Synchronous environments for distance learning: combinning network and collaborative approaches

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Synchronous Environments for Distance Learning: Combinning Network and Collaborative Approaches

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Abstract

Distance learning has much evolved since the development of the Internet. Many asynchronous web-based learning systems have been deployed to make the most of communication networks. Yet, these solutions do not provide the interactivity of face-to-face activities and they are not able to fit the specific requirements of the students. The use of synchronous collaboration systems appears as an interesting solution to tackle these problems. Several elements influence the quality of synchronous collaborative learning. First, collaboration structures are mandatory for the development of appropriate educational strategies. Then, distributed systems have to be able to support these collaboration structures. The underlying network infrastructure has an influence on the quality of communication. In order to provide the best collaboration quality to distance learners, it appears necessary to support all those different contributions. Researches on collaborative learning, distributed systems and network fields are often lead independently, which leads to the development of unbalanced environments. This research identified the relationship between these fields through a series of distance learning activities performed with synchronous collaborative learning environment. From these experiments, a model of this relationship has been proposed. This model aims at supporting the development of a synchronous collaborative learning environment of a new generation referred as Content and Communication Management System (CCMS). The CCMS itself was not implemented but it leads to improvements of the Platine environment. Platine is the collaborative learning environment developed in the LAAS-CNRS. These improvements were tested within an experiment and showed progress of the collaborative support provided by the environment.

Key Words: Synchronous Computer Supported Collaborative Learning (CSCL) Environments , Videoconferencing, Distance Learning

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List of Papers

Main Papers (Journals)

1. David Raymond, Kazuhide Kanenishi, Kenji Matsuura, Veronique Baudin-Thomas, Thierry Gayraud, Michel Diaz and Yoneo Yano, "A Model for Content and Communication Management in Synchronous Learning", Kinshuk, Demetrios G. Sampson, Reinhard Oppermann & Ashok Patel (Eds.), Journal of Educational Technology & Society, International Forum of Educational Technology & Society Publisher, ISSN (Online) 1436-4522, ISSN (print) 1176-3647, Vol.8 Issue 3, 2005, pp. 187-205.

2. David Raymond, Kazuhide Kanenishi, Kenji Matsuura and Yoneo Yano, "Feasibility of videoconference-based lectures over the Internet" Lorna Uden, David Hung & Jon Mason (Eds.), International Journal of Learning Technology (IJLT), Inderscience Publishers, ISSN (Online): 1741-8119, ISSN (Print): 1477-8386, Vol.2 No.1, pp. 5-27

Secondary Papers (Refereed International Conference)

1. David Raymond, Veronique Baudin-Thomas, Kazuhide Kanenishi, Thierry Gayraud, Kenji Matsuura, Michel Diaz and Yoneo Yano, "Contents and Communication Modelisation in Synchronous Learning", Piet Kommers & Griff Richards (Eds.), *Proceedings of the world Conference on Educational Multimedia, Hypermedia and Telecommunications (ED-MEDIA2005)*, Montreal, Canada, Association for the Advancement of Computing in Education (AACE) Publisher, Norflok USA, ISBN: 1-880094-56-8, pp.1606-1611, June 2005.

2. David Raymond, Veronique Baudin-Thomas, Kazuhide Kanenishi, Thierry Gayraud, Kenji Matsuura, Michel Diaz and Yoneo Yano, "Distant e-learning using Synchronous Collaborative Environment *Platine*", Bob Werner (Ed.), *Proceedings of the IEEE Sixth International Symposium on Multimedia Software Engineering (ISMSE2004)*, Miami, USA, IEEE Computer Society Publisher, Los Alamitos, California, USA, ISBN 0-7695-2217-3, pp.88-95, December 2004

3. David Raymond, Kazuhide Kanenishi, Kenji Matsuura and Yoneo Yano, "IP Videoconferencing in Distance Education: Ideas for a Successful Integration", Lorenzo Cantoni & Catherine McLoughlin (Eds.), *Proceedings of the world Conference on Educational Multimedia, Hypermedia and Telecommunications (ED-MEDIA2004)*, Lugano, Switzerland, Association for the Advancement of Computing in Education (AACE) Publisher, Norflok USA, ISBN: 1-880094-53-3, pp.4179-4184, June 2004.

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Chapter 1

Introduction

1.1 Preamble

During antiquity, the wise were able to master a wide range of disciplines e.g. mathematics, philosophy and medicine. Nowadays, the fields of knowledge have expanded and individuals usually specialize in some specific domains. Populations of users interested in a specific domain become scarce and it is becoming more difficult to gather professors and students.

The development of large networks began in 1984 with the National Science Foundation (NFS) [1] Network (NFSNet). Then, this network has been interconnected with other networks, e.g. UUCP [2], CompuServe [3] , ARPANet [4]; it founded the public Internet. During the last ten years, the Internet has influenced the way of working of several professional categories. Technologies are evolving very quickly thus making it difficult to keep one's skills up-to-date. Providing training to working persons on top of of their initial education has to face many constraints.

Developed countries have educational systems far more elaborated than developing countries. In Japan, many universities are facing financial problems because of the lack of students. Students from developing countries are willing to get education but their countries do not provide an easy access to appropriate institutions. Populations of professors and populations of learners are thus separated.

Communication technologies provide interesting solutions to tackle those problems. This research studies solutions for distance learning within the frame of communication technologies and proposes directions to improve these solutions. There has been a surge in the development of asynchronous systems to implement distance-learning solutions. However, creating online lectures is time consuming and asynchronous content do not seem to bring enough interactivity to the students. "Giving prompt feedback" has been identified by Chickering and Gamson [5] as one of the key principles of education. This research is interested in bringing the interactivity of the traditional classroom to distance learners. The development of synchronous communications appears as an interesting opportunity to keep learning activities interactive and adapt them to the students. The professor and the students would join an activity at the same time from different locations; e.g. home, office, university. All users would collaborate within a synchronous environment over the Internet.

It appears necessary to understand the needs of distance learners in order to evaluate distance learning solutions. This introduction chapter outlines the specificities of users engaged in distance learning and presents the different categories of distance learning environments.

1.2 Understanding the Challenges of Distance Learning

1.2.1 Diversity of Learners

In order to understand the challenges of distance learning, it is very important to know the populations of distance learners. Distance learning refers to the concept of learners who are physically in various locations. Different kinds of restrictions prevent them from direct face-to-face interactions, e.g. time restriction, distance, transportation limitations and expenses. Distance Learning can also be the choice of persons who do not think of the traditional classroom as an effective way to of study. Schnepf et al. [6] present these individuals as: "

- ***Full time Employees*** *who may be seeking advanced degrees or receiving corporate/job training.*
- ***Rural Population*** *who may be away from centers of population and educations;*

- ***Physically challenged*** *and home bounds who may find physically attending the educational institutions difficult or impossible;*
- ***Older adults*** *who may be more interested in learning and not necessarily in receiving a degree;*
- ***Traditional Students*** *who are physically attending classrooms today, but given the distance education choice may opt to switch;*
- ***Lifetime Learners*** *who continue their education throughout their lives."*

The distance learning population is very heterogeneous. The physical environment of learners may be very different from one person to another. The facilities that can be used for distance learning are different in each place. The educational background of the learners and their skill are different. A same topic has often been studied from different perspectives; for examples:

- **Practical vs. Theoretical**, in engineering sciences;
- **Artistic vs. Technical**, in web design;
- **Academic vs. Professional**, in research activities.

This diversity makes it difficult to plan in advance the specific needs of each individual. It is a challenge but also a chance. If it is difficult to provide an adapted solution to different users, it is a chance for learners to exchange different concepts of a same idea. A senior engineer working in a company deals with information technology differently from a fresh graduate born in the Internet era. The senior engineer would learn from his junior's knowledge of technologies. The freshman would benefit from the professional approach of his senior.

The difference of learning approach is also true from a point of view of culture differences [7]. Learning is a social activity; communication and collaboration cultures varies from one country to another, e.g. France and Japan. This factor is related to both the distance learners and to the educational systems.

1.2.2 Diversity of Activities

Traditional institutions usually provide different type of activities:

- **Lectures**support the communication of a theoretical knowledge;
- **Supervised Reviews** support the communication of a know-how related to the lecture content;
- **Supervised Practical Works**support the application of knowledge;
- **Field Activities**are used to confront students' theoretical knowledge to real situations;
- **Review activities**support memorization of content studied in the activity.

Those activities have various goals that depend on their organizations and communication styles. For example, students may work autonomously or collaboratively. The professor leads or supports the students during the activity. For an efficient education, distance learning has to support different kinds of activities. However, it is usually impossible to reproduce the traditional communication styles over distance. Some key-principles for education are very weakly supported, which limits directly learning efficiency in distance learning. Among them [5]:

- **Developing reciprocity and cooperation** among the students. Learners are often isolated from one another in distance learning;
- **Using active learning techniques**. Content is often delivered passively in distance learning;
- **Giving prompt feedback**. In distance learning, exchanges are usually asynchronous;

- **Emphasizing time on task**. Distance learners have to control the time they spent to make an exercise by themselves. They are not stimulated by other learners' performances.

The communication styles also vary according to the topic taught. Remotely, it is easier to support communication of absolute and neutral content rather than relative and emotional content. The medium used to support communication may distort the communication leading to alterations of references. Artistic skills, oral skills for language are thus difficult to teach over a distance compared to sciences and written language skills. The diversity of communication styles and topics in traditional education is not usually available in distance-learning programs.

The development of the Internet offered revolutionary communication means compared to traditional distance learning solutions (i.e. postal exchange of written documents). This step opened new perspectives to support collaboration between distance learners but also for traditional students. The different approaches promoted by e-learning systems are presented and analyzed in the next section.

1.3 Distance-Learning Solutions: Identifying Approaches

1.3.1 General View

Table 1 presents communication tools and some e-learning systems using those tools. They are categorized in asynchronous and synchronous systems.

Table 1: Tools and environments used in distance learning

Level of Organization	Asynchronous	Synchronous
Environments	WebCT [8], Lotus LMS [9], Scolastance [10]	LiveMeeting [11], Lotus Web Conferencing, Webex [12]
Communication Tools	Email, Web pages Bulletin Board System Forum	Chat, Whiteboard, Videoconferencing Application sharing

Such strict classification does not reflect exactly the nuance of communication approaches, e.g. web pages are modified rarely; the content of a forum changes more often and chat allows exchanging text messages instantly. More and more asynchronous systems offer synchronous communication tools. In the meantime, asynchronous learning environments are organized according to learning models whereas synchronous environments are often circumscribed to a package of tools. The different approaches for sharing and delivering content are presented in a non-strict view (Fig.1). The vertical axis represents the level of organization. Organization represents the ability of a system to combine, present and support information and communication in an organized way. These organizations reflects themselves educational theories. The horizontal axis represents the level of synchronization of communicationss and collaboration.

1.3.2 Asynchronous Environments: Mass Learning Systems

The approaches for organizing such content can be roughly splited in two categories [13] Content Management Systems (CMS) and Learning Management Systems (LMS). Pure CMS environments are used off-line for course creation and management. Pure LMS systems support on-line lectures with remote accesses. Nowadays, a lot of e-learning systems are supporting the two functions: they are gathered inside Learning Content Management Systems (LCMS).

They offer complete approaches to support educational activities from the creation to the delivery of content. They contribute to the pedagogical efficiency of learning by helping structuring content and easing its access. They also support educational strategies thanks to various steps, evaluations and controls throughout a course.

The content of asynchronous environments is mainly static, i.e. web pages. Content can also integrate video, audio clips and flash animations to improve the interactivity. The advantage of asynchronous environments is that they can be used by a very large number of users, making it effective for

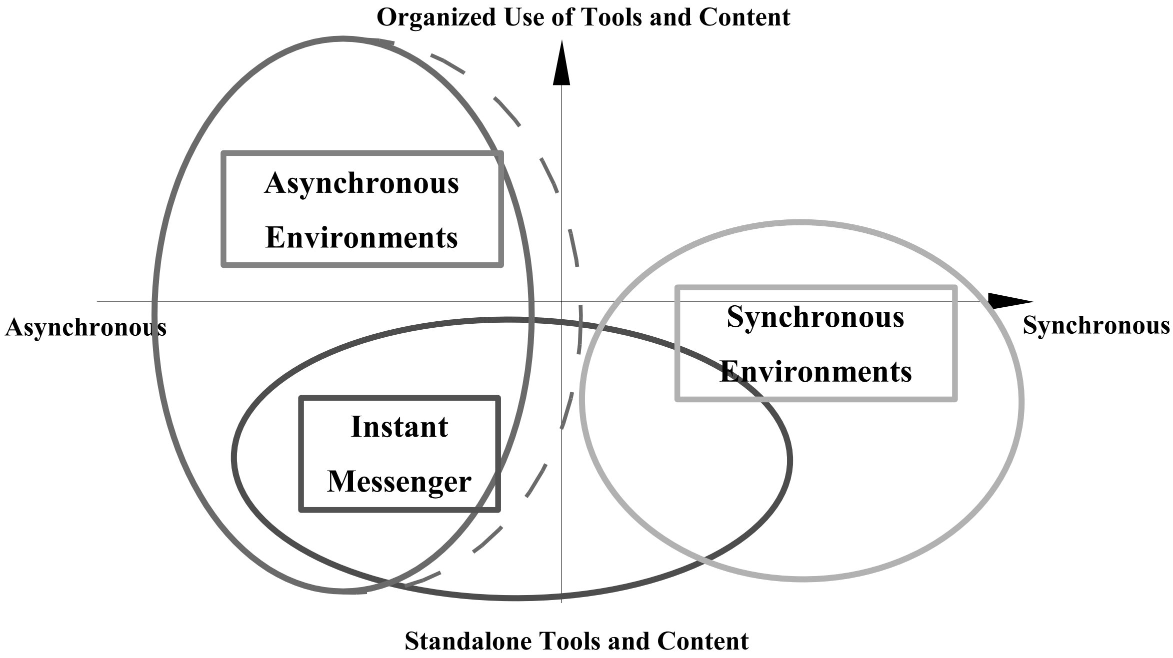

Figure 1: Distance Learning Approaches

recurrent mass education. Once the content is developed, it can be reused as many times as wished. However, the cost and time required to develop interactive content is high. These environments are thus not effective when content is changing quickly or when learners' population is limited.

The support of active communication is one of the main elements for the success of web-based learning environments [14]. Asynchronous systems deliver static content and they are not able to provide an adapted feedback to students' questions. Thus, some students may feel lost and drop the course. Some systems have evolved to provide more interactivity and promote communication with their peers. Different communication tools are now usually integrated within asynchronous environments; e.g. email, Bulletin Board System (BBS). Some environments also integrate a chat or videoconferencing tool to support discussion between the professor and the students. These synchronous interactions are cited as a key factor to prevent dropout [15]. Nevertheless, synchronous communication tools are not used to deliver and share content but just as a solution to support punctual collaboration during review activities.

In most civilizations, the learning culture is synchronous. Children are taught by oral communication before they can even read. Written documents support learning but most of the communication is made orally until advanced levels. It would certainly be beneficial to introduce environments that deliver and share content synchronously.

1.3.3 Synchronous Distance Learning Environments: The Specific Situation

Synchronous distance learning solutions can be divided in 2 different approaches: educational and technical.

On the first hand, the importance of interactivity during the learning process has led a part of the educational community to an interest in synchronous communications. Communication is not the only research area related to interactivity, yet, it is one of the central element. Synchronous communications bring several solutions in a matter of supporting key learning principles presented in this chapter (see section 1.2.2). Synchronous communication allows to give prompt and adapted feedback; the feedback is given directly by the professor. Activities performed synchronously offer the possibility to emphasize time on task, the professor is able to control directly and adapt the time spent by the students. Emotional expressions are lessen when delayed; synchronous communications offer the possibility to support them more efficiently than asynchronous communication. It contributes supporting social relationships between the learners and avoiding the feeling of being isolated. Synchronous distance learning can be considered as a specific application of synchronous CSCL.

On the other hand, telecommunication industries were among the first to develop synchronous communication tools. Those tools have been improved to support a wider range of collaborative ativities compared with educational approaches.

1.3.3.1 Educational Approaches

Chat-based Solutions Due to the technical complexity of synchronous communications, most synchronous environments with a strong educational approach are based on simple chat tools. These environments are not used to deliver content synchronously but just as solutions to support collaborative activities. Most of the time, those environments are not used in distance learning courses but in activities conducted within institutions.

Students participate in chat conversations that are analyzed later on. These approaches provide educational information on how students exchange ideas, how they structure dialogues [16]. Such software also allows evaluating the participation of students. A chat tool can be a powerful solution to practice language [17]. Some environments also offer strategies to stimulate the participation of users.

These environments provide a well-structured use of a chat-based activity. Pedagogical scenarios are well developed and effective. However, their field of application is very specific and a bit narrow. They represent interesting solutions for developing reciprocity and collaboration but they cannot be used to support general content delivering. It restricts their application range. Other synchronous communication tools can support different types of collaboration and their use could help diversifying the use of synchronous communications.

General Collaborative Solutions Generic approaches of collaboration offer solutions to structure distributed collaborative activities [18, 19]. Bourguin and Derycke proposed the DARE system [20] for integration of CSCL activities in virtual Campuses. "It introduces a meta-level architecture supporting Distributed Collective Activities and featuring a generic activity-support model, its meta-model, a component approach, and a distributed architecture." This works provide a technical solution to organize CSCL activities at an educational level.

These approaches do not provide a solution to organize communications within synchronous collaborative activities. If the educational organization is mandatory, the collaboration structure and the underlying collaboration infrastructure remain at the center of synchronous activities. There are several tools that can support synchronous collaboration. Such tools can be used in several different ways. Communication infrastructures rely on several technical fields that have a large influence on the quality of communications.

Educational approaches provide interesting directions for the management of curriculum and the definition of collaboration content. However, they do not provide appropriate technical approaches to support synchronous communications.

1.3.3.2 Technical Approaches

This section presents the distance learning solutions derived from technical developments. Synchronous communication tools represent technological challenges that are addressed by various technical research fields. It is interesting to look at the historical development of synchronous communications to understand its relation with educational fields.

The Origins: the telecommunication industry approach Synchronous communication tools have been developed originally by the telecommunication industry. Those tools have been used for distance learning for long time. The phone was used from time to time in order to keep contact between distance learners and their professor. Telecommunication industry provided the first solutions for videoconferencing years ago. The International Telecommunication Union (ITU) [21] published the first version of the H.323 standard for multimedia communication in 1996 [22]. This standard developed for packet switch networks was first used on Integrated Service Digital Network (ISDN). This standard has been completed and improved over time; e.g. the T.120 standard [23] introduced a solution to exchange data. Those solutions are still widely used. However, the cost of equipments and communications made it a too expensive solution for individuals. These solutions were mainly developed between educational institutions as a way to communicate with distant sites or as an opportunity to promote interactions. Cultural exchanges and class activities involving videoconferencing are numerous [24, 25, 26].

With the same approach, high quality videoconferencing systems over satellite networks [27] provide higher interactivity for a large group of users but it is not well suited for a single individual.

The Internet factor: generalization of synchronous communication The development of Internet allowed bringing synchronous communication to individuals. The network industry through the International Engineering Task Force (IETF) [28] provided technical solutions for multimedia communications. The Request For Comment (RFC) describing the Real-time Transport Protocol (RTP) [29] and Session Initiation Protocol (SIP) [30] are among the most famous contributions. RTP describes real time communication of information and SIP describes simple connection between users. These contributions stand as a technical basis for real time communications but they do not constitute solutions for communication by themselves. These contributions have been integrated in Instant Messenging Programs, Voice over IP (VoIP) and videoconferencing solutions.

The H.323 protocol was adapted to fit the specificities of Internet communications. Even if this software was released in the prehistoric ages of synchronous communication (in 1996), Microsoft NetMeeting [31] is still the most famous H.323 solution for Internet communications. This environment highly participated in the gain of popularity of videoconferencing and synchronous collaborative environments. Numerous distance-learning environments are integrating and built on top of the Microsoft NetMeeting Technology; e.g. Speaker tool [32].

In Japan, the Nova language school [33] performs learning sessions by videoconferencing. They provide a set top box including a modem and a web camera; the students connect the box to their TV and to their telephone land-line and are then able to join a learning session of about 4 persons. In this case, videoconferencing is just a tool for distance communication and such solution does not support any pedagogical strategies.

Computer Supported Collaborative Learning and Work Environments Based on multimedia communication technologies, several synchronous CSCL and Computer Supported Collaborative Work (CSCW) solutions have been developed. Those environments provide a large variety of high quality communication tools as extentions to videoconferencing, e.g. whiteboard, shared applications.

In The CSCW area, those environments are mainly commercial products from large companies, e.g. IBM Lotus [9], Microsoft LiveMeeting [11], Webex [12], Elluminate [34]. Versions dedicated to education are sometime provided (i.e. IBM Workplace Collaborative Learning, Elluminate Live Academic Edition). Several Collaboration products are the result of academic researches that lead to commercial solutions, e.g. ISABEL [35], WorkSpace 3D [36]. Non-commercial product are also numerous, they often are a way to demonstrate the skills of laboratories or departments of university; e.g. TANGO [37], DISCIPLE [38], Interactive Distance Learning (IDL) by Kamolphiwong et al. [39], Helpmate by Curran [40]. The LAAS-CNRS first developed the Platine Environment as a CSCW solution for Airbus Industries in the 90's. The environment has evolved and has been adapted to some learning requirements. The VRVS environment is well developed and often used for Workshop, Meetings and other Collaborative activities [41].

These environments are the starting point of this research work. Most of them are presented in the Appendix A. This appendix gives details about the history and the functionalities of these environments.

These environments provide a generic solution for synchronous collaborative activities. They can be used to support a wide variety of educational scenarios. However, these environments are not developed according to any learning model. They are often limited to a collection of tools and compared one to another based on the list of their functionalities [42]. They do not provide a solution for distance learning but tools that can be used for distance learning. The difference is that they are not optimized for learning; they do not support the social context of learning activities; often, no distinction is made between students and professors; the solution is identical to teach sciences or languages. They do not provide any solution to support teaching strategies; the communication architecture is the same for a meeting, a lecture or supervised practical work. The tools often let uninitiated users decide which technical variables to use [43]. Technical manipulations disturb users and distract them from their educational goal.

Technical solutions can be used to share content but they cannot account for full distance learning solutions. They do not support learning as asynchronous environments does. The enhancements of these environments are traditionally technical: focused on tools and multimedia communications.

1.4 The Challenge: Conciliating the two Approaches

It is a common belief that the quality of synchronous activities is limited by the quality of the video and audio communications. When facing a new solution, the judgment of users tends to be superficial at first. It deals with the quality of the communication before evaluating the educational interests. Indeed, most synchronous activities for distance learning are performed with videoconferencing tools. Thus, users tend to consider that technical approaches are more capable. The benefit of educational approaches is difficult to evaluate and these approaches are not always compatible with the pedagogical views of the schools and teachers.

The contribution of technical fields (e.g. network, codecs) to the quality of synchronous communication is fundamental. They contribute to the quality of communication continually. The quality of communication can be a determining factor to differentiate synchronous learning environments. Thus, it appears necessary to integrate the contributions of technical fields to the development of synchronous environments. It would guarantee the quality of communication in synchronous CSCL environments. Moreover, there is an important shift from learning objects to learning services driven by business models in learning environments. In telecommunication, business models are already developed and could be used to ease this shift. The corresponding services are part of our daily life: Internet access, voice, image and text services on cellular phones.

We must consider that synchronous learning activities are more than a simple videoconference. It would be a mistake to think that synchronous CSCL environments only have to create a copy of the distant environment as perfectly as possible; learning and collaboration cannot be reduced to voice and image communications. Technical research fields can provide high quality communication tools but they are not able to support communication in a structured way; i.e. environments support communications in a same way for a meeting, a lecture, and a videoconference chat. In order to improve the learning experience, the interactions should be organized and active participation should be promoted. The organization and the collaboration strategies depend on the topic taught, the type of activity, the learners and the professor. It appears impossible to define all the learning strategies in advance. Thus it seems necessary to let professors responsible for the learning strategy and to provide an environment that can support them with the best communication quality.

Professors and educational experts are responsible for collaboration strategies and technical experts are responsible for communication support. Their fields of research are independent but related. The development of distance learning environments without both expertises is likely to produce heterogeneous solutions. Rather than mastering all technical and educational fields, the goal of this research is to identify how those fields are related and how we can support this relationship. The educational contributions are studied through collaborative learning and the technical contributions through network and communication. The relationship between those fields is studied within the application framework of synchronous environments for distance learning. This approach does not substitute to technical and educational researches but promote interface between those fields. The goal of this interface is first to give value to both fields through the development of homogeneous environments. The development of an interface would allow matching network infrastructures with collaboration structures. It would be a solution to optimize network resources, improve efficiently the quality of communication and thus support collaboration in a more appropriate way. Videoconferencing is used by thousands of users everyday over the Internet with instant messenging software; compared with its potential, synchronous collaboration appears underused in distance education.

This work introduces in the next chapter a review of educational and HCI contributions to synchronous distance learning. These contributions make it possible to identify what elements should be taken into account to support collaboration strategies.

The third chapter introduces the contribution of network-related researches: distributed systems, multimedia communications and network. This chapter presents the technical constraints that have to be taken into account to support communication in a group of distributed and heterogeneous computing devices and network accesses.

Then, the fourth chapter presents experiments of synchronous distance learning realized in Tokushima University. Those experiments enabled us to identify the specific relation that exists between collaborative and network contributions.

The fifth chapter presents the Content and Communication Management System (CCMS) model. This model proposes a solution to support the relationship between collaboration and network and the chapter identifies the potential of such cross-disciplinary approach. The model was not implemented but it lead to improvement of the Platine collaborative environment.

The sixth chapter presents experiments realized with the latest version of the Platine environment. These experiments describe a complete distance learning scenario and an original approach to support them.

Finally, some global conclusions and a few perspectives are given.

Chapter 2
Contributions of Collaborative Approaches

In order to identify the contribution of educational and technical approaches in the learning process, it seems relevant to have an overview of the whole communication and exchange process of computer-supported learning. This state of the art presents several points of view of communication. They range from treatment of information in the Open System Interconnection (OSI) Reference Model to communication within collaboration strategies and educational theory (Fig.2). This figure represents the communication between individuals at several levels. The lowest level is the physical layer of the OSI model. Each layer of the OSI model has an influence on the communication. The different levels have an impact on the access, the transport, and the delivery of information and thus the quality of communication.

At a user level, two points of view are available. The first one represents the Human Computer Interactions (HCI) between the user and the interface of the computing device. HCI issues count as a strong factor in the user's judgement.

The second point of view of the users represents communication as an exchange of information between users. It represents the different ways to exchange information and their specifies.

The collaboration between the individuals addresses communication with a higher point of view. The organization of communication to the favor of one form of communication over another is an element that defines how users collaborate.

Educational theories are at the origin of collaboration strategies; they influence collaboration strategies.

All these different elements have an impact on the communication and thus have an impact on the user satisfaction. This chapter presents the relative influence of those different layers on communication. Following is an outline of how this chapter is organized: educational strategies are introduced in a first section. Based on collaboration strategies, communications and interactions between the users are organized into structures. The second section identifies the organization structures of traditional education and evaluates the potential of synchronous CSCL environments to support these organizations. Communication and interactions are influenced by the computer's interfaces system. HCI research helps to identify some of the issues of synchronous CSCL. This contribution is presented in section three. The technical contributions related to network approaches are presented in the next chapter.

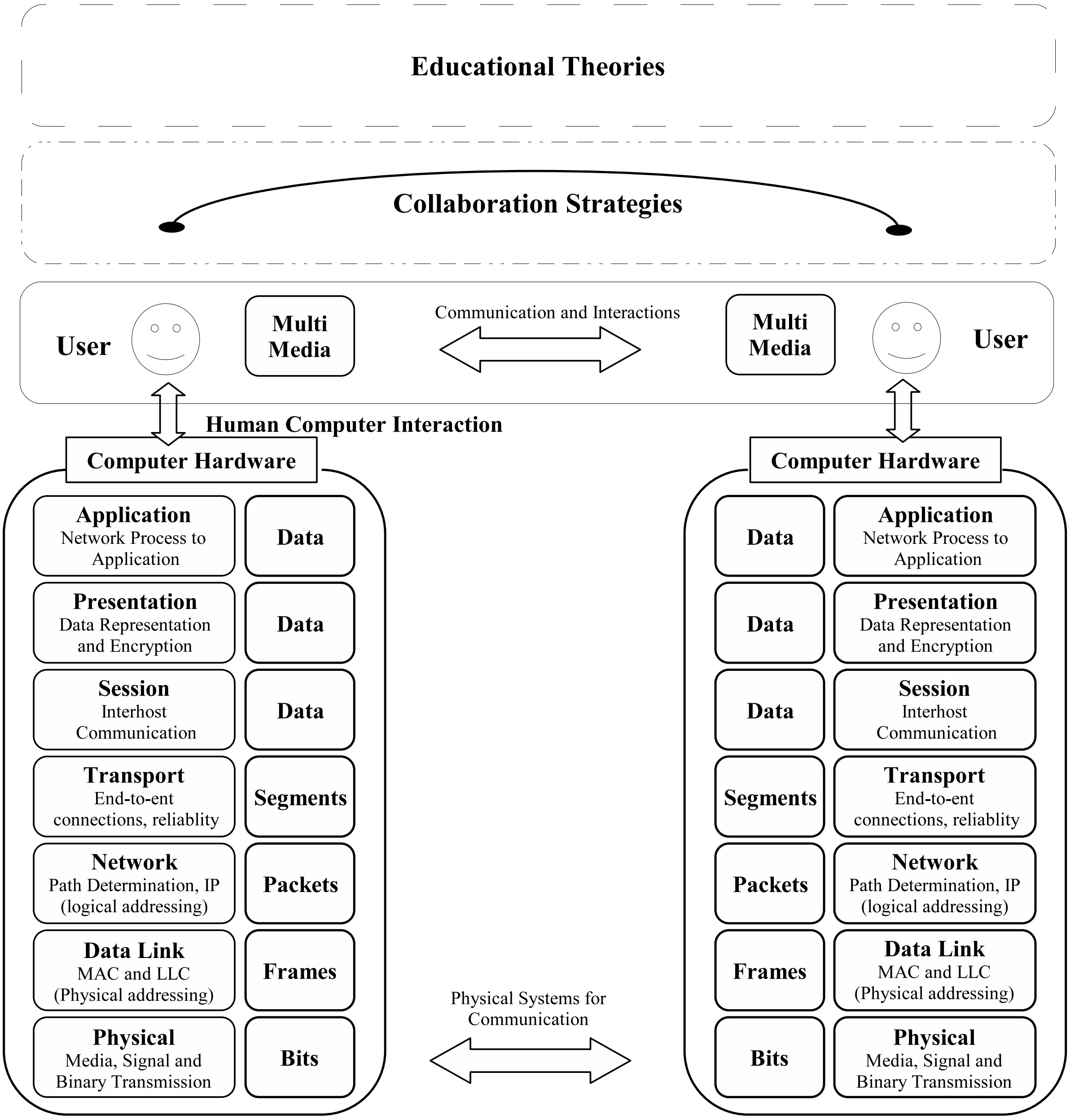

Figure 2: Overview of exchange in computer supported education

2.1 Educational Theories: The Fundamental Contribution

Educational theories provide the conceptual foundations of learning activities. They explore the interaction of users with their peers and their environments, and support a philosophy of action. This section introduces educational theories within the frame of computer-supported education. Collaboration strategies are justified by educational theories. In order to understand how to evaluate collaboration strategies in an environment, it appears necessary to review the contributions of educational theories. This section gives a historical point of view of the computer supported learning environments. This historical perspective is imperative to understanding the evolution of the educational approaches and the importance of collaboration in education.

The structure of this presentation is inspired from a tutorial presented by Claire O'Malley [44] at the Computer Supported Collaborative Learning Conference (CSCL2005) in Taiwan.

2.1.1 Forerunners Approaches

2.1.1.1 Computer Assisted Learning (CAL): the '60s

CAL is the first approach to computer-based education. It refers to Computer Assisted Instruction (CAI), Computer Based Training (CBT), Computer Based Learning (CBL) and others. These systems are based on learning theories of behaviorism, reinforcement and associationism. Computers play the role of a tutor and transmit a model to the students. Learning activities are mainly drills and practice activities, or presentation of information, test/evaluation and feedback.

These solutions provide adapted support for individual learning, but they are not able to diagnose errors and give the right feedback at the right time. Also, they do not support representation of learner's knowledge. In a traditional classroom, the professor is able to solve these issues, so she or he has the ability to detect misunderstandings and provide explanations adapted to the learner's knowledge.

2.1.1.2 Intelligent Tutoring Systems (ITS): the '70s

Intelligent Tutoring Systems (ITS), Intelligent Computer Assisted Instruction (ICAI), Artificial Intelligence in Education (AI Ed) along with other systems, provide adaptive control of teaching. These systems integrate a student model (a representation of what the student knows) and domain representation (what to teach). They develop teaching strategies to lead the student to the knowledge of the domain. These learning theories are based on the representation of educational changes. They restructure prior knowledge to accommodate new information and they make explicit knowledge which is implicit.

Compared to CAL, the computer is an intelligent tutor, and the instruction is based on an adaptive transmission of various models. The other systems provide better feedback, but this is done at the cost of detailed models of domain and learners. The development of those models may be difficult and time consuming. In a traditional classroom, the professor has an intuitive representation of the domain and the learner's model.

2.1.1.3 Interactive Learning Environments: the '80s

Interactive Learning Environments are based on the constructivism theory (Piaget, Bruner). These environments are not directly on information but they provide a "tool" to think with, for example simulations, micro worlds and spreadsheets. One of the most famous Interactive Learning Environment is Papert's LOGO system developed in 1980. These environments are based on a mode of representation (e.g. iconic, symbolic). In these environments, students learn by discovery and build their knowledge actively by interacting with the environment.

These environments present the opportunity to make thinking explicit by making reasoning and its consequences "visible". Thus, it allows students to learn from errors and to develop effective problem solving and planning skills.

Logo was introduced in the classroom to develop reflective metacognitive skills such as Latin for some western countries' languages. These environments appeared promising, but their real benefits are difficult to evaluate.

2.1.2 Computer Supported Collaborative Learning (CSCL) Environments: the ‘90s

CSCL focus on the importance of group work and of the relation between peers. Environments are used to favor and support communication between the users. CSCL is often associated to Computer Mediated Communications (CMC). The CSCL environments are based on different theories of Collaborative learning.

2.1.2.1 Sociocognitive Theory: Jean Piaget, Wilhelm Doise & Gabriel Mugny

As described in the free encyclopedia wikipedia, "Cognitive science tends to view the world outside the mind much as other sciences do; thus it has an objective, observer-independent existence." In collaborative learning activities, the students interact with peers with different views. These activities allows the sharing of views which contributes to the equilibrium of knowledge structures. The social interaction leads to a recognition of alternative perspectives. This difference leads to mutual challenge (cognitive conflict) that motivates the coordination of alternatives to arrive at a solution. Students have to coordinate old and new knowledge, which leads them to restructure their prior knowledge.

As well, inter-individual conflict is a more powerful stimulus for cognitive change than intra-individual conflict for many reasons. First, social conflict is harder to ignore than individual conflict. Second, the partner can provide cues for solving the problem. Therefore, the social nature of the task leads to more active involvement.

Based on this theory, technology should be a catalyst for discussion. Environments should propose activities that promote competing perspectives and solutions. The environments should structure the discussion to making hypotheses and predictions more explicit. It should provide the opportunity for criticism by ways such as disconfirming hypotheses. The role of the individual should be differentiated to support the discussion.

The support of this learning theory by collaborative means has faced several issues. Indeed, the definition of a cognitive conflict is subject to discussion (for example conflict in prediction or in conception). As well, if the social context may provide a catalyst for discussion, it is merely a catalyst for individual change.

2.1.2.2 Sociocultural Theory: Lev Vygotsky and Michael Cole

This introduction to social theory is inspired from the presentation of Julia Scherba de Valenzuela [45].

Current conceptualizations of sociocultural theory draw heavily on the work of Vygotsky [46]. According to Tharp and Gallimore [47, page 6-7] "This view [the sociocultural perspective] has profound implications for teaching, schooling, and education. A key feature of this emergent view of human development is that higher order functions develop out of social interaction. Vygotsky argues that a child's development cannot be understood by a study of the individual. We must also examine the external social world in which that individual life has developed...Through participation in activities that require cognitive and communicative functions, children are drawn into the use of these functions in ways that nurture and 'scaffold' them".

The importance of communication and collaboration in the learning process is shown by the concept of "Zone Of Proximal Development" (ZOPD). "The notion of a zone of proximal development reveals a pattern of developmental change in which a phase of adult support precedes a phase of independent infant accomplishment. Each cycle begins with a newly displayed behavior, such as a smile, a visually directed reach, or a babble. The adult's reaction and interpretations transform the infant's emerging behavior into a social act." [48]. From a learning point of view, the ZOPD is defined as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers." [46]. One of the implications for learning is the asymmetric nature of learning groups (adult or more competent peer is required). The ZOPD is related to other instructional theories such as Instructional Scaffolding, Contingent Instruction, and Apprenticeship.

Applied to CSCL, the socio-cultural theory supports the idea that development proceeds from the inter-psychological to the intra-psychological. Learners should focus on joint construction of solutions in order to support their individual development. The attempts to coordinate perspectives and co-construct hypotheses to arrive at a joint answer are more valuable than simply differences in perspectives. In order to collaborate, learners have to share a same language and representation. Thus, the socio-cultural theory has direct implications with semiotics. As described in the wikipedia encyclopedia, "semiotics is the study of signs, both individually and grouped in sign systems, and includes the study of how meaning is transmitted and understood".

Environments must therefore provide mediation tools in order to support joint construction of solutions. These tools should be adapted to the sign systems of the learning community.

2.1.2.3 Situated Learning Theory: Barbara Rogoff, Jean Lave and Etienne Wenger

Practical action is not always driven by plans. Ask a person to take three quarters of two thirds of a cup of cottage cheese. Most people will first take two thirds of a cup of cottage cheese, then from that take three quarters. By reasoning, however, you can solve the simple problem: $3/4*2/3=1/2$ and directly take half a cup of cottage cheese. Cognition considers context as a nuisance variable whereas situated learning emphasizes the importance of the situation. The contextual approach enhances the recognition of the relationship between psychological processes and their social, cultural and historical settings.

According to this theory, "knowledge resides in the world" [49, 50] and several educational activities take place in situated learning conditions (Wikipedia):

- workshops, kitchens, greenhouses and gardens used as classrooms
- stand-up role playing in the real world setting, such as most military training
- field trips, including archaeological digs and participant-observer studies in an alien culture
- on the job training, including apprenticeship and cooperative education
- sports practice, music practice and doing art are situated learning by definition, as the exact actions in the real setting are those of practice - with the same equipment or instruments

The implication of this theory is that learning mostly occurs in situation resembling those of eventual practice. Traditional education partially supports elements of this theory with supervised practical work. Supervised practical work puts the learners in an intermediate situation between the "real world" and the classroom. Situated action is inherently social as learning should involve "legitimate peripheral participation" in communities of practice [51].

Thus, a learning environment should support legitimate communication and collaboration among a community of practice. To a certain extent, environment can support the creation and management of the community of practice.

The situated learning theory is sometimes challenged by other schools of thought. Some approaches tend to support the idea that knowledge does not reside in the world but within the persons [52]. The contribution of this learning theory resides in the importance of the relationship between the learner and its environment (social or concrete). These elements are important from a communication point of view.

2.1.2.4 Activity Theory: Alexei Nikolaevich Leontiev and Yrjo Engestrom

As described by Verenikina & Gould [53], "Vygotsky provided the initial impetus towards activity theory by introducing the notion of *tool* as a form of "mediated action" which "is externally oriented [and] must lead to changes in objects". As described in wikipedia (Wiki Active Theory), "after Vygotsky's death [in 1934], Leontiev became the leader of the activity theory research group and extended the framework in significantly new ways." He explained the crucial difference between an individual action and a collective activity. "The distinction between activity, action and operation became the basis of Leontiev's three-level model of activity. The uppermost level of collective activity is driven by an object-related motive; the middle level of individual (or group) action is driven by a conscious goal; and the bottom level of automatic operations is driven by the conditions and tools of the action at hand.” [54].

Engestrom studied application to learning of the theory of activity and published a foundation representation of the structure of human activity system in his paper: ”Learning by expanding” [55]. Fig.3

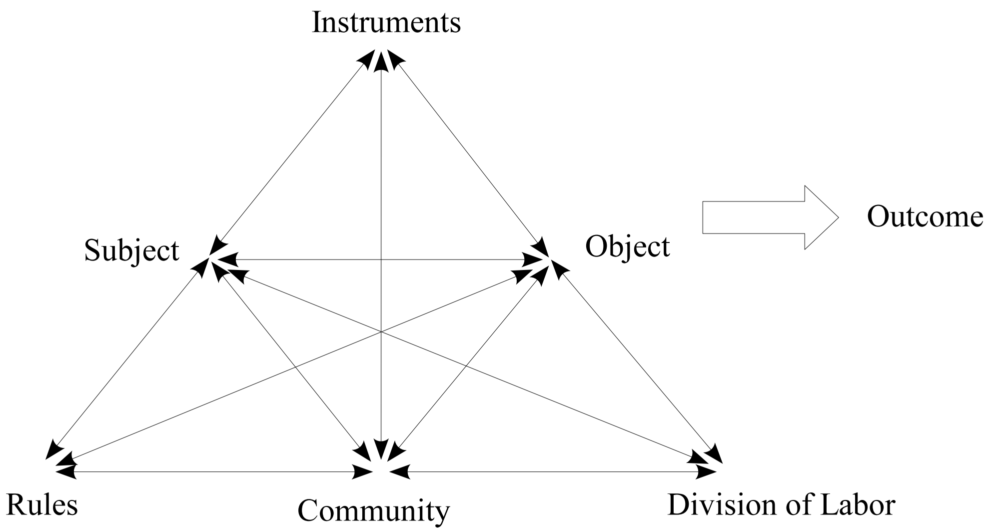

Figure 3: Structure of Human Activity

The three main elements of this figure (i.e. Subject, Community and Object) are related together by different means (i.e. Rules, Instruments and Division of Labour). For example, Subjects respect rules in a Community, they use tools to interact with objects. The Division of Labor in a Community defines the work of a Subject. This organization leads to a global outcome shared among the different actors.

2.1.3 Mobile and Ubiquitous Learning: the ‘00s

Ubiquitous Learning is often described as to enable learning at any time and any place. However, the fundamental issue is how to provide information at the right time and in the right way. [56, 57].

The main concepts behind Ubiquitous Learning have been described hereinafter [58, 59] cited in [57]:

1. ”Permanency: Learners can never lose their work unless it is purposefully deleted. In addition, all the learning processes are recorded continuously in everyday.
2. Accessibility: Learners have access to their documents, data, or videos from anywhere. That information is provided based on their requests. Therefore, the learning involved is self-directed.
3. Immediacy: Wherever learners are, they can get any information immediately. Therefore learners can solve problems quickly. Otherwise, the learner may record the questions and find the answer later.
4. Interactivity: Learners can interact with experts, teachers, or peers in the form of synchronous or asynchronous communication. Hence, the experts are more reachable and the knowledge is more available.
5. Situating of instructional activities: The learning could be embedded in our daily life. The problems encountered as well as the knowledge required are all presented in the nature al and

authentic forms. This helps learners to notice the features of the problem situations that make particular actions relevant.

6. Adaptability: Learners can get the right information at the right place with the right way."

Ubiquitous is another step after CSCL learning theories. It provides a perspective that takes into account their contributions. First, it emphasizes the location issue in the learning process. It offers thus a parallel with the theory of Situated Learning. Then, collaboration is supported by addressing the time issue (i.e. permanency and immediacy). Collaboration is beneficial if it is apropos.

According to Ogata, Akamatsu et Yano [60], ubiquitous learning can be CSCL environments that focus on the socio-cognitive process of social knowledge building and sharing.

Ubiquitous learning also introduces practical issues as it deals with issues Human Computer Interaction issues (i.e. accessibility and interactivity).

2.2 Collaboration Strategies in synchronous CSCL: Supporting Educational Theories

During face-to-face activities, students and professors use various forms of communications and interactions to collaborate. This section introduce the different forms of communication and their usage:

- Direct Communication:
  - Vocal Communication: Vocal Communication supports both informative and affective (emotional and factual) exchanges. The script of the vocal communication holds informative content, whereas affective communication is supported by the expression and the intonation of the voice.
  - Visual and Sign Communication: Visual or sign communication is a major support for affective information. Facial expression shows feelings and fatigue. Visual communication does not allow much informative exchange except for in particular cases, for exemple in sign language, or artistic expression.
- Mediated Communication:
  - Textual Communication: Textual communication usually supports informative exchanges. This way of communication supports simple and complex exchanges of information. Textual representation allows users to acquire the textual flow of information at their own speed. It is very useful in language learning by supporting oral communication.
  - Graphic, or Symbolic Communication: Graphic or symbolic communication is a powerful means of communication for informative exchanges. It allows the representation of concepts and ideas that are sorely exchanged by textual communication. It is a major communication channel for abstract and technical fields, such as mathematical equations, and schematic representations. It can also be an artistical form of communication, for example, through paintings.
  - Object Supported Communication: Physical or virtual objects offer support for communication. These objects often represent the object of the learning activities. They provide a system that responds to stimulations. The manipulation and analysis of the system is a form of communication. Artistic and technical activities often use object support for teaching, as when playing an instrument or manipulating an electronic circuit.

These modes of communication are used to interact with one another and the environment. The choice of the communication modes depends on the purpose and context of the communication. The stimulation of several senses and the use of related communication modes are necessary to reach learning objectives. When studying language, learners are often presented with pictures, with the name of the object written on it; they repeat the word several times to memorize it. In traditional learning, the blackboard supports mediated communications. In this thesis, the term "blackboard" is used to refers to the traditional education tool whereas the "whiteboard" refers to its digital counterpart.

This section presents communication and interaction at the collaborative level. Collaboration strategies have a large influence on the learning process. The learning environments and the contribution of other research are presented in this section with regards to their ability to support collaboration strategies. The different subsections of this chapter evalute different aspects of the collaboration. Appendix A presents the different environments for distance work or learning. The tables included in this appendix address the potential of the environment. In this section, the environments rating the best in the evaluation criterias are cited. For further details on the potential of each environment, please refer to appendix A.

2.2.1 Collaboration Strategies: Experimental Contributions

As presented in the introduction, videoconferencing solutions were first provided by the telecommunication industry. The interest of educational staff to use this communication tool has lead to many experiments. Even if the communication is only supported by voice and image, the comments of educational experts on these systems have made a worthy contribution. They show the necessity to structure the collaboration by defining educational roles and defining the timing of interaction. Teaching using videoconferencing seems to require much effort and adaptation for teaching staff and students. Technical difficulties in the manipulation is also a major issue in preventing the use of synchronous communication.

2.2.1.1 Need for Preparation

The first issue of importance is the preparation of synchronous activities. Confusion in the activity is increased by the limited interactivity of videoconferencing. Unprepared activities lead to chaotic communication and frustrated students [61]. The result is a loss of motivation for learning.

