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Implementation of an E-Learning System Using P2P, Web and Sensor Technologies

Keita Matsuo†, Leonard Barolli‡, Fatos Xhafa††, Vladi Kolici†‡, Akio Koyama‡†, Arjan Durresi‡‡, Rozeta Miho†‡

†Graduate School of Engineering, Fukuoka Institute of Technology (FIT)
E-mail: bd07002@bene.fit.ac.jp
‡Department of Information and Communication Engineering, FIT
3-30-1 Wajiro-Higashi, Higashi-Ku, Fukuoka 811-0295, Japan
E-mail: barolli@fit.ac.jp
††Department of Languages and Informatics Systems, Technical University of Catalonia
Jordi Girona 1-3, 08034 Barcelona, Spain
E-mail: fatos@lsi.upc.edu
†‡Department of Electronics and Telecommunication, Polytechnic University of Tirana
Mother Teresa Square, Nr.4, Tirana, Albania
E-mail: vladi.kolici@itirana.com, rmiho@fie.upt.al
‡†Department of Informatics, Faculty of Engineering, Yamagata University
4-3-13 Jonan, Yonezawa 992-8510, Yamagata, Japan
E-mail: akoyama@yz.yamagata-u.ac.jp
‡‡Department of Computer and Information Science
Indiana University Purdue University at Indianapolis (IUPUI)
723 W. Michigan Street SL 280, Indianapolis, IN 46202, USA
E-mail: durresi@cs.iupui.edu

Abstract

This work is motivated by the need to develop decentralized P2P approaches to support learning and teaching activity in virtual universities. In this paper, we present the implementation of the JXTA-based e-Learning P2P system. We also show the design and implementation of a smart box environment that will be used for stimulating the learners to increase the learning efficiency. The proposed e-learning P2P system is a useful tool for monitoring and controlling learners' activity. We evaluate the proposed system by experimental results and show that proposed system has a good performance. In the future, we aim to use it in real virtual campus environments.

1. Introduction

In the past few years we have observed an explosive growth of multimedia computing, communication and applications. Information Technology (IT) has a great impact in our everyday life and is transforming the way people live, work, and interact with each other, and is revolutionizing the way businesses, government services, education, entertainment, and health care are operating.

The Internet is growing every day and the performance of computers is significantly increased. However, the Internet architecture is based on Client/Server (C/S) topology and can not use efficiently the clients' features. Also, with appearance of new technologies such as ad-hoc networks, sensor networks, body networks, home networking, new network devices and application are appearing. Therefore, it is very important to monitor and control the network devices via communication channels and exploit their capabilities for the everyday real life activities. However, in large scale networks such as Internet, it is very difficult to control the network devices, because of the security problems. Each network has its own security policy and the information should overcome the firewalls, which are used for checking the information between private and public networks. The information is transmitted according to some decided rules and it is very difficult to change the network security policy. Therefore, recently many researchers are working

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on Peer-to-Peer (P2P) networks, which are able to overcome the firewalls, Network Address Translations (NATs) and other security devices without changing the network policy. The P2P architecture is thus very important for future e-learning systems. In such systems, the computational burden of the system can be distributed to peer nodes of the system. Therefore, in decentralized systems users become themselves actors by sharing, contributing and controlling the resources of the systems. This characteristic makes P2P systems very interesting for the development of decentralized applications [1-5] for virtual campuses and virtual organizations.

During the last decade, many e-learning systems are proposed and implemented, mostly using web technologies. With emerging new technologies such as P2P, sensor and ad-hoc networks, it will be possible to build ubiquitous systems that can offer an equal educational environment regardless the region, age, time or the place [6, 7].

This work is motivated by the need to develop decentralized P2P approaches to support learning and teaching activity in virtual universities. We present the implementation of the main features of a JXTA-based P2P system (called JXTA-Overlay) that support in many ways the development of e-learning applications. We also show the implementation of a SmartBox environment that is used for stimulating the learners to increase the learning efficiency. The SmartBox is integrated with the JXTA-Overlay by using efficient message sending between peers in the system.

