machine can host a number of VMs. With reduced number of physical machines, the administration workload decreases as well. On the other hand, participants reported slow response time working on VMs as the system load was high[19]. The CPU utilization of a virtualization server were 30% running 6 FreeBSD VMs and 10% running 6 Fedora Core4 VMs in their idle states, and reached 90% during some peak periods[6]. In the StarBED environment with a dedicated high-performance machine for each participant, the average CPU utilizations measured during the workshop were 0.63% and 0.59% for FreeBSD and Fedora Core6 respectively[19]. Table 5 shows participants' opinions on the response time of computer virtualization and StarBED implementations, StarBED got a very positive result which corresponds to the above CPU utilization data.

Table 3 Evaluation of the communications qualities in the distance learning workshop

	Year	Positive	Fair	Negative
Video quality	2008	95.8%	4.2%	0%
	2006	87%	13%	0%
Audio quality	2008	91.7%	8.3%	0%
	2006	77%	23%	0%
IRC usage	2008	91.7%	8.3%	0%
	2006	100%	0%	0%
LivePresenter	2008 only	91.7%	8.3%	0%
LiveTTY	2008 only	95.8%	4.2%	0%

Table 4 Comparative data of laboratory platforms

Year	2005	2006	2008
Approach	Face-to-Face + local computer laboratory	Distance learning + Virtualization laboratory	Distance learning + StarBED Laboratory
Hardware lesson	Yes	No	No
Integrity	Medium	High	High
Laboratory deployment time	M x N	M + αN	M + μN
Hardware fault possibilities	High	Low	High
Response time, System load	Low	High	Low
Physical laboratory PCs or servers	N + E	N/V	N + E
Remote terminal PC	0	N	N

M = Time used to prepare one laboratory machine
N = Number of participants
α = Average time to duplicate one VM from master image
μ = Average time to copy master disk image to one StarBED node
E = Extra machines for lecturers, spares, etc.
V = A number of VMs hosted in a virtualization server

5.3 Remote Class Supervision Model

The proposed remote class supervision model is evaluated by feedbacks from participants and lecturers as shown in Table 6. The lecturer questionnaire was replied from 4 out of 4 in 2006 and 4 out of 6 in 2008. For the distributed TAs structure, lecturers and learners found the local TAs were helpful to assist them through the workshop. A pre-workshop TA training session is considered to be an important process to improve TAs ability to supervise local participants. With the provided communications system, most learners felt they could communicate well with other sites, however some lecturers expected more conversations since participants mostly communicated with local TA first. For the effectiveness of the proposed progress tracking system to realize the class progress, 100% positive feedbacks from lecturers were received.

5.4 Overall Evaluations

Table 7 shows the overall evaluations by learners in 2006 and 2008. In general, learners' impressions toward both workshops were highly positive. Most of them found the lessons and practical experiences they gained from the workshops will be useful for their future operations. The effectiveness of distance learning workshop with computer virtualization was evaluated 95% positive. As well, 91.7% of participants gave positive feedbacks on the distance learning workshop with StarBED. In term of teaching workshop, most lecturers found participants obtained

Table 5 Evaluation data of the response time

	Year	Positive	Fair	Negative
Lab response time	2008	100%	0%	0%
	2006	60%	20%	16%

knowledge useful for operation while the effectiveness of the model was moderately evaluated.

With affordable system requirement which utilizes PC-based communications services, it increases the possibility for a site to participate in as a lecturer or a learner site. The satellite UDL is a cost-effective solution to ensure lecture quality when terrestrial infrastructure is not ready or inadequate. The total number of participating sites, both lecturer and learner sites, are 17 and 20 sites in 2006 and 2008 respectively. The workshop content can also cover more topics which is PC-based operation, e.g. programming, Internet services. Workshop content with GUI is possible but the design has to carefully consider the required bandwidth of remote access with the class members' network qualities. With the proposed technologies, a hands-on workshop can scale to accommodate more learners at more locations concurrently. To maintain education performance, the workshop scale must consider other factors including learners' backgrounds, content level, TAs quality.

6 Conclusion

The importance of researching new educational environments for IT human resource development in developing region is addressed as there are shortages of resources, facilities and budgets to teach practical IT knowledge. Distance learning approach is proposed to construct an environment which region-wide learners can receive high-quality theoretical lecture and also learn practical hands-on lessons. The proposed communications system supports live multi-site human interactivities to collaboratively work even when they are at different locations. Two approaches of remote computer laboratory were researched

Table 6 Evaluation data of the remote class supervision

	Source	Year	Positive	Fair	Negative
Local TA	Lecturers	2008	100%	0%	0%
	Learners	2008	79.2%	20.8%	0%
	Lecturers	2006	100%	0%	0%
	Learners	2006	82.5%	12.5%	5%
Communications	Lecturers	2008	50%	50%	0%
	Learners	2008	91.7%	8.3%	0%
	Lecturers	2006	0%	50%	50%
	Learners	2006	92.5%	5%	2.5%
Progress tracking	Lecturers	2008 only	100%	0%	0%
	Learners	2008 only	87.5%	4.2%	8.3%

Table 7 Evaluation data of the overall workshop quality

	Year	Positive	Fair	Negative
Usefulness to operation	2006	98%	2%	0%
	2008	100%	0%	0%
Workshop effectiveness	2006	95%	5%	0%
	2008	91.7%	8.3%	0%
Future participation	2006	87%	13%	0%
	2008	100%	0%	0%

and proven feasible through actual implementations of SOI Asia workshop. Computer virtualization technology has advantages on its reduced resources and convenient administration but the system load of a virtualization server must be controlled for acceptable response time. StarBED provides high-performance nodes with efficient adminstration, therefore it is satisfactory to lecturers, participants and TAs.

Evaluations and analysis from actual implementations of SOI Asia workshop 2005 (face-to-face), 2006 (distance learning & virtualization), 2008 (distance learning & StarBED) have shown interesting aspects of performance, incurred costs and opinions of class members toward these approaches. Learners and lecturers gave very positive responses in their participations in distance learning approach as they could obtain knowledge useful for their future operations. The design aspects, implementation details and evaluations provided in this paper can contribute to the future researches and deployments of IT hands-on distance education.

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