Some professors are interested in using videoconferencing and try to use it to give value to their class. However, good teaching practices should define first educational goals, and then, select the appropriate technology for supporting those goals [62]. Educational goals are the first step to define the teaching/learning model. Then professors are able to develop collaboration strategies for their activities.

In the experiments of Schullo, Siekmann & Szydlo [42], videoconferencing is used in combination with asynchronous web-based learning. 80% of the study time is spent on asynchronous materials and 20% on interactive learning sessions. In this case, the use of videoconferencing is well defined and integrated in a global instructional strategy.

Communication with videoconferencing systems is different from face-to-face interactions. Thus, preparation is also necessary for students and staff involved in these activities. The staff have to first become familiar with the technology and be able to manipulate it easily so it does not interfere with his/her teaching. The familiarization process, or "gestation period" [63], is required to let the staff realize the subtle differences between face-to-face and videoconferencing communication [64]. The setup of the system also requires the help of appropriate technical staff. Systems are not "plug and play" and installation requires working through a lot of technical issues [43, 65]

Students mus also get used with videoconferencing technology. Their initial reaction is often to watch the professor as we watch television. However, it is important for them to be involved in the activity and for the activity to stimulate participation. In face-to-face situation, students feel sometimes afraid to talk in front of the classroom. "For students engaged in videoconferencing, there is the additional pressure of being broadcasted to the world" [64]. It is thus important to prepare a frame where their participation is more natural.

2.2.1.2 Teaching Models

Teaching models need to be adapted to videoconferencing communication.

Distribution Model In most videoconferencing experiments, two distant classrooms of students with only one professor are connected together. This distribution model allows a controlled participation of the students on both sides. The professor is able to control the communication in their local site and bring a social presence that helps the students to talk over the videoconferencing communication. Without changing the technical structure, different organizations can be supported and have been the subject of comparison [65].

Only one professor may be involved in the activity, this professor being located in one of the classrooms. In this case, the students who are without the professor may feel less involved in the classroom. Indeed, the professor tends to favor communication with the local group of students through social communication (gestures, eye contact). To involve the other site, the professor has to stimulate remote participation.

When the professor is left alone on one site and the students are only located in another site, he or she can address the distant students exclusively and create a direct relationship with them.

In the set up, where more than two sites are connected, the communication is a bit more difficult to manage. Indeed, it is difficult to identify the person who is talking and it is not rare that two users try to speak at the same time. In face-to-face situations, eye contact allows a quick agreement on who has the floor. In videoconferencing communication, this eye contact cannot be established.

Type of Activities Several videoconferencing experiments are organized upon a lecture communication model. However, lecture is not always seen as the best model. Technical manipulations put a burden on the professor and reduce professor interactions with the students at both ends [66]. From this point of view, collaboration activities may be more beneficial.

The importance of interaction is pointed out in several experiments [64, 62]. For this purpose, lectures or other activities performed by videoconferencing are encouraged to introduce high interactivity phases within the activity. For example, in a lecture, the professor might stop every 15 minutes his lecture to engage students in a discussion.

In Pendergrass' experiment [66], the class began with a small quiz on the reading materials and was followed by a small presentation of problems. Then, students had to solve the problem locally in small groups. After a while, one student was picked up to present the solution of his group to all the local and remote groups with the videoconferencing application. Performing work locally allowed preventing network problems that have an impact on communication quality and thus on collaboration. This mixed model of distant and local work is motivational for the students.

In the experiments of Andrews and Klease [64], the group work structure was also selected. The groups were based on a structure of three people with one manager, one questioner/sceptic and one recorder/checker. Groups were given a problem to investigate over the week, and at the end of the week, the results were presented to all the campuses.

2.2.1.3 Communication Means

Most recorded experiments of synchronous activities have been performed with videoconferencing communication only. However, the use of mediated communication has been increasing.

Candace [61] performed experiments with different kind of environments and compared the efficiency of the systems for synchronous online learning. The environments tested were divided in three categories: text-based conferencing systems, audio-video conferencing system and virtual reality systems. For each category, two environments were selected and tested. Students took part in different activities: lecture with guest speaker from remote sites, online debate and role-play. Text-based systems were considered as providing a good structure to communicate with several users. They created a sense of virtual place where students can gather. Videoconferencing systems provided high quality interactions. Virtual reality systems provided a strong social context, which was much appreciated by the students. Among all the environments, the text-based and virtual reality systems were found most efficient for synchronous collaboration activities.

Schullo, Siekmann & Szydlo [42] compared two environments according to their functionalities. This evaluation goes further than the use of videoconferencing, and all the communication means are treated.

Olson et al. [67] compared the work performed with an audio conferencing system, a videoconferencing system, and a face-to-face situation. In their experiments, people worked in small groups on the design of a system. They all used a text editor to communicate. The comparison of results with the face-to-face situation shows that with video, work was as good from an academic point of view. With audio only, the quality of work suffered a small but significant amount compared with the face-to-face results. When working at a distance, "groups *rated the audio-only condition as having a lower discussion quality, and reported more difficulty communicating. Perceptions suffer without video and work is accomplished in slightly different manner, but the quality of work suffers very little*".

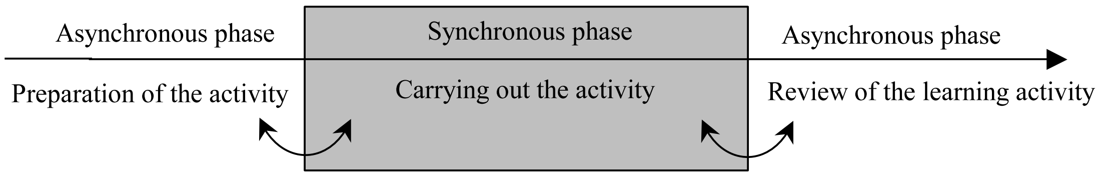

Figure 4: Temporal relationship between synchronous activities and asynchronous phases

2.2.2 Temporal Perspective of Synchronous Activities

Synchronous interactions are the central part of a learning activity (Fig.4). The synchronous interaction phase is preceded by a preparation phase and followed by a review phase.

2.2.2.1 Preparation

In traditional education, students and professors are supposed to prepare for the activity, for example reading documents for a lecture, reviewing the related lecture before the supervised work, or preparing a presentation. Preparation is at the origin of synchronous activities.

From an educational point of view, preparation of a videoconferencing session could be supported by introducing references to content along with the time table. There is a need for better integration between asynchronous educational tools and synchronous collaborative environments.

From a technical point of view, preparation is necessary to support teaching during the synchronous phase. With most synchronous CSCL environments [31, 68], users start collaboration tools manually during the synchronous phase from a central interface. The tools often let uninitiated users decide which technical variables to use [43]. When a user must modify the technical settings, it disturbs them and distracts them from their educational goal.

2.2.2.2 Scheduling

In traditional education, the beginning and the end of the synchronous phase are managed by the timetable. Scheduling is an asynchronous function. Most environments do not provide any solutions for scheduling sessions. Thus, it can be difficult to know when to connect. Email can provide a solution for a punctual event but it is ill suited for repetitive activities.

Various solutions [69, 41] provide functional means of scheduling activities by managing automatic generation of emails. The LiveMeeting environment [11] provides a virtual lobby where users that have not been invited are able to request entrance to the session. The manager of the session is then able to grant them acceptance or refuse them. This solution could ease the transition between asynchronous and synchronous phases.

These solutions are interesting but are still a bit limited. They do not support any educational preparation of the activity.

2.2.2.3 Review

After the synchronous communication phase, the professor and students often have to perform other activities, sucg as reviewing the lecture notes, or practicing exercises. Review is often necessary to remember content studied during the class.

Review could be supported by redirecting students to review systems after the end of the lecture. A set of documents (unformatted and formatted text, images, videos, slides...) is used during the life of a synchronous session. Several environments [35, 12, 11, 34] provide a solution to save these documents and record sounds. These documents are archived by some systems for a later access. It allows a user that was not able to join a meeting to find out what was discussed. It provides a first solution to support the review. However, content produced in this way is difficult to use. Indeed, it would require editing in order to format to provide faster access to content of interest, such as the separation of the chapters in the activities.

2.2.3 Collaboration during Synchronous Phases: Structuring Communications and Interactions

In a meeting users *discuss*. In a lecture, the professor *teaches* to the students. In supervised work, students *practice* under the supervision of the professor. These verbs correspond to concepts of communication and lead to different organizations. In a given activity (like a lecture), a given class of individuals (such as professors, students) has specific rights and duties. Each activity has a set of social rules to structure communication and interaction. Differentiation of the users is necessary to differentiate individual goals and define hierarchy. Users' rights in a classroom represent the social rules that are the basis for interaction. Orientation of the communication allows establishing hierarchal information flows. Dynamic collaboration protocols allow the communication and interactions between individuals to be structured dynamically.

This section evaluates the ability of synchronous CSCL environments to structure communication and interactions.

2.2.3.1 Differentiation of Users: Educational Roles

The role of the user is different in each educational activity. As introduced previously, a lecture is likely to gather a professor and several students. An observer could be allowed to join the lecture without the educational constraints and advantages of students (for example evaluations, or getting a diploma). During a lecture, the professor may also ask an expert to help. This expert might give a small presentation and students could ask him questions.

Most of the synchronous CSCL environments do not support categorization of the users. All the users participate on the same level from an educational point of view. This situation can be tolerated in meetings where users participate on the same level most of the time. However, this situation does not reflect educational scenarios where organization is asymmetric. The Platine environment [70] is one of the very few synchronous CSCL environments to provide user's categories. They are, however, limited to the following list: professor, student, observer and expert. Even if this differentiation is suitable for a lecture, it may not be suitable for other types of activities. It appears necessary to let educational experts and professor to define the educational roles of users in their activity.

From a more general point of view, synchronous CSCL environments do not provide solutions to differentiate users. In many asynchronous environments, information related to the users actions is collected and contributes to define a user profile. This profile is then used after for educational purpose, for example to create groups with homogeneous level, or to relate users sharing an interest. User modeling systems provide such services. These systems are developed for asynchronous environments but they could be adapted to synchronous environment to a certain extent. Environments specially developed for ubiquitous learning [71] provide interesting tracks of research. Yet, integration of user modeling systems in synchronous CSCL environments has to be studied.

2.2.3.2 Frame of Collaboration

Among all rules in a learning activity, some are likely to continually produce the same outcome. These rules are organizational and avoid confusion and misbehaviors. For example, in a lecture, a student is not supposed to get up and write something unrelated to the activity on the blackboard. These rules are related to organizational, and to a certain extent, security issues. The access to a classroom is also usually restricted to a limited group of people.

In synchronous CSCL environments, some tools provide limitation access to their functionalities. For example, users are not allowed to manipulate distant applications, but can only see the results of the professor's manipulations. Such settings are often limited to one communication tool (the application sharing). Most commercial environments give the control of communication means to specific users often called the "chairman". Several users can be chairman during the life of one session. The chairman is provided with an interface or with the ability to modifiy rights on tools. In some systems the rights on specific tools can be defined in advance [41, 72, 70]. It is possible to define the communication means used and the related users' rights. These solutions provide control of the user's rights in a group.

Synchronous CSCL environments do not have a global approach of rights and security in the group. Indeed, rights on a means of communication is often related to the rights on other means. This support is only possible if educational roles can been defined in a session. A professor has some rights and students have other rights. Those rights depend on the type of activity, for example the students are not allowed to write on the whiteboard during a lecture but they are allowed to use it for supervised exercise activities. It appears necessary to support unequivocally a global hierarchy in synchronous sessions.

2.2.3.3 Orientation of the Communication

In a synchronous activity, each user is potentially a producer and consumer of information. Each user contributes to an activity in an independent and unpredictable way. In order to avoid a mess, the flow of information is structured by communication guidelines that remain the same during the synchronous activities.

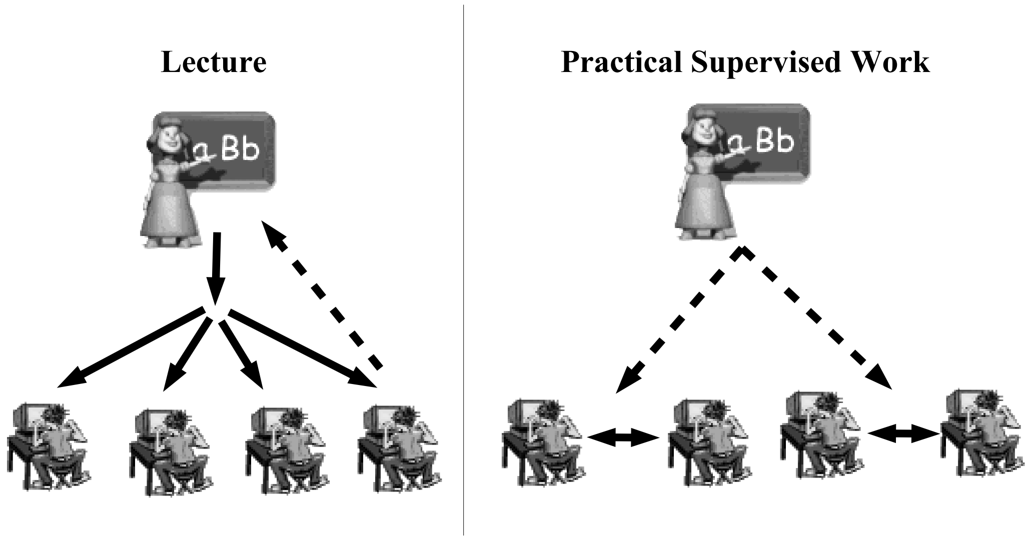

Figure 5: Communication Orientations in a Traditional Learning Activities

For example, traditional learning activities could be orientated as in Fig.5. In a lecture, the professor is the main speaker, which means that communication is mainly oriented from the professor to the students. In supervised practical work, small groups of users talk together to solve a problem, and the professor goes from group to group to evaluate the work and help the students. The communication is oriented fairly inside each group. The professor is also able to communicate with each group independently.

In synchronous CSCL environments, the communication structure is usually the simplest one, i.e. all the users talk to all the others. The communication is not organized at all. The communication structure is the same for a meeting, lecture or supervised practical work, althought some environments provide conference communication modes. In this mode, there is one main presenter who is the source of the information.

ISABEL [35] is a noticeable solution that provides an option for a better flow of communication. This environment provides a control interface that can be compared to the technical functionalities of television production. The ISABEL environment provides a solution to control the audio and video communication flow delivered to the group.

The orientation and the selection of the means of communication are necessary to differentiate activities and optimize the flow of communication. When users have too much information they are not able to identify the relevant information. It therefore appears necessary to avoid the transmission of useless communication flows.

Some options of communication tools allow defining asymmetric communication flows. For example, a user is able to listen and see without sending his video. A user can also send a private message to a friend in a chat tool. These solutions depend on the tools available.

There are no global approaches to orientate the communications. It seems necessary to support original collaboration structures in order to support several collaboration strategies.

2.2.3.4 Dynamic Collaboration Protocols

In this work, dynamic collaboration protocols describe rules that structure dynamic interactions between users. There are several collaboration protocols in traditional learning. Most of them are not explicit and belong to the "learning culture", for example asking a question, or chatting with a friend. These dynamic collaboration protocols are oriented and belong to a social set of rules in education. In a lecture, students may not be allowed to speak until the professor invites them to do so. The students speak with a low voice level when they chat with a friend. They raise their hand to ask a question. The professor may reject a question to avoid being interrupted in reasoning.

Some systems provide tools to manage questions in synchronous sessions [11]. Users write down questions in a specific tool; they are sent to all the participants with some options (such as priority).

The Platine environment provides a way of controlling the communication means of a system. A user of a session is granted with special rights on the other user. This user is called the chairman. The chairman is provided with an interface that gives him the ability to hide or show a window on all users' computers. The chairman is also able to prevent the use of a tool to some user by locking an application. These rights can be directed towards all, or to a single user. This solution can be used to draw the attention of the users. This function does not modify the collaboration structure but provides a dynamic hierarchy between the communication means. Other environments provide a user with similar rights. However the functionalities provided to the chairman are much more restricted than the in the Platine environment.

Synchronous CSCL environments do not support much original dynamic collaboration protocols. According to ubiquitous learning theory, the challenge is to provide information in the right place and at the right time. If the communication structure was settled once and for all, the users would not likely realize the importance of new information. Dynamic communication allows information to be put to the foreground and is thus necessary to support communication strategies.

Experimental results show that users tend to follow collaboration protocols even if they are not supported by computing means. For example, students keep raising their hands to ask questions within a videoconference. These results show the faculties of adaptation of users towards technologies. This adaptation has some limits and it is very difficult to establish eye contact when asking a question with a videoconferencing system.

2.3 Human Computer Interaction (HCI) Contribution: Concepts for Interactions.

2.3.1 The Historical Contribution of Human Computer Interaction (HCI)

In computer-based education, users do not communicate with each others directly; communication is mediated by computers. Educational theories describe the reasons why users collaborate. HCI research proposes solutions to manage communication and interactions between individuals and computers. They define concepts that can be understood by both users and computers. Thus, HCI research is the origin of many collaborative concepts. Learning can be viewed as a complex type of collaboration and the outcomes of HCI research is at the heart of web-based learning systems. HCI research produced the conceptual framework to relate users and computers; it is thus a forerunner and contributor to e-learning developments.

2.3.1.1 Representation and Manipulation of Objects: Graphic Interfaces

The first graphical interfaces were studied at Stanford Research Laboratory and Massachusetts Institute of Technology. Concepts were developed and improved at Xerox Park; they became famous with MacIntosh and get widely spread with Microsoft Windows 95. Graphical interface still remains the main interface for distance learning.

In his Ph.D thesis in 1963 at MIT, Ivan Shuterland demonstrated the direct manipulation of objects on a screen using a light pen and his program SketchPad [73] cited in [74]. It allowed grabbing objects, moving them and changing their size. His research was carried out in different universities and research centers. "Many of the interaction techniques popular in direct manipulation interfaces, such as how objects and text are selected, opened, and manipulated, were researched at Xerox PARC in the 1970's" [74]. If much of the current concepts in drawing were demonstrated in 1963 by Shuterland in his Sketchpad system, "the first computer painting program was probably Dick Shoup's "Superpaint" at PARC (1974-75)" [74]. Drawing functions and concepts for the manipulation of documents and images are often used in collaboration tools. Drawing functions are used to put annotation on content.

From a technical point of view, displays have not evolved much and are still based on a 2D representation of information. Video projectors are used in videoconferencing systems between large groups of users and monitors are preferred for individuals. 3D systems have been used in Computer Aided Design (CAD), the first system being probably developed by Timothy Johnson in 1963. However, displays usually remains 2D. A few solutions have been developed for a 3D representation with specific goggles but are not much spread for educational use. The few exceptions are Virtual Reality (VR) environments that became popular for visits of museums or cities. The original work on VR is attributed to Ivan Shuterland in 1965. Proper solutions for representation of VR scenes, such as head-mounted displays, were researched by NASA. NASA also developed solutions for manipulation and navigation in VR scenes with devices like data gloves.

2.3.1.2 Manipulating a Computer: Input Devices

The Mouse was developed at Stanford Research Laboratory in 1965 as part of the NLS project [75] cited in [74] and became popular in commercial solutions only at the beginning of the 80's with Xerox Star, the Apple Lisa and MacIntosh.

In 1964, the RAND tablet, the first pen-based input device, came out of gesture recognition interface research. Tablet input and gesture recognition was used in Computer Aided Design environments since the 1970s, however, it only became popular with Apple Newton PDA in 1992. Nowadays, graphic tablets or pen-based input device are often used for drawing on a whiteboard for collaborative activities. PDAs, which are a major technical basis of ubiquitous learning environments, also integrate a pen-based input system. Such writing systems contribute to a natural interaction solution for distance learning. Companies such as SmartBoard [76] provided interactive whiteboards that are sometimes used in synchronous distance-learning sessions. These materials are quite expensive and are usually only available to private or public institutions. For a personal use, graphic tablets are available at affordable prices.

Nowadays, microphones and video cameras are available at very low prices. It is thus possible to capture sound and video and use them as new media for communication and collaboration. The quality of these inputs depends on the devices used but also on the configuration of these devices. It is sometimes difficult to configure these devices appropriately for non-initiated users. Indeed, the devices are often able to acquire high quality video and audio content but the computer or the networks are not always able to handle such quality. Thus, wrong settings may give the user technical problems. The configuration of such devices disturbs the user from his main learning goal and is often seen as a barrier.

2.3.1.3 Relating Concepts: the Origin of Hypertext and Hypermedia

The idea of hypertext, which is one of the foundation technologies of Internet, was first introduced by Vanevar Bush in 1945 [77]. "Bush realized that the number of publications has already extended far beyond our present ability to make real use of the record. [...] According to Bush, the major problem was storing the information in a way easy to access at a later time. As a solution for this problem of information storage and retrieval, he designed a device he called the Memory Expander (memex). "A memex," he explains, "is a device in which an individual stores his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory [77]" [78].

The term "hypertext" itself was coined by Ted Nelson in 1965. "The University of Vermont's PROMIS (1976) was the first Hypertext system released to the user community. It was used to link patient and patient care information at the University of Vermont's medical center." [74]. Hypertext is one of the foundation technology of web pages, which is still the largest amount of educational content available on the Internet. In 1982, the Diamond project at BBN [79] studied the combination of multimedia information (text, spreadsheets, graphics, speech).

Hypertext and hypermedia allow the creationof a relationship between two documents. Associationism is one of the first educational theories behind computer based education systems.

2.3.1.4 Distributed Communities: the origin of Computer Supported Collaborative Environments

The oN Line System (NLS) project was directed by Englebart throughout the 60's and 70's. It settled most of the principle of HCI that have been described previously. This project defined a conceptual framework within which could grow coordinated research. Within this project, the participation of several people at distant sites was demonstrated. This was the first demonstration of a distributed system for computer supported collaborative activities. Online interactive communities were predicted in 1968 by Licklider and Taylor [80]. Online learning communities have been identified as a major support for distance learning systems.

"An early computer conferencing system was Turoff's EIES system at the New Jersey Institute of Technology (1975)" [74].

2.3.2 Present HCI Issues in Ubiquitous and Mobile Learning: Leaving the Room for New Experiences

Ubiquitous Learning theory supports the idea that learning should be provided at the right time and in the right place. These challenges are conceptual but also technical. They have to be taken into account in the development of ubiquitous learning environments. Indeed, It is necessary to find a device that can fulfill the communication and interaction requirements of ubiquitous learning scenarios.

2.3.2.1 Mobility: Supporting Learning Anywhere

Contrary to recent technologies that bring additional functionalities, mobility is acquired for the price of limited hardware and software resources. The global performance on the communication device remains a balance between the autonomy, processing power, and portability factors. This global balance depends on the type of activity, for example some activities last for long time and require a large autonomy, others require lighter communication devices for better mobility. Main developments of ubiquitous learning systems are developed for Personal Digital Assistant (PDA). PDAs seem to offer a balanced solution between the different issues: portability, autonomy, processing power and connectivity. Cellular phones appear promising but are still limited in terms of processing power.

The DISCIPLE [38] project provides an interesting approach to support the heterogeneous and limited and variables ressources of mobile computing devices.

2.3.2.2 Interacting with the Environment: Identification of the Context

In a traditional classroom, contextual information, contents and physical tools are directly available and understandable by the students. The context is in the heart of situated learning and ubiquitous learning theories. Computers are not able to interact directly with physical elements; they are not able to discover the context by themselves. This results in limited implementation of learning scenarios. To solve interaction issues between computers and the real world, several solutions have been developed.

Solutions such as Radio Frequency Identification (RFID) tags require the introduction of additional elements, called tags, to acquire the contextual information. For example, RFID tags are used in a ubiquitous system for language learning in [60]. When the user approaches his PDA with a tag reader close to a RFID tag, the system asks the user the name of the object in English or Japanese (depending on the language of learning).

Image processing offers a solution to discover the environment without adding any additional elements like tags. Image processing can be used for the identification of a person; it could be useful to identify the person speaking in a multi-part video conferencing. Image processing is used in video conferencing systems to track the face of the professor in front of the video camera.

2.4 Conclusion

There are a wide range of educational theories with different points of view. The development of environments for a specific theory would reduce their potential use. Thus, this research focuses on the ability to support organized collaboration and communication between users. The professor in charge of an activity would define the organization according to his beliefs towards educational theories. It may reduce the educational potential of this research nevertheless it appears necessary to promote the usability of the envionrment. Moreover, communication is a key element of most educational theories which therfore guarantees the benefit of this research.

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Chapter 3

Contributions of Network Approaches

This chapter presents the contribution of the lower layers of fig.2 presented at the beginning of chapter two. It presents how to support the acquisition, the transport of information within a group of distributed users. This support of the communication is performed differently according to the type of the activity and according to the users. This section presents the strategies to support communication regarding the heterogenity of users and activities.

Technical research fields that contribute to the organization of communication in a distributed group of users is presented in the first section. Then technical tools for communication and their underlying infrastructure conclude this chapter.

3.1 Distributed Systems: Managing a Group of Distributed Users:

Research of distributed systems offer interesting suggestion for coordinating groups of computers. The technical solutions to coordinate a group of computers have a direct influence on the quality of the communication and services to the users. The architecture of a distributed system defines the limits of a collaborative learning environment at many levels. This section introduces criteria to evaluate synchronous CSCL environments from the distributed system point of view. The last section presents coordination protocols specific to synchronous CSCL environments.

3.1.1 Transparency: Hiding Infrastructures to the User

Transparency refers to user-friendliness aspects of a system. If a system is transparent, it should hide its distributed nature to the users. The criteria for transparency detailed in this section has been selected from among the ones presented in the article of the Wikipedia encyclopedia on "Transparency (Computing)". These criteria establish an interesting parallel with the principles of ubiquitous learning (see section 2.1.3). Ubiquitous learning represents an educational approach, whereas distributed systems represent a technical approach. Nevertheless, both of these approaches share some common views on how to provide resources to users.

3.1.1.1 Access Transparency:

Regardless of how communication and content are supported on each computing device, users of a synchronous CSCL environment should always access the functions of the system in a single, uniform way. Access transparency reduces the time necessary for users to become familiar with the system. In synchronous CSCL environments, access transparency can be evaluated at two levels: access to the system and access to the communication means.

Some collaborative environments [12, 11, 41] provide a web-based access. It provides uniform access to the system. Their environment can be accessed with a web browser and proper Internet connectivity. However, underlying software components support web-based solutions and access to the communication means is often heterogeneous. Java based collaborative systems [70] provide a single uniform access to the system's functionalities on many platforms.

This does not, however, guarantee homogeneous access to the communication means. Indeed, specific network configurations (firewalls, Network Address Translation systems) often introduce restrictions over the use of communication means. Peer-to-Peer systems [68, 72] or HTTP based solutions [12, 34] provide uniform access to their communication means independently from the network communication.

3.1.1.2 Location Transparency:

Users of a synchronous CSCL system should not need to be aware of where content and resources supporting collaboration are physically located.

This is the case with most of the systems. However, the quality of communication is influenced by distance. Thus, on the Internet, location transparency is never guaranteed.

Time difference makes it difficult to gather people from some locations. It requires flexibility to fix a meeting time. Several environments [41, 11, 12] provide a scheduling system that respect the local time zone of the user. Also in the VRVS system, servers distributed in different countries support the broadcast of information. The server selected for the support of information depends on the location of the participants. This feature contributes to location transparency.

3.1.1.3 Migration Transparency:

Users should not be aware of whether content and the functionalities provided by the system possess the ability to move to a different physical or logical location.

In synchronous CSCL environments, migration has an influence on the access transparency. Web-based systems guarantee partial migration transparency as they are accessed by a web address.

Access to communication means is often influenced by migration. Communication means are usually associated with technical elements (for example IP addresses) within a session. Thus the migration of resources supporting communication means requires the modification of the session profile [70]. From a user point of view, this migration can be transparent.

In systems where access to the communication means is not defined in a session profile, users have to configure the access to the system by themselves. Thus, migration of the resources is not transparent.

3.1.1.4 Concurrent Transparency:

While multiple users may compete for and share a single content or communication mean, this should not be apparent to any of them. For example, a user should not feel any difference if he or she is the only one viewing a video stream stored on a server, or if several other users are viewing the same video.

Synchronous CSCL environments provide concurrent transparency for communication means. The concurrent transparency for content is also provided when users are just reading documents.

The modification of content is also possible within synchronous CSCL environments. It raises social issues that have different answers according to the context. In a lecture, the professor would allow personal annotations on slides. In other activities, concurrent transparency would be avoided to allow collaboration. Some environments provide shared edition systems to concurrently edit a document.

3.1.1.5 Failure Transparency:

A system is transparent to failure if it hides failure and recovery of computing resources to the user. Failure transparency may be required for strategic collaborative activities or when financial contribution is engaged. In synchronous CSCL systems, communication means are usually addressed in architecture-related terms. Thus, users are directly concerned by failures. The redundancy of the different forms of communication is a natural advantage of synchronous CSCL environments.

3.1.1.6 Persistence Transparency:

Persistence transparency is given to systems that hide from the user if a resources lies in volatile or permanent memory. Synchronous activities defined by sessions can be reproduced over time. However, the settings saved in the definition of a session are often limited and setting up a session always requires several actions to be done by the users.

Activities are often seen as a single event, and persistence is not supported. For repetitive activities persistence transparency would be interesting, as it would save time for setting up a session.

3.1.1.7 Scalability of a System

Scalability refers to the ability of the system to maintain performance level when users and content are added or removed. Scalability can be seen as load, geographic and administrative factors.

3.1.1.8 Load Scalability

The system should be easy to expand or contract, according to the number of users connected and to the amount of content shared.

Synchronous environments are usually designed to connect a very few number of sites due to network limitations. Videoconferencing requires network resources that are not usually available for large group of users. Nevertheless, the addition of resources in the architecture allows the support of several users. Special events like the Megaconference [81] allow a lot of users to be connected at the same time. These organizations are rare and require expensive infrastructures.

The definition of collaboration strategies may contribute to overcoming load scalability issues. It may have an educational meaning to gather a group of 5 to 10 users and to allow direct video interaction among them. However, receiving visual and vocal information from more than ten persons has little meaning; the user is overcome by information and is not able to select the elements of interest. In a lecture, it may mean that hundreds of students look at one professor. Many commercial environments are able to support conference architecture and are quite scalable. In Webex, LiveMeeting and ISABEL, [12, 11, 35] video, audio and documents are made available through a webcast. In these situations, the interactivity provided to the participants is often null. Multicast provides a scalable audio and video communication solution. Other communication tools have to develop strategies for scalability.

3.1.1.9 Geographic Scalability

Geographic scalability represents the ability of synchronous CSCL systems to provide communication means regardless of how far apart its users are. The geographical distribution of users in a distributed environment has no influence on the system, provided the network supports the communication transparently.

3.1.1.10 Administrative Scalability

The administrative scalability refers to the ability of the synchronous environment to administrate several synchronous activities in parallel.

Few systems provide administrative function; most of them are limited to a single session. In the VRVS system, users enter a community according to his profile and select a room where the synchronous communication begins. The user may schedule the use of a room for meeting purposes. The Platine system provides access according to predefined groups, such as research project, or meeting. Then the user selects the session available for this group.

3.1.2 Architecture

The coordination of communication is supported by different architectures. Figure 6 presents a few concepts for the definition of a distributed architecture. These concepts are then described with more details in the following subsections.

Synchronous CSCL environments are mainly based on the Client-Server architecture. Some environments involved more complex architectures. Communication means of a synchronous CSCL system are often based on their own architecture independently from the main coordination system.

3.1.2.1 Client-Server

In such architecture (upper part of fig.6), clients format and display the content that they get from or send to the server. Clients have an active role (master), thin clients utilize as few resources on the host PC whereas fat clients rely more on local hosts to perform data treatment. The server is passive (slave); it is stateless if it does not keep information between requests, stateful otherwise.

Clients developed for light communication devices (PDA and mobile phones) are usually thin clients and have limited functionality compared to fat clients for desktop computers [41, 70].

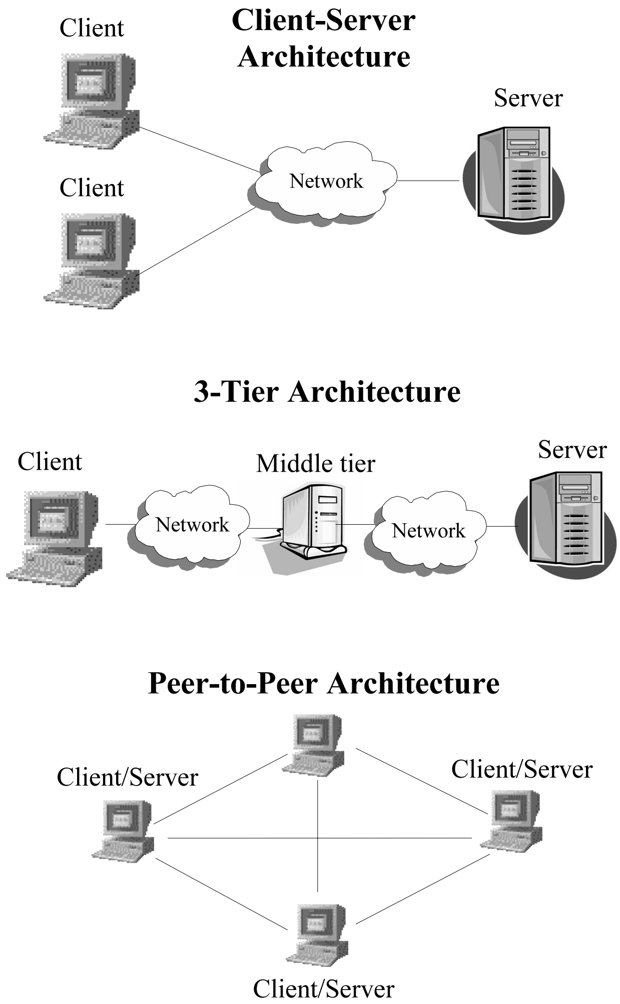

Figure 6: Architecture Model References

3.1.2.2 3-Tier and N-Tier

In such architecture (middle part of fig.6), the intelligence of the client is moved to a *middle tier* so that the processing on the client is reduced. Stateless clients can be supported by 3-tier architecture. Most web applications are 3-tier. Each component of the 3-tier architecture can be upgraded or replaced independently. The definition of 3-tier architecture for synchronous CSCL environment may contribute to the integration of lighter communication devices.

In N-tiers architecture, several middle tiers can be involved in the treatment of a client request. N-tier architectures allow the separating and distributing the intelligence of the system in independent servers. A complete synchronous CSCL environment can be seen as N-tier architecture if communication means are considered as one part of the whole system. Considering the relative independence of communication means, it is also fair to consider synchronous CSCL environments as a juxtaposition of client-server architectures.

3.1.2.3 Peer-to-Peer (P2P)

In Peer-to-Peer architecture (lower part of fig.6), the system and the communication means are not managed nor provided by a special machine. The responsibility of management and communication means is divided among all the involved machines. Computer power and bandwidth are shared for the purpose of the group. Such architectures provide technical functionalities that contribute to the transparency of the distributed system; for example Network Address Translation, or firewall crossing.

The JXCube [68] and Qnext environments [72] are based on a peer-to-peer architecture. They provide several communication plug-ins for communication between the different peers. Skype [82] is an audio conferencing tool based on peer-to-peer. These systems provide interesting tracks of development for synchronous CSCL environments.

3.1.2.4 Mobile Code

In mobile code architectures, the intelligence of the distributed system has not a fixed place in the architecture. The code supporting server functions is transmitted over computer networks to be executed at another location. It allows moving the server closer to the clients to provide better services.

This architecture is mainly used for remote evaluation of a computer, mobile agents. There are no synchronous CSCL environments based on this architecture. It could be interesting to adapt the communication architecture with mobile code; it could be a solution to limit the influence of the network and improve the quality of communication.

3.1.2.5 Openness: Standards and Protocols for Communication

Openness refers to the ability of a system to connect and interact with other systems. It favors integration and scalability. Standard protocols and data representation are technical solutions supporting openness.

In synchronous CSCL environments, there are several communication means. Each environment usually provides a proprietary implementation. There are a few standards for video and audio conferencing. As far as this report is concerned, the T.120 [23] standard is the only standard available for other communication means (for example text-based, or documents based) and for coordination of the system. Few environments have implemented this standard [31, 12]. This standard is said to be difficult to implement.

Asynchronous web-based learning systems and information services are based on standards and protocols. These protocols are not adapted to synchronous learning activities, but they provide reference information for integration purposes.

3.1.2.6 Content: Data Standards

Hyper Text Markup Language (HTML) allows data to be formatted and focuses on the look of the data. The eXtensible Markup Language [83] allows describing content in a structured form independent from the technical specificities of computing entities. Document Type Definition (DTD) and XML Schema are two standards that can be used to describe the structure of a XML document. XML, XML

Schemas and DTD are used in different synchronous CSCL environments to give a formal structure to collaboration [84, 18].

The Dublin Core Metadata Initiative [85] is an open forum engaged in the development of interoperable online metadata standards. They provide a set of elements for cross-domain information resource description (like title, date, contributor, source, and language). This set of elements is often used for formal description in learning content.

The Learning Object Metadata (LOM) [86] is a standard that specifies the syntax and semantics of learning objects. The LOM standard is supported by the IEEE Learning Technology Standard Committee [87]. Learning Objects are defined as either a digital or a non-digital entity, which can be used, re-used or referenced during technology-supported learning (e.g. distance learning, collaborative learning systems). Learning objects refer to multimedia and instructional content, software tools, persons, organizations, etc. This approach allows the development of reusable educational content. This standard is a base for artificial intelligence entities to manipulate educational data. LOM is one of the major standard of web-based learning systems.

3.1.2.7 Communication Protocol: Services

Communication protocols define the format and the exchange of messages between computing entities. The development of Internet brought heterogeneous computing entities to exchange messages. Different groups proposed platform independent protocols that allow relating heterogeneous computing entities. The messages of those communication protocols are usually described in XML.

Distributed systems were often designed to communicate with protocols like Remote Procedure Call (RPC) or CORBA. However, firewall, proxy server, and Network Address Translation (NAT) normally blocked this kind of traffic. The Simple Object Access Protocol (SOAP) is a protocol that supports HTTP communications between applications. It provides a way to solve the network issues previously cited.

The Web Services Description Language (WSDL) is a language for describing web services and how to access them. Web services are components of applications developed for the Internet. Web services are self-contained and self-describing. They can be discovered using Universal Description, Discovery and Integration (UDDI). Web services represent a way to relate systems between them. Several Commercial developments for the Internet are developed with WSDL and SOAP protocols. Their support provide the access to several services.

The eXtensible Messaging and Presence Protocol (XMMP) is the IETF formalization of the base XML streaming protocols for instant messenging and presence developed within the Jabber community [88]. The normal architecture of XMMP is a pure client-server model. Wanadoo, Europe's largest provider of Internet solutions, provide integrated voice, video, and chat service using XMMP. Presence is a fundamental functionality of Instant Messenger that contributes to create a social context in a distributed group.

3.1.2.8 Standard Videoconferencing Architecture

Videoconferencing systems have specific requirements and let to the development of specific architectures. This section presents the main recommendations from the telecommunication and network industry: H323 and SIP architecture respectively.

H.323 H.323 [22] is an International Telecommunication Union (ITU) recommendation for audio, video and data communication on packet commutation networks without QoS guarantee. H.323 is composed of set of protocols and codecs for the proper use of those communication services over networks.

The H.323 norm defines four types of components: terminals, gateways, gatekeeper and MCU (Multipoint Control Unit). Main functionalities are detailed here:

- <u>Client Terminals:</u> Terminal is the client used for multimedia communications in real-time, e.g. desktop and laptop computer, H.323 phones and standalone terminals.

- Gateways: Gateways are bridges that enable interaction between packet commutation networks (like the Internet) and circuit commutation networks (like PSTN, traditional phone). The gateway translates address from one system to another, and handles connection requests.

- Gatekeepers: Gatekeepers are the managers of the H.323 zone. They provide different services, like admission control, bandwidth control, or address translation. This component is optional.

- MCU: MCU supports conferencing between several users. Clients connect directly to MCU in a multi-user conference. The MCU manages attribution of available resources in term of bandwidth and determines codecs to be used.

All those components constitute a H.323 zone (Fig.7), gathering several terminals, gateways, MCU all managed by a single gatekeeper.

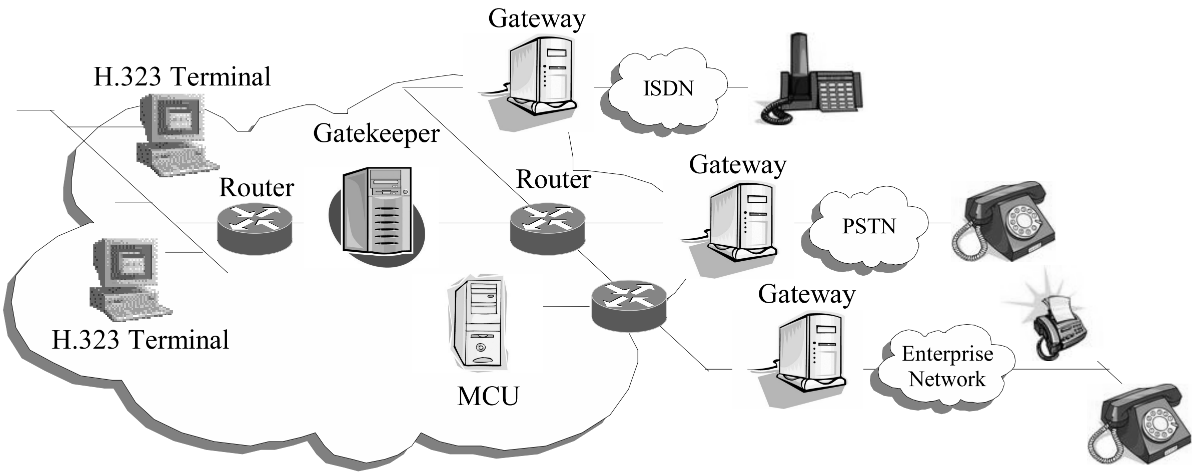

Figure 7: An H.323 Zone

SIP SIP (Session Initiation Protocol) is a protocol defined in Request For Comment (RFC) 2543 [30] by the SIP Working group in the International Engineering Task Force (IETF). SIP protocol describes opening and closing of sessions on IP networks. Sessions can be used for telephony, but also for videoconference, instant messaging, games or any other protocol that require session opening and data exchange during this session.

Services provided by SIP are as follows:

- User Location: A SIP address is built around the following scheme: user@company.com. The corresponding company set up a server that will look for the user inside its company every time it receives a session opening request (a call). This server puts both sides in touch and communication can start. The important part of this kind of address is that the user can be located anywhere in the company and can move inside the company. The address is also easy to be memorized, like an email address.

- Session Definition Profile: SIP define session characteristics by an exchange of messages. For telephony, the exchange can be about the audio codec used. In a more general use, any kind of information can be used. The session profile can be modified during the life of a session.

- Session Control: Sessions are independant. During a session, another session targeting the same destination can be opened. Some telephony applications have developed queue solutions when receiving session openning request. It makes user wait or transfers the session request, according to the type of the call. A lot of optional services are provided and reflect the possibilities offered by telephony for what SIP was firstly developed for.

Technically, SIP does not operate at the application level but at level five of the OSI model. From Internet experts point of view it is seen as an application level protocol, which makes it independent from networks used and operating system (OS, user interface, media type, codec, call number control).

There are two kinds of SIP entities:

- SIP Agent: SIP agent is divided into client and server parts. In point-to-point calls, clients initiate calls and servers answer calls. SIP allows users to create peer to peer communication thanks to client-server architecture.
- SIP Servers: SIP servers are located in the network and can handle several user conferences. Their main function is to provide address translation service and to locate and identify users. Proxy servers receive requests and decide where the next server is to transmit requests. A difference is made between stateful, stateless and redirect servers:
  - Stateful Proxy Servers: Stateful proxy servers memorize the path linked to a request, which allows them to try several paths to find quickly a user. Those servers are mainly implemented at a local level as first interface for SIP agent.
  - Stateless Proxy Servers: Stateless proxy servers do not memorize requests and corresponding paths. These servers are used as the heart of the network, as they can treat requests faster than stateful proxy servers.
  - Re-direct Servers: Re-direct servers receive requests but do not forward them; instead they send the address of the next server to the request client. Thus, this one can contact directly to the next server.

3.1.2.9 Standard Distributed Architecture

The industry proposes standard architecture of distributed systems. These architectures provide an organized structure and are supported by reference implementation. They allow the fastest development of distributed system. The Java 2 Platform Enterprise Edition (J2EE) proposed the standard for developing component-based multitier applications. The dot NET framework also proposes a standard for developing such applications. Paredes Juarez et al. [89] developed a user model server based on the J2EE architecture. This user model is used in a System for ubiquitous learning, the Basic Support for Ubiquitous Learning (BSUL) [71]. These approaches provide components that could be reused for the development of another environment.

The Sharable Content Object Reference Model (SCORM) [90] is a common specification and standard for technology-based learning supported by the Advanced Distributed Learning (ADL) organization. This standardization effort started in 1999 and different versions of the standard have been released. The SCORM standard defines interrelationships of content objects, data models and protocols such that objects are sharable across systems that conform to the same model. This set of standards, specifications, guidelines and models helps to define the technical foundations of Web-based learning systems. SCORM is organized into a collection of "technical books" that gather specifications and guidelines taken from other organizations such as IMS Global Learning Consortium [91], Aviation Industry CBT Committee [92], Alliance of Remote Instructional Authoring and Distribution Networks for Europe [93], and the IEEE LTSC [87]. The 2004 SCORM library consisted of the following books: Content Aggregation Model, Run-time Environment, Sequencing and Navigation and Overview. SCORM integrates technology developments from groups within a single reference model to specify consistent implementations that can be used across the e-learning community.

Other organizations like the IMS Global Learning Consortium provide specification for the design of web-based learning environments [94]. These specifications provide an interesting look on how to manage content in a learning system.

3.1.3 Original Coordination Protocols

The requirements of synchronous collaboration lead to the development of original protocols and architectures. The contribution of collaborative work environments is very interesting. Synchronous

Computer Supported Collaborative Work (CSCW) environments rely on a common technical basis with synchronous CSCL.

The TANGO collaboration platform [37] is provided through a web based access. Communication is supported by Java applets integrated into the web pages. Web pages are then accessed through a HTTP server. These applets communicate with a central server linked to a database. The system also allows the use of local programs by the clients. This approach proposes an integration of web-based and local applications in a uniform interface.

The HTTP-ICE proposes a HTTP-based distributed application framework for Interactive Collaborative Environments [95]. In this architecture, the content is transmitted with the HTTP protocol, which solves network access issues (such as firewall and private IP).

The Genesys environment [69] is based on architecture with several servers representing the different functionalities of the environment, for example visual communication, or slideshow. The servers are independent and can be distributed to different geographical locations. The load is thus partitioned, and it prevents functions from having an impact on one other. Slideshow presentations are converted into Dynamic HTML web pages for compact firewall friendly communication. These web pages can be cached on proxy servers and shared among different participants [96].