The structure of this paper is as follows. In Section 2, we introduce the related work. In Section 3, we give a short description of the JXTA library and explain JXTA-Overlay platform. In Section 4, we present the proposed JXTA-based P2P e-learning system. In Section 5, we discuss experimental results. We give the conclusions in Section 6.

2. Related Work

In this section, we discuss the related work for P2P systems and Web based e-learning systems. Much of the initial research efforts on P2P systems were concerned with investigation of overlay networks. These efforts were oriented towards the design and implementation of libraries and platforms to support development of real P2P applications, which could actually combine both Grid and P2P technologies. Bal et. al. [8] consider the conceptual, algorithmic and application level tools to facilitate the application development task, that is, tools that enable writing, deploying and running Grid/P2P applications.

Since in P2P applications file sharing plays an important role, a lot of research effort is being devoted to the development of reliable file sharing systems to be used in P2P applications [9]. In particular, several studies are done for measuring the efficiency in P2P systems [10, 11].

Another research work in this direction is reported in [12] where a NAT traversal for pure P2P e-learning system is proposed. The authors in [13] analyzed the potential of P2P and Grid for e-Learning environments and proposed a P2P environment for sharing services of education resources. P2P technology is addressed also in [14] for developing a self-managed learning community.

During the last few years enormous research efforts have been dedicated to the development of e-learning systems. Consequently, many large projects have been established [15-17]. However, in these systems the e-learning completion rate is low. One of the reasons is the low study interest when the learner studies the subjects. Therefore, it is very important to stimulate the learner's motivation during the study. In our previous works [18, 19], we proposed an agent based distance learning system to deliver appropriate studying materials to learners and stimulate learner's motivation.

3. JXTA- Overlay Architecture

JXTA technology [20] is a generalized group of protocols that allow different devices to communicate and collaborate among them. JXTA offers a platform covering basic needs in developing P2P networks. By using JXTA framework it is possible that a peer in a private network can be connected to a peer in the Internet by overcoming existing firewalls.

3.1. JXTA Entities

The main entities of JXTA are as follows.

- **Peer:** Any interconnected node is called peer. Peers work independently and asynchronously with other peers. Peers publish one or more interfaces that are used by other peers to establish peer-to-peer connections. Peers can be classified in different types (Limited Edge Peer, Complete Edge Peer, Rendezvous Peer, Relay Peer) according to their role in the P2P network.
- **PeerGroup:** A PeerGroup is a collection of peers that provide a secure shared environment for participating peers. A PeerGroup can decide its own policy of peer membership. Peers can belong to more than one PeerGroup.

- **Pipes:** A pipe is a virtual communication channel established between two processes. A computer connected to the network can open, at transport level, as many pipes as its operating system permits. JXTA offers both unidirectional, not secure pipes and bidirectional secure pipes.
- **Messages:** Messages are objects used for communicating and interchanging data. A message is essentially an ordered sequence of tags/values, which could also include binary code (appropriately encoded).
- **Advertisements:** JXTA resources and services are represented using advertisements. An advertisement is a meta-data structured information (XML document), which is published with a certain lifetime specifying its availability.

3.2. JXTA-Overlay

JXTA-Overlay comprises primitives for: (a) *peer discovery*; (b) *peer's resources discovery*; (c) *resource allocation*; (d) *task submission and execution*; (e) *file/data sharing, discovery and transmission*; (f) *instant communication*; (g) *peer group functionalities (groups, rooms etc.)*; and, *monitoring of peers, groups, and tasks*.

This set of basic functionalities is intended to be as complete as possible to satisfy the needs of JXTA-based applications. The overlay is built on top of JXTA layer and provides a set of primitives that can be used by other applications, which on their hand, will be built on top of the overlay, with complete independence. The JXTA-Overlay offers several improvements of the original JXTA protocols/services to increase the reliability of JXTA-based distributed applications and to support group management and file sharing [1-5].