Ubiquitous collaboration architectures have been the subject of much research. The Garnet Message System Micro Edition (GMSME) [97] is a middleware layer dedicated to the adaptation of content for mobile devices such as PDAs and mobile phones. This layer allows the adaptation of the Garnet Collaborative system [98]. This system defines an architecture where computer, programs and users are described in XML. It contributes to the easiness of deployment and guarantees high openness of the architecture.

The DIstributed System for Collaborative Information Processing and Learning [38] project is developed at Rutgers University. This project defined a strong framework in mobile computing and collaboration. The architecture is intended to support collaboration with limited and heterogeneous resources and to adapt itself to the variability of the context. It has developed semantic consistency strategies [99], and adaptation strategies for mobile-usage users [100]. This research project provides a lot of technical adaptation mechanisms that contribute to the quality of the collaboration.

Rodriguez Peralta, Villemur, Drira, and Molina Espinosa [84] present an interesting solution for the management of dependencies in collaboration activities. The flow of data between users is represented by a graph. The graph approach guarantees strictness in the collaboration protocols and prevent unexpected behaviors due to poor design. The structure of collaboration is defined and exchanged between computers in XML messages.

Other researches have addressed infrastructure patterns for collaboration activities [101] and architecture for the dynamic deployment of functionalities in collaborative activities [102]. These works bring interesting technical solutions, however they are based on limited collaboration models. The architecture is developed without strong relationship with the interactions and communications at the user level. Professors are responsible for their teaching strategy, however their choices are not reflected within the architecture of the communication. Collaboration strategies would benefit from the development of a relationship with communication architectures and strategies for the transport of information.

3.2 Network Contribution: Multimedia Communications

3.2.1 Different Ways to Collaborate: Communication Tools

Several tools are used to support collaboration, each tool representing a particular mode of communication. The selection of these tools allows the support of different collaboration strategies. The implementation of the tools also has an influence on the users' experience, for exemple on communication quality and on ergonomy. This section presents these tools according to the classification established by Baudin, Drira, Villemur & Tazi [13].

3.2.1.1 Direct Communication Tools

The main communication tools are audio and video conferencing, although chat tools also support informal communication.

Audio and Video Conferencing Process Audio and video conferencing tools support sound and visual communications between users. The tools manage the acquisition of sound and video through the capture devices: microphone and video camera. Then, sound and video samples are encoded and transmitted over the Internet. On the other end, audio and video conferencing tools receive the encoded samples, decode them and reproduce them.

The acquisition of sound and video defines the reference quality that users intend to work with. The parameters for the acquisition of sound and video are defined hereinafter.

Samples are encoded into packets according to specific algorithms called codec (for coding decoding). Encoding samples allows reducing the information sent over the Internet. The size of the packets can be reduced at the price of computing and time. Mobile communication devices often have limited CPU and energy resources. The codec has to be chosen according to the quality expected, the network resources available, and the type of communication devices. Video information is large and often requires large processing ressources or specific chips, for example acquisition card with encoding functionalities.

There are several codecs for audio and video communications. It is important to differentiate codecs that are developed for immediate transmission of audio and video over the network and codec that encode audio and video for later use. There are a lot of codecs for video; it appears impossible to present them all; however differences in coding techniques have a tactful impact on the communication. MJPEG is a codec that encodes each image captured individually. Thus, the loss of packets over the network only has effect on one frame of the video and does not affect the other. H.263 and MPEG-family codecs encode images in a format related to the other frames of the video. This technique allows the amount of data sent over the network to be dramatically reduced. However, the loss of one image has an impact on the quality of other frames. An activity that requires a very clear image without much fluidity would benefit from using the MJPEG codec.

The H.323 norm define the video and audio codecs supported; e.g. H.263, H.261 for video, G.711 for audio.

Speex [103] is an Open Source patent-free audio compression format designed for speech. This codec is well adapted to Internet applications and provides a free alternative to expensive proprietary speech codecs.

The transmission of packets over the network is treated in a later section.

The requirements of audio and video quality depend on the activity performed. Most of the activities can be performed with tools default settings. However, specific activities may require particular settings. For example, language and music activities would probably require a better sound quality. When several users join a videoconference from a same location, it is better to have a larger video. In activities where emotional content and social presence are central, a good quality is necessary.

Higher quality requires higher computing and network resources. The choice of the parameters should be adapted to the activity performed.

Audio Conferencing: Acquisition Parameters This section presents the main parameters for the acquisition of audio:

- Sampling Frequency: Music on a Compact Disc (CD) is sampled at the frequency of 44 100Hz. Voice can be transmitted with lower sampling frequencies, e.g. 8000Hz. However, it is necessary to keep a high sampling frequency in order to transmit sound from musical instruments. The higher the frequency, the greater the amount of information produced is.
- Bit Per Sample: Bit per sampel corresponds to the scale used to describe one sample. If a limited number of bits (8 bits) can just support a voice communication, it is necessary to provide larger number of bits to guarantee high-resolution sound.
- Number of Channels: The number of channels corresponds to the number of audio sources recorded by the application: one for mono, two for stereo. The number of channels supports the spatial localization of the sound. Such localization can be useful for some activities, provided the audio reproduction system can support this redistribution.

Video Conferencing: Acquisition Parameters This section presents the main parameters for the acquisition of videos:

- Resolution of the Video: The size of the video H.323 videoconferencing tools is either CIF (in pixels 352x288) or Quarter CIF (in pixels 176x144). Other videoconferencing tools can support larger sizes. Web cameras are usually able to capture images up to a resolution of 640x480. The resolution in PAL is 720x576, and 720x486 in NTSC. Such large sizes are not available over the Internet, but they can be found in satellite-based videoconferences. Such large sizes also require dedicated encoding solutions.
- Bits per Pixel: As for audio communication, the amount of bits used to encode the video information defines the number of colors that can be displayed. The fidelity of the image can be a determining factor for some activities, for example color of a precipitate.
- Frame Rate: This parameter defines the fluidity of the video. Traditional television has a frame rate of 25 images per second. In video conferencing, the frame rate is often reduced to limit the amount of information sent over the network. A talking head can be transmitted with resolutions as low as 5 fps without much disturbance for the user. When 10 to 15 fps are transmitted, it corresponds to quite a good web conferencing quality.

Audio and Video Conferencing: Applications Several applications provide audio and video conferencing functionalities. The most popular are probably Instant Messenging programs. In this section, we focus on open source or freely available solutions for audio conferencing. Freely available solutions are the only choice to manipulate communication flows in an original way.

The Java Media Framework [104] is an Application Programming Interface (API) developed to synchronize and control audio, video and data streams in real-time. The Platine audio and video conferencing tools are based on JMF.

The Mbone (Mbone, multicast network) suite is an open source collection of tools for conferencing over the Internet. It integrates an audio conferencing tool, the Robust Audio Tool (RAT) [105], and a VIdeo Conferencing tool (VIC) [106]. They run on a large range of platforms. RAT features a range of different rate and quality codecs, and techniques for better audio quality. VIC and RAT interfaces have been recently improved within the VRVS project. Fig.8 presents the RAT interface and the option setting panel for the transmission of packets. Fig.9 shows the VIC interface with the control panel for the transmission of video.

The OpenH323 project [107] aims to create a full featured, interoperable, Open Source implementation of the ITU-T H.323 teleconferencing protocol that can be used by personal developers and commercial users without charge. This project provides several elements of the H.323 architecture (see section 3.1.2.8): GUI and command line client, MCU, gatekeeper, gateway and answering machine.

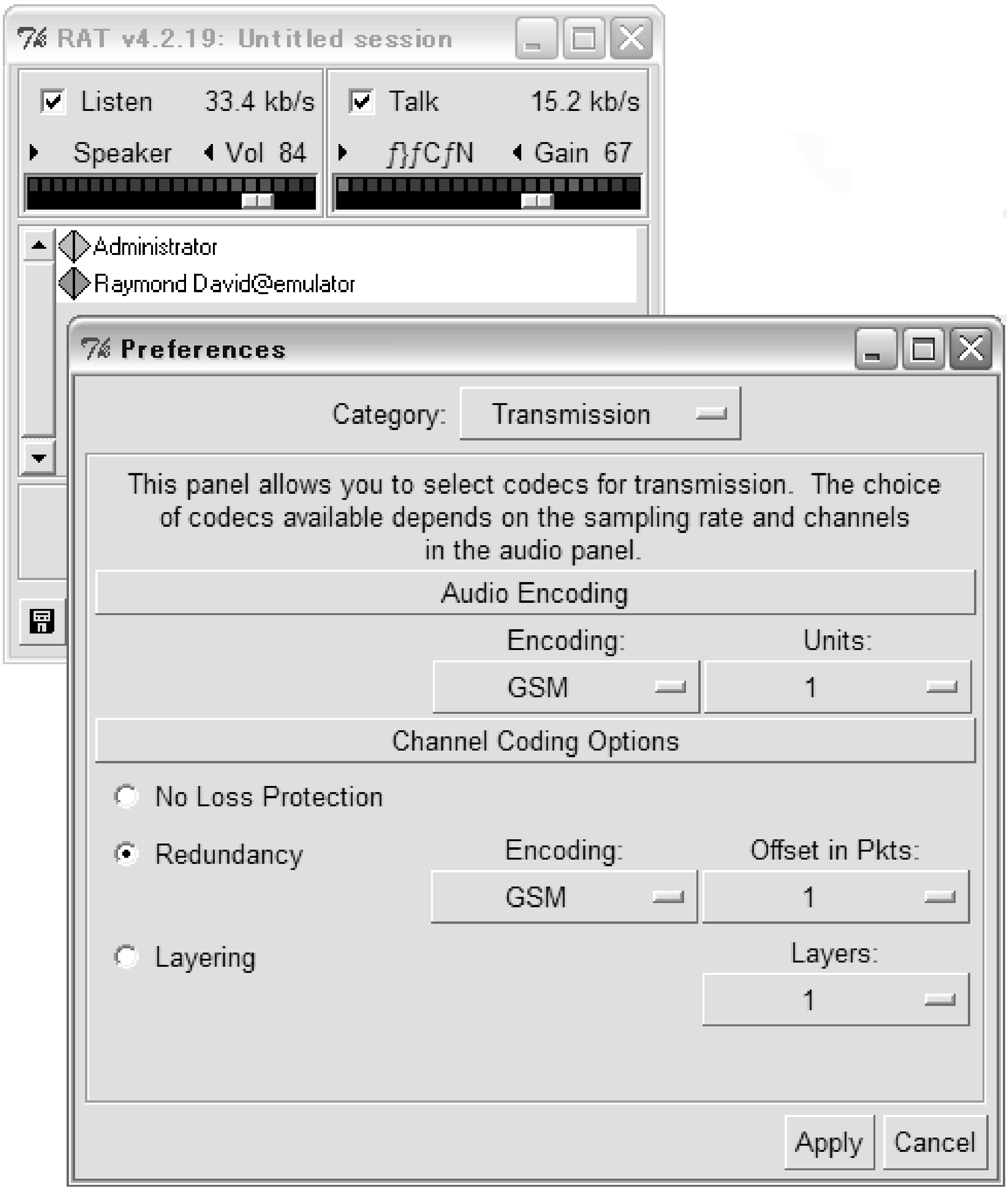

Figure 8: Interface of RAT Software

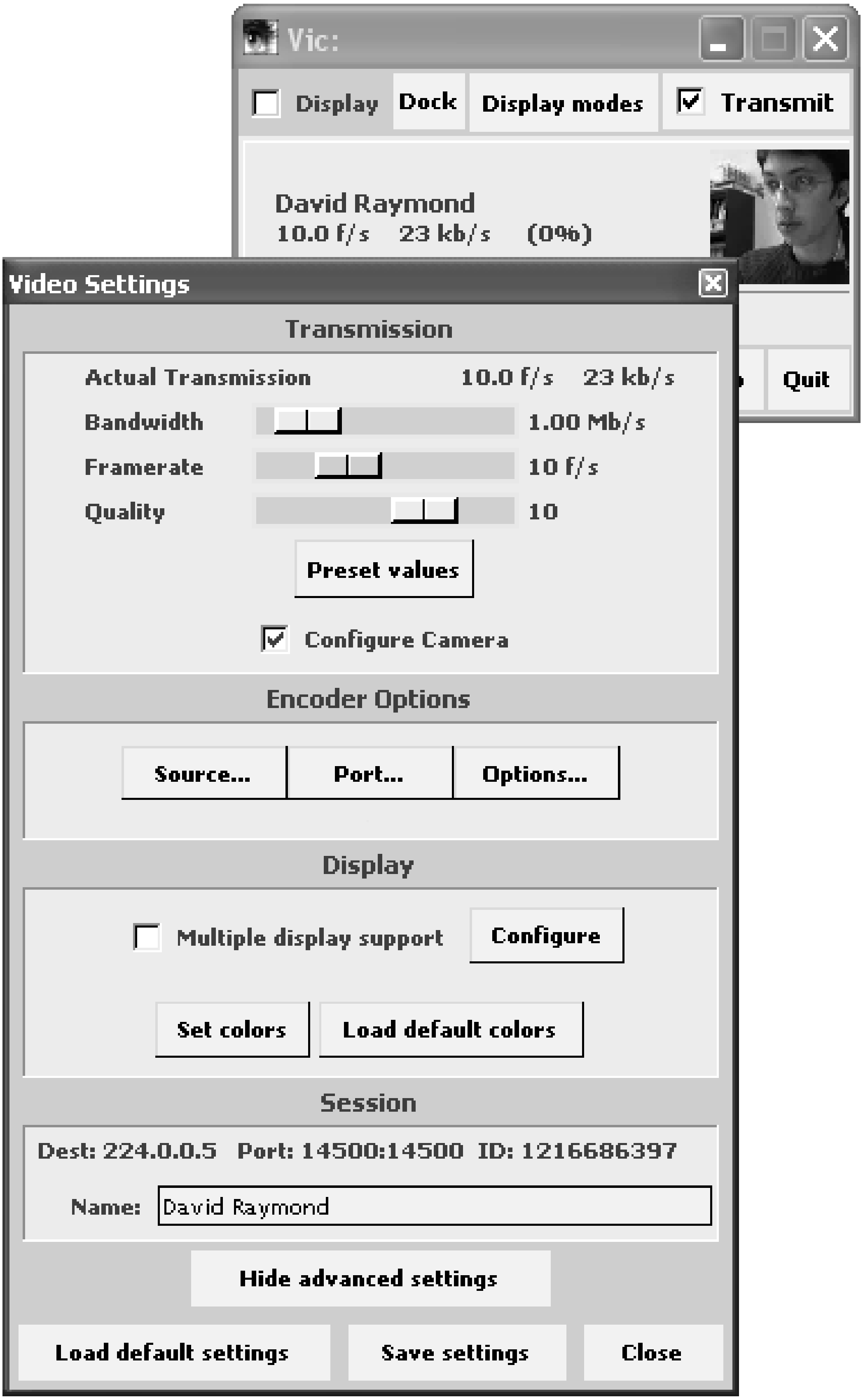

Figure 9: Interface of VIC Software

Chat Chat is a tool for sending text information. Chat tools are used primarily for direct and informal communications rather than formal communications.

The chat tools manage the input of text, and the transmission to and display for the other users. Some tools provide a way to personalize the text input with the definition of font, size, and color of the text. These features may seem superficial but they appear very useful to differentiate the contribution of each user and avoid confusion: each user is associated with a different color. Moreover, it can be used to express behaviors. Indeed, writing with larger letters can be associated to speaking loud and writing to small letter can be associated with low voice. The color of the text can be used for emotional content, for example red could be associated to anger.

Chat also provides the possibility for private conversation. The user can choose to send the message to the whole group of user or to a limited number of persons. Some tools provide the possibility to disable private conversation in order to avoid students being distracted. [34]

The display of the message is usually linear; messages appear in the order of their arrival. It leads to communication that shared several topics without any structure. In a large group, it becomes very difficult to follow discussions. To answer this problem, some chat tools provide a structure system; users have the possibility to initiate new thread of discussion or to contribute to one thread. Thus, the chat is structured into threads of discussion.

3.2.1.2 Document Sharing Tools

These tools support mediated communications. The main mediated communication tool is the whiteboard. Other tools provide document-specific mediated communication.

Whiteboard The whiteboard is the virtual counterpart of the traditional blackboard. It is used to write down notes, display and share content. Implementations of the whiteboard use white "working sheets" where the user can write or draw. The basic writing and drawing functionalities are the same as for basic paint programs, for example free hand writing, lines, squares, circles, or text input from the keyboard.

The user can share graphical documents. Annotation can be put on the top of these graphical documents. Some tools provide the ability to use several working sheets, which helps to present and navigate among large content. In other tools, content can be prepared in advance and shared at the start of the whiteboard.

The Webex environment [12] integrates a modules to import word documents or presentations onto the whiteboard. This allows a quick integration of content. The Webex whiteboard also support transparency in the annotations. It allows sections of a text to be underlined without hiding another part.

The Platine and the Webex whiteboard tools [70, 12] provide an identification mark associated with the name of the user. It supports the identification of the source of the annotations. The use of a different color for each user is also a solution to differentiate the participation.

The Mbone suite integrates a whiteboard called WB. This tool was available for a large range of platforms.

Video Streamer Video streamer tools allow the sharing audio and video documents using live streaming. Some tools provide parameters to adapt audio and video documents to the distribution over the network. In order to minimize the network load, the quality can be reduced; the document can then be encoded in a different format.

VLC [108], initially VideoLAN Client, is a highly portable multimedia player for various audio and video formats, CDs, DVDs and streaming protocols. This software can be used for streaming over unicast or multicast network. Several parameters allow the adaptation of the stream to the specific requirements of the users. This software is free and distributed under the GNU General Public License. It can be used for the development of a video streaming solution. Fig.10 shows the interface of VLC

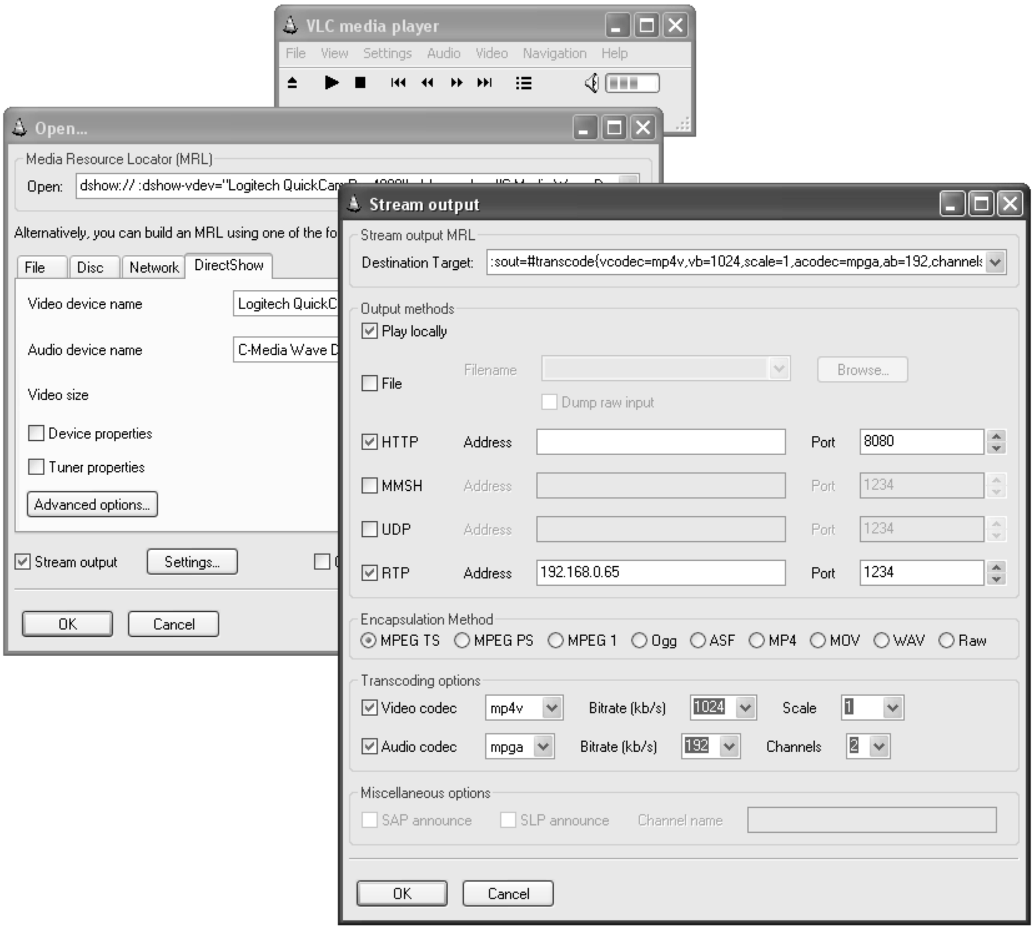

Figure 10: Interface of VLC

application (in the back), the interface window to select the source of the stream to send (in the middle) and the windows that defines the destination and the streaming parameters (in the front).

The JMF API [104], introduced in the section on audio and video conferencing, provides the components to build a video streamer. The API itself is distributed with a demonstration application JMStudio that support simple streaming. The JMStudio application is presented in the lecture of a videostream in fig.11.

Figure 11: Interface of JMStudio

Windows Media Encoder [109] provides a solution for streaming video documents with Microsoft Windows Media Video formats.

3.2.1.3 Multiple User Applications

Multiple user applications support mediated communications between users. Users can use these applications to collaboratively manipulate a system; for example a software, or an experimental setting. Most of the multi user applications share software. Some environmnents, like the "Laboratoire Virtuel de Physique" LVP from TELUQ (Quebec University) [110], and Lab@Future Project [111], provide solutions for manipulations of real experimental settings.

Application Sharing This tool provides users with a generic service for sharing any application. Users are able to manipulate an application as if they were manipulating it on their local computer. Different points of view may also be considered:

- Centralized Server: A central server is set up and specific applications that need to be shared during a session are installed on the server. All the users connect with a client to see the execution of the application; users may interact with the application according to their access right. This can be utilized to show the demonstration of a software to a group of users or to watch some users manipulating this software.
- Distributed Servers: Users host a server with the application they are interested in sharing. Users can connect through their client to see, and possibly access, in a remote control mode, other user's applications. This can allow a distant user take control over the local application. For example, a professor would be able to help a student manipulate the software on his local computer.

In both cases, the client side of the application-sharing tool represents a remote view of the shared application. Through the client interface, users can request and, if accepted, accomplish the remote control of the shared application.

Technically, most application sharing tools periodically capture screen dumps of the shared application and sends them over the network. They are displayed on a specific video window for each user. When operated at a distance, the movements of the mouse over this window are reproduced over the real application. The text input on the keyboard is also transmitted to the application on the server.

The application-sharing tool used in the Platine environment is based on the Virtual Network Computing (VNC) tool of the University of Lancaster. This application is now distributed by a private company RealVNC [112]. The original version of VNC remains free, but the enhancements offered by RealVNC are lucrative.

Many other application-sharing systems are based on the VNC tool. TightVNC [113] is an open source implementation of the VNC protocols and it provides numerous additional features.

There are several other implementations of application sharing. Commercial environments have developed their own standards and solutions [11, 12, 41]. Some of these are popular for remote assistance to the user.

The VRVS application provides the ability to share a part of each user's desktop through videoconferencing. Also, Camtasia Recorder [114] is a capture plugin that can be substituted for other camera input in most videoconferencing applications. These solutions provide a client view of an application and do not allow the control of this application. However it is an interesting solution for the scalability of application sharing. The users interested in viewing the manipulation of an application could rely on videoconferencing scalability solution. The number of participants that would like to manipulate the application would be more limited and could be managed by a real application sharing solution.

Virtual Reality Applications Application sharing environments may be used as a solution to share virtual reality applications. However, this solution does not provide a satisfactory user experience. 3D scenes are often composed of sophisticated shapes and processor-consuming animations that are not rendered smoothly enough with screen captures. In shared virtual worlds, users are able to move and explore independently the 3D scenes, whereas application sharing tool restricts all users to the same view.

Parallel Graphics Multi-user solution [115] is a client-server based networking system that allows virtual worlds to be shared among different users. Movements and events from within the virtual environments are synchronized over the distributed users related an IP network. The virtual worlds are described with the Virtual Reality Modelling Language standard (VRML). The Multi-User Server (MUS) monitors user events in order to synchronize them. For example, once a user moves or modify an object in a 3D world, the MUS transmits the information to the rest of the clients. Clients connect to the MUS from a standalone application or a Web-browser with a VRML plug-in.

It is also possible to join ready-to-use environments for a collaborative virtual reality experience. *Active worlds* [117] is a virtual reality environment where users are represented by avatars and move into 3D worlds created on its own or by other users. They interact with each other using a chat. *The Palace* [118] is a virtual reality world that offers the possibility to change emotional expressions and to dress avatars.

The TixeoSoft commpany provide WorkSpace3D [36], a collaborative solution with audio, video conferencing and a virtual environment. In the virtual space, the user can express behaviours to all of the other users, for exmaple wishes to speak, or want to attract attention. Other communication tools and document sharing tools complete the system (Fig.12). This environment provide a new and interesting way to interact and appears very promising.

Collaborative Browser "Collaborative browsing consists in allowing several users to browse the Web synchronously, in such a way that a set of users follows the browsing activity of a privileged user." [119] cited in [120].

Figure 12: Interface of WorkSpace 3D

Collaborative browsing tools support the synchronization of web browsing between the users. Application sharing could support collaborative browsing. However, this sharing mechanism is high-bandwidth consuming since it is based on the transmission of screen dumps. Browsing of a web page can be summarized by the download of a specific web paged described by its URL. Thus, sharing only the URL is less bandwidth consuming. Moreover, adaptation mechanisms provided by application-sharing systems are limited. Web sites sometimes provide regional adaptation that can be useful to support collaboration, for example sites could be accessed in the French language for French users and in Japanese for Japanese users.

The Platine environment can integrate a collaborative browser CoLab [121] developed in Java. The architecture is composed of a Web Proxy server, responsible for tracking all browsing activity, and a Collaboration Engine, responsible for dynamically defining access rights to Web resources based on policy rules. The collaborative browsing clients are Java applets, synchronized by the server for Web page visualization.

3.2.2 Specificities of Real-Time Multimedia Communications

3.2.2.1 Introduction

Multimedia Communication refers to the use of several different medias to convey information. Fig.13 [122] describes the different media families: symbolic representation, digital representation, and geometry and characteristics representation. Each family has its own characteristics even if it gathers different medias. Stakes of multimedia communication lies in acquisition, transmission and restitution of media combinations by respecting their own constraints.

From a computer science point of view, the first thing that makes the difference between multimedia data and classic computer data (text, binary data...) is the way they are managed. The first ones are handled by streams, whereas text and data are managed by files. Audio and video data are a sequence of pictures or sound samples that follow one another at a constant or irregular rate. This type of data is not incompatible with the idea of filing as files are always used to store video and audio documents. However, treatment of information is done unit by unit (for example pictures by pictures); these data units all together create a stream. A stream can handle text and binary data.

Multimedia content is now common in web-based learning systems; asynchronous systems that provide web pages with video clips, animations. The challenge of synchronous CSCL systems is that content is produced in real time. The following section describes the technical aspects of transport of information and their impact from the user point of view.

3.2.2.2 Transport Protocol

In order to face the constraints of streams and classic computer data, different transport protocols are available. The User Datagram Protocol (UDP) and the Transmission Control Protocol (TCP) are at the core transport protocol of the Internet. TCP creates a connection between two hosts, and this connection can be used to exchange data. TCP guarantees reliable and in order delivery of sender to receiver data. UDP, on the other hand, does not provide reliability and ordering guarantees; UDP datagrams may arrive out of order or missing without notice. As a result UDP is faster and more efficient for lightweight or time-sensitive purposes than TCP.

Stream based applications use UDP as transport protocol while other classic computer medias use TCP: audio, video conferencing are based on UDP and chat, whiteboard, and application sharing are based on TCP. TCP does not fit for high-interactivity communication tools, use of it can multiply by 3 the time of transmission of information. The source application sends information over the network by packets. It waits for the acknoledgement of the receiving application before sending the next part of the information in a new packet. After the acknowlegement is received, the next part of data is sent again. Information that is temporaly close to each other sometimes requires a wait for the acknolwedgment process so it reaches the final destination with a very large time difference. This process forces TCP applications on the receiver side to wait for acknowledgement based on a window. Reliability of the protocol can be reached with several RTT (Round Time Trip), which is too long. The slow start

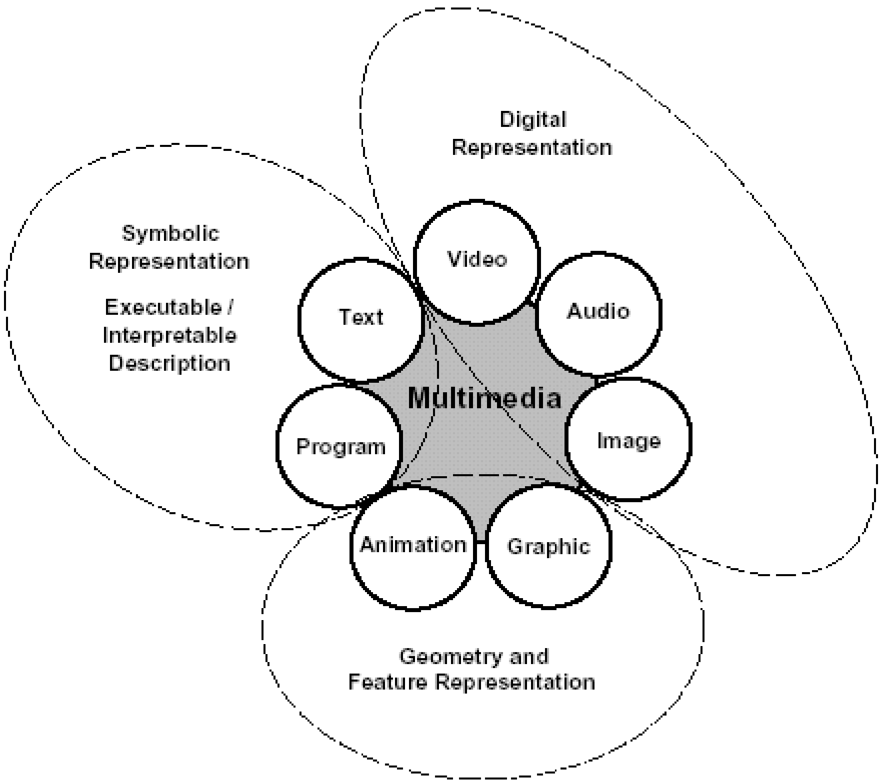

Figure 13: Type of Media

mechanism is set up when packet losses are detected, but video and audio have a constant flow rate that cannot be changed, and that cuase too much delay.

3.2.2.3 Quality of Services (QoS)

This section introduces the parameters of evaluation of a network.

Bandwidth The bandwidth expresses the amount of information that can be sent on a network every second. The bandwidth necessary for the operation of a synchronous CSCL system is the addition of the bandwidth necessary for all users and for all tools. The more users who are involved in an activity, the more bandwidth necessary is. Bandwidth usually determines the reference quality of the system.

Table 2 presents the requirements of different communication tools for a one-way transmission. The requirements for a full duplex communication between two or more users is proportionally multiplied. The main characteristics of multimedia communication is that the amount of bandwidth sent over the network is highly variable. The bandwidth required for a video transmission depends on the picture transmitted characteristics (for exemple background, or users' clothes) and on the movements of the objects between the pictures (still image, moving image). Application sharing can require more or less bandwidth depending on the size of the window shared and the actions within the applications. The figures presented in this table should be seen as indicatory values.

Type of Stream	**Bandwidth required**
Audio, Phone Quality, ulaw Codec	64 kb/s
Audio, Phone Quality, Speex Codec	4 to 42 kb/s
Audio, Cellular Phone Quality, GSM Codec	13 kb/s
CD Audio Quality Stream (Compressed)	100-200 kb/s
Video, QCIF (176x144), 30 fps, H263 Codec	50 to 350 kb/s
Video, CIF (352x288), 30 fps, H263 Codec	200 kb/s to 800 kb/s
Video, CIF, 30 fps, MJPEG Codec, Low Quality	0.6 to 1Mb/s
Video, CIF, 30 fps, MJPEG Codec, High Quality	13 to 19 Mb/s
MPEG-2 Video	Around 2 Mb/s
Video, TV Size, DV Codec	20 to 30 Mb/s
Standard Quality Video (Not Compressed)	140 Mb/s
TV High Definition (Not Compressed)	1.2 Gb/s
TV High Definition (Compressed)	128 Mb/s
Fixed Picture	Minimum
Data Stream	Minimum
Application Sharing	20 to 300 kb/s

Table 2: Bandwidth Requirements for Multimedia Applications

As seen in the table, the amount of bandwidth necessary depends on the quality required and the encoding technique used.

Delay Delay is the average time required to send information between two points. Delay is influenced by the physical distance between the points, the technology used for the transmission of information and the computing time necessary to process information at the local point. In synchronous communication, the delay has an impact on the interactivity of the system [123]. The requirements usually depend on the type and the content of the application [124].

In order to play an instrument together with another person (for example a piano with a violin), the delay should not be higher than 40-50ms. Indeed, music is based on high temporal constraints that are beyond traditional communication. Higher delays prevent synchronization of the instruments and the users cannot play together. Virtual Reality environments or online games are best performed with very low levels of delay (100ms). With higher delay, the coordination of movements with other user's movement is difficult. For a phone conversation, the requirements are often said to be around 250ms [125] and acceptable up to 400ms.

Jitter Jitter represents a variation of delay. If the time necessary to send a packet is comprised between 60ms and 150ms with an average delay of 100ms, the maximum jitter is 50ms.

Distribution of jitter has also an influence on the quality of communications. We can consider a link with an average delay of 100ms and a maximum jitter of 50ms. If 99% of the packets sent would have a delay comprised between 90ms and 110ms, the jitter influence would be less important than if only 50% were comprised between 90 and 110ms. Jitter has an influence on the ordering of the stream. The packets of information are likely to arrive in a different order than the production order over a network with high jitter.

In audio and video streams, jitter causes a loss of information. Indeed, when a packet is delayed over average time, the application waits for the late packet. If the packet did not arrive, it means that either it is very late or that it is lost. After a certain amount of time (depending on buffer size), the application considers that the information hold by the packed is too old and display the stream without the missing information. If the packet is faster than the average time, the average delay is thus reduced and more late packets are ignored. Thus jitter leads to degradations of audio and video quality. The influence of jitter on the quality of the information can be as high as the influence of packet drops [126]. Jitter is balanced at the application level by a buffer. This process is double edged; it prevents the loss of some information but, it increases the delay perceived by users and thus limits interactivity. The amount of buffering has to be chosen carefully.

According to to the work of Schopis and Calyam [127] on H.323 traffic, without any buffering, a level of jitter of 0-20ms is considered good, 20-50ms acceptable and >50ms poor.

Packet Drops and Errors Packet drops or errors reflect the percentage of information lost in the transmission between users. They have different causes according to the technology; this is the reason why the expression "packet drops" and "errors" are different even if they both reflect a loss of information from an application point of view.

Packet drops cause a reduction of frame rate or deformation on the video and reduce the quality of audio. The relationship between packet loss and the worsening of multimedia quality have been demonstrated by several researches [128, 129]. The amount of information lost depends on the size of the packets; the size of the packets depending on codec and protocol used.

According to Jayant and Christensen [130], a voice loss of 20ms often exceeds syllable duration and may cause a loss of informative content. If conversations are composed of only brief exchanges, this loss may be disturbing. Redundancy of information in a speech may cover this loss.

According to Procter et al. [131], losses may impair information uptake and user interest. Users can detect low levels of loss even if they do not rate them as disturbing.

3.2.2.4 QoS Requirements for End Users Communications

Traditional Results

Table 3 summarizes the requirements that are usually specified for communication tools [132].

Compared to the audio and video streams, the requirements of the collaborative tools are not high, except for reliability. The reliability is provided by the use of TCP. Each media has its own specific properties; therefore, the corresponding communication tools have different requirements. The evaluation of the requirements is the subject of discussion. The level of tolerance seems to depend on the users' needs [133].

Methodology of Evaluation There are two main ways to evaluate the quality of communication: objective and subjective. An objective evaluation may compare technical elements such as codec and protocols. This research focuses on the definition of a distance-learning solution from a user point of view. Thus, this section introduces subjective assessment methods.

Different subjective methods have been defined to evaluate the quality of communication; in particular, the International Telecommunication Union (ITU) has developed certain rules to evaluate audio

Application Type	*Bandwidth requirements*	*Delay Tolerance*	*Jitter Tolerance*	*Packet drop Tolerance*
Video H.263	High	$<$ 250ms	$<$ 20ms	$<$ 20%
Audio (compressed, phone quality)	Low	$<$ 250ms	$<$ 20ms	$<$ 10%
Application Sharing	Low	High	High	0%
Chat	Very low	High	High	0%
Whiteboard	Very low	High	High	0%

Table 3: QoS requirements for different multimedia applications

quality [134] and video quality [135]. The MOS (Mean Opinion Score) is the most famous and it defines a scale for the evaluation of audio quality: (Excellent, Good, Fair, Poor, Bad).

Wilson and Sasse [136] have highlighted the ineffectiveness of these methods in evaluating audio and video communication for the Internet.

- "The scales were designed to rate toll-quality audio and high-quality video, whereas MMC [Multi Media Conferencing] audio and video are subject to unique impairments such as packet loss and delay.
- The scales are mainly concerned with determining if a particular degradation in quality can be detected, whereas with MMC it is more important to determine if the quality is *good enough* for the task.
- The short time duration of the test material used means that there is not the opportunity for the viewer/listener to experience all the degradations that impact upon MMC. Subsequently, a dynamic rating scale for video is now recommended by the ITU [135] in order to account for changes in network conditions.
- The vocabulary on the scales (Excellent, Good, Fair, Poor, Bad) is unrepresentative of MMC quality and the scales are not interval in many languages, therefore scores obtained can be misleading.
- Finally, the scales treat quality as a one-dimension phenomenon. This is questionable as there are many factors that are recognized to contribute to users perception of audio [137] and video quality." [136]

Unlabelled scales can be used to evaluate quality of the media; for exmaple (1) bad – excellent (4). In another study [133], Watson and Sasse compared the two scales (MOS and unlabelled) and they appeared to follow the same trend.

Context Related Evaluations "There has been a surge in literature addressing Quality of Services (QoS) issues, but the emphasis has been on the quality of services at the network level rather than from the end-user's point of view. Since it is the end user who will determine whether a service or application is a success, it is vital to carry out subjective assessment of the multimedia quality delivered through these." [138].

Fujiki et al. [139, 140] studied the influence of packet loss in videoconference lectures for distance learning. The videoconferencing communication relied on high bandwidth MPEG video. Very small loses of video (2 to 4%) appeared as disturbing. MPEG is ill suited for transmission over best-effort packet networks without any Quality of Service (QoS) policies like the Internet [141].

Lamont evaluated the end user satisfaction with a low-cost motion video. These experiments were performed to evaluate if end-users are satisfied with a lower quality of video, which means lower production cost. Videos were small (160x120) and captured with cheap video solution. "*End-users appear to be tolerant of lower quality motion video, even though they recognize its shortcomings*" [142]. The user clearly answered that the video could be used for good effect in educational software even if they rated the quality as poor. The QoS requirements for sending a small video over a network are low.

3.2.2.5 Multimedia Streams

Synchronization IP networks are packet switched networks. The use of UDP over IP does not provide ordering guarantee. Two packets with a same origin may use different path to reach the destination. The path is determined dynamically and depends on the traffic of the network.

Such situation introduces changes in the order of the packets of a stream, different delays for each packet of the stream. It leads to temporal constraints when streams have to be reproduced at the remote location. Those constraints are usually called multimedia synchronization constraints. The main issues of interest are detailed here.

- Intra-stream Synchronization Intra-stream synchronization specifies temporal constraints existing between different information units in the same stream. It consists of being able to play information units in the order at the rate they are produced, and to free them from the jitter acquired through the network. It keeps the rhythm of the stream.
- Inter-stream Synchronization Inter-stream synchronization specifies temporal constraints that exist between different streams. It aims to make playing of the streams coherent by suppressing the differences due to the separated management of stream in the network and the system. In a videoconference, it represents the coordination of video and sound or the "lip synchronization" issue.

RTP and RTCP Real Time Protocol (RTP), described in RFC 1889, is a protocol dedicated to real-time transmission of audio, video and data streams. RTP was developed to solve synchronization and congestion problems of streams over the Internet. RTP is deployed on IP networks and use UDP protocol to send packets. However, it is considered as a level 4 protocol. RTP uses the multiplexing and checksum services of UDP and offers itself several services:

RTP put a time stamp on the unit of information of the stream (for example frame, or sound sample). This temporal information allows the evaluation of the average delay of the unit. Then, this temporal information is used to manage the influence of jitter in a network. Time stamps are used to reorganize the units of information in the order they were produced and to play them with the right rhythm (intra stream synchronization).

In case a unit of information arrives with a high jitter, time stamps allow the application to choose whether the information carried is too old or not. In the first case, the unit of information is discarded because the corresponding part of the stream has already been displayed. In the second case, the unit of information is reintroduced into the stream at the correct temporal positions.

When two streams are transmitted (audio and video, for example), time stamps allow synchronization between those two streams (inter stream synchronization). In a general way, the time stamp is initialized by the source and incremented when units of information are sent through the network.

RTP provides sequence numeration. Time stamps are attached to units of information. However units of information must sometimes be separated into several packets when sent over the network. UDP does not provide sequence numeration and units of information require this service to be rearranged properly.

RTP also supports the source and content identification, more precisely the type of information transmitted and the codec used.

RTP works over UDP. However, UDP does not provide any congestion detection and management services. Congestion and reliability problems are reported to the application layer. RTP is associated with RTCP (Real-Time Control Protocol) that sends periodic reports on the received information quality to the sender. RTCP messages can be of the following type:

- Messages from Receiver to Broadcaster: Messages from receiver to broadcaster give a feedback on quality of broadcasted information.

- Messages from Broadcaster to Receiver: Messages from broadcaster to receiver support stream synchronizations.
- End Session Messages

RTP is used in the H.323 and SIP protocols. RTP is also used for the Real-Time Streaming Protocol (RTSP). RTSP [143] was developed by IETF and published in 1998 as RFC 2326. RTSP is a protocol used for streaming systems. It allows a client to remotely control a streaming server and gives them time-based access to files.

3.2.2.6 Multi User Strategy

When information needs to be sent not only to one user but to several users, different strategies can be developed. Most systems support distribution with specific servers; this is the case with the H.323 set of protocols for videoconference that use MCU. These solutions often lack scalability. Some networks provide multicast services in order to deliver information to a group of destinations by using the most efficient strategy. Some IP networks offer IP multicast that can be used for audio and video conferencing. Internet2 [144] is a non-profit consortium that developed the Abilene Network. This network deploys advanced network applications and technologies, among them IP multicast. IP multicast is used in this network to support videoconferencing.

The Mbone is an experimental public network that supports IP multicast. The VIC and RAT tools were designed for multipoint videoconferencing on this network. No specific servers support the communications. Now, the VLC environment is used for conferences over the Mbone.

Many routers do not support multicast, and multicast service is not always available on the public Internet. Thus, multipoint videoconferences cannot always be performed with this distribution strategy.

3.2.3 Networks for Transporting Information

The physical network used for information transmission has a direct influence on the quality of service of the communication. Physical networks are also associated with physical advantages, which can be of as much value from a user's point of view as the quality of service of the network.

The choice of the network access depends on the requirements of the users. However, this choice has a large impact on the quality of communication, so when collaboration scenarios are defined, the type of access should be taken into account to prevent communication problems. The relations between the different layers of the OSI model and the collaboration scenarios are rich and complex. The study of synchronous CSCL from a single point of view misses these relations.

3.2.3.1 Private and Public Network

Videoconferences were first performed over phone networks. Integrated Services Digital Network (ISDN) is a connected end-to-end digital data transport system developed for phone networks. This solution provides a QoS guarantee but it is very costly. The price of communicating depends on the distance and on its duration. Conferences between different countries are therefore very expensive. Moreover, in order to get sufficient bandwidth, several ISDN lines are required, multiplying the cost of the communication by the number of lines. One line guarantees a bandwidth of 64 kb/s in full duplex. Nowadays, such systems are still available but the use of them is decreasing.

The development of the Internet changed the structure of the whole telecommunication industry. The packet switched networks ("computer networks" used in the transport of data) grew very fast and were able to transport more data than traditional circuit switched networks like the Public Switched Telephone Network (PSTN) used for voice. It became therfore more convenient to use data networks to transport voice than the opposite. This technique has several advantages. Use of IP network allows paying only the access to the network. This was the basic idea that lead to the development of Voice over Data (VoD) solutions (Voice over IP VoIP being its most famous application). Nowadays, most of the videoconferences are supported by packet switched networks.

Some companies (e.g. Webex) provide videoconferencing solutions with dedicated lines for the communication. In this case, the quality of service is guaranteed and the communication is of very good quality. These solutions are, however, expensive. Private and Public institutions are usually interested in paying for the guarantee of the communication quality. However, individual users are often more reluctant to pay.

Over the public Internet, it is impossible to predict the quality of service that will be available when using it. The quality of service depends on the traffic generated by the other users. Problems are therefore often correlated: when the load of the network rises, routers have to treat more and more packets, which results in greater delay and jitter which leads also to packet drops. Without a predetermined QoS routing policy in a network, the higher the bandwidth required for a videoconference, the more prone it is to network perturbation.

3.2.3.2 Network Access

Communication over the public Internet is constituted of two-parts: the communication provided by the Internet Service Providers (ISP) and the communication within public Internet itself. The communication over the public Internet cannot be specified in terms of quality of service. Only the network access and the services provided by the ISP can usually be known.

Analog Modem used over telephone lines provides a limited bandwidth. They can be used for audio conferences, chat, and whiteboard applications but are ill suited for video communication. ADSL is now the most common and popular Internet access in many developed countries. ADSL provides an asymmetric access, which means that the user is able to receive more information than it can send. This type of access is sufficient for a client but is not appropriate for host servers of synchronous communication tools.

Internet services providers have started to develop Wifi access offers. This type of access provides a ubiquitous solution to support of synchronous communication. These technologies are interesting but present some limitations as well. Buildings, concrete walls, distance and a large number of users reduce the quality of the communication. The QoS of wireless networks also has an impact on multimedia communications [145].

Wireless access is also available over cellular phone networks. In the same way as ISDN lines use PSTN to send data, this access allows data to be sent over cellular phone networks. If this access is developed, it is likely that wireless data networks will transmit more data than wireless voice networks in the future.

One of the issues of wireless access is the mobility of users from a technical point of view. When accessing a network by wireless, the user connects to a central base. If the user moves, the base access point may change. This change may interrupt the communication. In a synchronous CSCL scenario, users should be supported appropriately.

Satellites provide access to Internet in locations where all the other kinds of networks are not available. The satellite link can be of two types Low Earth Orbit (LEO) and Geostationary Earth Orbit (GEO). In the case of GEO satellites, the propagation delay introduced is about 250ms with a limited jitter. LEO satellites introduce a delay from 5 to 60ms with an noticeable jitter and are not yet deployed. The error rate of satellites is usually very low but can be increased by stormy weather.

3.3 Conclusion

The definition of an environment that can support many types of communication requires knowledge in several fields. In order to provide the best quality of communication from a user point of view, it is necessary to take into account the usage of computing devices by the user, the structure of the communication, and the type of information exchanged. From these elements, it is possible to adapt the network access, the transport of information and the architecture of the environment. It is therefore necessary to develop a relationship between the educational goals of an activity and its technical support. This research attempts to identify, charaterize and support this relationship.

Chapter 4
Identification of the Relationship between Collaboration and Networks

The previous chapters described the contribution of the different fields to synchronous distance learning. This chapter presents experiments of synchronous distance-learning that were realized at the University of Tokushima. These experiments were performed to identify and characterize the relationship between collaboration and network in synchronous CSCL activities. This chapter is separated in three sections. The first section is a general section describing the goals and the methodology of those experiments. The second section presents the details and the results of the multipoint experiment. The third section describes the point-to-point experiment.

4.1 Presentation of the Experiments

4.1.1 Introduction

In order to respect independence of learners and provide an easy access to distance learning solutions, the use of the public Internet appeared necessary. The use of dedicated private communication lines would prevent many users from being able to access synchronous CSCL systems. Indeed, financial difficulties or unavailability of such services at their location are characteristics of the distance learners as identified in the introduction chapter; i.e. rural community. A majority of users have already access to the Internet.

Experiments of IP videoconferencing between two Universities have already been performed [146]. These solutions are available for institutions and based on specific equipment. It would be interesting to evaluate the use of IP videoconferencing solutions for a group of distributed users linked only by Internet. The scheme of interaction between the users would be as seen in Fig.14. The professor would be located at the University while the students would join an activity alone or in small groups at different locations; e.g. home, university, office. Another professor or expert could also contribute to the activity. All users would collaborate within a synchronous collaborative environment. These experiments evaluate the feasibility of such an approach.

The potentially large number of users and the use of the Internet as a communication medium lead us to choose to perform activities within a low bandwidth videoconference-based environment. This choice may appear as a handicap from a quality point of view. Indeed, the quality of videoconferencing on the Internet is not guaranteed and is generally poorer than the quality of high bandwidth systems over specific networks. It is a common belief that the quality of videoconference-based lectures is equal to the quality of the video and audio elements. As other research has demonstrated the quality of audio and video communications can be poor on the Internet, it is believed that videoconference-based lectures on the Internet would be of equally poor quality. Consequently, reasoning by syllogism is often the source of errors and we must consider that a lecture is more than a simple videoconference. It would be a mistake to think that videoconference-based communication systems only have to recreate the distant environment as perfectly as possible. Tools such as chat, application sharing and whiteboards offer different interactive modes and videoconferencing is only one tool of the collaborative work environment. If the influence of a network on videoconferencing is strong, other collaborative tools might not be as

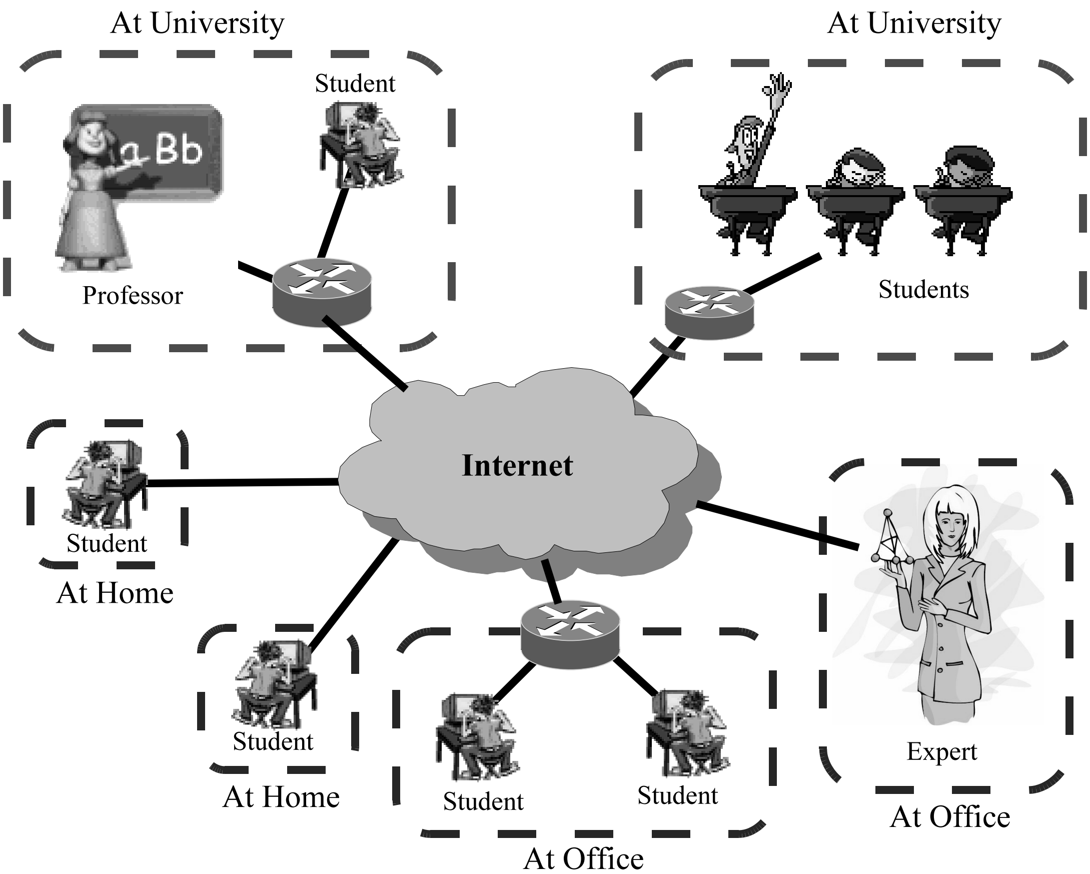

Figure 14: Students and teachers in the distance-learning environment

affected Fig.15.

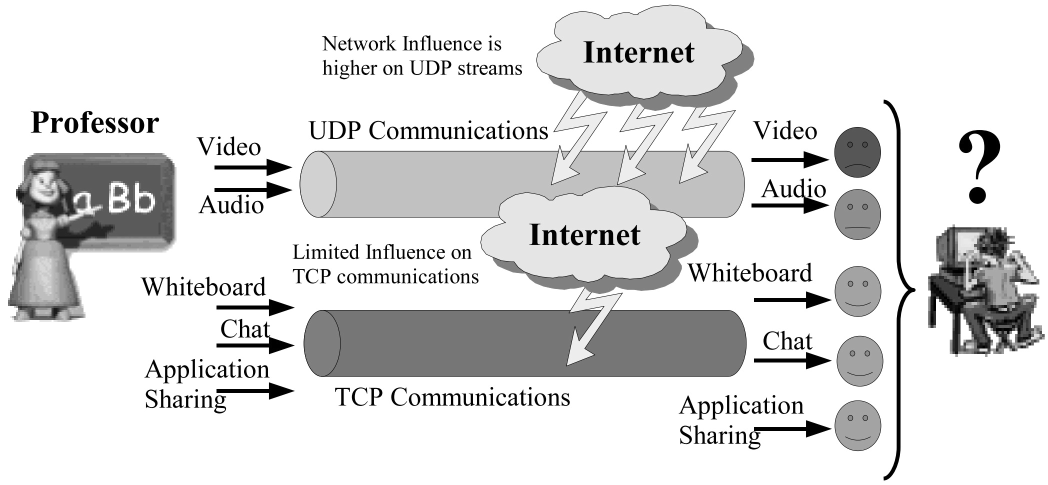

Figure 15: Interaction model for distance learning with collaborative work environments

According to Mullin et al. [147], the tolerance levels are greatly dependent upon users' needs. Consequently, it is necessary to evaluate not only videoconference quality but also the learners' feelings towards a whole learning scenario. Published research about the influence of the network on communication is limited to the study of audio and video communications without any particular context. To our knowledge, no evaluation that takes into account simultaneously audio, video and other collaborative tools have been studied. Communication quality, collaboration quality and learning efficiency correspond to three points of view for the evaluation of the system. These experiments focus on the evaluation of the communication and collaboration quality. The evaluation of the learning efficiency has not yet been performed. It seemed interesting to compare these different points of view in order to understand the relationship between network and collaboration strategies. The identification and the characterization of this relationship is a first step to manage the influence of network perturbations and to provide better end-user experiences.

4.1.2 Learning Scenario

4.1.2.1 Type of Activity

This experiment relied on a lecture-type scenario. Lecture is a simple and well-known activity. Thus, the type of the activity did not constitute a new parameter for the evaluation of the experiments. This activity was also chosen, as it is the most common use of a web-based learning environment over the Internet and in traditional education. The development of another types of activity is treated in the chapter 6. These experiments address communication and collaboration issues as one of many facets of a lecture. The social or learning interpretations of interactivity are only addressed indirectly in these experiments.

In contemporary experiments, videoconferencing is sometimes used as a way to communicate with distant sites or as an opportunity to generate interaction in the activity. In those cases, a professor supports the collaboration; the classroom is the frame for sharing content and videoconferencing completes face-to-face communication. In the experiments conducted at Tokushima University, synchronous communications was defined as the only communication channel. Synchronous environments are tested as a fully autonomous solution for the production of a lecture-style presentation.

4.1.2.2 Communication Strategy

The different means of collaboration and communication available in a traditional lecture were recreated using the video and audio conferencing, the chat, the whiteboard and the application sharing.

The video and audio were used for informal communication. The chat was used to communicate and to ask questions to the professor. Video is sometimes the vector used to transmit written notes or slides. In our strategy, because of the low resolution of the video, the slides and written documents were shared with the whiteboard or the application sharing (sharing Microsoft PowerPoint). This choice provided more interactivity than a simple video showing a real blackboard. The professor and the students were able to add notes and to write comments on the whiteboard. The application sharing allows a manipulation and the use of a pointer to the slides (the mouse cursor). The quality in the reproduction of the document is also perfect as the members share exactly the same visual information.

The professor had a central role in the lecture and his video (head and shoulders) and audio speech were transmitted to all the end users. Furthermore, he was able to see and to listen to all the participants of the lecture. Students were only able to see the "professor" video but not the video of the other student's participants. This limitation was introduced to simulate an optimized use of network resources; communication between the students was not considered as a main channel of collaboration for a lecture activity. To provide interactions between them, the students were able to communicate with a chat tool. If they wanted to ask a question to the professor, they were able either to talk to him directly (using the videoconferencing tool) or to send it using the chat tool.

There were no students in the same room with the professor in order to put them on an equal basis. When a professor has an immediate face-to-face group of students and distance learners, he is likely to favor the direct interaction with the face-to-face group and the distant learners would feel left out [65](see section 2.2.1.2).

This communication strategy was developed for a lecture-type activity. Other scenario would certainly require different strategies.

4.1.3 Experimental Protocol

4.1.3.1 Presentation

Despite our wishes to realize an experiment where all students would have been independent and would have had one computer, the lectures involved only groups of students. We could have managed to get more computers and to provide one for every student but we realized that the environment was not so easy to use without any prior explanations. Students might have had some difficulties to get connected. Videoconferencing systems provide good interaction possibilities but the connection to a session is not something intuitive for a student. This issue is treated and explained in the presentation of the results of the multiple site experiments (See Section 4.2.2). Consequently, the session were configured and the clients were connected before the beginning of the lectures. The system was ready to be used when the professor and the students joined the experiment.

The population of subject tested was divided into three groups. Four lessons were delivered to each of the three groups of students.

4.1.3.2 Technical Elements

The tests were performed with the help of a technical assistant for each group; his role was only to input the message in the chat if requested by students. The professor introduced assistants from his remote site and they did not intervene at all except when requested by the students.

The slides, the chat content and the professor's video elements were displayed on a screen by a video projector so as to be fully accessible to all the students. The video of the students was transmitted to the professor using an inexpensive web camera, i.e. Logitech Quickcam Pro 4000. The size of the video was CIF size (176x144) and the encoding was H.263_RTP. The video of the professor was captured with a same model web camera and the size of the video was the same. The figure 16 presents the setting of the room; the web camera can be seen on the top of the screen.

During the lectures, loudspeakers broadcasted the voice of the professor in each room. Students spoke to him if they wished to ask a question or when the professor engaged them in conversation. The microphone of the web camera was used on the students' sites to capture the sound. The sound was sampled at 8000 kHz, in 8 bits, mono channel and encoded with the u-law_RTP codec. Silence suppression was not activated so that the professor could hear the background noise of the groups; it gave him the "atmosphere" of the class. The professor used a headset with a microphone and the quality of the sound transmitted was the same as the one from the students to the professor. The professor was sitting in front of his computer and was directing his lecture in a very relaxing way (Fig.17).

In terms of bandwidth, such settings generate streams of 150Kb/s to 180kbi/s (one way) in a perturbation free environment. It means that such system can be used over basic ADSL connection. With different parameters, the system could also be used on slower Internet access.

Figure 16: Settings of the Classroom for the group of students

4.1.3.3 Method for the Analysis of the Results

At the end of each lesson, a questionnaire was submitted to the students to get their feedback. In the multipoint experiment, a labeled scale was used whereas an unlabelled scale was used in the two points experiments. Students had to score different elements of the lecture; e.g. audio, video quality, whiteboard. delay. They were also able to give free comments.

For the presentation of the results, Question 1 is designated as "Q1" and the average of the answers as "A". There was N possible answers for the questions. The most negative answer has a value of 0 and the most positive answer has a value of N-1. The average is represented in a scale from 0 to (N-1); e.g. Q2, A=3/4. It allows evaluating the answer in a scale starting from 0. An average higher, respectively lower, than the median (i.e. "(N-1)/2") shows a positive, respectively negative, result to the question. For example,

"Can you evaluate the quality of the audio communication?"

(1) "I could not hear anyhting"

(10) "I heard as if we were in the same room"

"Less than (5): the quality is not sufficient for learning"

The scale for interpretation is from 0 to 9 and the median is 4.5.

In human computer interaction experiments, results can be subjective. When the population tested is limited, the answers average values can be the subject of discussion. Indeed, the population is not large enough to guarantee a good representativeness of the target population. The change of one parameter between two experiments brings more reliable results even for small population. It is thus interesting to evaluate the difference of answers between two lectures.

For a given question, the difference of resultant averages brings a first indication. However, this difference can be caused by a perturbation due to external and uncontrolled parameters (”experimental noise”). Thus, to determine a real difference, the statistical tool Ttest is used. Ttest evaluate the statistical distribution of the answers to prove a difference. Ttest results of less than 0.05 prove a difference. Lower scores prove an even more significant difference; 0.05, 0.01 and 0.001 (also quoted as .05, .01 and .001) are reference values to express the reliability of the result. Ttests are calculated between two populations that have answered the same question for different levels of perturbations.

The questionnaire was modified a bit between the two experiments. The questionnaire was written in Japanese, a traduction of the two versions is included in appendix B and C.

Figure 17: Professor directing the lecture

4.1.3.4 Distribution of Parameters

For each group, the first lecture was performed without introducing network problems. Then, the influence of one of the three parameters (delay, jitter, packet drops) was studied. For each parameter, 3 levels were selected: Small, Medium and Large. The choice of only three levels of perturbations does not allow a precise identification of the network influence but it is sufficient for a general evaluation. A more precise evaluation would have required a larger number of experiments. The goal of these experiments was not to develop a precise scale for the influence of the network parameters.

In the Internet, the influence of the different parameters occurs simultaneously but they were separated in this experiment because each parameter has a different impact. From a user point of view, it can be grouped into two main elements: delay which influences interactivity, and jitter and packet drops which have an impact on communication quality. The impact of packet drops cannot be avoided whereas jitter can be compensated for by buffering. However, buffering adds delay. Thus the buffering solution would increase quality but reduce interactivity. It appears important to determine the level of quality and interactivity required by end-users and also to provide an answer to the specific case of jitter; i.e., interactivity versus quality, which one should be favored?

The lecture content, time of day and composition of student groups are external parameters that have an influence on experimental results. To avoid these influences, parameters were allocated according to the Latin square distribution [148] represented in Tab.4. This distribution is used in experimental design for behavioral sciences. It prevents correlations between the influences of "Group number" (i.e. population of the group) or "Lesson number" (i.e. lesson content) and the parameters studied (nature of the network problem and intensity of the network problem) and was, therefore, a guarantee for higher quality and more realistic results.

The perturbations were bidirectional. They were simulated from the professor to one group of student and from the group of student to the professor.

	Group 1	*Group 2*	*Group 3*
Lesson 1	Normal	Normal	Normal
Lesson 2	(Delay, L)	(Jitter, M)	(Packet drop, S)
Lesson 3	(Packet drop, M)	(Delay, S)	(Jitter, L)
Lesson 4	(Jitter, S)	(Packet drop, L)	(Delay, M)

Table 4: Latin Square Distribution for Network Parameters

4.1.3.5 Network Parameters

The parameter values are presented in Tab.5. The values selected are based first upon values presented in the literature (see section 3.2.2.4 and Tab.3), second upon results of some short tests completed by a small sample of people and third upon measurements realized between Tokushima University and other Universities around the world (Tab.6). These tests were performed on a Monday in June 2003 between 14:00 and 16:00 Japan Standard Time. A range of countries were selected and, a variety of universities within each country. In technical terms, *"ping"* was used to send 100 packets from Tokushima University. Such results can give us an idea of the variety of quality of intercommunication that can be encountered on the Internet, from country to country.

Most of the delay values collected in Tab.6 did not appear compatible with the one proposed for an acceptable and meaningful videoconference. They indicated that videoconference-based learning over the Internet might have meaning only in a limited geographical range. Such restriction would reduce interest in this distance learning approach. According to the short tests, we supposed that lectures were less sensitive to delay than the videoconference. Consequently, we chose to test higher values of delay in order to evaluate the feasibility of the approach for distant locations.

The small level of jitter corresponds to the one quoted in the previous section. The maximum values of jitter may appear high but they correspond to values that can be commonly encountered on the Internet. Even if higher values are rare, their effect on communication might be important. If, for example, a lecture is disturbed for a few minutes only by higher jitter, it is important to evaluate the feelings of the student during these few minutes.

The amount of packet drops simulated can be compared to that found in other literature [138, 126].

4.1.4 Network Simulation

In order to evaluate precisely the influence of the network perturbations, experiments were realized on a private network isolated from external traffic. The cables, hub and routers were private ones used

	Small	*Medium*	*Large*
Delay (ms)	500	1000	1500
Jitter (ms) [delay in ms]	10 [10]	150 [150]	300 [300]
Packet drop (%)	5	17.5	30

Table 5: Network Parameter Values

Country (URL) & Local Time	*Delay [ms]*	*Jitter [ms]*	*Error [%]*
South Korea (www.snu.ac.kr) 14:00	30	9	0
France (www.insa-tlse.fr) 06:00	326	20	0
Australia (www.unimelb.edu.au) 15:00	463	50	0
Thailand (www.tu.ac.th) 12:00	874	500	12
Indonesia (www.ut.ac.id) 12:00	964	310	6

Table 6: Network quality test with different Universities

only for the purpose of the experiments. The local network created in this way was not linked to any other network. This is a condition to avoid the influences of the local traffic of the University.

Network perturbations were simulated by the "NIST Net" software [149]. NIST Net is free software developed by the National Institute of Standard and Technologies (NIST)[150]. "In use, the tool allows an inexpensive PC-based router to emulate numerous complex performance scenarios, including: tunable packet delay distributions, congestion and background loss, bandwidth limitation, and packet reordering / duplication. The X interface [see Fig.18] allows the user to select and monitor specific traffic streams passing through the router and to apply selected performance "effects" to the IP packets of the stream." [149]. The packet loss distribution and the jitter distribution of the NIST Net software are designed to reflect distributions that can be encountered on the Internet. More details about the mathematical models of the distribution are available online in the FAQ of the website.

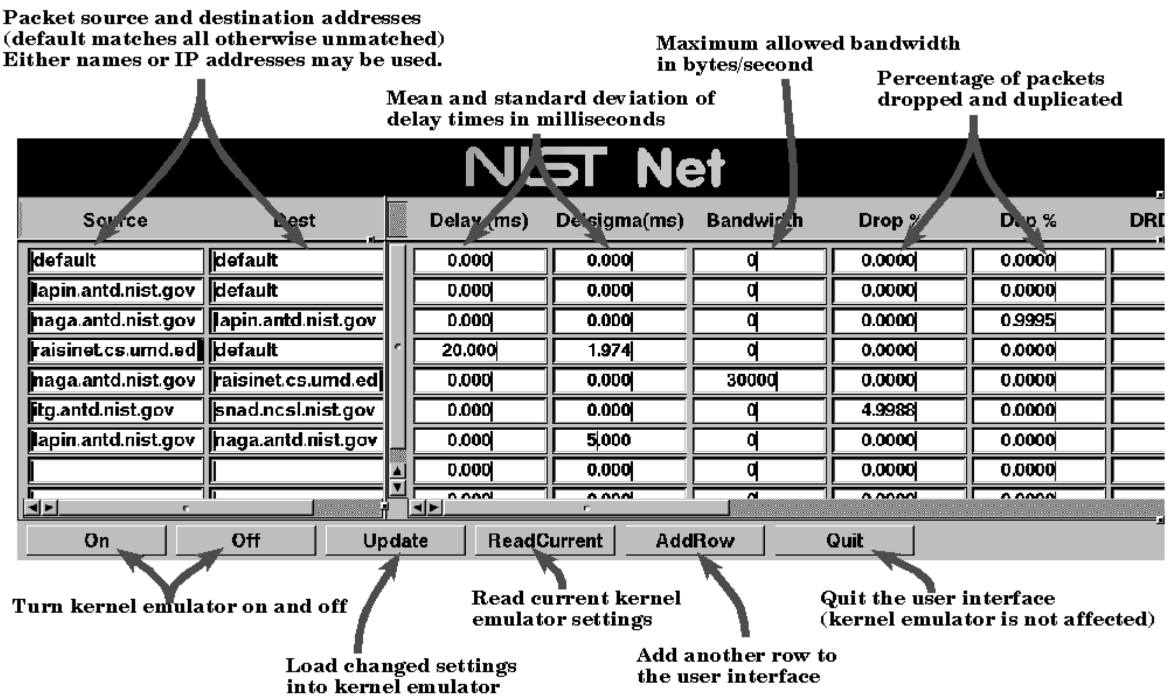

Figure 18: NistNet Interface

In our experiments, the NIST Net software was installed on a Linux RedHat 9.0 Pentium III processor cadenced at 550MHz, with 256MB of RAM and 10/100Mbits Ethernet cards. The router handled easily the traffic generated for the experiment.

4.2 The Multiple site Experiment: Evaluation of a Distance Learning Solution

In the Multiple site experiment, all users took part in the lectures at the same time.

4.2.1 Presentation of the Experiment

4.2.1.1 Protocol Specificities

In this experiment, the test population was constituted of a group of 26 undergraduate students (3^{rd} year) in the department of Information Sciences at the Faculty of Engineering of the University of Tokushima. Groups A and B were constituted of 9 students and group C of 8 students.

They attended the lecture as part of their regular curriculum. The lectures were part of the module on discrete mathematics and graph theory. The length of the lecture was reduced. Each group of students attended four 40 minutes long lectures.

In these lectures, the lesson content (i.e. slides) was shared with the whiteboard. The application sharing was not used.

The questionnaire of this experiment can be found in appendix B.

4.2.1.2 Software Solution: Platine Environment

In order to study the influence of the network, a solution that can be implemented using local servers was necessary. Commercial products were avoided. They can provide nice interface and good communication quality, it is not possible to modify and improve them in a later time. The LAAS-CNRS had developed the Platine Environmnent in version 1.0 and they were interested in testing it for real learning activities and not only test laboratories. Platine provided all the tools required for the learning scenario and was thus selected to perform the multiple site experiments.

This environment allows a multipoint usage, which is still rare in freely available products. As this environment has already been cited and presented in the state of the art, this section introduces just the version that was used and describes briefly the functional architecture of this software. The version used for this experiment was the version available in 2003. The environment has evolved since our first use. Latest developments are introduced in the next chapter (Chapt.5).

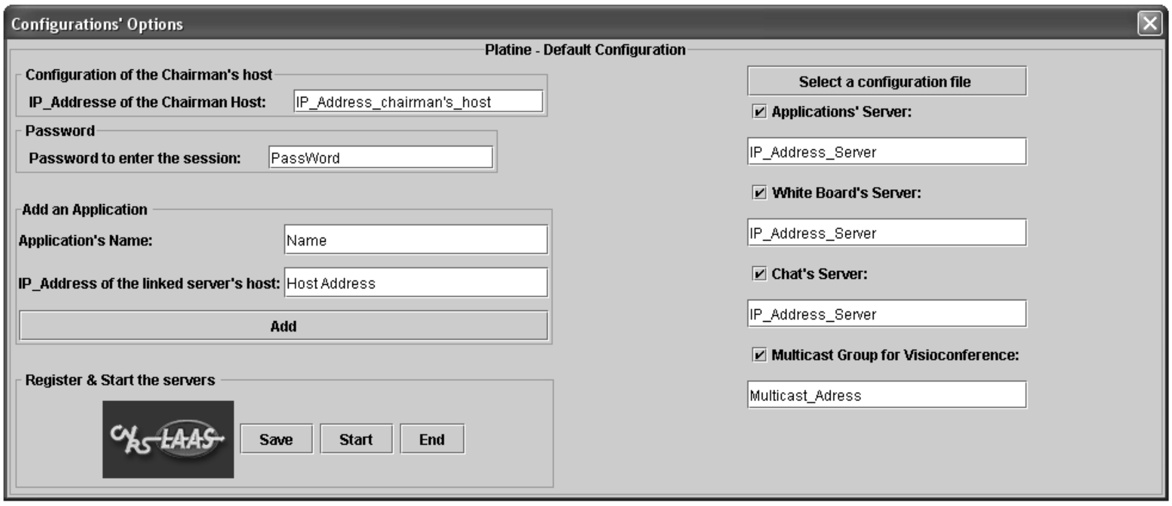

Figure 19: Configuration Tool for a session Platine V1.0

The Platine environment provided the functionalities requested for the learning scenario: video and audio conferencing, chat, whiteboard and application sharing. The Platine Tool also provided an administrative tool for creating and configuring a synchronous session (Fig.19). The configuration of a session includes the definition of several parameters, including:

- Organization parameters: the password required for registering the session, the collaboration service that need to be used during the session. . .

- Technical parameters: the IP address of the session configuration server, the IP address of the collaborative tools servers, the multicast address for audio and video conferencing...

This session profile was defined before the beginning of the session and it eased the start of the environment. The person who defined a session profile and the one who starts the session can be different. In the specific case of the lecture, this tool allows a technician to prepare the lecture for the professor. Once prepared, the session can be started easily and the professor can focus on teaching without having to worry about technical details.

The Platine environment V1.0 also provided a tool to control the display and the rights of the users over windows (see section 2.2.3.4). This tools was not used because of technical incompatibilities, at the time of the experiment, with the Windows XP.

The functional architecture of the Platine environment is presented in Fig.20. The administrator created and configured a session. The Platine tools servers and the session server are started. The users of the Platine environment start the client software on their local PC. Then they enter the IP address of the session server and the password of the session. The client program connects to the session server and retrieves the profile of the session. Then it connects to the Platine tools servers and the communication tools are started.

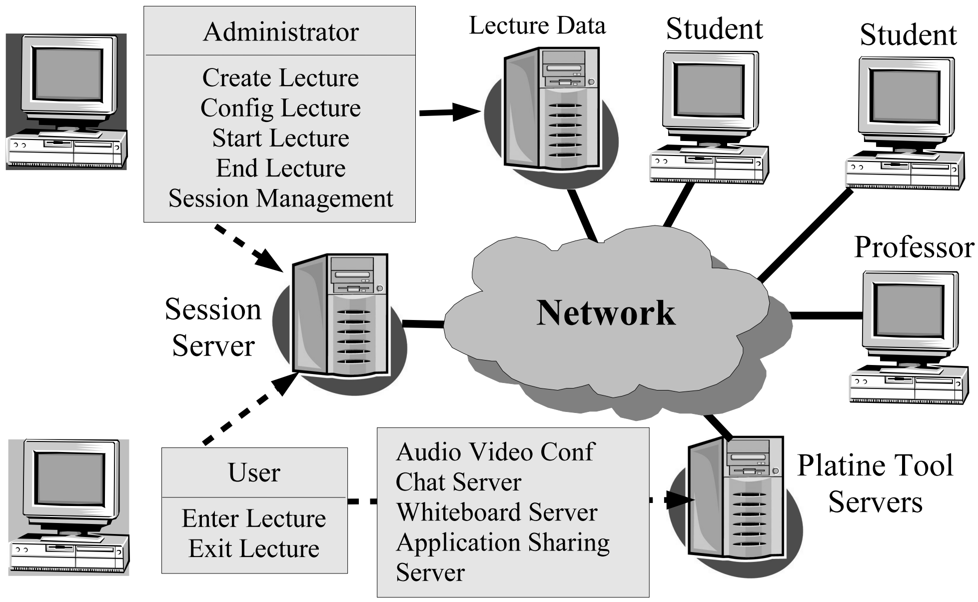

Figure 20: Functional architecture

For multipart videoconferencing, the Platine software relies on the multicast service of the network. The multicast service is not available on all networks. Thus, the Platine environment provide gateways that allow the users to link "multicast islands" (isolated multicast networks that are not linked by networks supporting multicast). The gateways read multicast stream and transmit them to a distant location. On the distant location, a single computer read the unicast stream or another gateway receives unicast streams and broadcast them in multicast format to the local network.

4.2.1.3 Communication Architecture

The Architecture of the experiment is presented in figure 21. On the upper part of the figure, the client PC of the professor, the Platine session and tools servers (chat and whiteboard) and the multicast gateways were installed. The video of the professor was sent with the multicast protocol on this network. The default gateway for all computers was the local interface of the central router. In an operational implementation, this network would be the university network.

In the lower part of the figure 21, the PCs of each group of students were installed. Each group was on an independent network. Group A, B and C were connected to the central router on separate Interfaces. The clients of the students were connected to the Platine servers through the central router.

The central router hosts the NISTNET emulation software as presented in section 4.1.4. In order to simulate network perturbations differently according to the group of students, the central router did not forward the multicast streams. Indeed, usual multicast does not allow differentiating the destination of the stream. Multicast also introduces correlation in the influence of network perturbations. The video and audio streams of the professor were captured by the multicast gateways in the "upper" network. Then, the video and audio streams were sent with unicast to each group of students. The unicast streams were identified in the central router and the network perturbations were simulated according to the rules defined in the introduction (see Tab.4 and Tab.5). The video and audio streams of the students were sent by unicast to the professor.

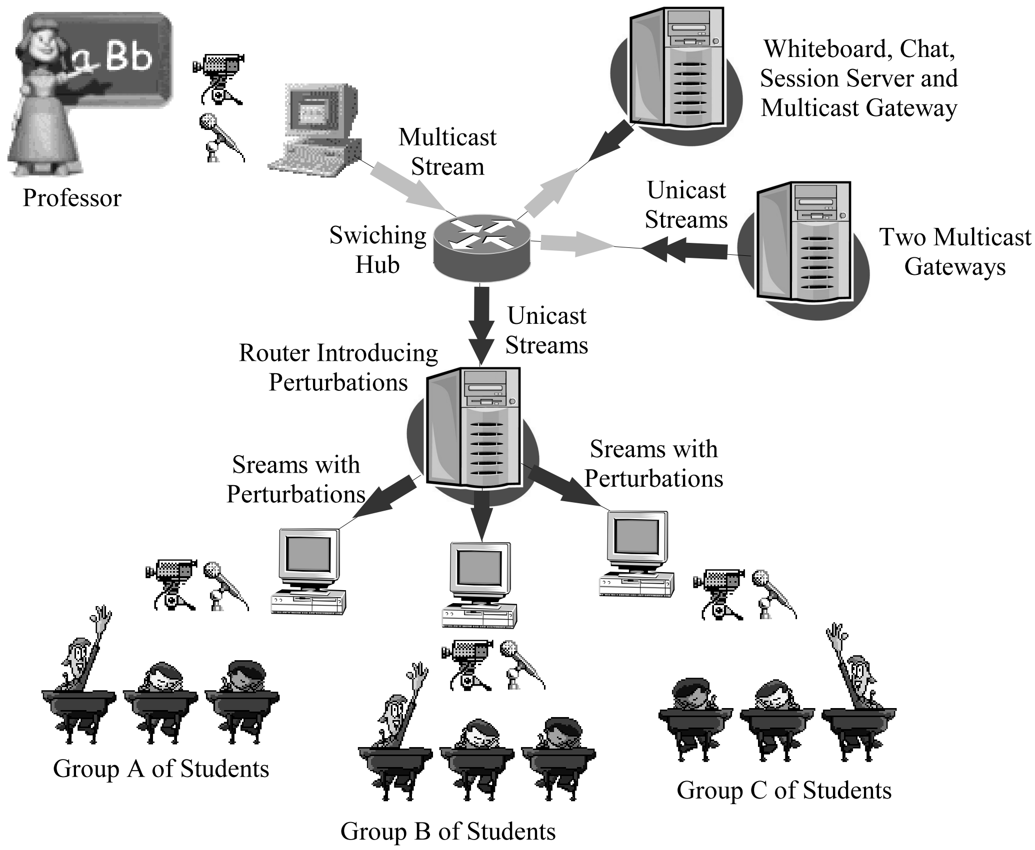

Figure 21: Network Architecture for the Multipoint Experiment

The interface of the professor in a pre test lecture is presented in Fig.22. The professor was able to see the video of the three groups of students (in the bottom). He also displayed the whiteboard and the chat. The picture shows annotations over the slide of the whiteboard. The interface of the student was similar to the one of the professor except that only one video was displayed (it was displayed in the right hand corner).

4.2.1.4 Technical Specifications

The computer used for this experiments were inexpensive computers.

- Students: For group A and B, Pentium IV 2.40 GHz, 512 Mo RAM, Ethernet 100Mbs full duplex. For group C, Pentium IV 2.8 GHz, 1 Go RAM, Ethernet 100Mbs full duplex. Windows XP Pro Japanese Version. Java2 SDK 1.4.1_02 and Java Media Framework 2.1.1e.

- Professor: Pentium IV 2.53 GHz, 512 Mo RAM, Ethernet 100Mbs full duplex. Windows XP Pro English Version. Java2 SDK 1.4.1_02 and Java Media Framework 2.1.1e.
- Platine Servers and 1st Multicast Gateway: Pentium III 500MHz, 256 Mo RAM, Ethernet 100Mbs full duplex. Windows XP Pro English Version. Java2 SDK 1.4.1_02 and Java Media Framework 2.1.1e.
- 2nd and 3rd Multicast Gateways: Pentium III 1 GHz, 256 RAM, Ethernet 100Mbs full duplex. Windows 2000 SP3 Japanese Version. Java2 SDK 1.4.1_02 and Java Media Framework 2.1.1e.

The video and audio capture solution are described in the technical elements presentation of the first section of this chapter (see section 4.1.3.2).

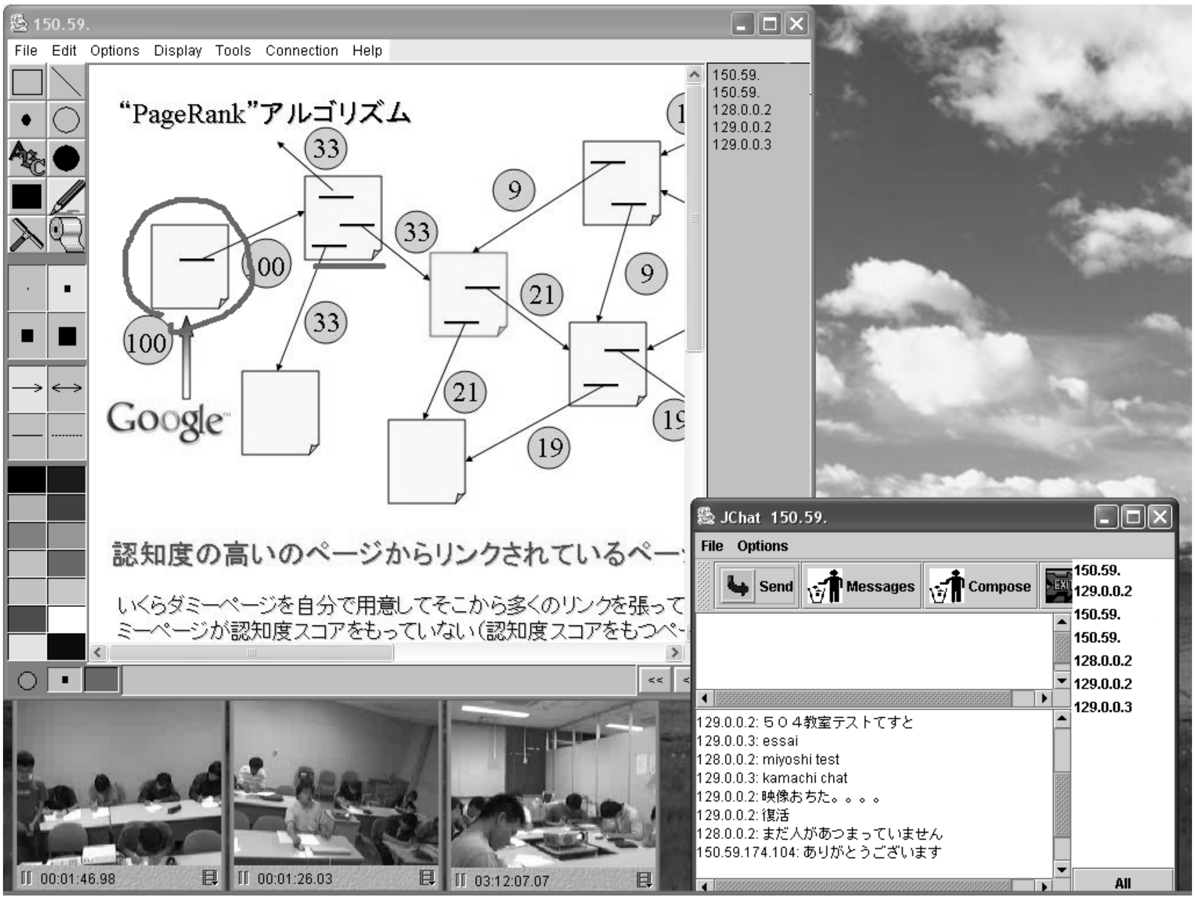

Figure 22: Interface of the Professor

4.2.2 Mixed Results: A First Step

4.2.2.1 Joining Versus Connecting

The connection with the Platine environment requires the user to input the address of the server and the password. The address of the server and the password have to be transmitted by other means. The Platine environment itself did not support this transmission.

If it is easy to establish a communication between two users, it appeared more difficult to manage several users. At what time should the students connect? What the students should do when they are connected but the class is not started yet? How the professor should decide when the class would start and how he should notify the students? If it is easy to manage such issues in small groups using direct communication, it is more difficult to manage them with large groups. The Platine systems tested did not provide functionalities to manage these issues at that time.

In traditional education, students enter the room before the time of the lecture; the professor enters the room and starts the class at the time scheduled. The professor may delay for a few minutes the start of the class if the students are late. Each student enters the classroom independently (i.e. asynchronously) and the activity really starts to be synchronous when the professor starts talking.

Synchronous distance learning environments do not provide such transition place. This situation can be explained from a historical point of view. As explained in the introduction, the contribution of the technical community in synchronous collaboration tools is important. Tools are mostly based on network or telecommunication models. To establish a communication between two distant users, tools establish a connection. It means the exchange of messages to determine if the distant user accepts the communication and how they will communicate.

It leads to the development of standards and architecture to connect people. These features are developed in the section 3.1.2.8. Joining a classroom is a social action whereas connecting to a server is a technical action. The example of Instant Messenger software shows the importance of these issues.

The goal of Instant Messenger programs is to allow people who share a same interest to interact with each other, as they would do if they were meeting in a café. Taking a coffee with a friend at a café requires 3 main elements: the friend, the café and the time to meet (see Fig.23). In Instant Messenger programs, the user has first to log on in order to be identified. The program has recorded and then can display the user's list of contact. Either it knew the contacts before his first use of Instant Messenger (relatives, friends) or he has been able to get in touch with them according to the search engine of the program. An icon and a name represent each contact; those icons are usually representing a person or a face, which makes the association intuitive for the user. The user knows when his contacts are online or not according to the icon. The icon is different and changes according to the contact status: connected, not connected, busy, away for lunch. This system allows representing temporal and behavioral information. Then, when the user and one of his contacts are connected and available at the same time, they can decide to discuss in a chat room. Starting a conversation or entering a chat room is also very easy and intuitive. Once in the chat room, different tools are available to discuss and a videoconference can be started. The rules for interacting depend on the relationship between the user and his/her contact.

Instant Messenger programs are able to reproduce a behavior of the real life in a virtual environment over the Internet. The chat room is just like a café and the list of contacts of a user represents a list of real people. The temporal information is based on different icon representations.

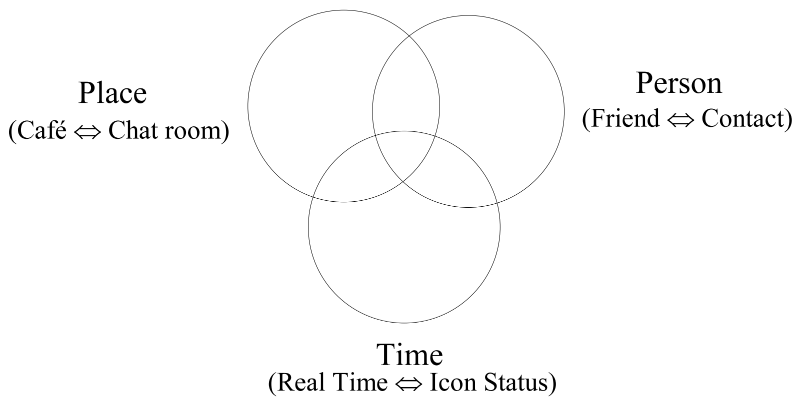

Figure 23: Synchronous interaction

Instant Messenger software is used by millions of people everyday. One of the first collaborative applications, NetMeeting, was officially abandoned in the end of 2003 to the benefit of MSN Messenger! [151]. The number of videoconferences realized with such software exceeds by far the use of videoconferences in education. Instant Messenger software are often use for personal feedback between distance learners and professors.

4.2.2.2 Communication and Collaboration Quality in Perturbation-Free Conditions

This section presents the results of all three groups of students in Normal condition (i.e. no perturbation introduced).

1. Communication Tools

   The students identified the audio quality as poor but ranked it as sufficient for learning. The audio communication was said to be of lesser quality than cell phones (Q2, A=1.04/3); listening required higher concentration and was more tiring than face-to-face activities (Q3, A=1.65/4; Q4, A=1.38/3). However, the quality was considered sufficient for learning (Q5, A=5.19/9).

   For video also, the quality was considered as poor (Q6, A=1.42/4; Q7, A=1.27/4) and the deformations disturbed the concentration of the students (Q8, A=1.58/4). However, the quality was considered sufficient for learning (Q10, A=5.27/9).

   The use of the whiteboard provided a satisfactory presentation system; the slides were easy to read and understand (Q16, A=2.25/4); the comments were synchronized with the slides and the annotations (Q17, A=2.63/4). The overall evaluation was also positive (Q19, A=5.48/9). However, the whiteboard was not considered as good as a traditional blackboard (Q18, A=1.72/4).

2. Learning with this environment

   The organization of the windows was considered not easy to read (Q20, A=1.69/4). However, the tools were sufficient to recreate the classroom environment (Q21, A=2.63/3). The audio communication was considered as the most important communication tools (Q24, Audio A>Other Average). However, it is impossible to differentiate with Ttest the importance of one tool compared to another. Indeed, the answers appeared to be very different according to students. It seems that students have different way of learning or that they followed the lecture differently. Some of them did not considered the slides as very important; it may means that they focus more on the comment of the professor and write down their own notes. Other considered slides as important and audio communication not so important; it may mean that they try to understand the content of the lecture from the slides without paying attention to the comments of the professor. When asked which part of the system should be improved (i.e. Q27), audio communication appeared as the element that requires the higher improvement. It suggests the importance of audio communication in the lecture and the effort that should be made to guarantee a good quality of audio.

   The quality of the system for communication was rated as average (Q28, A=4.88/9). It is interesting to notice that the quality of the system for learning was rated as higher (Q29, A=5.23/9).

4.2.2.3 Comments of the students

According to the free comments of the students, different observations were made.

Even if at first they felt surprised, it took only a very few time for students to get accustomed to this new environment and to find their marks. Some of them felt lesser pressure because of the professor not being in front of them. Other students felt observed by the webcam; they were not able to know whether the professor was looking at them or not and felt afraid of being watched without knowing it.

Some students suggested that the use of such environment disturbed their way of learning. They felt "strange" and express difficulties to take part in the lecture. The interaction with the teacher was said to be more difficult. For example, eye contact could not be established with the teacher.

In traditional classroom, the interactions are easier because they rely on a well-known way of learning. The interactions between the users rely on the perception of the physical environment and on the application of common educational rules. Elements of the physical environment are not available in synchronous collaborative environments and the users feel lost. They expect videoconferencing to be a copy of a real classroom but they cannot find the same references. Thus, they do not know how to interact. For example, students do not know how to ask questions when they cannot establish eye contact.

Students might get used to those new environments and learn the etiquette of such lecture (e.g. ask a question with the chat tool). Nevertheless, it would also be interesting to introduce references and representation that refers to the learning culture of students. Systems for asking questions are a way to support such interaction in the videoconference-based lectures.

Students thought the experiment was very interesting. This experiment opened them new views about education and they were interested in the possibility to follow lectures from home. However, their expectations towards future version of this system were principally focused on interactivity, among others: a better interface, possibility to get eyes contact and so forth.

These expectations suggest importance of interactivity in the learning process and why synchronous collaboration is promising. Videoconferencing allowed adjustments in real time and made learning easier. It appears interesting to support actively collaboration with teacher or with other learners.

4.2.2.4 Network Influence Identification

One of the primary goals of this experiment was to identify the influence of the network perturbations on the quality of the communication. These results did not completely meet our expectations. The introduction of delay, jitter and error leads to a decrease of quality between the different lectures. However, the influence of each parameter could not be isolated separately. The lectures were performed in three locations at the same time, each of them with a different type of perturbation and the results show intercorrelations in the influence of those parameters. For example, groups of student detected delay when only jitter or error perturbations were introduced.

After analysis, this correlation was caused by the collaborative tools (i.e. the whiteboard and the chat). For example, when a group of student annotated the slides, the time to send the modification to all the other members was affected by the network perturbation associated with the group writing annotations.

When used over a long time, the solution to transmit video and audio was sensitive to high jitter. Instead of decrease of quality, the application had a tendency to "freeze" and the audio and video communication became totally stopped. This problem is application specific. Such issues did not allowed us to identify precisely the influence of each parameter independently.