The architecture of the P2P distributed platform we have developed using JXTA technology has these building blocks: Broker Module, Primitives Module and Client Module. Altogether these three modules form a new overlay on top of JXTA. The JXTA-Overlay structure is shown in Fig. 1 and the system image in Fig. 2.

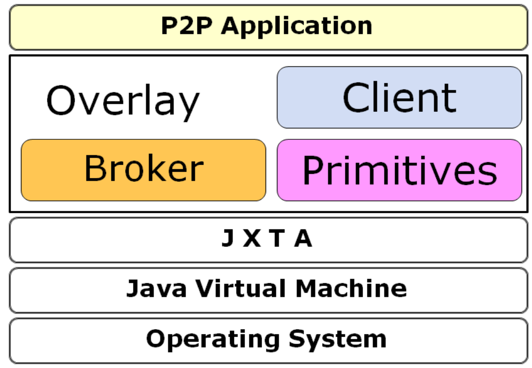

Fig. 1. Structure of JXTA-Overlay.

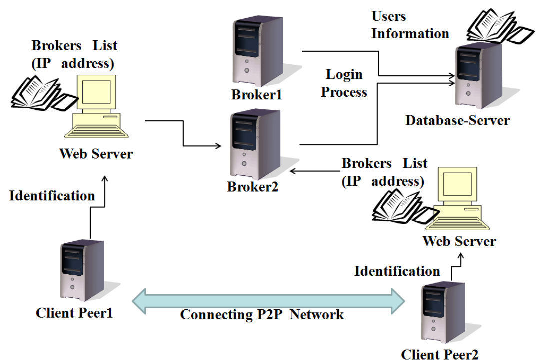

Fig. 2. System image of JXTA-Overlay.

JXTA protocol uses Universally Unique Identifier (UUID) in order to identify the peers in the private network from the Internet. We implemented a control system that is able to control a peer in a private network from a peer in the Internet. The control targets are considered the network devices such as RS232C port, LPT port and USB port. By implementing this kind of control system, we are able to collect data and control the peers in a Wide Area Network (WAN). Thus, we will be able to control all devices that are connected to the peers. The application of this control function will be described in detail in the following section. We are concentrated on the control of USB devices and RS232C equipment. This is because USB devices are very popular and are used almost in every computer. Also, by using USB is possible to control the motors and LEDs. The RS232C is a legal interface and many devices have implemented it.

4. Proposed P2P E-Learning System

4.1Transmission Control and Management in JXTA-Overlay

The most important part in e-learning systems is the efficient communication between peers (groups of students) or between teachers and students. By using JXTA-Overlay, it is possible to overcome, firewalls, routers and NATs in the private networks. We explain in following the message transmission by the JXTA protocol.

4.2 P2P e-Learning System

In our proposed system we combine P2P, Web and Sensor technologies. Our goal is not only to monitor and control the students' activity in a WAN but also to stimulate and increase learners' motivation.

Our target implementation is, on the one hand, to develop efficient P2P file sharing systems, and on the other hand, to build a Smart Room to control and stimulate the learners' motivation.

Because it is very expensive to build the Smart Room, we proposed and implemented a SmartBox as shown in Fig. 3. The SmartBox uses RFID (Radio Frequency Identification) and Vital Sensors. In our system, we use JXTA-Overlay for communication between peers.

We have implemented the following functions to stimulate the learners' motivation.

- **Vibration Function:** This function is achieved by using the vibration function of PDA and Cellular Phone or by moving the learner's chair. This is done when the learner does not use the computer keyboard for a determined period of time.
- **Smell Function:** By this function, the system changes the mood of the learner.
- **Sound Function:** Using this function, a relaxing sound is emitted from the speaker to create a relaxing environment.
- **Room Light Control:** By changing the brightness or lighting of the room the student's mood and the concentration is controlled.
- **Temperature Control:** This function controls the temperature of the room to change the mood of learners.

The learner's mood is quantified and measured by the vital sensors and the e-learning management computer checks the learner's motivation level. The learner identification is carried out by RFID. Using the RFID, the system can check whether the learner is or is not in the room and if the learner doesn't return to the room for a long time, the system automatically sends an e-mail to the cellular phone of the learner and urges him/her to return to the study room.

4.3 SmartBox Implementation

The size of the SmartBox is 50×10×15 cm and is put in the learner's desk. The SmartBox has the following sensors and functions (see Fig. 3).

- **Body Sensor**: for detecting whether the learner is in the room or not.
- **Hand Sensors**: for detecting the learner's hand.
- **RFID Sensor**: for identifying learner's IC tag card.
- **Chair Vibrator Control**: for vibrating the learner's chair.
- **Light Control**: for adjusting the room light.
- **Aromatic Control**: for controlling the room smell.
- **Buzzer Control**: to emit relaxing sounds.
- **Remote Control Socket**: for controlling AC 100V socket (on-off control).

A snapshot of the implemented SmartBox is shown in Fig. 4 and its structure for e-learning in Fig. 5. SmarBox can detect the learners' movement by using body sensor and hand sensors. The body sensor is used for controlling the body movement of the learner. On the other hand, the hand sensors control the hand motion of the learner. The RFID sensor can read IC tag information and record the learner's study history. It is used also to check whether the learner is in the room or not.

The SmartBox is the end device in P2P e-learning system and we control its functions by using JXTA-Overlay. We developed a P2P software for the SmartBox e-learning system. In Fig. 6 is shown the SmartBox control interface, which is used to select the stimulation devices. By combining Web and Sensor technologies, the proposed system not only can monitor and control the learners in the internet, but also can stimulate the learner's motivation. We developed the SmartBox system as an application of JXTA-Overlay, which uses the JXTA-Overlay as a black box. Therefore, when we need to create an application, it isn't necessary to modify Business and Control Layers.

5. Experimental Results

In our experimental study, we consider three different scenarios to cover different aspects of our P2P e-learning system. First, we study the performance of the P2P file sharing system in order to see the feasibility of using it for learning purposes. Second, we experimentally evaluate the use of SmartBox in detecting learner's activity (body and hand movement). Finally, a questionnaire evaluation is also presented.

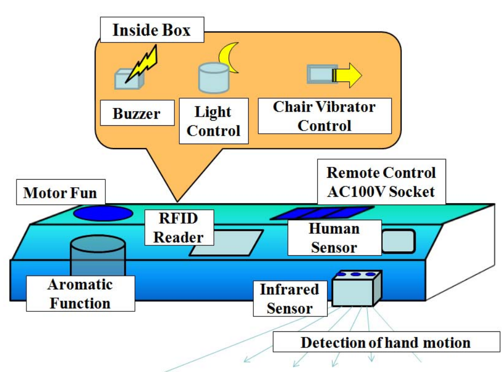

Fig. 3. SmartBox functions.

Fig. 4. A snapshot of implemented SmartBox.

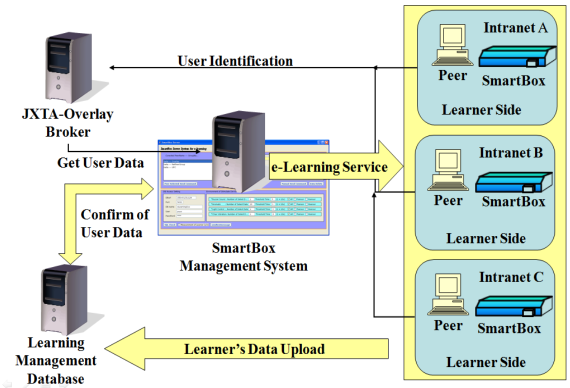

Fig. 5. Structure of SmartBox for e-learning.