The experiments brought however interesting elements. The introduction of network perturbations affected the audio and video communication differently than the collaborative tools. The collaborative tools send information using the TCP protocol. The impact of delay on this protocol is more important than on UDP protocol used in audio and video communication. Thus, when delay was introduced, the synchronization between audio comments and the whiteboard decreased (Q17, A=2.63/4 with no delay, A=2.25/4 with medium delay, A=2/4 with large delay). Sometime, the professor loaded a new slide and started to make some comments. Some groups were able to listen to the comments but the slides were not loaded and they could not see them. It appears interesting to avoid those problems by loading the set of slides before the start of the lecture.

The delay did not have any influence on the quality of the audio and video communication. The average of audio and video communication quality was rated about the same (slightly higher) with the lectures performed with delay.

4.2.3 Summary of the Multipoint Experiment

This experiment brought interesting results on the opinion of the students on the system. It allowed validating the use of the environment in network-perturbation free conditions. This experiment helped us to define direction for the improvement of the Platine system. It appears necessary to improve the interaction quality of the system and to support specific interaction protocols of the classroom. Access to the environment should also be improved. In multipoint experiment, it is likely that there is intercorrelation of network perturbations between the different points.

The characterization of the network influence could not be performed properly. It still appeared important to provide answers on how to manage network perturbations and it lead to perform a second experiment.

4.3 The two site experiment: Characterization of the network influence.

4.3.1 Presentation of the Experiment

4.3.1.1 Protocol Specificities

In this experiment, the test population was constituted of a group of 22 undergraduate and graduate students of the department of Information Sciences at the Faculty of Engineering of the University of Tokushima. Groups A and B were constituted of 7 students and group C of 8 students.

They attend the lecture as an extra assignment regarding their curriculum. The students are involved in research or development of e-learning system. The lectures dealt with the history of Computer Aided Instruction (CAI).

The length of the lecture was reduced from the first environment. Each group of students attended four 20 minutes long lectures.

In these lectures, the lesson content (i.e. slides) was exchanged with the application sharing. The content material was produced in slides and the professor prefered the ability to point out to a certain area of the slides with the mouse pointer.

The questionnaire of this experiment can be found in appendix C.

In the previous experiment, the feasibility of IP videoconference between different sites had already been demonstrated. Thus, this experiment focused on the evaluation and the identification of each network perturbation and the experiments were performed between two different sites only.

The same experimental design was kept for the distribution of the parameters (see Tab.4 and Tab.5). However, the groups of students did not attend the lectures at the same time. The series of four lectures were delivered one group after the other.

4.3.1.2 Software Solution: NetMeeting

In this experiment, the NetMeeting software was used. This environment provided all the tools necessary for the learning scenario. This software is well known and freely available. It allows anyone interested in performing similar experiments to compare its results with the results of our environmen. The interest of this test was to identify the influence of the network and the use od , thus, the use of a freely available environment express our concern for the clearness of the results.

In NetMeeting, everything is accessed from the main interface (Fig.24). The audio and video communication is established by entering the distant address. Then, the tools are started individually. The use of the application sharing is a bit tricky for first-time users. It is not easy to define the programs to share and how to give the rights to share. The system was ready to use when the professor and the students started the class.

4.3.1.3 Communication Architecture

The Architecture of the experiment is presented in figure 25. On the upper part of the figure, the computer of the professor was installed. In the lower part of the figure, the computer of the group of students was installed. The two PCs were connected with the central router simulating network perturbations as presented in section 4.1.4.

The interface of the professor in a lecture is presented in Fig.26. The professor was able to see the video of the students, the chat and the slides shared by using application sharing with MS PowerPoint. The interface of the student was similar to the one of the professor.

4.3.1.4 Technical Specifications

The computer used for this experiments were common computers.

- Group of Students: Pentium III 500MHz, 256 Mo RAM, Ethernet 100Mbs full duplex. Windows XP Pro English Version.

- Professor: Pentium IV 2.53 GHz, 512 Mo RAM, Ethernet 100Mbs full duplex. Windows XP Pro English Version.

Figure 24: The NetMeeting Interface

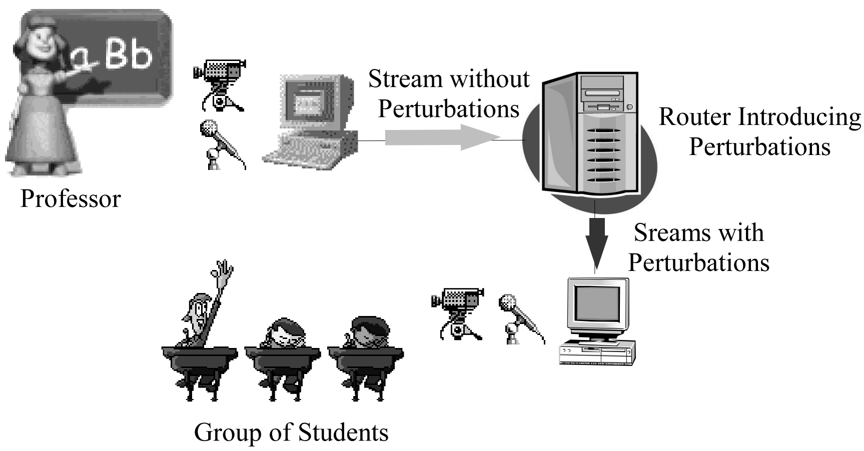

Figure 25: Two site Experiment Architecture

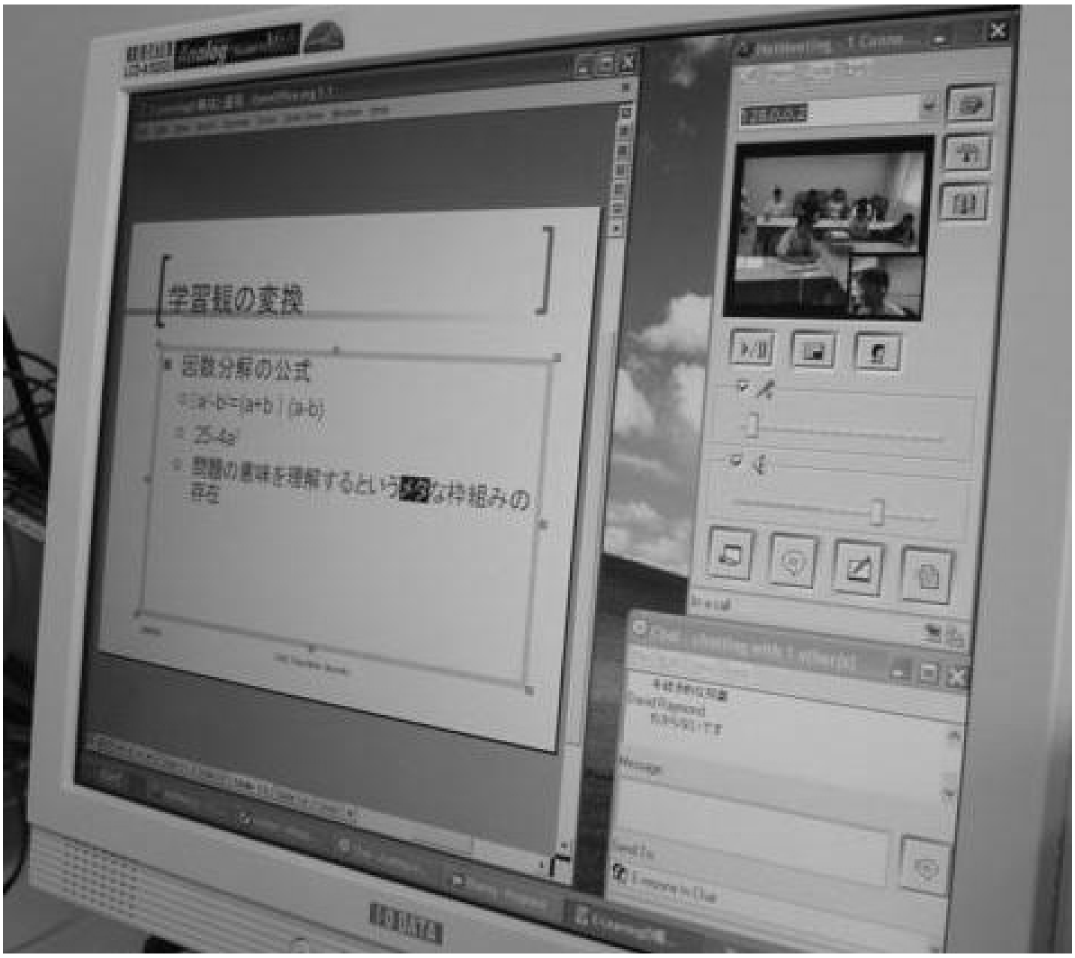

Figure 26: Interface of the Professor

The video and audio capture solutions are described in the Introduction part of this chapter (see section 4.1.3.2).

4.3.2 Presentation of the Results

4.3.2.1 Methodology for the presentation of results

The results in this section are presented using 3D block diagram.

These graphics present on the x axis the several questions related to one topic. For exemple, the questions related to delay are the questions 10, 11 and 13. From the view point of the reader, the question 10 has the highest value on the x axis and the data related to this question is seen in the foreground. The question 11 is presented in middle distance and the question 13 in the background (lowest value on the x axis).

The values of the network perturbations are presented on the y axis. The four levels of network perturbations are abreviated for presentation purposes. N refers to Normal conditions (No perturbations); S refers to Small perturbation; M refers to Medium perturbations and L refers to Large perturbations.

The average answers for each question and each network perturbation is seen on the z axis. The students were asked to answer question on a scale from 1 to 5 or 1 to 10 depending on the questions. The answers have been reformated to present results on a scale starting from 0, the new scales are thus from 0 to 4 and 0 to 9 respectively. In order to difference those two types of scales easily, the shape of the bars used to represent the results are parallelepipeds for the question with a scale from 0 to 4 and cylinders for the questions with a scale from 0 to 9. For exemple, the question related to delay number 10 and 11 have a scale from 0 to 4 and are thus represented in parallelepipeds. The question 13 have a scale from 0 to 9 and is represented using cylinders.

The evolution of the average answers of a question to network pertubations can be evaluated regarding the y axis. Tendencies in the evolution of the answers are illustrated with a curved line. Differences between the average answers have been analyzed with the T test tool (see section 4.1.3.3). When significant difference have been identified with this tool, the results are presented in a table.

4.3.2.2 Influence of Delay

The results of the three questions related to delay are presented in Fig.27. Question 10 is presented in the foreground, question 11 in the middle distance and question 13 in the background.

When delay was detected, it appeared disturbing to the lecture. Such a correlation was expected but the average for a large value (L) of delay was surprisingly high. After analysis, this result was explained by the influence of the experimental conditions. During the lecture in which high delay was simulated, there were no interactions between the professor and the students: they didn't ask him any questions and they remain silent when the professor asked them questions regarding the lecture. Thus, the lecture was not interactive during that period of time and the one-way communication that did take place can be compared to a simple streaming of video and audio and to the transmission of documents.

The particular circumstances of this lecture probably caused the unusual result. They can be compared to those generally found in higher education. During a lecture, the main speaker is the professor and the dialogue with students only occurs at certain points. The frequency of this dialogue is highly variable, depending on the number of parameters such as the subject taught, the professor, the students, the educational culture and so forth. In a meeting or supervised practical work, however, the interactions would appear very often and delay would probably be considered a more disturbing element.

As expected, the quality of the audio and video communications was rated at a same level with and without delay perturbations.

Regarding intensity, a Small delay (500ms) seems to be accepted by the students even if it is beyond the values presented for videoconferencing. Students noticed the small delay (Q10, Ttest significant if the samples considered of equal variance), however they did not consider this level as disturbing (Q11, Ttest not significant).

The Medium delay showed low scores and appeared to reduce greatly the interaction quality. A

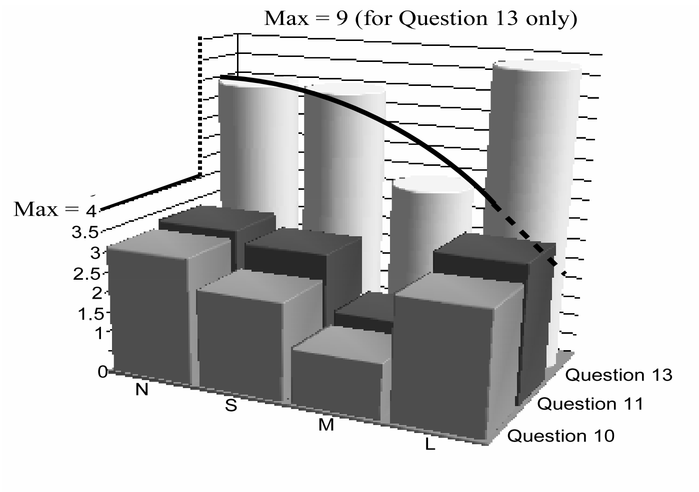

Figure 27: Influence of Delay

	Question 10	*Question 11*	*Question 13*
Small to Medium	.0398*	.0015**	.0165*

Table 7: Ttest results for Delay questions between Small and Medium value of delay *(Ttest: two-tailed, type 3. * P<.05 ; ** P<.01 ; *** P<.001.)*

Ttest performed between the Small and the Medium level answers showed significant differences (Tab.7). According to this experiment, for lectures, the maximum value of acceptable delay seems to be between 500ms and 1000ms. This value may be variable and highly depends on the type of lecture. Nevertheless, it confirmed that students were ready to accept higher values of delay for lecture-style communications than for videoconferences.

4.3.2.3 Influence of Jitter

Impact on Audio Quality Scores for questions concerning the jitter influence on audio quality are presented in Fig.28. Question 2 is presented in the foreground, question 3 followed by 1 in the middle distance and question 4 in the background.

Scores show little variation between the Normal, the Small and the Medium levels; jitter appears to be detected only when the value is large (L) with significant difference in Ttest between Medium and Large levels as shown in Tab.8.

	Question 2	*Question 3*	*Question 1*	*Question 4*
Medium to Large	.28	.0117*	.0002***	.0048**

Table 8: Ttest results for Audio questions between Medium and Large value of jitter *(Ttest: two tailed test, type 3. * P<.05 ; ** P<.01 ; *** P<.001.)*

Only the High level of jitter seems to have an impact on audio quality. It might be explained in technical terms by a programming feature of the videoconferencing application, i.e., the large (L) value of jitter exceeds the buffer value and as a result, some information was lost and the quality decreased.

The results presented here are directly linked to the size of the buffer implemented in NetMeeting; thus they only have meaning in this experiment and should not be generalized. In hindsight, it would have been better to structure the experiment without buffering but, unfortunately it was not possible, from a technical point of view. Moreover, it is noteworthy that buffers are used in real situations so it

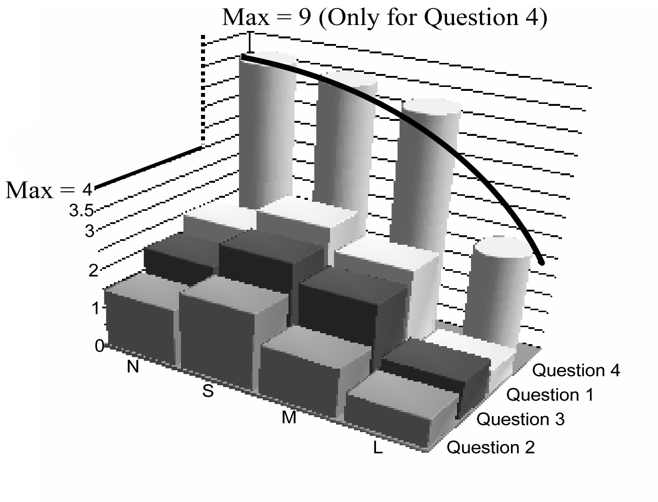

Figure 28: Influence of jitter on audio quality

is useful to retain them in an experimental setting.

The importance of the result presented here is different from that discussed above. According to the results, the difference in value between the Medium level and the Large level (300-150 = 150ms) altered the audio quality from good (suitable for learning) to very poor (insufficient for learning). It appears that, had the buffer size been greater (i.e. able to store packects corresponding to 150ms of communication), audio quality would have probably permitted learning. We believe that a small increase of buffer size would greatly improve audio quality. However, increasing buffer size brings about more delay and latency. Thus, the amount of buffering should be chosen carefully.

Impact on Video Quality Scores for questions concerning the jitter influence on video quality are presented in Fig.29. Question 5 is presented in the foreground, question 8 followed by 6 and 7 in the middle distance and question 9 in the background.

Even if this experiment was performed with a low bandwidth, the quality and the resolution of the video was satisfactory when there was no jitter. Significant differences between the Normal and Small levels were found by the Ttest results as shown in Tab.9. Between the Small and Medium levels, only question 9 showed significant difference for the Ttest (0.0082<0.01). Analysis about the impact of buffering on audio quality is interesting here too. A small increase of buffer size would greatly increase video quality.

The jitter appeared to have more influence on the video element of the presentation than on the audio element. This result may be due to different sizes of audio and video buffers. However, it might also suggest that the students were expecting high quality at the outset. In that case, even a small increase of jitter would have an impact on video quality, thus, reducing it from a satisfactory level to an insufficient one.

As a consequence, before building a new lesson it seemed necessary to evaluate the benefit of video to the learning process. If video were considered a central element of the lectures, it would mean that the lectures given in this experiment could not be performed without a guarantee for network QoS or large buffering.

4.3.2.4 Influence of Packet Drop

Impact on Audio Quality The influence of packet drops is presented in Fig.30. Question 2 is presented in the foreground, question 3 followed by 1 in the middle distance and question 4 in the background.

The results show that as packet drops increased, audio quality decreased. The "Small" level (5%)

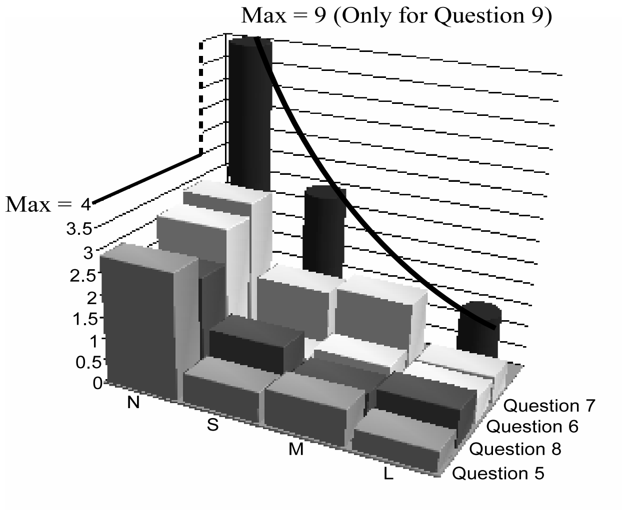

Figure 29: Influence of jitter on video quality

	Question 5	*Question 8*	*Question 6*	*Question 7*	*Question 9*
Normal to Small	.0001***	.043*	.0001***	.002**	.011*

Table 9: Ttest results between Normal and Small level of jitter *(Ttest: two tailed test, type 3. * P<.05 ; ** P<.01 ; *** P<.001.)*

did not seem to have a significant impact on the audio quality. The answers to question 4 gave statistical evidence (Ttest=0.031<0.05) that a Medium level of packet drops (17.5%) could bring about a significant diminution of audio quality. Watson and Sasse [152] studied the intelligibility of audio communication under the influence of packet loss. Those tests were performed for different codec and packet sizes. Significant decreases in intelligibility were found for packet drops between 15% and 30% depending on the protocol and the packet size. In our experiment, the codec used was different from the ones tested by Watson and Sasse but the level of 15% (Medium level) similarly caused a significant loss of quality for the learners. Those figures suggest that the learners can tolerate a small amount of packet drops whereas a larger amount (30%) is intolerable.

Impact on Video Quality As seen on Fig.31, the influence of packet drop was identified for Small and Medium levels. The differences between the Normal and Small, and the Small and Medium levels are significant as seen in Tab.10.

In this experiment, small levels of packet drops appeared to be tolerated by the students and the role of video was guaranteed. However, Medium and Large levels of packet drops appeared to change the perception of the system from average to insufficient.

	Question 5	*Question 8*	*Question 6*	*Question 7*	*Question 9*
Normal to Small	.085	.024*	.0006***	.0002***	.039*
Small to Medium	.44	.015*	.0085**	.09	.039*

Table 10: Ttest results for packet drop influence on video *(Ttest: two tailed test, type 3. * P<.05 ; ** P<.01 ; *** P<.001.)*

Evaluation of the Communication Strategy

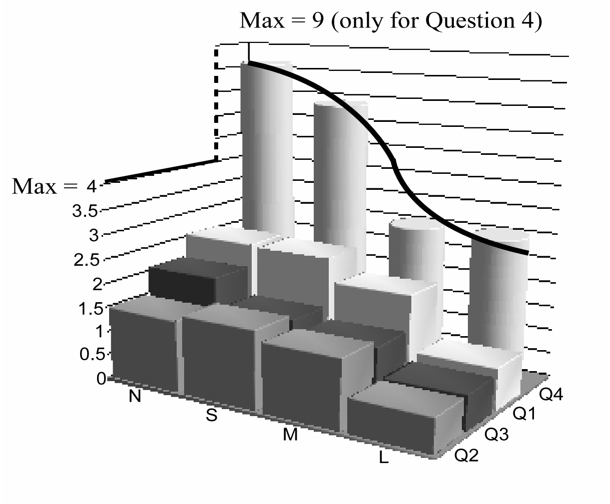

Figure 30: Influence of packet drops on audio quality

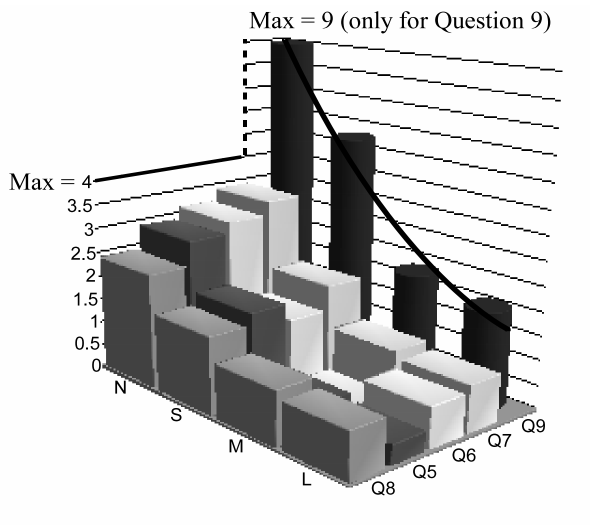

Figure 31: Influence of packet drops on video quality

Influence on Whiteboard Assessments of the whiteboard used to present the slides were also performed. The legibility and presentation quality did not show significant variation upon the introduction of network problems. It confirmed the hypothesis that network problems have little influence on the collaborative tools, making them a useful support in the communication. In this experiment, the slides were a central element of the lecture and they were transmitted perfectly. Synchronization problem between voice and slides identified in the previous experiment were also identified here.

In a traditional classroom, the students are able to see the professor in front of the whiteboard. The students were asked explicitly if the separation in two different windows of these elements presented them with difficulties in following the lecture. According to their answers (Q16, A=2.5/4), it did not appear to be a problem for this strategy.

Media Importance As presented previously, the influence of the network is diverse: audio and video qualities are affected differently and the quality of video appeared to be more influenced by jitter and packet drops. Buffering, however, can compensate for jitter influence but it increases delay. To choose between quality and interactivity, and therefore to determine if the low bandwidth video would be sufficient, it appeared necessary to draw up the relative importance between the elements of the lectures. Students were asked to rate the influence of the following elements on the lecture process: audio, video, delay (interactivity), whiteboard/slides, and lecture organization. The relative importance between the elements appeared independent from the influence of the network. The answers produced the following order:

1st Audio;
2nd Slides/Whiteboard;
3rd Lesson procedure;
3rd equally placed Delay (Interactivity);
5th Video.

Lesson organization and delay (interactivity) were approximately at the same level and could not be differentiated by a Ttest. Otherwise:

Between 1st and 2nd: 0.031<0.05;
Between 2nd and 3rd: 0.008<0.01;
Between 3rd equally placed and 5th: 0.014<0.05;

4.3.2.5 Interpretation of Results

In this experiment, audio appeared to be the element that had the most influence on the lecture. It was followed by the slides/whiteboard. The significance of these two elements was well ahead of the others. The video was considered the least important element in this communication scenario. It may be suggested that the video aspect was small and of poor quality and thus did not contribute much towards the lecture. Nevertheless, in "Normal" conditions, when asked if the size, video resolution and smoothness were sufficient, students answered positively to all of these questions. It suggests that, for those kinds of lectures, the quality of video was satisfactory for the role to which it was attributed. The students did not expect a greater role for the video in the lecture.

The communication scenario can explain this result: in our experiments, the video was only showing what could be described as a "talking head". The video element did not transmit any major information but only affective information (factual and emotional content only, and not data for the lecture). This affective information did not appear critical for the lectures. Such a suggestion would correlate with the previous results concerning the influence of jitter and packet drop on the video. Procter et al. [131] found that a little reduction of quality may introduce a loss of affective information without any loss of informative information. In this experiment, when the quality of video was not very good, no affective information was properly transmitted. Thus, the video became ineffective under the influence of packet drops or jitter.

However, video appeared to create a specific relation between the students and the professor. In this experiment, when asked if they would mind not having a video, the students clearly answered that they would miss it. Olson et al. [67] compared the work performed with an audio conferencing system and with a videoconferencing system. Even if users "rated the audio-only condition as having a lower discussion quality, [...] the quality of work suffers very little". Thus, video presence is necessary for good communication experience but it did not have a significant pedagogical impact on the lectures performed in this experiment. For lectures, the quality of audio and slides is more important than video quality; the implication is that the larger bandwidth required for high quality video is unnecessary for lectures.

According to the previous results, the students seemed to tolerate a higher delay in this experiment than in a videoconference conversation. Also, for those lectures, delay (interactivity) was considered of lesser importance than audio quality. The choice of the communication scenario may explain this tolerance; interactions did not occur as often in the lecture scenario as in a conversation. This result is very interesting with regards to the setting of buffer size. If high delay seems to be tolerated, it appears useful to increase buffer size at the expense of delay. A small increase of buffer size can avoid the loss caused by jitter and it would have a great impact on the perceived quality. This solution would probably be suitable for lectures but it might not be a good solution for other communication scenarios.

4.4 Relation between Network and Collaboration

These experiments tried to propose a solution for presenting a distance lecture and to evaluate the QoS requirements for a specific scenario. These requirements brought interesting results related to QoS in synchronous activities. First, they confirm that the QoS available on the public Internet is likely to support some synchronous distance learning activities. Secondly, even if the QoS control over the Internet is not possible, these figures are interesting for the definition of policies in private network where a QoS control can be performed. The strategies for the QoS control in private network are not defined within this research. Several orientations are possible for supporting QoS Control, e.g RSVP, IPv6 with QoS. Such strategies are studied within the OLC research group of the LAAS-CNRS.

From an overall point of view, these experiments bring others interests for researches on QoS. These experiments brings new figures on the requirements at the user level. QoS policies are traditionally defined according to the media transported; i.e. low jitter and packet drops for audio applications, high bandwidth but higher packet drop tolerance for video applications. These experiments expresses the need to support QoS requirements not only ccording for the type of media but also according to the type of activities. Indeed the requirements observed for a lecture are different from the ITU requirements that were established for telephony. Such differences are explained by the use of other collaborative tools as complements to videoconferencing but also by the user needs, which are different in a simple videoconferencing context compared to a learning context.

It also appears also necessary to reflect the hierarchy between the communication channels in the QoS policy. The contributions of audio and slides (i.e. whiteboard) were considered more important than the others. Thus they should be supported according to the their media specificities (low jitter and packet drops) and according to their hierarchy (relative guarantee compared to video streams). The central role of audio communication is not itself a surprising result. These experiments suggests however that the relative importance of audio communication is related to the collaboration scenario. Other scenarios would have certainly other requirements and the efficient support of communication on a private network requires a correspondance between collaboration strategies and QoS policies.

The QoS available on a network would determine the quality of the communication between participants of a synchronous activity. The participants should not be focused on trying to "capture" the communication but they should have thoughts for the topic treated. This quality of the communication has thus an influence on the involvement in the activity and the motivation of the participants. The QoS available have thus an indirect impact on the learning effectiveness of the activity. This effectiveness is however influenced more directly by several educational aspects; e.g. the collaboration strategy, the content shared, the motivation of the participants. The evaluation of learning effectiveness is thus subject of many questions. In order to evaluate learning effectiveness, it requires to define what can be considered as "learning". Such issues are beyond the scope of this research. Thus, the interest of this work is to search how to optimize the efficiency of synchronous environments given a set of technical and educational constraints. The collaboration strategy is the entry point for the educational constraints. For example, the collaboration strategy would reflect the specificities of the topic, the participants and the learning theory. Distributed systems and network issues are the main element technical constraints. They reflects the physical network access constraints of the participants, the QoS available on the network. Given both technical and educational these constraints, the performance of a synchronous environment would represent its ability to provide the best quality. Most of synchronous environments have restricted entries for both educational and technical constraints. It means that they are not able to cope with original collaboration strategies or with original network constraints. Moreover, the variation of those entries does not lead to modifications of the environment support strategy. The interest of this research is to understand how to widen these entries. Widenning educational entries would allow provide new alternatives for distance education. Widening technical entries would allow to reach more distance learners. The students said they would be interested in using such a system from home as an alternative to going to the university. This confirms the interest of using such a system not only for distance learning but also as an alternative to the traditional learning environment.

The state of the art presented in the chapter 2 and 3 have been partially organized and structured according to the experience learned from these experiments. These experiments were a chance to test several environments and they showed the necessity to establish criterias for their evaluation. These experiments also allowed us to identify key steps of synchronous distance learning activities and to make a parallel with traditional activities. The lesson learned from this parallel lead to the definition of criterias that are presented mainly in section 2.2:

1. Temporal relation: asynchronous preparation, synchronous interactions, asynchronous review
2. Differentiation of the users: educational roles and user's rights in a synchronous activity
3. Communication structure: orientation of the communication and dynamic communication protocols
4. Environmental Information: awareness and social framework of the activities

In order to support relationship between collaboration structure and communication infrastructure, this research proposed the Content and Communication Management System (CCMS) model presented in the next chapter. The definition of such correspondance is a first step towards the optimization of the architecture of synchronous environments.

Chapter 5
Conciliating Educational Collaboration and Technical Communication

This chapter presents the strategy developed to support the relation between collaboration strategies and communication infrastructures. It presents in a first section the model developed in this research that defines an interface for both communities of experts. This model is the base for the development of a Communication and Content Management System (CCMS). Then in a second section, the potential of its interface is discussed within the frame of a potential application. Ideas for the implementation of this model and improvement of the Platine environment are developed in a third section. The model has not been implemented yet, however it was used partially to support an experiment of synchronous collaborative learning. This experiment is presented in the chapter six.

5.1 Content and Communication Model

5.1.1 Overview of the Model

The Content and Communication Management System (CCMS) model (Fig.32) is organized in two groups of objects: the foundation objects and the association objects.

The foundation objects represent the basic components used to define interaction and communication in synchronous activities. They define an access point for the integration of multimedia communication developments.

The association objects represent interactions and collaboration structures reflecting educational strategies. They define a model interface for the educational expertise interested in structuring collaboration according to their own learning theories. They also allow technical experts to match communication infrastructure with user collaboration structure.

This section does not present technical issues for the implementation of the model, however, it gives some examples that help the reader understands the role of the objects.

5.1.2 Foundation Elements

5.1.2.1 Variable

The elements involved in this model are associated with variables. Variables reflect specific characteristics of an element. Each field of experts is able to define the variables it is interested in. For each variable created, an interface for the instantiation, the domain of existence and the default value are given. In videoconferencing communication, the video size could be defined by its width and height. The following example proposes a representation of this variable as an ordered pair of integer (width, height).

- Name: the name of this variable "video size"
- Type: Object used to represent the video size (integer, integer)
- Domain of existence ={ (160,120) (176,144) (320,240) (352,288) (640,480) }
- Default Value: (176,144)
- Interface for the instantiation of the variable: "*GetVideoCaptureSize*"

The format of the interface is not defined within the scope of this model. This format is related to the implementation of the model; object oriented programming languages defines interfaces model that can be understood by most users.

The model defines public variables to promote collaboration between experts and non-experts users. A public variable is an association of a technical value with a name that has meaning for uninitiated users. Such association eases the setting of variables. The domain of existence of public variables may be a restriction of the domain of existence of its counterpart. For example, the public representation of the video size could be defined by only three sizes: small, medium and large.

- Name: the name of the public variable "video size"
- Type: Object used to represent the public variable "string"
- Domain of existence = { "small" "medium" "large" }
- Default Value: "small"
- Association with technical parameters: "small"=(176,144); "medium"=(352,288); "large"=(640,480)

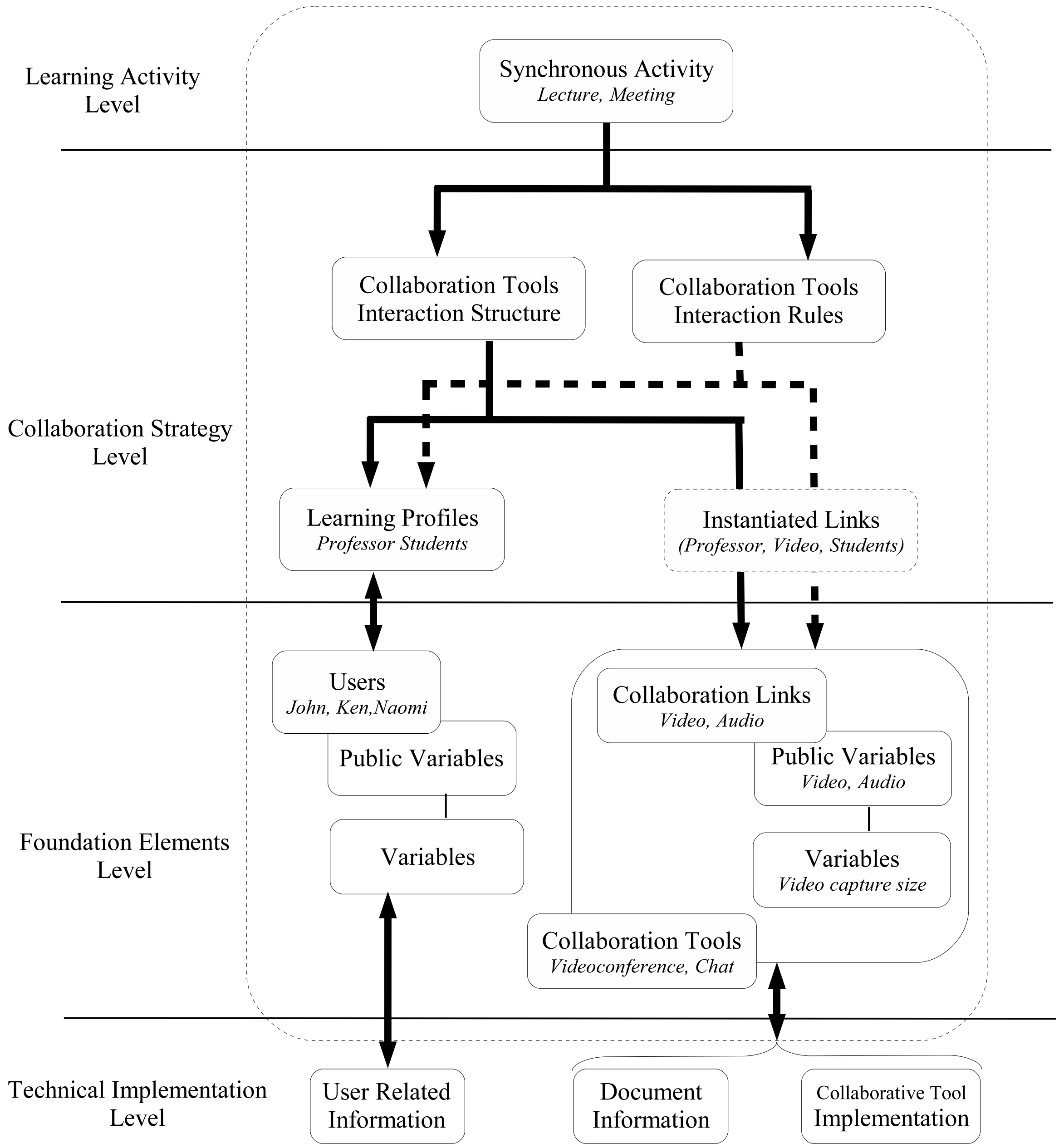

Figure 32: CCMS Model

5.1.2.2 User

A user represents an individual or a software agent taking part in the activity. A user is defined by several variables reflecting his features in learning activities. Users correspond to subjects or users presented in the section of theoretical foundations. Administrative information (e.g. first name, birth date), technical information (e.g. network access, computer characteristics) and learning support information (e.g. interests, past experience) are examples of variables of interest for a wide range of activities. Such variables may be used to support different collaboration strategies; users who possess a webcam may trigger the broadcast of their video when they ask a question.

Upon implementation, variables could be instantiated by other components of web-based learning architecture according to the interface of the variable selected. Administrative information could be implemented upon request to administrative database; technical information could be defined by a piece of software that detects the presence of a webcam and its parameter. The necessary variables depend on the activity to be performed.

5.1.2.3 Collaboration Tool

Collaboration tools are the main elements of this model; they reflect a way to create relationships between users engaged in a learning activity. They interface the technical functionalities of tools to a verbal expression that have meaning to educational expertise.

1. Group type: Two kinds of collaboration tools can be defined: group and personal collaboration tools. Group tools represent collaboration means associated to the group whereas personal tools are associated to one user. For example, a group videoconferencing would allow distributing video and audio streams to all the members whereas personal videoconferencing would allow private videoconferencing between two members of the group. This distinction is made to settle the computing resources used to support a communication tool. A personal tool would typically rely on the users computing resources whereas group tools would require a specific server; for example, a MCU for videoconferencing.

2. Variables: Collaboration tools define variables to reflect their customization level. For each variable, the domain of existence would depend on the technical limits of implementation. Technical experts providing a model of their collaboration tools would define this domain of existence. For example, a H.323 videoconferencing tool would have a "video size" variable limited to the following domain of existence { (176,144) (352,288) }. Indeed, the H.323 protocol does not support other size for the transmission of information. The domain of existence of the variables could be restricted for teaching purposes defining a "domain of usage".

   The value of a variable for the operation of the tool may be chosen in this domain of usage according to the technical profile of the user. A user with a PDA could set their variable to (176,144) while desktop owners will use a larger video size i.e. (320,240).

   Similar strategies can be also developed with public variables. These steps may introduce complexity but it offers a solution to adapt the collaboration tools to technical and educational constraints.

3. Collaboration Link:

   The functionalities offered by a collaboration tool are represented by collaboration links. Collaboration links define a way to communicate, to interact and to exchange information among users of a collaboration tool. Collaboration Links create an oriented relationship between users and are associated with the following parameters:

   - Source or Origin of the collaboration link
   - Destination or Recipient of the collaboration link

The source of communication would typically be a single user for personal collaboration tools whereas group collaboration tools may support several sources. Destination can be a single user or a group. Information exchanged within collaboration links is referred to as messages. Public or technical variables may be associated to the link in order to reflect the way the link is used.

A group videoconferencing tool may define "send video" and "send audio" links. Some of the variables of the video link would be video size and the encoding technique. Variables can also be a way to exchange documents; the link "send slide" could be considered for a whiteboard collaboration tool; a variable of this link could be the slide to send. The instantiation method of the slide could allow access to a digital library or to a local directory. Collaboration links are an abstract model of operations used to perform collaboration tool functionalities. Thus, the implementation of a collaborative link must define the format of the message exchanged as well as how to generate and interpret messages.

5.1.3 Association Elements

5.1.3.1 Learning Profile

A learning profile is an association between:

- A profile name
- A list of users

Learning profiles allow managing large groups of users; they reflect the "learning role" of users in activities. "A community which has expertise in a specific learning or teaching concept sets up a Learning Role" [153]. In a lecture, one would define the following profiles: all the users, professor profile and student profile. Different profiles reflecting technical specificities could be developed if these specificities have an influence on the pedagogical strategies. For example, educational experts may choose not to display video for students joining activities with limited capability devices such as PDA; they could define a "Field Student" profile. They may limit the use of some tools for users with a low bandwidth network connection.

5.1.3.2 Collaboration Tool Interaction Structure (CTIS)

Collaboration Tool Interaction Structure is a list of instantiated links that aim at the definition and the orientation of relationships between users of a tool. The instantiated links are a combination between:

- Source Profile or User
- Collaboration Link (and its associated parameters)
- Destination Profile or User

The list of CTIS defines an organization of the communication and the interactions within the members of a learning activity. Upon implementation, a system would set up automatically this structure at the beginning of a learning activity. The links instantiated within CTIS are likely to be up during the whole synchronous session. The lectures that were presented in chapter 4 may be described as follows: the professor is the main speaker and s/he shows slides of the lecture on the whiteboard. The other users' video and audio (students) are not transmitted to the group, as they just have to listen to the lecture most of the time. Students can communicate or ask question by chat. In this basic scenario, links would be modelled:

- For videoconferencing: (Professor, send video, all the users) ; (Professor, send audio, all the users) ; (Student, send video, Professor) ; (Student, send audio, Professor)
- For the whiteboard: (Professor, send slide, all the users)
- For chat: (any user, send message, all the users) ; (any user, send message, any user)

5.1.3.3 Collaboration Tool Interaction Rules (CTIR)

Collaboration Tools Interaction Rules are a list of combinations that aim to define a hierarchy among users of a tool. CTIR are combinations between:

- User or Profile invocating the link
- Collaboration Link Instantiation (Source Profile or User, link name, Destination Profile or User)
- Collaboration Link invocation rights or methods

CTIR allows the adaptation of the interaction-structure according to specific actions. Links established through CTIR are likely to represent limited-duration interactions or communications in a session. In order to limit the setting-up of those links to strategy-related actions, invocation rights or methods are specified. The user invocating a link can be different from the users related by the link. In the example of a lecture, the professor may allow students who want to ask a question to broadcast audio and video to the other users. A software agent could also be developed to identify when students want to ask a question and to give them the rights automatically. Those rules would be modelled as follows:

- For videoconferencing: [professor/agent, (student, send video, all the users), true]; [professor/agent, (student, send audio, all the users), true]

5.1.4 Learning Activity

5.1.4.1 Summary

Learning activities are composed of the following elements:

- List of Learning Profiles
- List of Collaboration Tools
- List of Collaboration Tool Interaction Structures
- List of Collaboration Tool Interaction Rules

All these elements define a communication structure and interaction rules between users (Fig.32). Learning is a social activity and the CTIS and the CTIR support the social nature of the interactions by reflecting hierarchical relationships between the users. Users and Collaborative tools of this model are abstractions of information and tool implementations used within CSCL environments. Learning activities gather all the necessary information for the technical set up of a communication structure.

5.1.4.2 Example

A graphic representation of a model instance (Fig.33) has been established to reflect the example of a lecture developed throughout the section. Four users are specified and they are associated to one of the three learning profiles. The three tools relate the profiles to each other in an asymmetric structure of collaboration. Field Students with a PDA have restricted functionalities due to the limitations of their communication device. Students have restricted functionalities compared to the Professor. This structure of organization is very simplified and different educational experts would probably model a lecture differently. Procter et al. [131] found that a little reduction of quality may introduce a loss of affective information without any loss of informative information. Lectures on artistic topics would thus be modeled with a very high video quality. Collaboration activities on language learning would require a very high sound quality. In the previous experiment, we found that audio and the whiteboard were the important communication channels required by the professor and the students. Video was considered less important but still necessary. The aim of these examples is to help the reader picture the use of the model. The representation chosen in figure 33 is not a formal representation of a model instance but a simple visual representation for illustrative purposes.

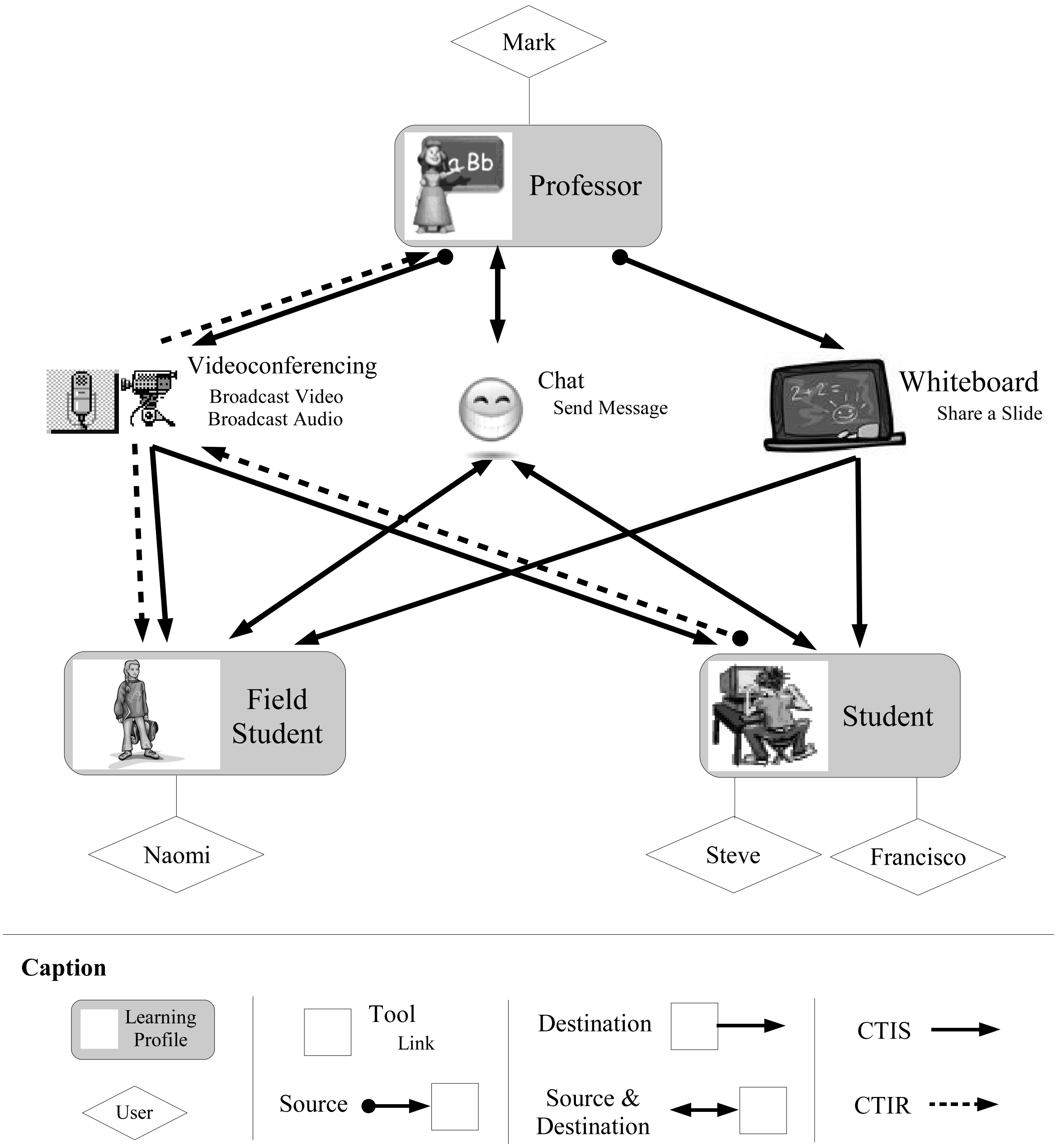

Figure 33: Visual Representation of a Lecture modeled with the CCMS

5.2 Discussion and Potential of the CCMS Model

5.2.1 Validation of the model

The model presented in this chapter try to represent the relationship between communication from a collaborative point of view and communication from a network and distributed system point of view.