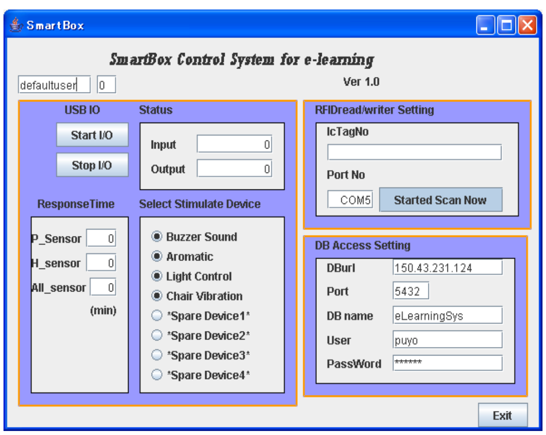

Fig. 6. SmartBox control interface.

5.1 Experimental Results for JXTA-Overlay P2P System

We present here the experimental study of the extended file sharing protocols of JXTA-Overlay. The aim is to measure the performance of file searching in the JXTA-Overlay system. The specifications of machines which we used for the experimental study are shown in Table 1. We study the performance of file searching. More precisely, we study the broker's search time when the number of connected peers and the number of shared files per peer increase.

Table 1. Specifications of P2P network.

Name	Online net
Peer Broker	Double dual core (4 CPUs with HT (8 CPUs))
Peer Client 1	Double dual core (4 CPUs with HT (8 CPUs))
Peer Client 2	Double dual core (4 CPUs with HT (8 CPUs))
Peer Client 3	Double dual core (4 CPUs with HT (8 CPUs))
Peer Client 4	The same machine: Double dual core (4 CPUs with HT (8 CPUs))
Peer Client 5	
Connection	1 Gbps

We have measured the broker's search time in 10 different tests for each possible combination of 3 components that can affect the search, in order to avoid biased results. The setup of the experiment is as follows:

Files shared by each peer: between 0 and 300, in groups of 50 files (10 for each possible type: audio, video, picture, application and text).

Peers: between 1 and 5.

Search: we consider 6 search possibilities:

No type files specified: Without selection, the broker doesn't search in any group of files.

1 type of files specified: Only 1 type of files is selected, corresponding to the group Text. The broker will find the files that are in this group.

2 types of files specified: The groups Text and Pictures are selected and the broker will find the files that are in these groups.

3 types of files specified: In this case, the groups are Text, Pictures and Video.

4 types of files specified: In this case, the groups are Text, Pictures Music and Video.

5 types of files specified: All the types are selected and broker will find all shared files.

In the search we previously loaded the P2P system as follows. All the peers have always the same quantity of files in every case, between 10 (50 files shared) and 60 (300 files in total shared).

We analyzed the broker processing time for file searching according to the number of shared files (specifically, when the number of peers sharing the files increases).

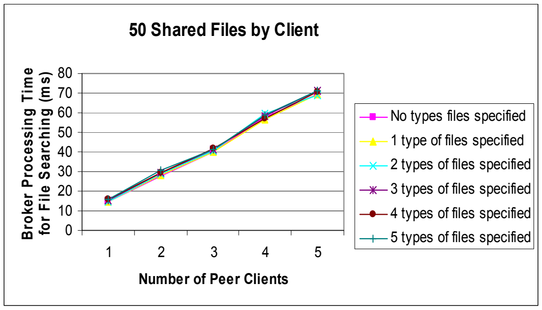

Fig. 7. Case of 50 shared files by client peer.

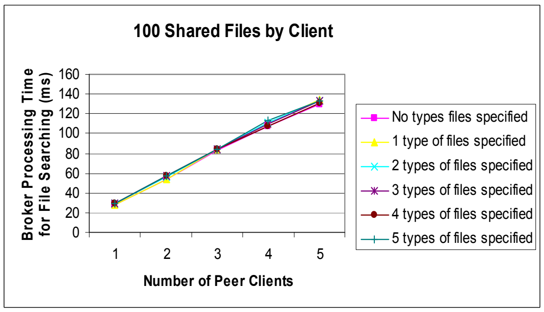

Fig. 8. Case of 100 shared files by client peer.

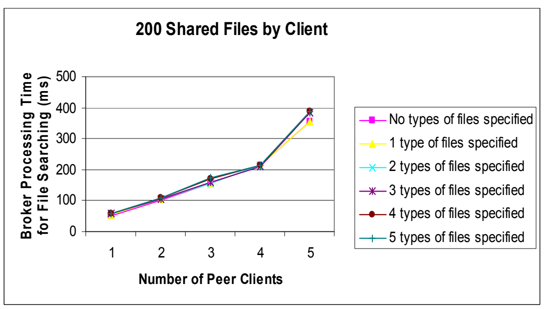

Fig. 9. Case of 200 shared files by client peer.

In Fig. 7, Fig. 8, and Fig. 9, we show the evolution of broker processing time. The evolution of the broker search time grows linearly with the increase of the number of connected peers and number of sharing files per peer. The broker processing time increases because the broker will have more advertisements to check and to analyze as the number of connected peers and number of shared files increases.

It is interesting to notice that when the number of shared files per peer is 200 or larger, the linearity of the search does not hold anymore. That is, there is a shift in processing time of the broker when the number of shared files is considerable. This is explained by the fact that when the number of files is considerably large, the broker's processing (both processing time and memory consumption) increase significantly. It should be noted however that this number of 200 files is not a limitation in our case since we are interested in using JXTA-Overlay for e-learning and in this case the number of shared files by students is rather small.

5.1 Measurement of Body and Hand Movement of Learners

The proposed system can detect the learner's movement by using hand and body sensors. In our experiments, we used one hand sensor and two body sensors. The hand sensor detects the hand motions, while the body sensors are used for detecting the body movements of the learner.

In Table 2, we show the sensor response range and the average value of response time. We got these data after observing two learners studying for 40 hours. We consider where is the point of effective stimulation for learners from the sensing rate values. We pay attention to the reaction frequency of each sensor. We can obtain the stimulation point by using the polynomial approximation curve. We used the non-linear least squares method for obtaining the polynomial approximation curve. It is proved that in general the people concentration is about 20 minutes. Looking at Table 2, we see that when the response range is about 35 seconds, the value of least squares is about 23.5 minutes. The calculation is done considering that the total experimental time is 40 hours. This value is very close with the region of human concentration (20 minutes).

After 20 minutes of losing concentration, we considered that is an effective way to stimulate the learner after 35 seconds, 55 seconds and 80 seconds as shown in Fig. 10. According to the results of experiment, we decided that if the learners don't move for 35 seconds, we should give them a slight stimulation by light, and then after about 55 seconds from the start give them a sound stimulation. Then, start to vibrate their chair after about 80 seconds. We will also give the smell stimulation to learners if they do not respond after more than 100 seconds.

5.3 Questionnaire Evaluation

In order to evaluate the proposed system, 40 learners used the system and after that we made a questionnaire.

We asked the learners how it was the system performance and especially how the system stimulated learner's motivation. The questionnaire content is shown in Table 3 and its results are shown in Table 4. The learners answer the questions by using a five-grade system from 1 to 5. Only Q2 is a threefold choice (see Table 4). The performance evaluation is better when the evaluation number is higher.