The existence of this relationship was demonstrated in the previous experiments. These experiments showed that the QoS requirements of the network are different according to the type of activity: telephony (ITU requirements) and lecture based (other requirements). However, this identification is not exhaustive. Indeed, it appears impossible to define completly this relationship as one may argue on the definition of what is a collaboration strategy and what is a distributed system.

In order to validate the model, it is necessary to check its ability to establish a symetry between the elements of the relationship: collaboration and network. This validation requires to demonstrate: the ability of the model to represent collaboration strategies within its elements and the ability to set up a distributed architecture within a representation of the model.

The ability of the model to represent activities have been partially evaluated all along its description. Indeed, an example of a simple activity is given. The deployement of architectures was also performed easily corresponding to model instances. In order to perform a sound validation, it would be necessary to ask many professor to use elements of the model to represent collaboration strategies and to ask several network experts to try setting up architectures supporting the instances. Such full validation process would have brought interesting information on the easiness of use and understanding of the model. However such validation process is time-consuming and expensive (it is difficult to gather a significant number of professors and network experts) and was not performed. In the field of education empirical evaluations are subjective and prone to criticism. Moreover, these evaluations would bring limited information on the interest of the model for the end user. Indeed, the implementation of the model is necessary to evaluate its potential for end users. We believe that it is possible to represent collaboration strategies using the model and that it is possible to deploy architectures corresponding to those elements.

The major interest of this model is to potentially raise the level of educational support provided by synchronous environments. The model provides a representation of sources, destinations and flows of information. The combination of those elements is likely to support new learning support strategies. The representation provided by the CCMS model is likely to support the implementation of those strategies. Thus, this section proposes learning support strategies that could be developped easily from an implementation of the model. The next chapter presents experiments in which some of those strategies have been evaluated.

5.2.2 The Collaboration Structure

5.2.2.1 Preparation of the Activities

The definition of an instance of the model is a first step in the preparation of the activity. It brings professors to define educational goals and collaboration strategies and avoid unstructured use of technology. It also provides a solution to define the technical parameters of the communication. Upon implementation of the CCMS, the system can used this information to set up the communication automatically. It helps to reduce the technical manipulation of the systems and lower the burden on the professor.

The educational contribution of the CCMS model may appear limited. The communication and collaboration are modeled but pedagogical objectives are not mentioned explicitly. Indeed, the concepts of task, division of labor, community are not addressed. The limitations of the model do not allow supporting educational theories. However this is not the purpose of the model. This model put mainly the communication in the center of the learning activities. Thus it can be viewed as oriented towards CSCL theory. However, the exchange of information is at the center of most theories. This model presents the exchange of information not only between users but also with other source or destination elements (e.g. agents, libraries). Thus, it can be viewed as open to other theories even if it does not support them specifically. Elements of the model can be combined to reflect the specificities of the educational theories. The only constraint towards learning and educational theory is that "human being's interactions with his or her environment are not direct but instead mediated through the use of tools" [46]. The CCMS approach can be seen as in between Computer Mediated Communication (CMC) and CSCL. Compared to current environments, the implementation of the model would raise the organizational level of synchronous activities and support teaching.

5.2.2.2 Original Collaboration Structure

The model allows defining original collaboration structure. It presents the possibility to test and evaluate organizations that are almost impossible to support in face-to-face communications. The collaboration structure can be optimized with the orientation of the communication and the introduction of hierarchy in the activity. In activities where a lot of users are involved, communication has a tendency to become messed-up. The definition of roles and rights help tp structure the communication within the group. The implementation of the CCMS model could thus propose mechanisms to support the control of the main speaker based on the collaboration structure.

Collaboration structures are uneasy to define from scratch and they could be optimized by trial-and-error methods. Once a professor has developed a learning scenario, s/he would define a model of the collaboration structure and perform experiments with this structure. According to the results of these activities, the collaboration structure would be refined to improve collaboration.

5.2.2.3 Sharing Educational Experience by Model of Activities

The modifications of the communication properties are a way for educational experts to express their own experiences of synchronous collaborative learning activities (section 2.2.1). One professor would probably define a model for lectures differently from the one presented in fig.33. The addition, suppression, and modification of collaborative links and variables would express an optimization of the structure towards a specific learning purpose, e.g. video is not a main communication channel, or group collaboration is supported differently. Instances of the model are a way to share educational experience, e.g. lecture models such as fig.33 could be exchanged between educational experts.

5.2.2.4 Network and Collaborative Independence

Technical and pedagogical expertises are independent. The model supports collaboration between them by interfacing their respective competences. Their independence is symbolized by the difference between foundation objects (users, collaboration tools) and association objects. Foundation objects are related to technical implementations however association objects are only related to foundation objects. The collaboration strategies are not symbolized by foundation objects but by the relationship between these objects. This difference defines a relationship that guarantees a certain level of independence for all experts.

Upon implementation of a system supporting the model, educational expertise would be autonomous, i.e. they would be able to modify the communication structure and perform tests without technical assistance. This autonomy is necessary to allow professor master synchronous collaboration environments and to focus on teaching.

On the other hand, network experts would be able to develop, modify and improve communication infrastructures without notice to the educational expert. An instance of the model defines a network challenge. Several solutions can be developed to answer this challenge without notice to the educational experts. From a model instance, a formal description of communication can be established. From this description, architectures of communication can be developed automatically.

Instances of the model allow the identification of the QoS requirements for the activity. Rather than the support of QoS control, the model provide an interface to represent QoS policies. Provided the network supports them, QoS policies could be set up automatically from an instance of the model. For different or for a same type of stream, different QoS service could be set up. For example, the video stream from the professor to the student would be transported with QoS guarantees whereas video from the students to the professor would be transported with a best effort policy.

5.2.3 Environment Awareness and Adaptability of the system

Instances of the model hold a lot of information of interest for the users. It would help them identify the context of the activity and support environmental information.

The model has the ability to be self-descriptive. Instantiation of model elements can be associated with variables describing their purpose. A numeric variable can be associated with a text variable describing how to choose the numeric value. This research does not provide any solutions for the representation of this information. This issue should be addressed within the implementation of the CCMS.

The vocabulary used to name foundation objects should be chosen carefully. It determines the clearness of the organization for both technical and educational experts. Objects are not defined in a way that can be represented to users. The model only proposes a frame for collaboration. The elements' name depends on the people gathered to define them. Cultural, language and educational differences would probably lead to different interpretations of what is a "videoconferencing collaboration tool", or what is a "user". There is a standardization effort to develop metadata that aim at being pedagogically neutral or unspecific to theories and models [86]. These standards could be used to define some of the variables of the model. However, these standards cannot describe all the technical elements of synchronous communications. Moreover, this approach can be questioned as learning situations are specific [153]. Thus, the support of several metadata approaches can be seen as a positive feature of the CCMS model.

Awareness is a first step toward adaptation mechanisms. Awareness represents information. Adaptation mechanisms process this information for optimization purposes. These optimizations can be technical or educational. They can be supported by user manipulations or they can be automatic. One of the goals of this research is to be able to implement software agents that would support such automatic optimizations.

5.2.3.1 Educational Awareness and Adaptations

The presentation of the collaboration structure would help learners to situate themselves in the activity. It would help users identify the communication streams and know who receive their messages when they talk. This information represent one facet of the social relationship between individual in the activity. It may reduce the pressure of being "broadcasted to the world" (see section 2.2.1).

Other strategies could be developed to reduce the social distance between users and prevent inhibition of participating in the activities. For exemple, the presentation of the list of user and the access to user variables (e.g. name, interests, skills) may contribute to give the feeling of being part of a community. In many learning systems, users are associated with a profile defining their educational interests. For example, the user "Kenji Matsuura" would have the following research interests: Java, JavaScript, XML. Students are often afraid to ask questions to the professor. Students are more likely to ask a question to a classmate. When a student want to ask a question to another student instead of the professor, an agent could process the content of the question and search among the user profiles for a matching interest. Then, the agent would set up a communication between the two users or between the group of users sharing the same interest. In our example, if I was interesting in JavaScript, the agent would redirect me to Kenji Matsuura and I could ask him a question directly by voice, chat or with any other tool (e.g. text editor sharing source code) depending on the settings of the agent.

For the professor, the presentation of social information would allow identifying the students that are joining the activity. When one of them asks a question, the professor would be able to adapt his answer regarding the educational background of the student. It is also a good solution to help professor memorize the name of their students.

Content could be adapted to the student profile as it is often done in asynchronous learning environments. Such content approaches are well described in other researches and are not treated here.

Learning profiles could be associated with text variables describing the objectives of the profiles. It would support the learner in identifying his/her role in the activity. The representation of the rights over the manipulation of the tools would help learners to understand what they are allowed to do or not. The representation of the dynamic collaboration protocols let users know how they can interact with each other. All those elements would contribute to prevent learners from being "lost" as expressed in the experiments of chapter 4 (See section 4.2.2).

These experiments pointed out the diversity of the learners. Some of them preferred to read the slides rather than listening to the comments of the professor on those slides. The diversity of the communication expectations could lead to adapt the communication means to the profile of the users. The system would retrieve the profile of the user according to his name in an educational database and apply the adapted communication strategy for this user.

5.2.3.2 Technical Awareness and Adaptations

Self-descriptive approaches would provide passive technical support. For example, tools could be associated with text variables describing how to use them.

Upon implementation, the CCMS system could be able to support information such as actual QoS provided by the network. This information would help to identify the perturbations of the communication on the network and to set up network communication strategies to lower the influence of the perturbations. Information on the quality of the communication could be presented to the professor, it would allow him to change his teaching strategy in case of sever perturbations. The professor could repeat comments, use the chat to send message, change the structure of collaboration to favor local work. Such technical awareness would help users of the system to speed up the gestation period (see section 2.2.1).

The technical solutions for the support of the communication could also be adapted to the specificities of the communication device. Some communication devices have limited computing and networking capabilities. It appears interesting to save network resources by sending less information. For example, the size and quality the video could be (small,low) for cell phones, (medium,average) for PDA and (large,high) for desktop computers.

The display of documents is also an issue on screens with a small device. Users with a PDA are not able to have the same view of a graphic document than a user with a large desktop screen. The documents shared could be presented to the users at a resolution in relation with their screen. The resolution would be calculated to the size of the screen and in order to keep the content of the document readable.

5.2.4 Session Archiving

One of the advantage of asynchronous learning system is that learner can review learning materials as many times as s/he wants. Synchronous learning sessions are a one shot event that cannot be reproduced; students are left with few materials to support their review.

As presented in section 2.2.2.3, some environments provide a solution to record and archive the set of documents (unformatted and formatted text, images, videos, slides...) used during the life of a synchronous session. Those files need editing in order to be used efficiently by the students. In a lecture, the video and audio files corresponding to static documents should be associated with temporal marks (i.e. chapters). It allows students to reach content directly and not to loose time searching for the section of interest. Unscheduled interactions such as questions are inclined to weaken content. In the model, those interactions are represented within the CTIR. The activation of these interactions could trigger special marking that would support the edition of video; e.g. questions and answers could be provided in independent video files.

Such kind of materials represent only one point of view, it can be used for activities where the professor is the main speaker (i.e. lectures). It is not suitable for activities where collaboration occurs frequently. One of the interests of synchronous CSCL environments is to support interactivity of the communication. For example, a student may ask: "Where are located the damaged cells?" and the professor would underline one element in the whiteboard. The annotation made through the Whiteboard tool is the consequence of the information exchanged through the videoconference tool. Those relations are as much important as the final state of the documents. Thus, it appears interesting to reproduce those interactions when the students review the activities. The CTIS support the identification of communication streams. It is a first step to represent interactions with several different points of view. The recognition of alternative points of view can lead learners to mutual challenges, which is a stimulus for cognitive change. For example, in collaborative activities, it could be interesting to save information on the participation of each user. Afterwards, users would be able to learn by reviewing their contribution and the contribution of other users.

5.2.5 Integration of Asynchronous and Synchronous Systems: The example of a virtual university

A large number of synchronous CSCL environments are usually developed without reference to asynchronous support (e.g. administration tools, Content Management Systems, learning review tools). The CCMS work this integration issue through *variables.* Variables are an interface for the exchange of information and objects. The format of the variable can be set to guarantee compatibility with other learning services. Upon implementation, variables could be instantiated by web-based learning components. They would allow the introduction of objects into the CCMS model and support relation with educational framework (virtual or real). The example of a virtual university is presented hereinafter to illustrate how to integrate synchronous activities in a virtual structure Fig.34.

Traditional universities are often organized around three main groups: administrative services, teaching staff and students. Administrative services manage the technical infrastructure and the organization of learning activities. Teachers are the main performers of learning activities and students attend the activities.

Administrative services manage curriculums and the resources required to support this curriculum. First, they define and schedule activities. Thus, they would create a pre-instance of the CCMS model including administrative information; e.g list of participants and the professor in charge of the activity. Secondly, administrative services also provide the infrastructure that supports activities. Thus, they would put forward the computing and network resources that can be used for the activity (cost management).

The professor would define his collaboration strategy and complete the pre-instance of the CCMS model. The synchronous activities would be supported by the implementation of the CCMS. The implementation of the CCMS system would provide information about the flow of the activity. For example, attendance to the activity could be checked by an agent that would transmit the information to the administrative services. Documents created during the life of the session would be transmitted to an asynchronous web-based learning system for review and indexed in a digital library. The learning pace of the activity would be used to synchronize the content of review support. The users' actions on tools would be transmitted to user-modeling services to determine the synchronous learners' profiles.

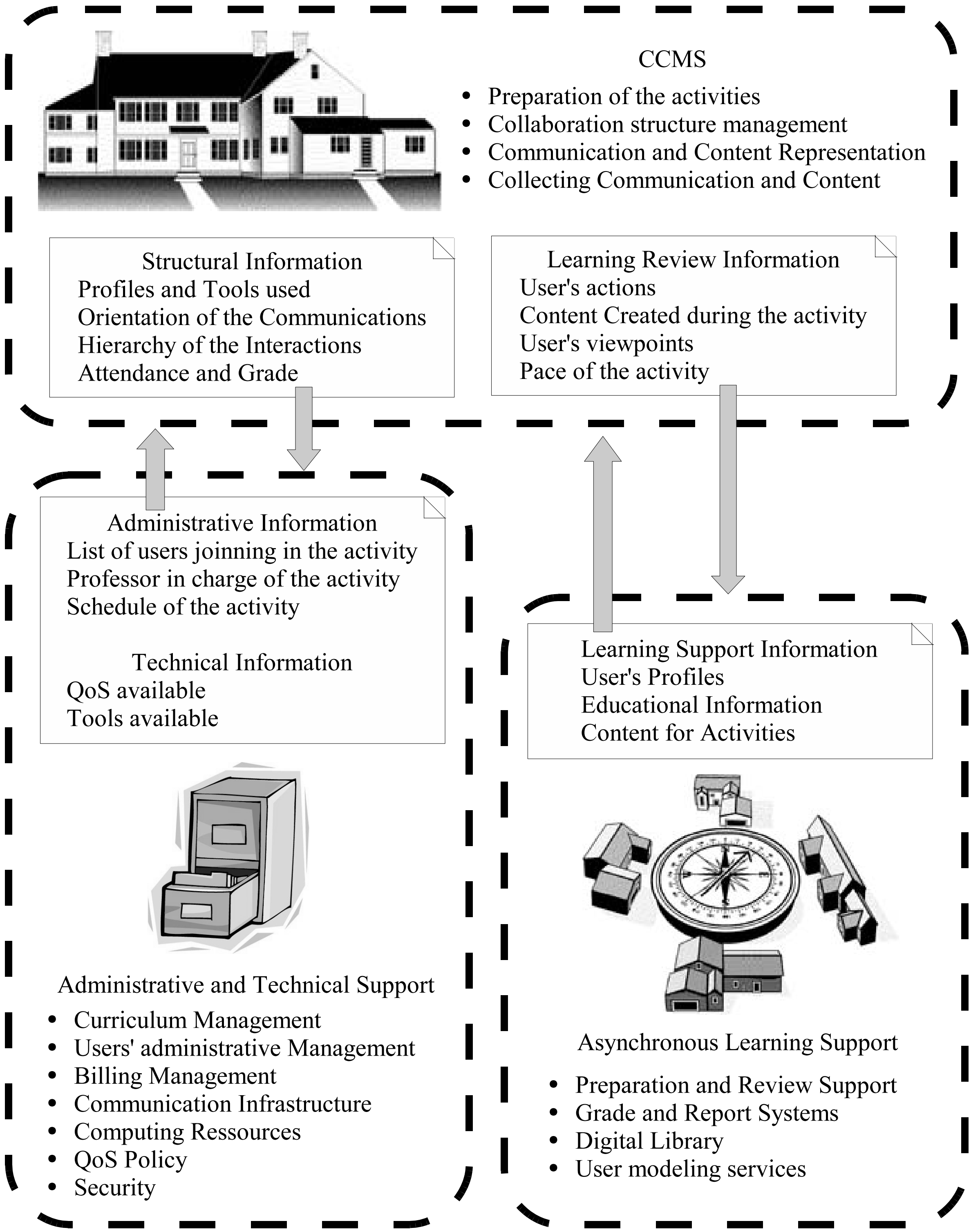

Figure 34: Integration of CCMS in a Virtual University

5.3 Content and Communication Management System (CCMS): Directions for the Implementation of the Model

The development of a Content and Communication Management System (CCMS) has not been performed yet but the technical feasibility and relevance of the implementation was taken into consideration along with the model definition. This section introduces the work performed and the directions selected for further implementations.

The CCMS is separated into two parts: a model editor and a deployment system. The editor is used to define model instances and the deployment system set up the interaction structure and the communication tools according to the model instances.

5.3.1 Edition of Model Instance

Model instances are represented in XML documents. The definition of a new model instance corresponds to the edition of a new XML document. Some elements of the model are likely to be the same upon several model instances, e.g. a user's variable detecting webcam presence, a student learning profile. In order to promote reusability, elements would be described in independent XML documents. Elements are represented literally in a format close to the one presented in the model.

For Illustration Purpose, elements of the model are presented in appendix D: a sample activty integrating all those elements.

- <u>Variables:</u> Username, Userincharge, BitperSample, Frequency, Date, Age, Admininfo
- <u>User:</u> David and Kenji defined with Username and Age variables
- <u>Learning Profiles:</u> Student
- <u>Link:</u> An audiolink with BitperSample and Frequency variables
- <u>Tool:</u> A Videoconferencing tool with an Audiolink
- <u>Learning Activity:</u> A sample activity with an Admininfo variable containing the Date and User in charge of the activity, the 2 users, the Student learning profile (associated with the user David) and an instantiated Audiolink (from Kenji to Student).

The format of the interface for instantiation of variables is not fixed and has been let open. According to the nature of the variable, the interface would have different formats, e.g. Graphic User Interface, Call to a Method (local or remote). These type of interface would likely reference to the class of a programming language object or a Uniform Resources Name (URN) referring to a document.

XML Schema [154] allows defining the structure and the content of XML documents (like Document Type Definition (DTD)). Thus, XML Schema documents could define a generic type of learning activity. For example, a lecture activity could be defined as an activity involving a limited set of learning profiles (professor and student), collaboration tools (videoconference, chat and whiteboard) and a specific set of CTIS and CTIR. An XML Schema document could represent such limitations and insure that the XML document created for an activity conforms to the lecture type. Schemas for representation of the different elements of the models are presented in appendix D. These schemas define the less restrictive view of an element. More restrictive schema could be developed for representing elements of the model; e.g. a specific type of learning activity, collaboration tool.

The graphic representation of a learning activity is presented in fig.35. This schema defines an activity as an element associated with

- 0 or more variables
- 0 or more users
- 0 or more learning profiles
- 0 or more collaborative tools

For simplifying the schema, CTIS and CTIR are represented directly as communication tools used in the activity. CTIR are associated with invocation rights on the link whereas CTIS are not. The fig.35 does not represent attribute of the elements however all the elements are associated with attributes supporting their identification (See appendix D for more details).

The XML Schemas language include a series of facets to restrict the value of elements and attribute in a XML document. The definition of a specific type of variable, user, learning profile or tool would correspond to the introduction of a facets in the general XML schema model presented in Fig.35.

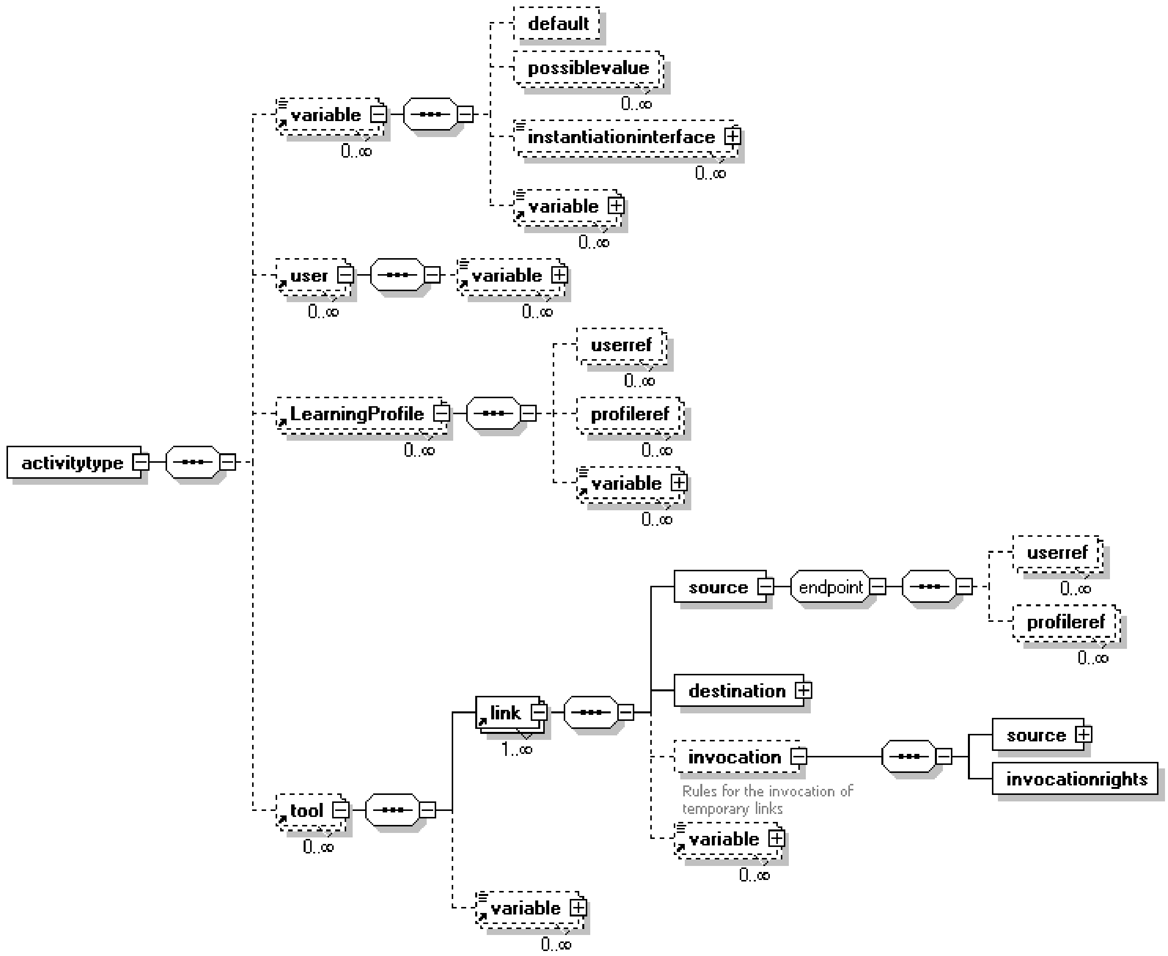

Figure 35: Graphic Representation of the XMLSchema of a Learning Activity

The edition of a new model instance would be faster within a framework. An editor integrated in the CCMS would detect elements defined in the XML Schema and propose them to the user for the edition of the model instance. Thus, the edition of a model instance could be limited to the definition of a few parameters, e.g association between Learning Profile and users, setting of variables.

An integrated editor could support a graphic edition of a model based on symbolic representation of the elements. A simple symbolic representation has been proposed in the description of the model fig.33; it should be completed to provide a full set of graphic elements but it illustrates the idea of graphic edition and representation.

The development of such editor has not been performed and models are edited with the XML Spy edition Tool [155]. This tool supports the edition of XML Schemas and of XML documents. The Elementary model instance (appendix D) and the schema for those instance Fig.35 have been edited with this tool.

5.3.2 Deployment and Control System

5.3.2.1 Strategy

The deployment of model instance is based on the following components:

- Model Coordination Service: it manages the distribution of model instance to User Clients and the coordination of Collaborative Tool Services.
- Collaborative Tool Service: it manages the transport of a specific type of information between user clients.
- User Client: it manages user related information (storage, advertisement), connection to other collaboration services, acquisition and reproduction of information for a collaborative tool service.

Such deployment and control system have not been implemented. Architectures of communication described in model instances have to be deployed manually. They could be deployed automatically providing communication interfaces are well defined between those components. The Model Coordination Server would be started first and would load the model instance (XML document). According to this instance, the required Collaborative Tool Servers would be started. Then, each User Client would contact the Model Coordination Server and retrieve the information necessary for the connection to Collaborative Tool Services.

Technical architectures that could support such deployment system have been studied and are presented in the next section.

5.3.3 A technical Architecture to Support the Model

5.3.3.1 Presentation

In order to support the deployment of the system, the Java implementation of JXTA Protocols was envisioned [156]. "JXTA is a set of open, generalized peer-to-peer (P2P) protocols that allow any connected device on the network – from cell phone to PDA, from PC to servers – to communicate and collaborate as peers".

The main elements of the JXTA architecture can be presented likewise [163]: "The JXTA network consists of a series of interconnected nodes, or peers. Peers can self-organize into peer groups, which provide a common set of services." "JXTA peers advertise their services in XML documents called advertisements. Advertisements enable other peers on the network to learn how to connect to, and interact with, a peer's services. JXTA peers use pipes to send messages to one another. Pipes are asynchronous and unidirectional message transfer mechanism used for service communication. Messages are simple XML documents whose envelope contains routing, digest, and credential information."

5.3.3.2 Implementation Strategy

The implementation strategy is to associate elements of the CCMS model with objects of JXTA Tab.11. *Users* are associated with *peers*. They are identified by a PeerID. *Collaboration Tools* are associated with *network services* and identified by services advertisements and ModuleClassID. JXTA provide a deployment solution to organize peers (users) in a group with specific tools (services). Services are organized in client and servers. The computing devices supporting collaboration tools would be connected to peer groups like other peers. Then, they would advertise their services to the group and support the server function of a service. Users would connect to a group and connect to the peer providing the services. The modularity of the JXTA peer groups supports the diversity of the collaborative organizations.

Different strategies can be considered for this implementation of services:

- Quick Integration: The service is an interface with an existing program and its functionalities. Links are associations between a link name and the command line executing the functionality;

CCMS Model	**JXTA**
Variables	**Interface as a Type**
Name	Name of the Interface
Type	Type of the object treated by the Interface
Possible Values	Restrictions on the Type
Default	Constant Value
Instantiation Interfaces	Setter, Getter Methods
Users	**Peer**
Ref	PeerID
Name	string
Collaboration Tools	**ModuleClass Advertisement**
Ref	ModuleClassID
Name	string
Group Type	Peer Group and Peer Services
Links	List of ModuleClass Advertisement
Learning Profile	**Learning Profile Object**
(Profile name,	(string,
List of user)	List of PeerID)
Instantiated Link	**Instantiated Link Object**
Link ref	ModuleClassID
(Instantiated Source,	(Peer ID or Learning Profile Object,
Instantiated Destination,	Peer ID or Learning Profile Object,
Instantiated Variables)	Objects implementing Interfaces)
Interaction Rule	**Interaction Rule**
Instantiated Link	Instantiated Link Object
Invocation Rights	Invocation Interface
Instantiated Tool	**Instantiated Tool Objects**
List of Instantiated Links	List of Instantiated Links objects
Instantiated Variables	Objects Implementing Interface
CTIS	**CTIS**
List of Instantiated Tools	List of Instantiated Tools Objects
CTIR	**CTIR**
List of Interaction Rules	List of Interaction Rules
Learning Activity	**Learning Activity**
List of users	List of PeerID
List of LearningProfiles	List of Learning Profiles
CTIS	CTIS
CTIR	CTIR

Table 11: Correspondence between CCMS objects and JXTA architecture objects

variables of the link are parameters of the command. This implementation relies on its own mechanisms for the transport and diffusion of messages within the group.

- JXTA Integration: The service relies on JXTA mechanisms for the security and the transport of information. This solution requires a deeper adaptation of existing programs but it provides interesting functionalities. The development of new collaboration tools can be fast and easy if generic implementations are available.

These approaches can also be mixed. A service can be deployed with a third party tool for some clients and with JXTA integration for others. The development of communication tools requires a lot of time and specific knowledge. It is sometimes easier and faster to integrate the work realized by others in order to support the heterogeneity of the clients. Developments focused on a platform are often optimized. The integration of PDA clients in synchronous environments requires knowledge in Windows Mobile Operating System. Rather than getting skills for software development on PDA, integration of a videoconferencing client for PDA could be a timesaving solution.

JXTA Peer ID allows defining communication stream directed to the user rather than streams directed on a physical network address. When a message has to be sent to a host, the physical path to that host is solved by JXTA core protocols. It allows defining virtual structure of communication in advance without knowing the physical structure of the network.

This architecture is not developed yet, however its technical feasibility appears realistic. The JXCube project is based on the JXTA architecture and support several communication tools (JXCube, 2004); with a little adaptation it might be possible to relate them to the CCMS model. Other tools could be adapted from the Platine environment (Platine, 2004), which was developed using Java.

5.3.3.3 Interest of the JXTA Platform

JXTA is implemented in Java and it provides firewall and NAT crossing functionalities, which guarantee access transparency.

With JXTA, it is possible to detect an object (i.e. a user (peer) or a Collaboration Tool Application Server (service)) with a request on the name of the object. This functionality supports the transparency of the system; i.e. location and migration transparency.

In the case of failure from a peer providing a service, the peer group is able to reorganize itself and another peer is defined to support the service. When entering a group, a peer A publish the services it is able to support. If a peer B is already providing the same service, the peer A will not provide the service. A same service can be provided by only one peer of the group. If the peer B has a breakdown, the peer A will provide the service in place of the peer B. This functionality contributes to failure transparency.

The development of the JXTA architecture has taken into account scalability and security issues. These features are very interesting in order to support activities with large groups of users and to guarantee the confidentiality of communications.

The integration in JXTA architecture allows a separation between the creation and treatment and transport of messages. As a consequence, these issues could be developed separately. The development of user interface for capture and presentation of information is itself a challenge. From a network point of view, the transport of information in the JXTA platform can be done in different ways (i.e. advanced pipes). This feature could be used to develop communication strategies adapted to the requirements of multimedia communications. It is also a solution to introduce QoS policy.

In traditional communication protocols, the address of a client is bind to a physical address. This address is used at the application level, which introduces issues for the support of mobility. The JXTA architecture proposes solutions to support mobility of the users. Mobile peers are associated with relay peers that manage the continuity of the communication with the peer group. The JXTA protocols define a complex architecture that mix peer-to-peer, N-tier and client-server concepts.

The JXTA community is very active and several improvements are regularly released. These improvements support the interoperability of the architecture with other platforms. For example, the iJXTA project develops a JXTA service for discovery and interconnection with other description networks: SLP, Jini, Apple Rendezvous. The JAAS membership project aim to make the JXTA membership compatible with existing authentication services (e.g JNDI, LDAP, NIS). Such kind of projects are numerous, it makes the JXTA platform open and interoperable.

Different projects have also been developed to monitor a peer group and its performances. It is a solution to support technical awareness of the environment. This awareness may be useful at the user level.

The JXTA protocols are implemented in Java but also in many other programming languages; e.g. C, Ruby, Python, C#. This guarantees the possibility to develop clients for several types of communication devices.

5.3.4 The Practical Implications

In order to evaluate the potential of the model, it appeared necessary to implement a system. As explained in this section, the relative Content and Communication Management System has not been implemented. However, the CCMS model and the experiments detailed in the chapter 4 have contributed to improve the PLATINE environment. This research has been performed in parallel with the Lab@Future European IST project [111] and the outcomes of both researches contributed to improvements of the Platine environment. Lab@Future is a learning platform that uses novel Information and Communication Technologies to support and expand laboratory teaching practices.

The Platine environments has been tested, modified and improved all along this research work. Modifications were mainly performed by Veronique Baudin; i.e. a research engineer at the LAAS-CNRS who leads the development of the Platine platform. The environment was tested between France and Japan and used to support the supervision of this thesis.

This section presents the developments that were performed in the Platine environment from its first use in the experiments of chapter 4. The environment does not support completely original architecture and several actions are still required by the user but it offers an interesting illustration of some outcomes of this research. An introduction to the architecture of the Platine environment is proposed first. Then the main improvements are introduced.

5.3.4.1 Architecture of the Platine Environment

The Platine environment is based on three main components. The session server, the configuration server and the user clients. The session server manages the access of the user to the collaborative sessions. The configuration server supports the collaborative sessions. Collaborative sessions are seperated in two phases; i.e. asynchronous and synchronous phase. The session server support the user in the asynchronous phase of a session while the configuration servers support the user during the synchronous phase of the sessions. The session server is a server application programed in Java. It is supported by a HTTP server. The HTTP server used in the Platine environment is the Appache web server.

The user clients use a web browser to access the Platine environment webpage. On this page a link to a JNLP file is defined. A JNLP file is a XML file describing ressources (Java classes) and parameteres necessary to run a Java application. Once the client click on the link, the JNLP file is read by the JavaWebStart Application. JavaWebStart identifies the jar files necessary to support the application and download them from the HTTP server. Then, it start a java application with the parameters described in the JNLP file.

The user is presented with an interface providing him two roles; i.e. the user role and the administrator role. The administrator has the ability to create, modify, start and stop sessions. If s/he select the user role, the user is presented with an interface Fig.36. Within this interface, the user has to enter a nickname, choose a group of experiments and select the activity and his role in the activity. Then, the user enters the password and registers the session. After registration, the user enters the asynchronous phase of the session.

5.3.4.2 Avatar of the classroom

The multipoint experiment presented in chapter 4 describes the difficulties for joining activities. The first issue was the access to the system; the user client was started on the local computer and the client had to enter the address of the configuration server (the server that hold the configuration of the session). When connection failed, there was no solution to know when the server was not started yet or the connection error was due to network problems. When the client was connected, the users had to wait for the beginning of the activity.

These issues were solved in different ways. The new architecture of the environment and the web access solved this issues. Thus, the client has not to enter the address of the server anymore, which eases the start of the environment. This functionality also allows the update of the Platine client at each connection. Indeed, the version of the JavaWebStart application checked the version of the files and update them if the ressources cached on the local machines are older.

This session server allows the management of several sessions in parallel. It provides a reference access point that contribute to access transparency. The session server is also a solution to perform in parallet several session.

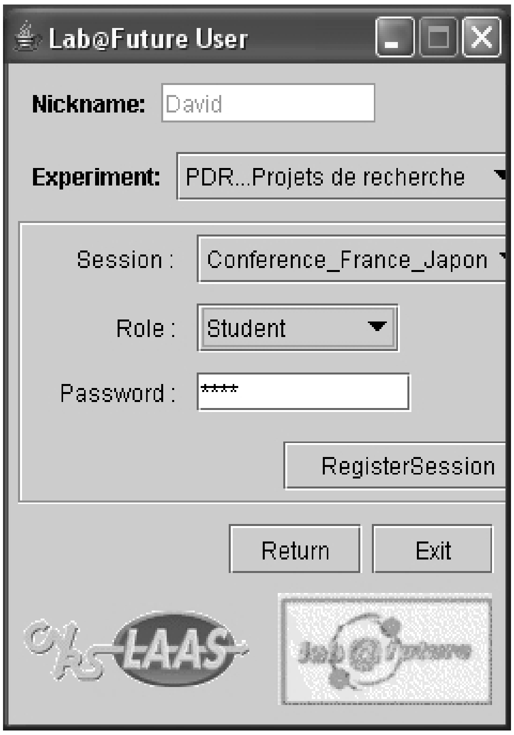

Figure 36: Session Access Interface

The interface of the user in the asynchronous phase of a session is represented in fig.37. The users can see information related to the session: the name, the goal, and the status of the session, the tools used for communication, the list of connected users, their role and status. The status of the session is represented in red with the message "Sync Phase Not Started" when the activity has not begun. While they wait for the beginning of the class, users can use the chat to communicate between them. When the administrator of the session starts the synchronous phase of the session, the status change to a green message "Synch Phase Started" and the users are able to join the synchronous phase by clicking the "Join Sync" button. Once the user clicks the join button, the tools supporting the communication are started automatically. This avatar of the classroom eases the start of activities.

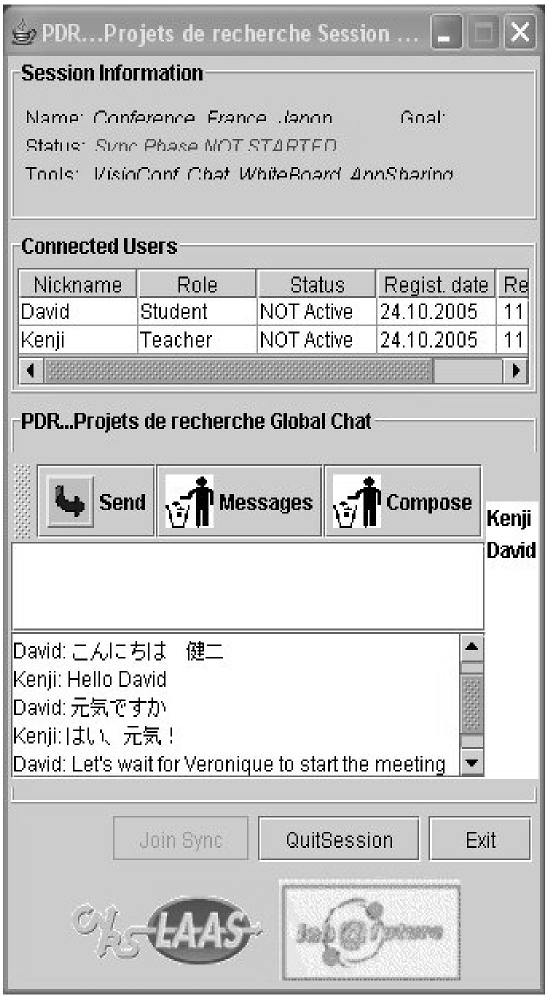

Figure 37: Avatar of the classroom

5.3.4.3 Administration of Sessions

The web access of the Platine environment allows the possibility to administrate session at a distance. To become an administrator, the user has to enter a password and choose the group of experiments to administrate. S/he can create new sessions or modify existing ones Fig.38. A wizard supports the creation of sessions. The administrator has to enter first general parameters about the session: name, goal, password and the address of external resources. Then, the administrator has to choose the profiles that will be used during a session. The Platine environment provides 4 profiles: professor, student, expert and observer. The administrator has to associate those profiles to educational roles in the following steps of a session definition. The administrator decides which categories of user can be chairman. Chairman represents the ability to manage the synchronous phase of the session. This functionality has been introduced in section 2.2.3.4. Then, the administrator selects the tools to be used in the session as well as the address of the servers supporting those tools. The administrator select the user rights for each tool. This functionality allows restricting the rights of a category of users in the manipulation of some tools. For example, students would not be able to load pictures on the whiteboard.

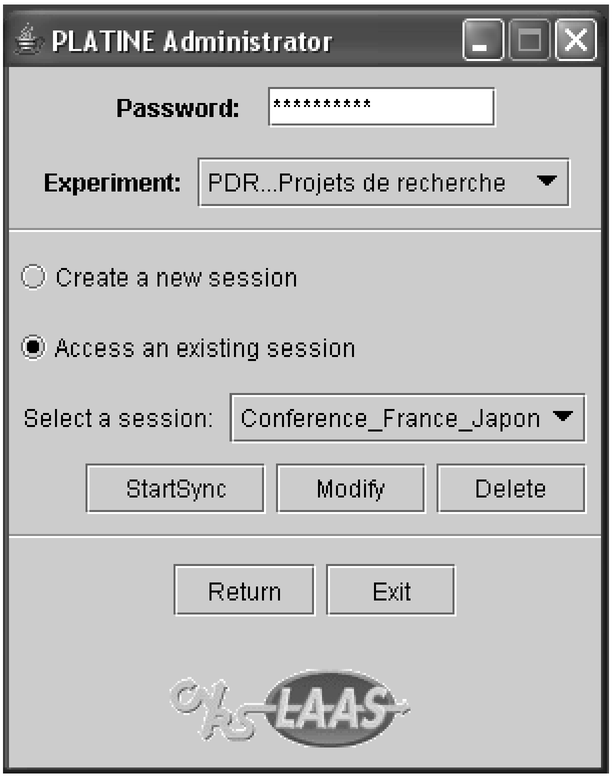

Figure 38: Platine Administrator Interface

Once sessions are created, they are saved on the session server and can be accessed and modified later on. The administrator interface allows the start and stop of the synchronous phase of a session. The user creating the session and the user starting the session can be different persons. A session file contains information related to the structure of collaboration. This information is not as detailed and precise as the CCMS model specify it. Nevertheless, it brings a first step towards a more complete model.

5.3.4.4 Synchronous Session State Display

Once the user has entered the synchronous phase of the session, the tools are started automatically together with a tool supporting environmental awareness. This tool is called the session state display. Fig.39 represents this tool in a chairman mode. In a non-chairman mode, the user does not have the control provided to the chairman.

It provides in the upper part information about the session; i.e. the list of active users for each role, the tools used and the rights of the users on each tool, the user who is chairman of the session. This tool provides information related to the state of the session. It is updated to reflect changes that occur in real time; e.g. presence of users, user who is the chairman.

In the lower part, it provides a solution to request the chairman ability if the user is not chairman. Once accepted as a chairman, the synchronous session state display window of the user is modified to include the chairman controls. It also provides a system to control requests from other users to be a chairman.

5.3.4.5 Platine for PDA

In order to support learning scenario where the users are mobile, a Platine client for the PDA has been developed. PDA can be considered as mobile limited computers. They offer mobility for the price of limited processing power, limited autonomy. Such miniaturization has an impact in HCI; e.g. the display size is reduced, the input system (stylus) is not always convenient and audio (microphone), video (camera) capture are still limited.

The PDA client was developed in Java, which allowed reusing some of the code already written for the Platine desktop environment. As the Platine collaboration environment requires an advanced user interface and powerful functionalities, the PDA client is developed on the Personal profile of the Connected Device Configuration (CDC) of the Java 2 Platform Micro Edition (J2ME) [157]. The Java Virtual Machine (JVM) selected for running the Platine environment for PDA is the IBM J9 JVM [158]. This virtual machine is well supported, well documented, and there is already a solid community who works with J9. The device specification selected to run Platine mobile Client is a 400 MHz or better Processor, 32 MB RAM or more Memory and a proper Internet connection.

The PDA client is started locally from the session and connects itself directly to the configuration server. The asynchronous phase of the classroom is supported as for the desktop clients. In terms of functionality, the PDA client provides a chat, whiteboard and the synchronous session state display Fig.40. The PDA whiteboard client is fully functional and can load pictures and put annotations on them in the same way as the computer client. Video and audio conferencing is not yet integrated in the PDA client but it is performed by third party applications; i.e. for video reception and audio conferencing the Pocket Bone (www.pocketbone.com), a H.323 Client for Pocket PC; for audio conferencing, the Skype client (www.skype.com). Video streaming solutions have been tested successfully with third party software VideoLAN Client (www.videolan.org/vlc). Application sharing client (VNC clients) are available for the pocket PC but they have not been integrated yet within the environment.

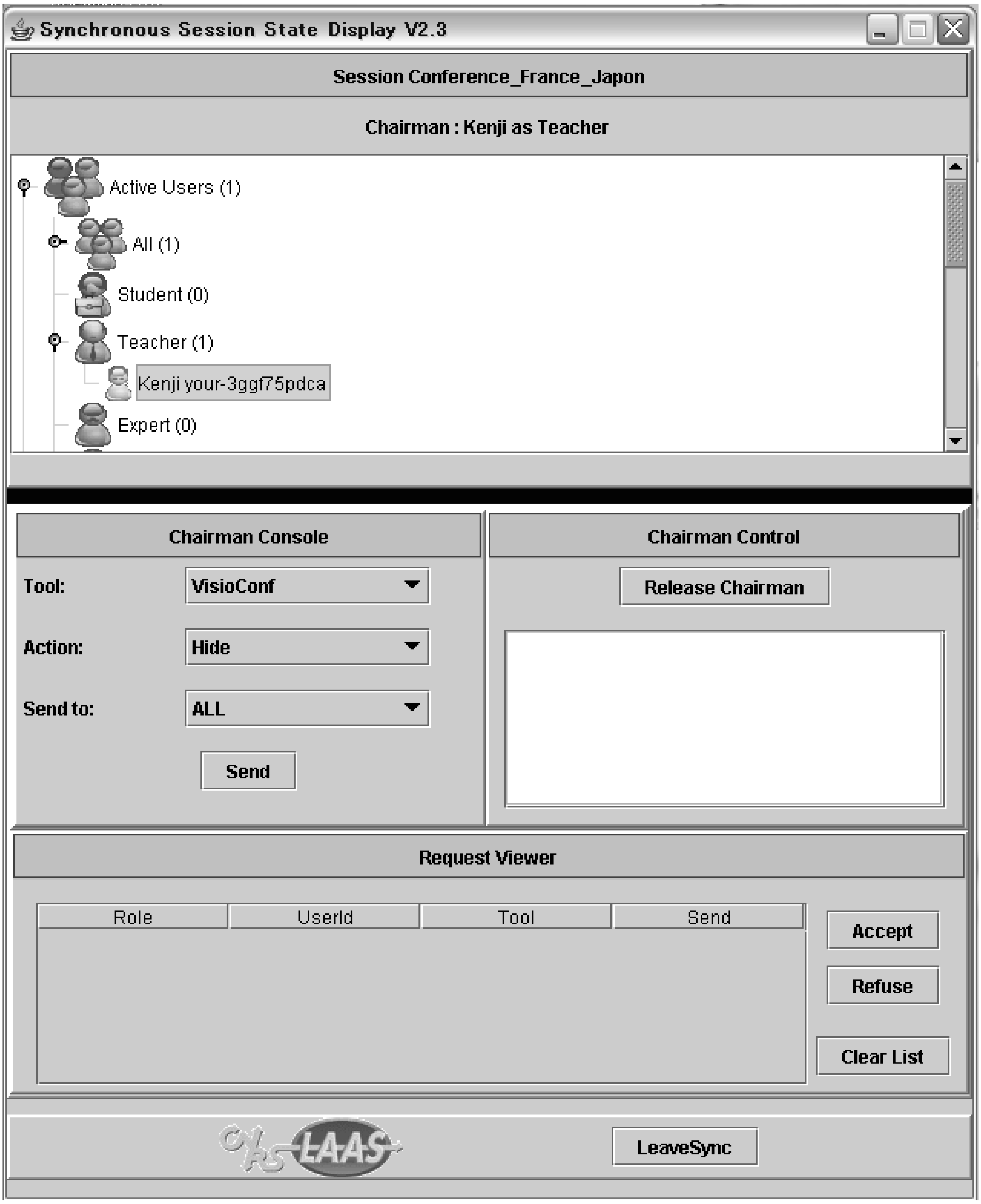

Figure 39: Synchronous Session State Display

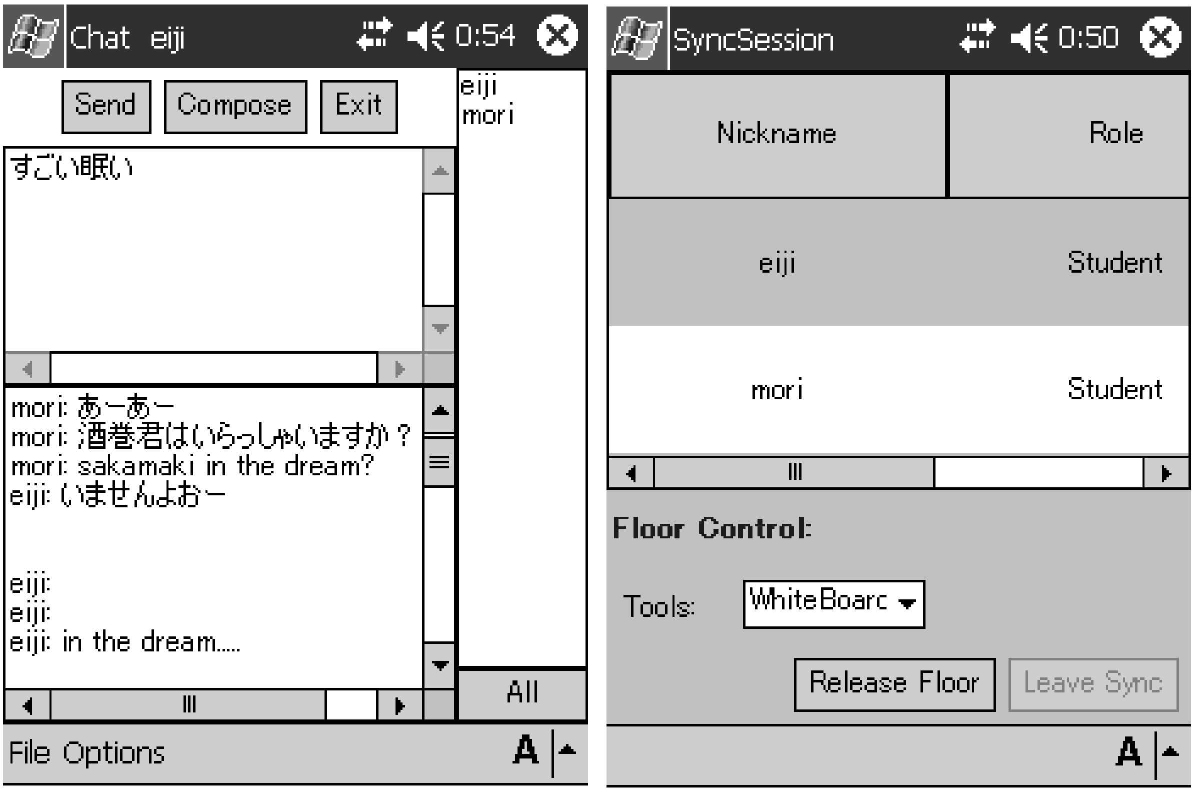

Figure 40: The Platine PDA Chat and Synchronous Session State Display

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Chapter 6

Evaluation of the latest Platine Improvements

6.1 Presentation of the Experiments

6.1.1 Introduction

These experiments were performed to illustrate and evaluate the global approach of this research work. This take into account several elements that have an influence on end-users's judgment. Thus, the idea of these experiments was to put users in a situation as close as possible to distance-learning conditions. This is a necessary condition to evaluate the potential of the Platine system and detect issues that may occur in real situations.

First, the users who joined this experiment took part independently. They had to use the distance-learning solution on their own. During the experiment, they did not have contacts with other learners except through the environment communication functionalities. In the previous experiment, students participated from within a group and the whole environment was set up for them. In this experiment, students accessed to and manipulated the environment unaided.

In Japan, the study of English is a major business. Several private schools get in native speakers from USA, Canada, Australia and England and several japanese students from all ages attend these classes.

The target population that participated in the experiments were students from Tokushima University. Thus, we focused on a language learning scenario. It is a credible learning scenario. Indeed, these students have to study english in their curriculum and they are potential users of English language services. Some participants of the experiments were already attending English classes in language schools. These experiments allow investigating alternative solutions to provide the same type of services, i.e. native speakers could be involved from their home countries.

In the experiments of chapter 4, the preparation and support of the activity was performed within the traditional frame of education. In distance learning, this educational frame is not available. Most of non-commercial synchronous CSCL environments do not provide any asynchronous learning support. The main reason for this lack of support is the limited domain of competency of experts developing such systems. This work has been performed in collaboration between the OLC group from the LAAS-CNRS, Toulouse, France, and the B4 laboratory (Yano's Lab) of the faculty of engineering, Tokushima University, Japan. It was a chance to combine the expertise of the two laboratories to provide a distance-learning solution with both synchronous and asynchronous support. It allows providing an education frame that supports a wider range of distance-learning needs. A full learning scenario including preparation, synchronous-based activities and review was set up.

In the experiments of chapter 4, the activities reflected the traditional lecture-type scenarios. These experiments offered the possibility to make a move towards CSCL and ubiquitous learning theories. The activities involved both lecture style communication and collaborative phases.

During the experiments, the students and the professor were using either TabletPC or PDA. These devices support hand writing and drawing on the screen. It allowed evaluating how to use these communication devices in synchronous collaborative activities. The full learning scenario is detailed in the following section.

6.1.2 Learning Scenario

The learning scenario was based on an English class. Before the beginning of the class, course materials were provided to the students. They included:

- A vocabulary list;
- A Report on the class (homework);
- Directions for the progress of the activity

This class was organized in three phases:

- Orientation and Evaluation: during this phase, the students and the professor got together. The professor checked that all the students had joined the class and presented the steps of the activity. The students were able to talk together during this phase. Then, the professor evaluated the English level of the students by performing a small test. In our case, the test was a listening comprehension test based on the Test Of English for International Communication (TOEIC) [159]. At the end of the test, the professor checked answers and presented results to the students. The professor established groups of two students for the second phase of the experiments. The best students were associated with students that get lower scores.
- Collaborative Activities: The students joined the collaborative activities in pairs. One student had the role of field learner and the other had the role of expert. The field learner had the assignment to go to an automatic vending machine, discuss in English with his partner and bring him a drink. Students had to use their English skill to solve several simple problems, e.g. location of the user, choice of the dringk according to price and availability limitations, description of choices available and types of drinks. The students were able to use the list of vocabulary included in the course materials to solve these problems more easily. At the end of the activity, students had to write a report on the content of this phase. This report evaluated their ability to get information from their partner (e.g. what is the favorite drink of your partner?) and their ability to express it in English. Students changed roles after the first collaboration phase. Experts became field learners and vice versa. During this phase, the professor had the possibility to join a group of students to check their communication and helped them.
- Final Meeting: After the end of collaborative phases, students gathered again to discuss about the class and the problems encountered.

6.1.3 Communication Strategy

6.1.3.1 Orientation and Evaluation

During the orientation phase, the students and the professor were able to talk to each others' directly audio conferencing. The professor was also broadcasting his/her video image to all the students. The students were not broadcasting video to the group. We were not able to provide a webcam for all of the students and we wanted to evaluate all the students on an equal basis. Thus video communication from the students to the group was not provided. In order to prevent the communication from being a cacophony, the students were asked to turn off the microphone when they do not have anything particular to say. This communication structure is presented in Fig.41.

Chat was also provided for communication between all the participants (Fig.42). It was used to support communication for students who had problems starting the audio conferencing tool.

During the listening part of the activity, the audio file used for the English test was broadcasted using audio streaming. The professor started the audio streaming headed for the students (Fig.43). Answers to the test were input and gathered with a survey tool (Fig.44). This tool shown graphic materials supporting the listening test and proposed a list of possible answers to choose from.

The whiteboard was used for the presentation of results. The professor had the possibility to load the list of users and to present corresponding the results (Fig.45). The composition of groups was also

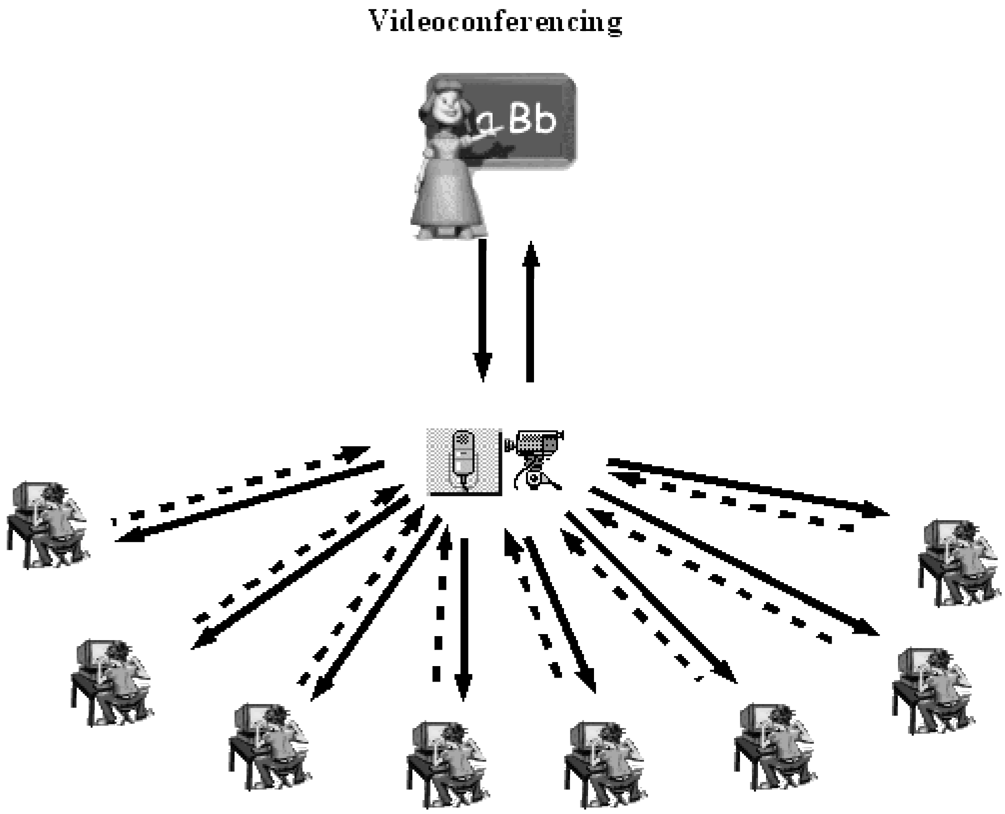

Figure 41: Structure of the Audio and Video Conferencing Communications

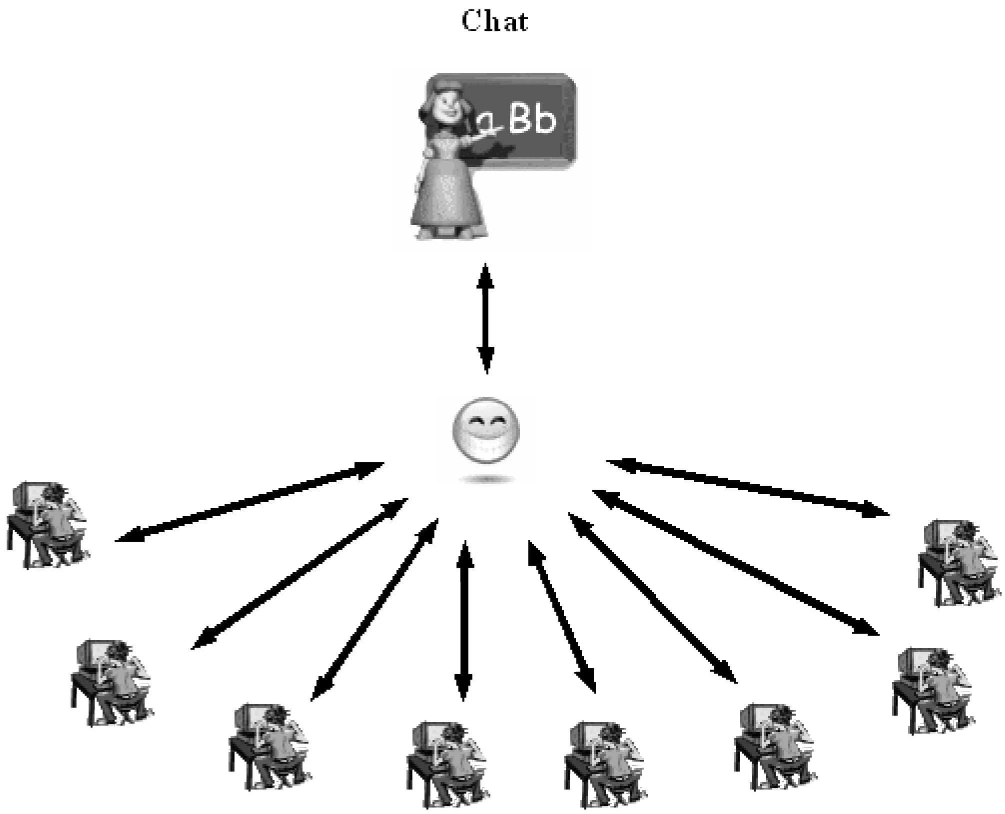

Figure 42: Structure of the Chat Communications

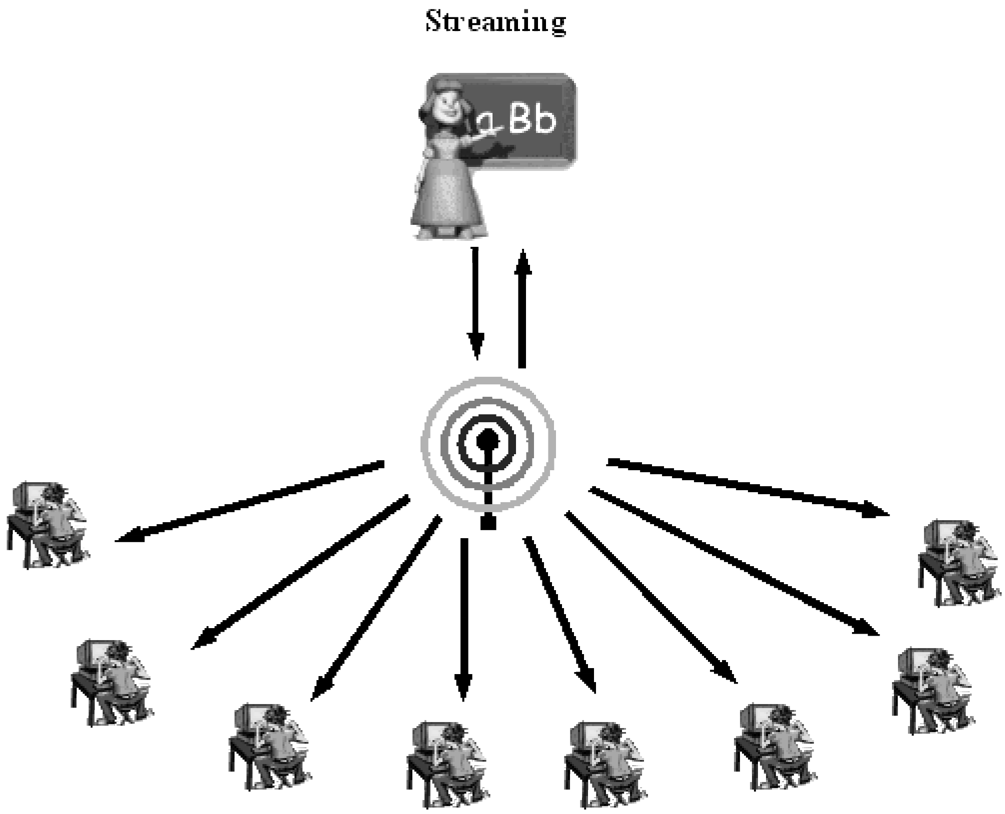

Figure 43: Structure of the Streaming Communications

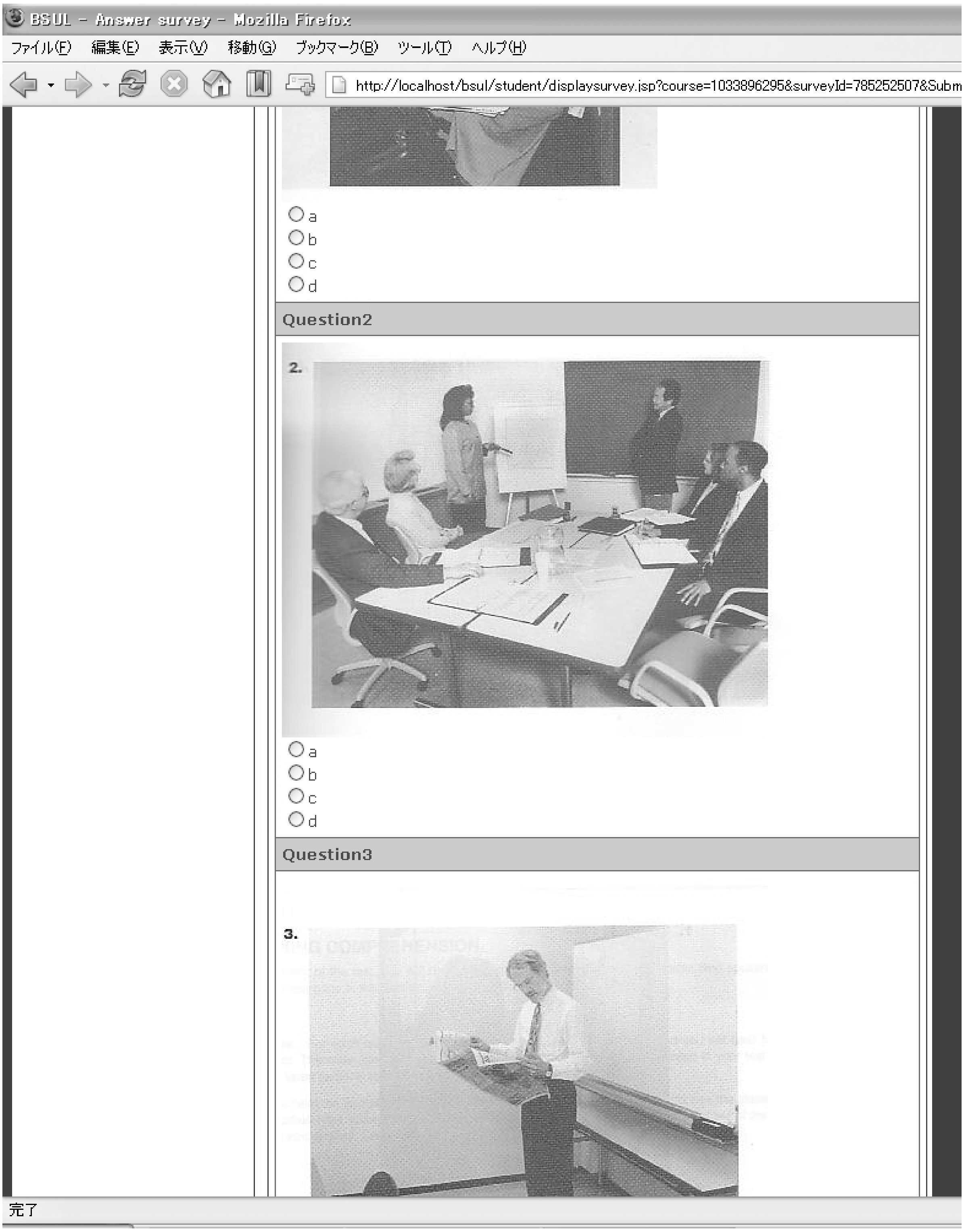

Figure 44: Interface for answering the Questions of the Test

displayed using the whiteboard. The professor also designed the student that had to play the role of the field learner for each group.

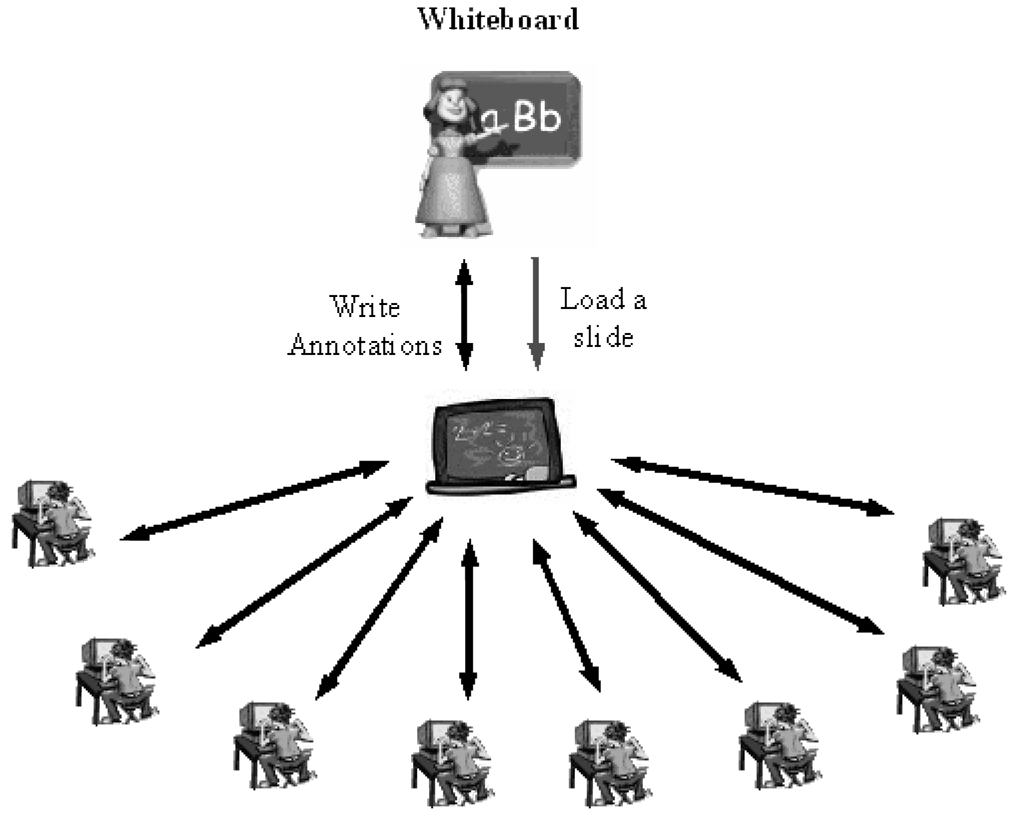

Figure 45: Structure of the Whiteboard Communications

6.1.3.2 Collaborative Activities

In this phase of the class, the students were collaborating on a one on one basis. They were able to use the chat and the whiteboard to communicate. A picture of the student using the PDA whiteboard is presented in Fig.46. The interface of the student using the Tablet PC is displayed in Fig.47 The initial plan was to use also audio communication. However, network technical problems prevented us from using audio communication on the PDA.

During that phase, the professor was able to join the groups of students to check their work and to help them if they encountered any problem.

6.1.3.3 Final Meeting

In the final meeting, all the users were supposed to communicate by audio conferencing on an equal basis. Due to overtime in the experimentation process, this phase was performed directly face-to-face.

6.1.4 Software Solution

In order to support this scenario, two environments were used, i.e. the Basic Support for Ubiquitous Learning (BSUL) and the Platine environment V3.0.

6.1.4.1 Basic Support for Ubiquoitous Learning

BSUL was developed in B4 laboratory, Dept. of Information Sciences and Intelligent Systems, Faculty of Enginering, Tokushima University. It was mainly used to provide an asynchronous support for the preparation and review phase of the class. A complete presentation of this model is available in the work of Saito et al. [71, 160]. BSUL allowed delivering course materials to the students. An

Figure 46: Student using the PDA during the "Collaborative Activities" session

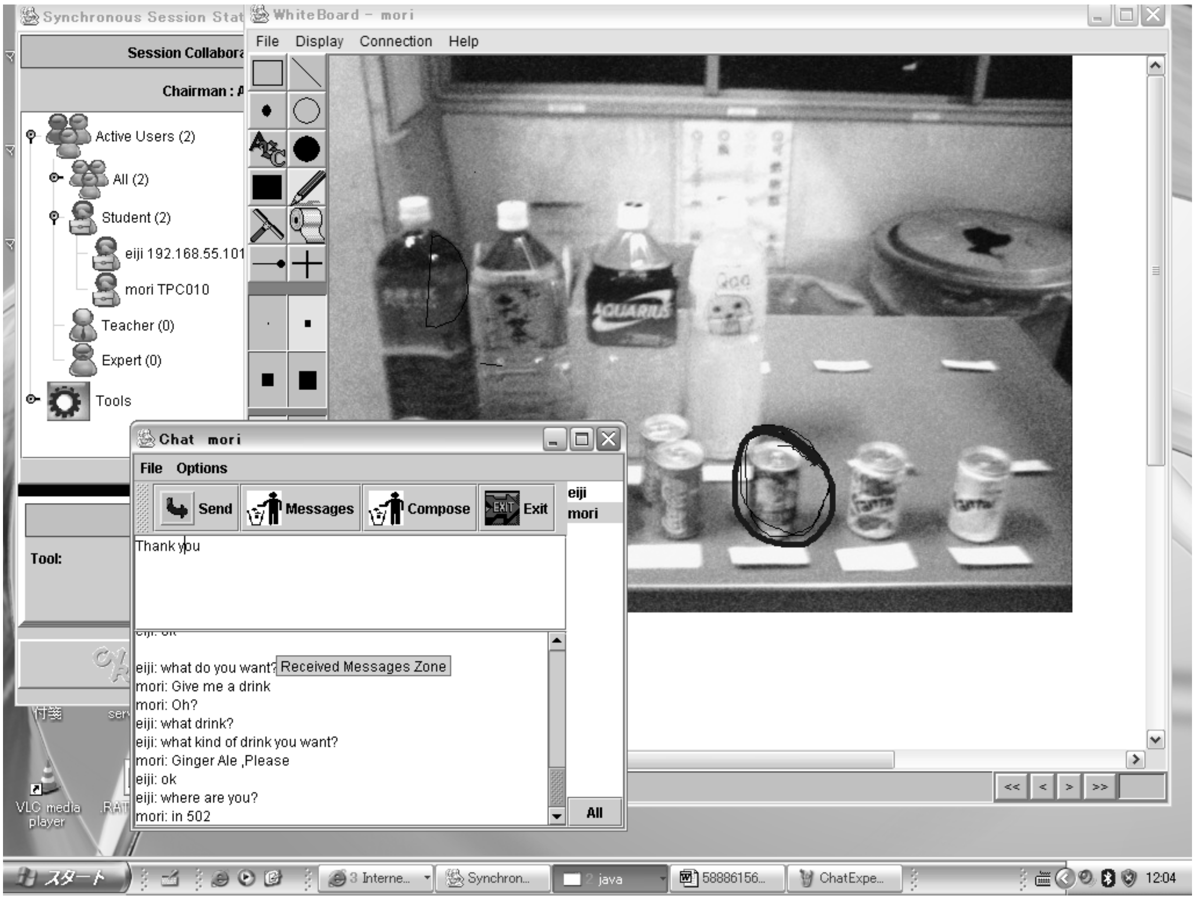

Figure 47: Interface of the Student using the Tablet PC during the "Collaborative Activities" session

activity was created within the BSUL system. This activity was associated with course materials (i.e. the vocabulary list and the report on the collaborative phase) and with a survey (i.e. the survey corresponding to the English test). A user profile was created within the BSUL system for each student and the students were registered in the activity created in the BSUL system. The students were able to access and read the vocabulary list befor the beginning of the activity.

The BSUL system provided the survey tool to support the English test during the first phase of the activity. After students answer a survey, the BSUL system is able to display the results of the survey in a table. This functionality was used to look at the results of the students.

Once the activity was completed, the students had to download the report and submit it using the BSUL System.

6.1.4.2 Platine Environment

The Platine environment was used to support communications during the different phases of the learning scenario. The environment and its latest developments are presented in chapter 5 section 5.3.4.

Using the wizard for the definition of session, six sessions were defined:

- "Orientation and Evaluation" session;
- "Group1 Collaborative Activity" Session
- "Group2 Collaborative Activity" Session
- "Group3 Collaborative Activity" Session
- "Group4 Collaborative Activity" Session
- "Final Meeting"

The tools were selected to reflect the communication strategy presented previously.

VIC and RAT (see within section 3.2.1.1) were used to support audio and video conferencing. The latest versions developed by the VRVS team [41] were used. The broadcast of audio and video to the whole groupwas supported by the multicast protocol.

Audio streaming was performed with the JMStudio application (See section 3.2.1.2) using the multicast protocol. Students did not had to do any specific manipulations to listen to the audio clip as the audio conferencing application was interpreted as the audio stream of any other participant.

6.1.5 Strategy for the Evaluation of the Model

6.1.5.1 Awareness Support

The CCMS system has not been implemented but the representation of a collaboration activity according to the model represent itself interesting information. These evaluations do not provide a validation of the CCMS model directly but indirectly. Indeed, they illustrate the ability of the model to lead to implementation of learning support strategies (see discussion in section 5.2.1). This section presents a learning support solution based on the description of environmental conditions (i.e. conditions defined within a model instance: users, communication structure and rights). The representation of this information aims at supporting collaborative and social awareness. The interest of such support solution is presented in section 5.2.3.

The awareness support was implemented with a webpage representing the information hold within the model. The main page is presented in Fig.48. It is separated in two frames. The first time it is loaded, the main frame display general information on how to use the page as well as technical guidance to use the Platine environment. On the left frame, a series of icons or text refers to elements of the model: activity information, learning roles and collaboration tools. When clicked, these icons displayed information in the main frame. Other pages are presented in appendix E.

For the activity information, the link represented the name of the activity. The activation of this link displayed educational support information; the different phases of the activity were introduced and

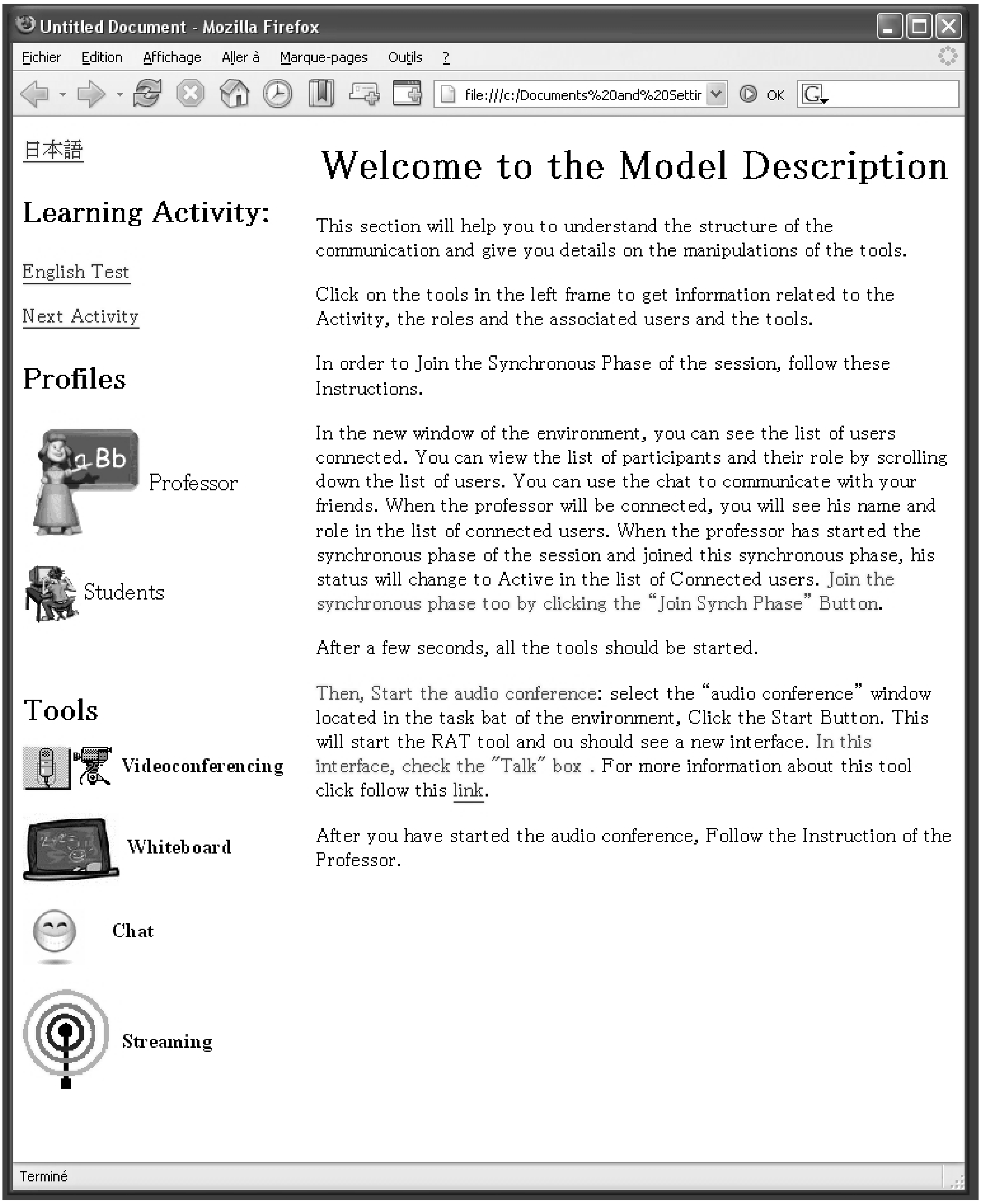

Figure 48: Web based Representation of the Model of the Activity

described briefly. This information would correspond to the content of a text variable "presentation" associated with the learning activity.

A link to the next activity was also introduced. This information would correspond to a variable "nextactivity_ref" of the learning activity.

For the students, the list of students and specific guidance in the activity were introduced. The list of users corresponds directly to the information hold by an instance of the learning profile elements. The guidance would correspond to a text variable "directions" associated with the learning profile.

For the professor, the name of the user and his contact email address. This information would correspond first to the display of the users associated with the professor learning profile. Then, it corresponds to the display of the users' variables associated with that profile.

For the tool, the simple communication structures presented in Fig.41 to Fig.45 were displayed. The technical parameters of the tools and a link to the tool manual were also available. The information of the figures 41 to 45 corresponds to the information of the CTIS and CTIR elements. The parameters of the tools and the link to the manual correspond to the representation of variables associated with the tools.

The web pages described in this section were available in both English and Japanese language. The user had just to click on a link to switch between either of the two pages.

When the students entered the asynchronous phase of a session, the Platine environment offer the possibility to open automatically a web page. This functionality of the Platine environment was used to integrate this awareness support. The web page was associated with the "Orientation and Evaluation" session.

6.1.5.2 Technical Implementation

The web pages describing the model were designed manually in XHTML using Macromedia Dreamweaver 8 [161]. All the information represented in this web page is available in the model. The generation of these WebPages could be thus automatic. In order to achieve such automatic transformation, the model instances of the activity would be associated with an eXtensible Stylesheet Language (XSL) files [162]. XSL is a language for formatting XML documents; it is the counterpart of Cascading Style Sheets (CSS) in HTML. XSL consists of three parts: XSL Transform (XSLT), XPath and XSL Formating Objects (XSL-FO). XSLT is used to transform an XML document into another XML document, or another type of document that is recognized by a browser, like HTML and XHTML. Normally XSLT does this by transforming each XML element into an (X)HTML element. The XSLT language allows to add/remove elements and attributes to or from the output file. It also allows rearranging and sorting elements, performing tests and making decisions about which elements to hide and display, and a lot more. A common way to describe the transformation process is to say that XSLT transforms an XML source-tree into an XML result-tree.

The use of XSLT is very interesting; it allows relating directly model instances to their representation in a standardized way. The XSL style for the representation of the model instances can be modified independently from the XML definition of model instances. It allows changing the style of representations according to other type of variables; e.g the type of activities, the user profile.

6.1.6 Communication Architecture

The communication architecture of the experiment is presented in Fig.49. All the computers were connected using Ethernet Local Area Network. The following computers were set up:

- <u>Platine Sessions Server:</u> this server was the reference access point of the experiment. The sessions server managed the access to all the sessions in parallel. The Apache server hosting the WebPages representing the model was hosted on this computer.

- <u>Platine Configuration Servers (Server 1 to 4)</u>: these servers support the synchronous part of the sessions. These servers were connected as "Administrator" clients to the Platine sessions server. The synchronous phase of the "Group i Collaborative Activity" session were started and let on

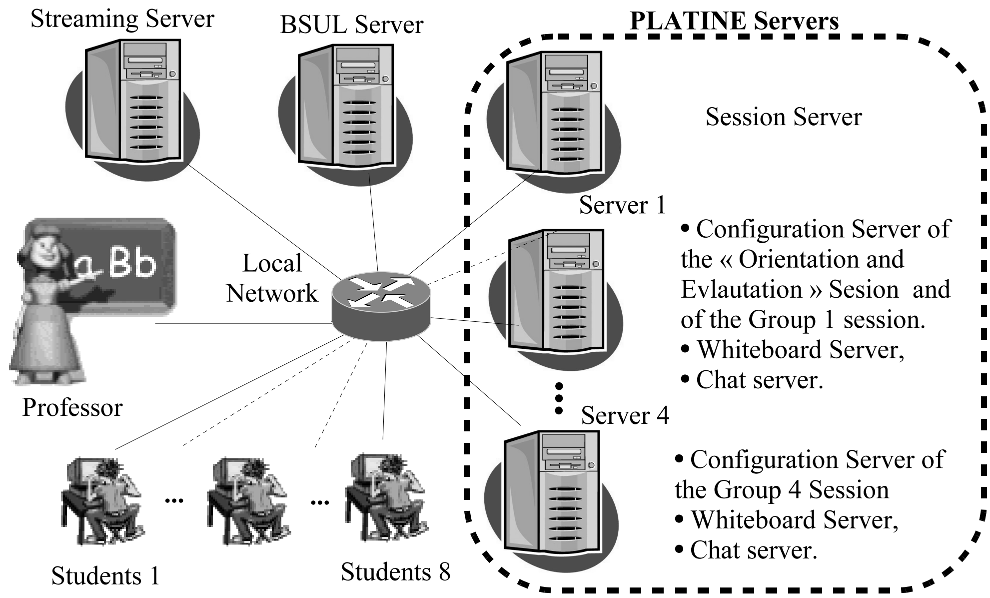

Figure 49: Architecture of the Experiment

for the duration of the experiment. The server 1 hosted the "Orientation and Evaluation", the "Group 1 Collaborative Activity" and the "Final Meeting" sessions. These sessions were started and stopped one after the other.

- BSUL Server: this server was hosting the BSUL system.
- Streaming Server: the audio file streamed to the students was stored on this server and sent to the students using multicast.
- Platine Clients: The professor and the students connected to the Platine Sessions Server as "user". Then they selected their session and their role as presented in section 5.3.4.2. The Student clients were available on Tablet PC and PDA.

The Platine servers were all running under Linux distributions.
The clients, the streaming server and the BSUL server were running Microsoft Windows XP.

6.1.7 Technical Specifications

The computers used for hosting the different servers were inexpensive desktop computer:

- Platine Sessions Server: Pentium IV, 3GHz Hyper Threading, 512Mo RAM. Linux Fedora Core 3 ; Java SDK 1.4.2 (blackdown distribution) ;
- Platine Configuration Server 1 : Pentium IV, 2.5GHz, 512Mo RAM, Linux Fedora Core 4; Java SDK 1.4.2_02 (blackdown distribution) ;
- Platine Configuration Server 2: Notebook, Pentium M 1.4Ghz, 512Mo RAM; Linux Fedora Core 3; Java SDK 1.4.2 (blackdown distribution) ;
- Platine Configuration Server 3: Pentium III, 730 MHz, 512Mo RAM; Linux RedHat 9.0; Java SDK 1.4.2_02 (blackdown distribution) ;
- Platine Configuration Server 4: Pentium III, 550Mhz, 256Mo RAM, Linux RedHat 9.0; Java SDK 1.4.2 (blackdown distribution);

- BSUL Server: Pentium IV, 3.0GHz Hyper Threading, 1Go RAM, Windows XP Japanese Edition
- Streaming Server: HP Tablet PC, 1GHz, 512 Mo RAM, Windows XP Japanese Edition, Tablet PC Edition; Java SDK 1.4.2_09; JMF 2.1.1e.

The user clients were all: HP Tablet PC, 1GHz, 512 Mo RAM, Windows XP, Tablet PC Edition; Java SDK 1.4.2_09. The screen of the Tablet PCs has the functionality of a graphic tablet; users are able to use a stylus in place of the mouse. The Tablet PC also integrates a microphone and loudspeakers.

The PDA used for this experiment were HP iPAQ 5550 models with an Intel Xscale PXA225 processor running at 400MHz and 64Mo RAM dedicated to running the programs. The operating system was Microsoft Pocket PC version 4.20.1081. The resolution of this PDA screen is 320x240. It is equipped with a microphone and an integrated wireless access interface.

The video from the professor was captured with a Logitech QuickCam Pro 4000 at the resolution of 176x144. It was encoded using H.263_RTP.

The audio was captured with the microphone integrated in the TabletPC at 8000HZ, 8 bit per sample, mono channel.

6.1.8 Experimental Protocol

The activity was performed as a one shot event for three groups of students. The test population was composed of Japanese and foreign students of the department of Information Sciences and Intelligent Systems. A total of 22 students joined the experiment. The first experiment was performed with 6 students and the other with 8 students. All the students had a previous experience of using a PDA and 17 had already used synchronous communication software (Instant Messenging Software or videoconferencing). A Japanese student performed the role of the professor. He did not had to speak much in English during the activity.

Students were gathered in a meeting room for a brief presentation of the experiment. They were distributed papers with directions for using the environment and a brief demonstration on how to connect to the "Orientation and Evaluation" session was done. A basic demonstration of the BSUL system was also performed.

Then each student was guided to a different room where s/he took part in the experiment. In each room, a Tablet PC was turned on and configured to access the local network. The students had to download course material from the BSUL server and to connect to the Platine environment by their own. They were able to use directions printed on a paper. From the connection to the asynchronous phase of the session, directions about the activity were also available through the webpage presented in section 6.1.5).

Almost all the students managed to connect to the synchronous phase of the session. Once connected to the synchronous phase of the session, the students had to start the audio conferencing tool by themselves. When a student encountered a problem, s/he has the possibility to go out of her/his room and inquire for assistance. The professor connected to the environment by himself.

Attendance of the participants was checked with the chat in a first time and with the audio communication in a second time.

The professor presented the activity. Then he explained the students how to answer survey using the BSUL system. The professor started the audio streaming. After the end of the test, the professor accessed the BSUL system and checked the answers of the students. The professor used the whiteboard to display the results. He defined groups of users and attributed a field learner role to one of the two students of each group.

The professor invited the other learners to quit the session and to connect to the session corresponding to their group number. These students had the role of expert; they joined the "Collaborative activity" from their TabletPC. The students with the field learner role were invited to gather in the Meeting room. Our initial wish was to connect the PDA using the campus wireless network. However, the PDA firmware did not supported the encryption method used to protect the access to this wireless network. Despite our attempt to upgrade the firmware we were not able to connect the PDAs to the university network. The rainy weather forecast for the days scheduled to evaluate the environment lead us to perform the PDA part of the experiment in the meeting room. The field learners joined the experiment with a PDA linked to the PC computers. Food and drinks were set over the meeting room table and associated with prices to simulate the automatic vending machine.

The initial duration scheduled for the learning scenario was one hour and 30 minutes. However, we underestimated the time required for performing the experiments. In order to respect the schedule of the participants, the collaborative activities were performed only one time. Thus only half of the student group performed the role of the field learner with the PDA.

At the end of the collaborative activities, the students were gathered again and asked to access the BSUL system to download a file “Automatic Vending Machine Report”. They had to answer the questions in the report and to upload the report in the BSUL system. This report dealt with content part of the activity, i.e. language learning.

In order to evaluate the experiment, the students were given three questionnaires: one to evaluate the “Orientation and Evaluation” session and the overall experiment, one to evaluate the collaborative phase with the PDAs and the last one to evaluate the BSUL system. The first questionnaire can be found in appendix F.

6.2 Results

This section presents the results of the experiments. The first section deals with the learning scenarios. It evaluates the learning scenario for the whole experiment.

In the other sections, the results concerning the PDA “Collaborative Activities” sessions are isolated from the results concerning the “Orientation and Evaluation” session performed with the Tablet PC. Indeed, the results relative to the PDA are given as a sample as the data gathered is too small for a real evaluation. Only half of the students performed the experiments with the PDA and among them, some of them encountered software problems and could not perform the full exercise. Thus the population evaluating the use of the PDA was too limited. It would be necessary to solve a few technical issues and to perform again a full evaluation of the PDA version of the Platine environment. The data related to PDA provide an interesting insight for further researches.

Despite our wish to perform experiments in a situation as close as possible to a distance-learning situation, there was still a gap between these experiments and the situation wanted. Among them, the professor performing the lecture was not an English teacher but a student; the experiments realized with the PDA were not realized on the field but in a simulated environment. Concerning the test population, this population was quite homogeneous compared to the social heterogeneity of distance learning groups. These factors could be used to question those results. Nevertheless, these results present interesting directions for the understanding of distance learning researches and should be interpreted as such.

The BSUL system is an independent research. The results presented in this work are thus limited to the relation with the Platine environment and to the learning scenario.

For each questions of the questionnaire, the students had to answer using a scale from 1 to 5 labeled at both end. See appendix F for more details. The results presented in this section (e.g. graphic and averages) are given for a scale from 0 to 4 as it is easier to have a scale starting from 0 to evaluate a value. Averages are associated with confidence interval of 95%. It means that the average answer of 95% of the population belong to this interval. This interval is calculated from the size and the standard deviation of the population. The interval of confidence may appear large. This was caused first by the relatively small size of the test population (22 students). It would be necessary to perform again the experiments with more users to get a smaller interval.

The results are presented in “stock chart” format. The vertical bars represent the interval of confidence. The horizontal lines represent the average values of the answers.

6.2.1 Learning Scenario

The results related to the distance-learning scenario are presented in Fig.50. The average answers to questions 35 to 37 are all over 2.9. It shows very positive results for a majority of students.