Table 2. Polynomial approximation curve.

i	Response Range Middle Value (sec) *x*	Average Response Time (min) *y*	Value of Least Squares (min)
1	5	0.9	3.1
2	15	2.1	0.7
3	25	10.0	7.5
4	35	24.5	23.5
5	45	52.2	48.7
6	55	70.6	83.1
7	65	133.3	126.6

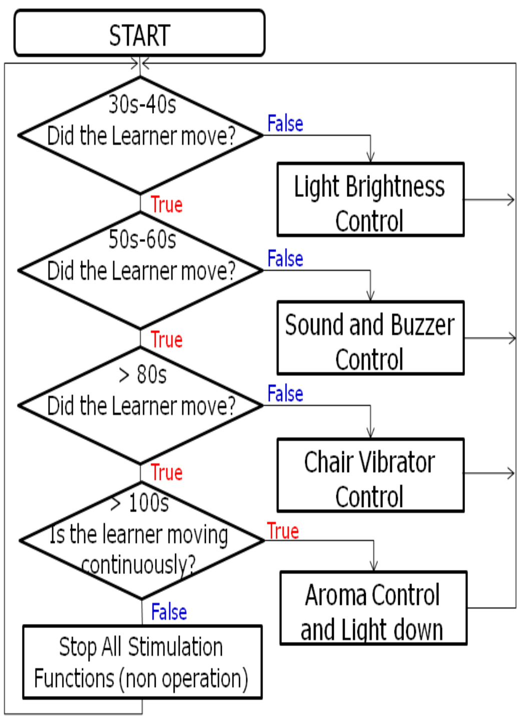

Fig. 10. Flowchart of learner's stimulation.

When a learner evaluates with 5, it means that the system had very good performance. The values shown in Table 4 are the average values collected from 40 learners. Considering the questionnaire results, we conclude that proposed system is an effective system for keeping the learner's motivation. The "Vibration and Movement" in Q2 has the highest result.

These results proved that by giving a direct physical stimulation to learners, the proposed system has a better efficiency than just using the computer display as in previous system. Especially, for the answer of Q2, the evaluation rate is 55 % for the question: "How you evaluate the directly stimulation to learners?".

Table 3. Questionnaire content.

Question Number	Content
Q1	*How much did the "Sound, Light Control, Chair Vibration and Smell function" keep your learning motivation?*
Q2	*How do you evaluate the stimulation by visual, sound and learner's body movement? Which one do you think is more effective? [visual and sound, vibration and movement, both]*
Q3	*Do you think that SmartBox is effective for e-learning?*
Q4	*How do you evaluate RFID control and management function?*
Q5	*How do you evaluate the e-mail attention function when the learner is not in the room?*

Table 4. Questionnaire results.

Question Number	Performance Results	
Q1	Sound	4.25
	Light	3.80
	Vibration	4.53
	Smell	3.10
Q2	Visual, Sound	15%
	Movement	55%
	Both	30%
Q3	4.13	
Q4	4.64	
Q5	4.15	

The result of Q2 also corresponds with the results of Q1. Therefore, we think that the proposed system is an effective e-learning system. Also, the implementation of RFID has a high evaluation value. We think that we can develop even more effective functions using RFID. However, the evaluation of smell function was low. This is because the learners have different smell tastes. But, we think that by selecting an appropriate taste for each learner, the evaluation for this function will be improved.

6. Conclusions and Future Work

In this work, we presented the implementation of JXTA Overlay P2P e-Learning system. The proposed system is able to overcome Firewalls, Routers and NATs by using JXTA-Overlay and can control and stimulate the learners' motivation by using implemented SmartBox. By using the

RFID, it is possible to read and write the IC tag card and manage the learner's study history.

In the future, we want to add other effective stimulation for each learner using IC tag card. Also, the ServoMotor has 12 control ports, so we will use some of ports for implementing other stimulating functions. We plan to extend our system with functionalities for presence mechanism of students in classrooms and activities. We plan also to evaluate the proposed system in a real environment of virtual campuses.

Moreover we would like to use our platform for peer coordination so that our students could accomplish group work in a coordinated way.

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