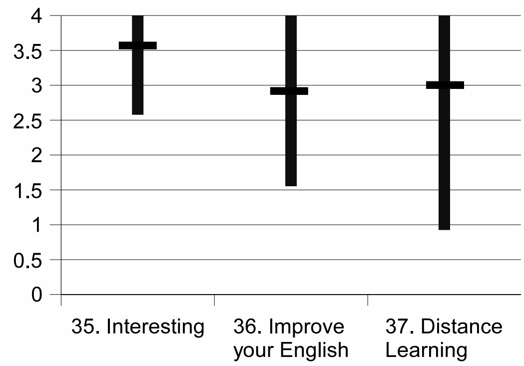

Figure 50: Evaluation of the Learning Scenario

The first column shows the average answers to question 35. The results show a high average, which means that the students considered the activity very interesting. The interval of confidence is small confirming the validity of the result.

The second column shows the average answers to question 36. The high average shows that a majority of the students considered this activity would help them to improve their English level. However, the real benefits of such activity are subject to caution as the interval of confidence is a bit large.

The third column shows the average answers to question 37. The high average shows that a majority of students would be interested in participating in this activity from home instead of going to the university. However the interval of confidence is very large. Thus, students seem to have relative different views for distance learning. This interval would mean that the system or the scenario have to be improved to be convenient for a larger percentage of the test population. The target population that evaluated the system is not a population of distance learners. Thus the benefits of such system for distance learning cannot be evaluated for certain. However, it appears necessary to identify the issues that limited the potential of this system for the test population. It is likely that they share some point of views concerning the limitations of the system.

6.2.2 Support of the Activity

This section presents the results for the support of the activity. It presents the results collected through for the "Orientation and Evaluation" session. At the end of this section, a sub section presents the few results gathered for the "Collaborative Activity" session performed with the PDA.

6.2.2.1 Overall Quality

The results related to the over quality of the system are presented in Fig.51.

The average of the answers to question 32 to 34 are all over 2.80. It shows positive results for a majority of students.

The answers to question 32 shows that all the users were not satisfied with the range of communication tools. If the average remains high, the confidence interval is stretching down to 1.27 on a scale from 0 to 4. After analysis, it could have been useful to use the application sharing in order to guide the student in the use of the BSUL system. The professor gave directions using the videoconference and it was difficult for some of them to access the system.

The answers to question 33 and 34 shows that the quality for communication and collaboration was sufficient for a very large majority of students.

6.2.2.2 Contribution of the Model related Support

The results related to the description of the activity supported by the model are presented in Fig.52.

The average of the answers to question 27 to 31 are all over 2.5. It shows positive contributions of the model-related support for a majority of students.

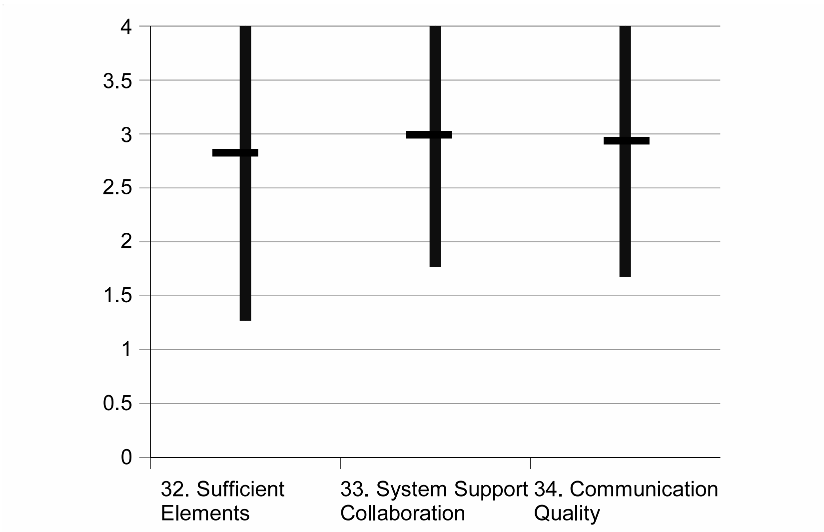

Figure 51: Evaluation of the Overall Quality

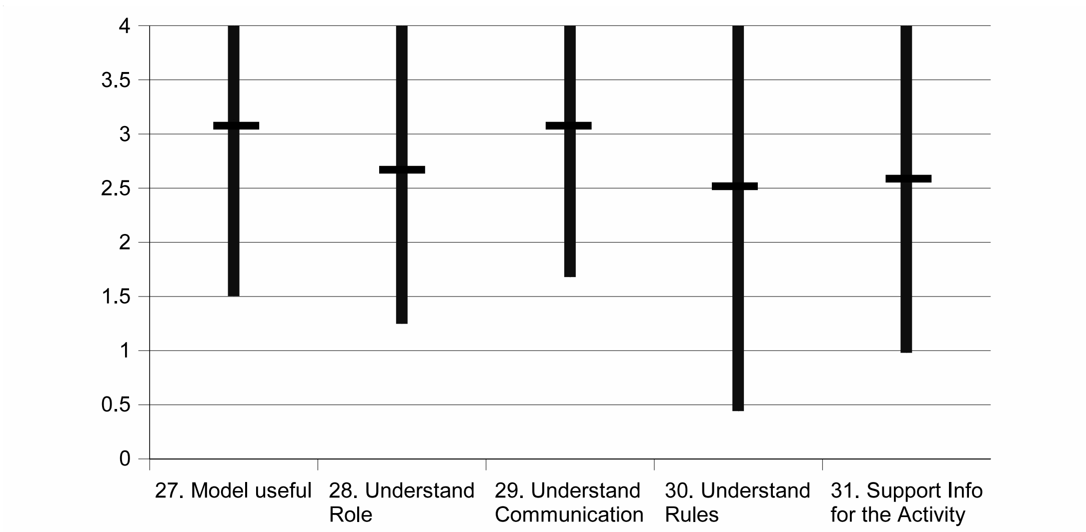

Figure 52: Evaluation of the CCMS Model Support

The confidence interval is limited for question 27 and 29. It shows the representation of the activity model was generally useful and specifically useful to understand the communication structure.

Concerning the representation of learning profiles (educational role), rules and general information of the activity, the confidence of interval stretch down to values below 1.5. It means the representation of this information was not satisfactory for some of the students. In this case, we believe that the choice of the representation and the content of the description had an influence on the results. The representation of users rights was not much explained and it might have been difficult to associate it with the rights to manipulate the tools. It appears necessary to improve the representation of those rights on the graphical model.

The description of the educational role was the main element to help the student understand about their role. The content of the description itself is likely to be the reason of this result. This description is not part of the model; it would be described by the professor and belongs thus to the learning scenario. In a same pattern, the information about the activity is related to the learning scenario.

6.2.2.3 Session State Display

The results related to the Session State Display are presented in Fig.53.

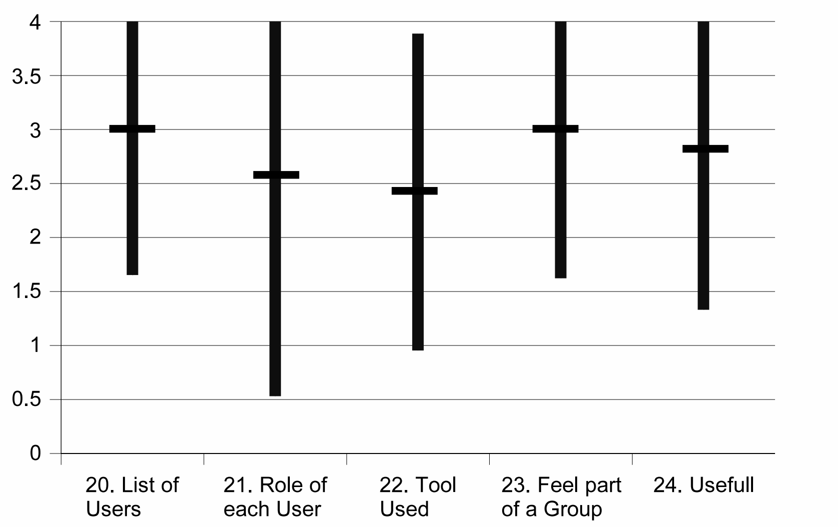

Figure 53: Evaluation of the Synchronous Session Stated Display

The average of the answers to question 20 to 24 are all over 2.4. It shows positive contributions of the Session State Display for a majority of students.

The Session State Display appeared useful to provide the list of users. An interesting point is that it contributed to make the learner feel part of a group. It is an interesting step to establish relationship between distance learners. This feature prevents students from feeling isolated, which is a recurrent issue of distance-learning environments.

The answers to question 21 and 22 shows that some students did not understood the role of each user and the tools that were used. The presentation of information of the synchronous session state display could be improved for best support of these features. These issues are related to the learning scenario as described in the previous subsection.

6.2.2.4 Control Support

The results related to the control support are presented in Fig.54. The control support refers to the ability of the chairman to show, hide, lock or unlock the window of a student at a distance. The questions evaluated the impact of those manipulations on the students. The average of the answers to question 25 and 26 are all over 2.5. It shows positive contributions of the control support for a majority of students.

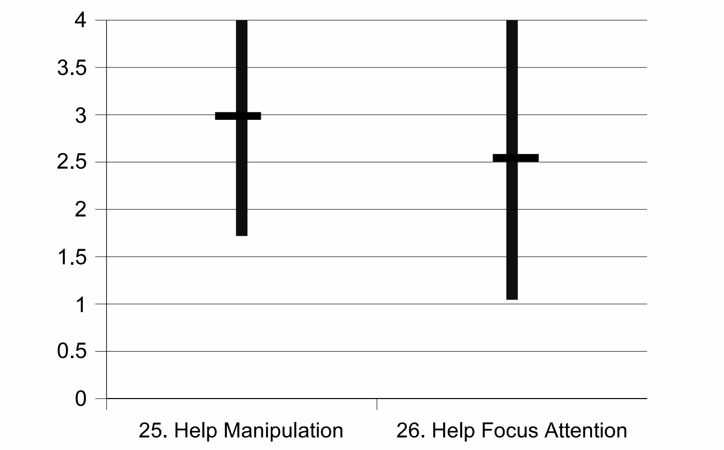

Figure 54: Evaluation of the Chairman Functionality

This management helped the manipulation of the environment for a large majority of students. Indeed, some students wrote down in the free comment part of the experiment that the environment provided too much windows and that it was sometime difficult to find the good one. The control from the chairman provided a solution to compensate this problem.

In order to provide a better solution to draw the students on a tool, it could be interesting to improve this control. For example, the chairman would hide all of the windows except one; the selection of one window by the professor would trigger a modification in the synchronous session state display.

One student suggested the use of a single integrated interface in place of the several windows. Another student said it was interesting to have one window for each tool. The representation of the content seems to be dependant on the user.

6.2.2.5 Support of the Activity on PDA

The support of the activity on the PDA was very limited. The students expressed the lack of tools to communicate with their partner. The chat and the whiteboard were only available. Nevertheless, the students said that these tools were sufficient for practicing their English and for supporting learning. The session state display was considered useful.

6.2.3 Access

This section is separated in two sections. First it evaluates the access from the Tablet PC. Then, it evaluates the access from the PDA.

6.2.3.1 Access from the Tablet PC

The results related to the access to the system are presented in Fig.55. The average of the answers to question 16 to 19 are all over 2.3. It shows positive opinion about the access for a majority of students.

The averages are positive for a majority of students but some of the students had difficulties to access the session. During the experiment, the setting up of the first communication took a lot of time. A few students asked for help because they were unsure of what to do. Student faced was very simple problems. Direstions on the use of the environment were given briefly at the beginning of the experiment but it did not appeared sufficient.

One of the reasons for the access difficulties of some students was a language problem. The interface of the Platine environment is in English and some students may have difficulties in relating the English word used in the interface to concepts of the environment. The user had to select an “Experiment”, then a “Session”, “Register” and finally “Join Sync”. These words did not mean much to some students with limited English skills. Moreover, the names of the “Experiments” were in French language. These names can be changed by accessing a specific collaboration file. However, the system does not support

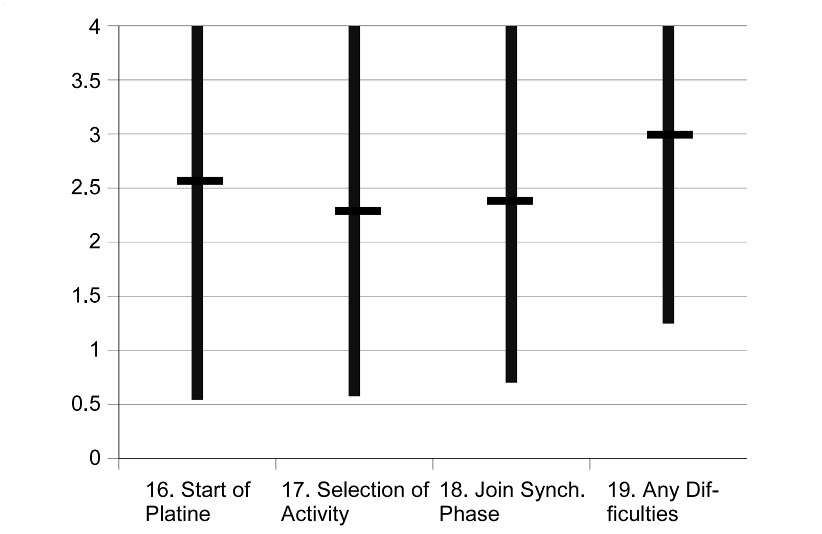

Figure 55: Evaluation of the Access to Platine

japanese characters. The environment provides a small help message when the user put his mouse cursor over a button however this help was also in English.

It would be interesting to provide a support for Internationalization and to provide a complete interface in Japanese and other language. It would probably help many learners to manipulate the environment.

6.2.3.2 Access from PDAs

The access from PDAs seemed to be a bit more difficult than the access from PCs. This difference is probably cuased by the reaction time of the PDA and the delay of connection to the server. These questions are treated in the HCI section.

6.2.4 Tools

This section is separated in three sub sections. The first sub section deals with the ease to use tools on the Tablet PC. The second sub section deals with the usefulness of the tools during the "Orientation and Evaluation" session. The last sub section deals with the tools of the PDA during the "Collaborative Activity" sessions.

6.2.4.1 Use of Tools for Tablet PC

The results related to the use of the tools (Chat, Whiteboard, Audio and Video conferencing) are presented in Fig.56. The students were asked if the tools were easy to use. The average of the answers to question 7, 9, and 11 are all over 2.8. It shows positive opinions about the use of the tool for a majority of students. In the preparation of the experiment, we thought about using VLC (see section 3.2.1.2) as a streaming solution. This option was considered as VLC provide one of the best open-source streaming solutions available. However, the use of this software would have required more explanations and manipulations for the students. Thus, it was decided to receive the stream with the same application as the audio conferencing application for the first group experiment. The students did not have to do anything to receive the audio stream. The question was kept in the questionnaire to let us the opportunity to eventually modify the streaming solution after the first group joining the experiment. The difficulties of some students with the use of some tools in the first experiment lead us to keep the original solution. Thus the students were asked to ignore the question 14 in the questionnaire.

Some students had difficulties with the start of the audio and video conferencing tools. The Platine environment opens two windows, one for the audio and one for the video (Fig.57). The user has to click the start button to start the audio or video application (RAT or VIC). In the window of the VIC and

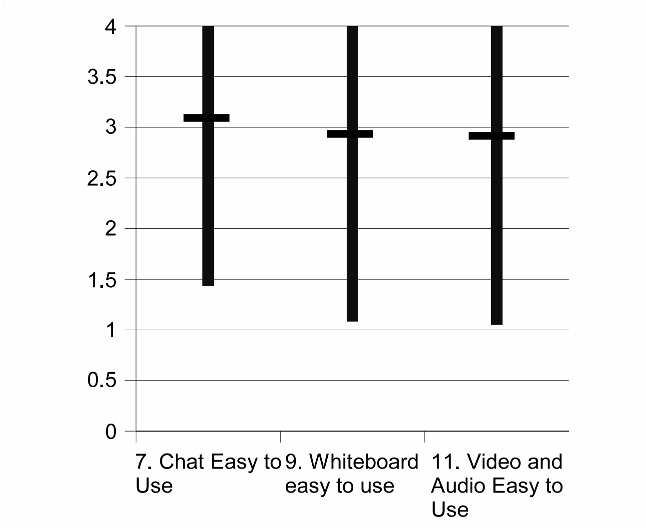

Figure 56: Evaluation of the Ease to Use the Tools

RAT application, the streams are received automatically. However, the user had to check the "Talk" box on the RAT interface to start sending audio. These manipulations were not much intuitive for some students.

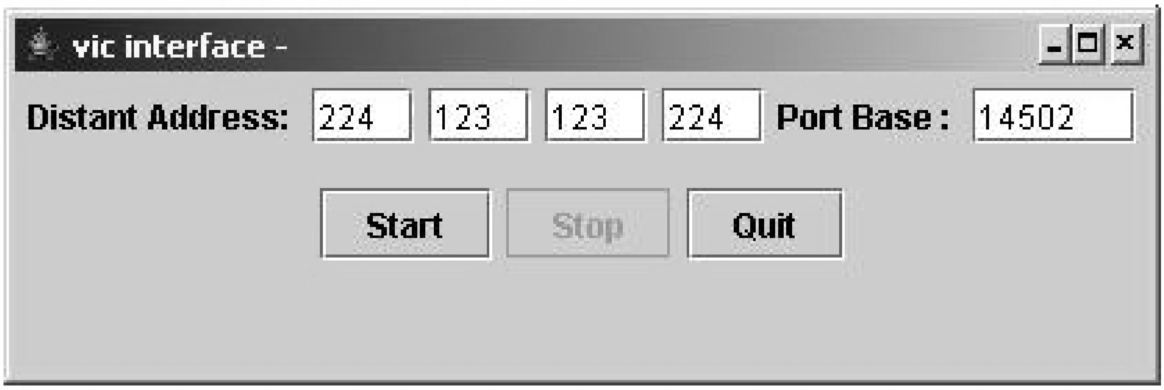

Figure 57: Start of the VIC Videoconferencing Tool from the Platine Environment

It would be interesting to start automatically the audio and video conferencing tools when a user joins a session. It would ease the beginning of the session.

The use of the whiteboard seemed a bit difficult for some of the students. The menu and the option offered to the users are not intuitive. Many users had never used a whiteboard and they were unfamiliar with its concept. Some students were not sure the modifications they put on the whiteboard were displayed to all the other users. It appears necessary to train students for the use of the whiteboard or to give them more details on its concepts; e.g. synchronize, Load images. They were given a link to the Platine user guide that included directions in English on the use of the whiteboard. However, few students took a look a it.

6.2.4.2 Useful Tools

The results related to how useful the tools were are presented in Fig.58. The students were asked if the tools were useful for the "Orientation and Evaluation" session. The average of the answers to question 8, 10, 12 and 13 are all over 3. It shows positive opinions about the need of the tools for a majority of students. The lowest limit of the interval of confidence is almost higher than 2 for the chat, the whiteboard and the audio conferencing. The chat tool was mainly used at the beginning of the activity until users get connected; it provided a reliable communication mode which students are familiar with. The audio conferencing tool was also ranked as very useful as it supported most of the direct communication. The whiteboard tool was less used than in the experiments described in the chapter 4 and appeared less useful.

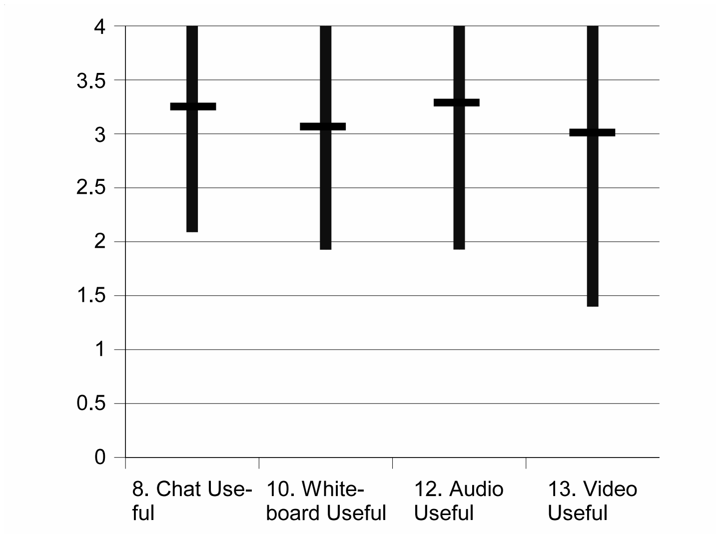

Figure 58: Evaluation of the Contribution of the Tools

The lowest limit of the interval of confidence for the video goes down to 1.4. It shows that some student did not consider video conferencing as a useful tool. This result correlates the results of the experiments presented in chapter 4. For this scenario, the video communication appears less important than the other means of communication.

6.2.4.3 Tools on PDA

The chat and the whiteboard were considered easy to use on the PDA. The answers to the respective questions showed averages of 3 and 3. The chat was the main support of communication. The students rated the chat as useful with an average to the answers of 3.8 out of 4. Comparatively the whiteboard was rated with an average of 3.

6.2.5 HCI

This section present HCI results. The first sub section deals with the answers on the quality of the communication during the “Orientation and Evaluation” session. The second part deals with the use of the stylus on the Tablet PC. The third section deals with the HCI issues on PDA.

6.2.5.1 Quality of the Communication

The results related to the quality of the communications are presented in Fig.59. The students were asked if the tools were easy to use. The average of the answers to question 3, 5, 6 and 15 are all over 2.2. It shows positive opinions about the need of the tools for a majority of students.

The opinion about the quality of the communication seems to be very different according to the students. The size of the interval of confidence is very large for almost all of the categories.

It is interesting to notice the difference between the quality of the audio conferencing and the streaming. They were both sent using the same network protocol (multicast). The traffic was not metered precisely but it is likely that there were no congestions on the local area network. Two factors may have caused this difference. First, the difference of encoding between the streaming and the audio conferencing is likely to have an influence on the quality. Streaming was performed with a u-law codec and voice was transmitted with GSM codec. The second factor is probably related to the

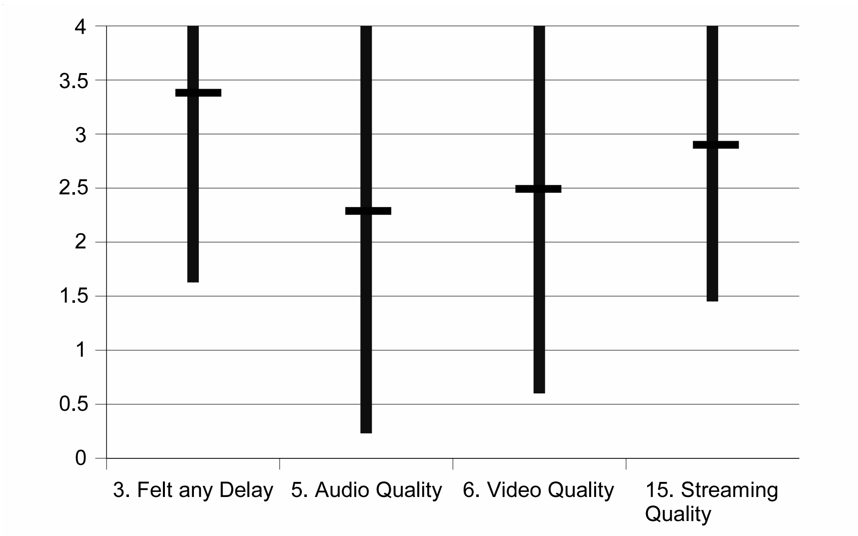

Figure 59: Evaluation of the Communication Quality

experimental settings. The microphone included in the Tablet PC was multidirectional and captured all kind of sounds. The students were taking part in the activity from rooms where regular students were studying. When a user of the room left or entered the room, the microphone captured the sound of the door. Some students wrote down such issues in the free comment part of the questionnaire. It seems that the use of uni-directional microphone is necessary.

6.2.5.2 Interactions with the Computer

The average answer to questions 1 (about the use of the stylus for the Chat) was equal to 1.6. The average answer to question 2 (about the use of the stylus for the Whiteboard) was equal to 2.65. These results shows that a majority of students did not find the stylus useful for using the chat but that they found it useful for the whiteboard. The intervals of confidence for those results are very large. It shows the heterogeneity of the user's need for using the stylus. Learning how to use a stylus seems to require time and it may not be worth having such input system for one-shot events. The interest for such input system would depend on the type of activities performed.

6.2.5.3 Interactions with the PDA

The students rated the size of the PDA screen as insufficient. The average answer was 1.2 out of 4. The resolution of the screen itself was considered sufficient (average of 2.8).

As for the Tablet PC, the use of the stylus was said to be convenient for the whiteboard and not for the chat.

When asked if they felt delay, the average answer to the question was 2. Some students felt delay and other did not. The connection of the PDA through the Tablet PC introduces a significant delay. Solving the network access issues with the PDA would probably enhance this figure.

One of the issues with the use of the PDA was the reaction time of the PDA. The reaction time was considered disturbing (average of 0.98 out of 4, 4 means no delay detected). This limitation is due to the processing power of the PDA.

6.2.6 BSUL System

The students considered that the BSUL system was easy to use. They did not have difficulties to access the course materials or to access and answer the survey.

The students expressed the difficulties to ask questions to the professor about the content of the English survey. It appears necessary to support questions to the professor either within the BSUL system either within the Platine environment.

The student expressed the wish to ask questions related to the English test. These questions could be answered either during the activity or after the activity. In the first case, the professor would understand the context of the question and could answer easily the students. However, if the questions are answered later, the professor and the student asking the questions are likely to forget the context in which the question was assked. It may introduce the loss of educational information of interest; e.g. what problem encountered by the student triggered the question? In order to support questions and answers, it would be interesting to reproduce the conditions that lead the student to ask a question. For this purpose, the contextual information and the content of the communication should be recorded and related to the question. For example, when reading the question, the professor would have the choice to take a look at the slides, listen the comments that were made within a few minutes before the question. Such solution requires a deep integration of asynchronous and synchronous system. The synchronous environment should be able to record contextual information and content exchanged during the life of a session and it should be able to accept identification mark on these information. The asynchronous environment should be able to reproduce the contextual information in a suitable way for the professor.

The ease to submit the report was considered average. Some students expressed the wish for localization and automatic setting of the language. The system is actually available in Japanese but the user has to change the language in his/her profile.

Some students expressed the wish to use the system to practice for the TOEIC test on their own. It shows the interest for a complete learning solution. Asynchronous review and training support seems the necessary complement to synchronous activities.

6.2.7 Comments of the users

The students expressed their interest for using the system in other situations. Students proposed to use the system for meetings or for interaction with a friend. In period of exam, they ask or they are asked questions from their classmates. Thus, they said it would be a good system to support teaching to another friend.

A student also said it would be interesting to use the system when he travel abroad. It would be nice way to get support and share his experience. One student said it would be interesting to have the version for the PDA instead of the cell phone. Provided audio communication is supported, it would be a nice communication terminal.

Some students expressed the too large number of windows as described in the previous sub section 6.2.2.4.

From a communication point of view, one student expressed the difficulties to gather several students. He said it took too much time to get everybody connected and to take attendance.The long time required to start the activity is related first to the scenario. The students and the professor were studying together and the professor was waiting for all the students. In a scenario with more students, it would be likely that the professor start the activity at the time scheduled and with the students that are connected. It would require too much time to wait for all the students and students should be responsible for their own connection to the system. The time taken to gather the students and the professor was still longer than in a face-to-face situation. The lack of trainning on how to use the system is the main reason for this extra time.

6.3 Discussion

One of the main purposes of this experiment was to evaluate if the students were able to use the system autonomously. If the answer are positive for a majority of students, some of them had difficulties in using the environment. It appears necessary to improve the access to the system and the way the synchronous session is started. Considering the observation of these experiments, we believe there were two main categories of issues that prevented these users from using the system easily. The first one is conceptual. The system was introduced briefly to the students and some of them expressed their surprise during the presentation of the environment. For example, they were not aware of the availability of whiteboard tools and showed their surprise when they were told that image and annotations put on the whiteboard were seen by all the distributed users. The ability for the chairman to control at a distance the tools' windows of the other users was also unexpected. These users did not devise the ability of computers to support such interactions. This conceptual "gap" can be related to the second categories of issues which are implementation choices. The implementation of the platine environment does not supported completly these conceptual issues. The answers to those issues should thus be seen as both technical and educational; it is necessary for the users to understand some of the basical concepts of the collaboration and it is necessary to find an appropriate implementation to reflect these concepts.

6.3.1 Start of Synchronous Phases

Concerning the synchronous phase, the video and audio conferencing tool could be started automatically to speed up the beginning of activities. One other interesting solution would be to merge the chat of the asynchronous phase of the session with the chat of the synchronous phase of the session. This would provide a tool that supports the communication under all conditions. The actual settings were developed for the Lab@Future Project. The chat of the asynchronous phase is shared by all the users of a same experiment. The user of a same experiment can be in different sessions however, the chat of the asynchronous phase is shared. The interface supporting the asynchronous phase of a session is associated with the list of the user joining the session and with the list of user of the chat (corresponding to the user that have joined the experiment). This solution was developed to help users that registered in the good experiment but in a wrong session. Such users can be helped by others. The access strategy is related to the type of activities and it would be interesting to support different strategies to access a session.

6.3.2 Awareness Support

The support of communication during the synchronous phase of the session seemed satisfactory. The Session State Display together with the representation of the Model supported awareness of the activity. It would be interesting to merge the concepts provided by those two elements. The Session State Display could be developed to provide a better representation of how users communicate within a session or the representation of the model could be modified to integrate the dynamic changes that occur in the life of a session.

6.3.3 Use of the Environment

In order to ease the manipulation of tools, it seems either necessary to adapt them or to train participants to use the environment.

The modification of tool interfaces and the development of language adaptation solutions are necessary. The comment of the users and the results learned from these experiments provide interesting directions for these improvements. However, it does not seem sufficient to ease the use of the environment for all users. Indeed, free comments showed that requirements depend on the users; i.e. too many window for some users, nice to have seperated windows for others. Thus, providing trainning to the users would develop their ability to manipulate the environment and their understanding of the concepts supported by the environment. However, by nature, it is difficult to gather a group of distance learners, thus asynchronous training is necessary. Movies, flash animation and documentation provide a simple and quick solution to help users manipulate the environment. The drawback of these solutions is their lack of interactivity. Moreover, the improvement of the environment may introduce changes in the interface that would require a new editing. The users taking part in this experiment were given written notes about the manipulation of the environment. However, few of them seem to be reading notes naturally. New forms of trainning could be provided.

In order to illustrate the capabilities of the environment, it seems necessary to gather at least two users. Indeed, the manipulation of the environment in a standalone way does not illustrate well the functionality. A challenging solution would be the development of an agent-based interactive tutorial. The user would learn how to use the environment step by step following a predefined path. For example, the user would have to connect to a session called “tutorial”. Once registered, an agent would detect a new user has entered the asynchronous phase of the session and sent automatically a welcome message in the chat. The message would guide the student to join the asynchronous phase of the session. Once the user joined the synchronous phase of the session, another agent would guide him in small exercise to use the whiteboard. Video games become more and more complex and many of them include such kind of tutorials. They are very useful to learn how to manipulate a complex system.

6.3.4 Asynchronous Synchronous Integration

The use of a complete solution for distance learning was a positive point of the scenario. The comments of the users on the BSUL systems show the interest for including asynchronous support to the environment. This task is not easy and the interface with asynchronous environments needs to be made clear. Asynchronous environments are developed around a content-based approach. Synchronous environments are developed around a communication-based approach. The relation between content and communication has been mentioned in the previous chapter. This relation should be made clear in order to support learners. The dynamic nature of the content in synchronous environment is a challenging issue.

6.3.5 HCI issues with Mobile Devices

Human Computer Interactions seems to have an influence on the use of the distance-learning environment. The solutions to capture audio, the solution to write using the stylus are elements that were briefly evaluated by these experiments. It seems necessary to provide audio communication on the PDA to support more learning scenarios. The use of the chat for language learning is interesting as students practice their writing skill. However, it would become quickly a constraint for other learning scenarios. The PDA could be used provided a technical support is available. However, it seemed a bit early to use PDA for activities where the students are completely autonomous. Improvements in the PDA version of the Platine environment are ongoing and it is just a matter of time to use PDA as any other Platine Client. These experiments showed promising results. The influence of wireless access on the communication should also be studied. Tests performed in the LAAS-CNRS did not showed any particular issues however, real experiments could make a light on new issues. Nevertheless, the PDA seems to be adapted for field learning activities.

6.3.6 Learning Scenarios

The learning scenario seemed to answer students' expectations. This scenario showed an evolution compared with the first series of experiment presented in chapter 4. The introduction of a collaboration phase seems motivating for the users. Such support could be used not only for distance learning but also for in class activities. In traditional learning activities, interactions between users are either direct (e.g. oral communications) or supported by a tool (e.g. blackboard, experimental set up). Very often, students are not participating as much as the professor would expect. Students are often afraid to ask a question or to present their results in front of the others. Mobile devices such as PDA or notebooks offer a solution to support those interactions and favour individual involvement (i.e. each student use his/her device). They are able to support direct interactions by controlling the distribution of information; e.g. they provide a solution for asking or answering questions and for expressing behaviours ("I am completely lost!"). A student may also be able to ask a question to one friend offering interactions opportunities that are not available in a traditional learning activity. Mobile devices can provide a solution to replace interaction tools like the blackboard; students may be able to share results such as equations. Sharing a picture of a test-tube after a chemical reaction is also an interesting way to present its results to the classroom. In order to support such kind of scenarios, it appears necessary to rely on a collaboration structure. Without structure, professors are likely to see their students using the communication tools in an unexpected way (e.g. chatting, talking, playing).

The development of mobile communication device also allows the support of a larger type of activities. Teachers sometimes create interest in their activities by introducing an expert related to the lesson topic. For example, they interview people related to historical events (e.g. second world war veterans); they ask professional experts to give advice to a school project. It is sometimes difficult to reach those persons because they are busy or have physical disabilities that prevent them from going to the school.

The use of mobile device is a solution for them to take part in the activity with fewer constraints. In this case, synchronous collaboration environments are used to go past the physical boundaries of a classroom.

Another scenario would be the use of PDA as a communication device for an technical expert. The technical expert user would be able to provide assistance at any time to another user. For example, a student having difficulties solving a problem would be able to contact her/his friend or her/his professor to get some help.

Many collaboration strategies and scenario could be developed to support learning. These experiments illustrated few of the possible uses of technology to support synchronous collaboration. Much work is still necessary to provide a larger support of those strategies.

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Chapter 7
Conclusion and Future Directions

7.1 Contributions of this Research

Synchronous distance learning solutions have to deal with the heterogeneity of activities, users, communication devices and networks. Researches related to those fields are often done independently. It leads to the development of unbalanced environments. These environments provide innovative solutions regarding a specific criterias. However, they have weakness concerning other criterias. This thesis provides a global point of view on synchronous distance-learning environments. It does not contribute to improve deeply a specific point but it interests in the relationship between several research fiels related to synchronous environments for distance-learning. This thesis has been done in collaboration between the B4 Laboratory of the Faculty of Engineering of the University of Tokushima and the OLC group of the LAAS-CNRS. Thus, it studied mainly the contribution corresponding to the field of expertise of this two laboratories: educational systems and network.

The second chapter presented contributions corresponding to the field of expertise of B4 laboratory. It presented educational theories and collaboration strategies. It defined also categories to evaluate how synchronous environments support heterogeneity of distance learning from an educational point of view. These researches are necessary as they provide meaning to the interactions and communications between the users.

The third chapter presented the contribution corresponding to the field of expertise of the OLC research group. It presented distributed systems and multimedia communications. It defined also categories to evaluate how synchronous environments support heterogenity of distance learning from a network point of view The researches on network and telecommunication are necessary as they improve the quality of communications and contribute to the seamless integration of distance learning solutions.

The fourth chapter presented experiments of distance learning. These experiments delivered much information on collaborative issues in synchronous environments. They showed the lack of contextual support to recreate a learning environment. Set up and access to synchronous activities appeared difficult. This lack of support may introduce difficulties in interacting with other participants. Learners seem to have different requirements in terms of communication and interaction approach. These experiments delivered also information on network issues in synchronous environemnts. Especially, they illustrated the inter-corelation of network perturbations in a synchronous distributed environment and the interest for cross-disciplinary approaches. These experiments also demonstrated that the relation between educational and network requires cross-disciplinary approaches. The quality perceived by the learner is different from the quality of communications from a technical point of view. Experiments were realized with perturbations that were above the tolerance cited for phone communications. However the quality was considered sufficient for the activity performed. When available, QoS policies should be defined according to the activity in order to optimize the use of network and computing ressources.

The fifth chapter proposed the CCMS model in order to depict the relationship between network and collaboration. It represents collaboration strategies in a way that can be translated in communication infrastructure. The ability to model original collaboration and interaction structure is necessary to support heterogeneity of the distance learning scenarios. The modelisation is a solution to foster the development of educational support strategies. It is also likely to contribute to the optimization of computing and network resources towards educational goals.

The development of a Content and Communication Management System has not been performed within this thesis. However, tracks of developments were provided and the ideas of this research lead to improvements of the Platine environment.

The last chapter presents an evaluation of the improvements of the Platine environment. These experiments were performed in conditions closed to constraints of distance learning. The latest improvements seem to support efficiently some of the issues identified in the experiments of chapter four. The access to and set up of the system was improved. Environmental information and controls were provided to support the activity. It proposed also a deeper integration between asynchronous and synchronous support.

These experiments identified directions to support synchronous learning activities and to improve the Platine environments in particular and other environments in general.

7.2 Next steps

This research proposed solutions to spread the use of synchronous environments, however there are still several issues that need to be solved. This section introduce directions to improve environments from both technical and educational point of views.

Synchronous environments could be used for several kinds of activities. Thus, it would be beneficial to provide a set of collaboration strategies to support the use of the environment. This set of strategies would ease the use of the environment and reduce the preparation required by professors. Indeed, the definition of a session is time consuming and some users appreciate ready to use applications. In order to provide such strategies, several experiments supporting different activities and topics would have to be performed.

The support of educational theory and collaboration strategies could also be improved with a better timing of interactions. Synchronous communications allow real time interactions. The exact moment of interactions reflect educational motivations of users. The experiments of the last chapter presented the potential of the functionalities provided to the chairman. These functionalities offered a solution to support dynamic collaboration. Such functionalities could be improved by the definition of more complex collaboration protocols. The automation of dynamic collaboration protocols according to environmental values would also be interesting. It would contribute to make activities more lively and lower the burden on the professor.

The last experiments showed the interest of students for contextual and awareness support. Indeed, the information hold within the model representation and the Synchronous Session State Display were rated as useful. The information provided by those tools could be extended. Users do not like to input environmental information. Thus, strategies for the acquisition of this information should be developed.

For example, image processing fields could be related to educational use. Students equipped with a web camera could have their face expression analysed by image processing techniques. Prototype software are able to detect information on the user, e.g. emotional expression and fatigue of the user.

Another direction for the acquisition of environmental information is the use of sensors. The use of sensors define a new facet of the relationship between networks and educational system. Indeed, sensors introduce a new type of information sources into distributed systems. The organization of sensors has to be treated from the point of view of both network and information systems. It would be interesting to carry on the work performed between the two laboratories to study this relationship. The implementation approach proposed for the CCMS could be extended to support such relationships. Indeed, the JXTA set of protocol has been ported for devices with limited computing capacities. Several members of the community have interests for the integration of captors in the JXTA architecture. Technical solutions are not yet fully available but it shows the growing importance of this topic in the community.

At the user level, solutions have to be developed to display environmental information in an appropriate way. The implementation of a CCMS system has not been performed partly for user interface issues. Implementation specifications at the network and architectural level have been detailed and the development of a CCMS system appeared feasible. However, interface issues have not been treated. As shown in the experiments, the actual version of the Platine environment does not provide an adequate interface for all the users. The represensentation of content and communication at a user level has to be specified. The strategies to represent content would likely depend on the type of activities. The presentation of several communication channels in an intelligible way for the users has been partially studied in web-based multimedia learning systems. It would be interesting to relate these contributions to the CCMS model. Collaboration links are associated with a source and a destination; the addition of variables to the source and destination elements would support the integration of interface elements in the CCMS model.

Technically, initiatives such as XML based User-interface Language (XUL) ([164]) are likely to support such developments. These issues have not been studied with enough details to be presented in this thesis. However, the model keeps the ability to integrate those contributions.

The specification of a peer-to-peer architecture to support collaboration would probably hinder some users of the environment. Peer-to-peer is often associated with the illegal exchange of music and movies over the Internet. Intellectual property is a matter not only for private companies but also for educational staff of public institutions. The creation of course contents requires a lot of time and resources. In most environments, anyone who join a synchronous activity is likely to copy and save the course contents. Contents delivered through synchronous collaborative sessions are not usually protected. In order to protect them, the adoption of Digital Rights Management (DRM) solutions would be an necessary. The distribution of audio, video, slides and other documents would be protected. However, the use of DRM raises legal issues on the intellectual property of content developed in collaboration.

There are still several directions to improve synchronous environments. This research presented a few of them and tried to understand the issues that prevent synchronous environment from being used for distance learning. This thesis have been led in collaboration between the university of Tokushima and the LAAS-CNRS. It seems necessary to carry on cross disciplinary researches as a complement to specific domain related contributions. Such approaches would bring new point of views to existing problems. The goal of this research is to spread the use of synchronous environments for distance learning. We hope it can also contribute to their spreading in other collaborative activities such as work and entertainment.

The Platine environment was used to support collaboration between France and Japan during this thesis.

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Appendix A
Synchronous Collaborative Environments

This section introduces major synchronous collaborative learning and work environments. The description of this environment is based upon the information available from websites, publications and sometime personal evaluation.

The first part of this Appendix presents the environments individually describing their history, their developers and their strong points. Then in a second part, environments are presented in a Table gathering the different element of evaluation.

A.0.0.1 Presentation of the Environments

VRVS (www.vrvs.org) VRVS was initially built in 1995-6 to provide a low cost, network efficient and globally scalable software system for multipoint audio/video conferencing and remote web collaboration for the worldwide High Energy and Nuclear Physics (HENP) research community. The VRVS system is operated, developed and maintained by the California Institute of Technology, USA together with other groups in CERN, Geneva and in Slovakia. A large number of users are registered and uses the VRVS system for collaboration.

A set of 81 VRVS Reflectors interconnected using unicast tunnels and multicast manage the traffic flow at HENP labs and universities in the US, Europe, Asia, and South America. These reflectors allow the combination of several communication streams: e.g. multicast, SIP, H.323. The main themes driving VRVS continued development have always been scalability, usability, functionality, reliability and security.

The VRVS system can be used free of charge

ISABEL (http://isabel.dit.upm.es/) The ISABEL environment is distributed by the "AGORA System" company. It is a collaborative environment developed by the Department of Telematic Systems Engineering of the Technical University of Madrid, Spain. This environment is used to support conference or special events. The particularity of the ISABEL system is the control of the audio and video communication flows. ISABEL is interesting for large events but limited for desktop conferencing due to the restrictive support of terminals.

A demo license is available for free.

PLATINE (www.laas.fr/PLATINE) This environment is developed by the LAAS-CNRS, France. It has been developed for collaborative work first in the end of the 90's and was used in several National (Topase, DeepCast, @irs++), European IST project (Lab@Future, GCAP, EUCHOS, Sat6) and International projects (Bresil, Japon). It has been improved regularly. This annex presents the version of the environment at the beginning of this work (V.1.0) and at the end of it (V3.0). More detail on the environment is provided directly inside the thesis.

The latest version of the Platine environment can be used free of charge

TANGO The TANGO environment is a project led by the Northeast Parallel Architectures Center (NPAC) at Syracuse University, USA. This project was part of the Education Outreach and Training Partnerships for Advanced Computational Infrastructure (EOT-PACI) that was part of the National

Partnership for Advanced Computational Infrastructure (NPACI). The NPACI ran from 1997 to 2004. The TANGO environment does not seem to be still supported. However, it brings interesting architectures issues and ideas at the time it was released. The strong point of the TANGO system is its accessibility. It is a pure Web based application with a stateless client. The TANGO provided interesting architectural ideas for the development of the collaborative system.

DISCIPLE (http://www.caip.rutgers.edu/disciple/) DISCIPLE (DIstributed System for Collaborative Information Processing and LEarning) is a project for mobile computing and collaboration of the Rutgers University, USA. The DISCIPLE project commenced in September 1994 and the initial version was named "InfoPlan". The disciple project supports the resources constraints of mobile computing, e.g. heterogeneous, limited and variables resources. It provides interesting network-aware adaptive approaches. The DISCIPLE project is used for medical and military applications.

The Disciple source code is available from the website of the project.

This environment has not been tested and not enough information is available to support its presentation in the Table.

TELUQ ENVIRONMENT MONTREAL The Tele-Universite and Centre de Recherche LICEF/CIRTA, Canada, developped several distance-learning solutions. Among them, the "Laboratoire Virtuel de Physique" (LVP) supports virtual experiments at a distance. This system can be downloaded freely. This system is interesting for the support of technical manipulations which is rare in distance learning.

WEBEX (www.webex.com) Webex is one of the leaders of commercial web conferencing and collaborative work solutions. It was started in 1996 and developed its functionalities to support collaborative work. This environment is oriented for companies rather than education. Nevertheless, it provides an interesting insight on integration issues (integration with other business applications) and it is supported by a private network that guarantee the quality and the security of the communications.

LIVEMEETING (http://www.microsoft.com/office/rtc/livemeeting/) LiveMeeting is the professional Collaborative Environment developed by Microsoft. This solution is one of the most integrated collaborative solutions of the market. The user can share easily Microsoft Office files. The management and scheduling of meetings is also well developed. The access to the session is accepted for people invited or also people can access a lobby and wait to be accepted in the session.

The Livemeeting system is available for a 14 days trial version

ELLUMINATE LIVE http://www.elluminate.com/ Elluminate Live is probably the most advanced commercial product for collaborative learning. With a specific academic edition of their environment, elluminate live provides several communication and control functionalities. Over all of the environments, it seems to be the more complete solution. A very interesting feature is the ability to breakout rooms for group collaboration. The support of awareness and monitoring of a session is also interesting for the professor to control the activity of the students. The recording of session and interaction is also available and the elluminate live environment manages the distribution of those recordings.

The Elluminate Live solution is available for a trial version

MARATECH PRO (http://www.marratech.com/) The Maratech pro environment is a collaborative work environment. It was first developed in 1995 at the Center for Distance-Spanning Technology at Lulea University of Technology, Sweden. It provides all the functionality this kind of environment and provides also the ability to have audio and video/private communications within a session. A session manager provides the ability to monitor the users engaged in conversation or private meetings. This environment also provides information on the network condition performance. Maratech is used in some universities for educational purposes, e.g. Scottish education department.

WORKSPACE 3D (www.tixeo.com/) Workspace 3D is a collaborative work and learning environment developed by the Tixeo, a company located in Monptellier, France. This environment was developed with the help of research laboratories Laboratory of Computer Science, Robotics and Microelectronics of Monptellier (LIRMM), Monptellier University II and National Center for Scientific Research (CNRS). This company is still young but present a very promising collaborative solution. The strong point of this environment is the 3D modelisation of the space of interaction in which are introduced the document to share.

This environment is available for purchase a demonstration is available.

A.0.0.2 Table of comparison between the environments

The tables present the functionalities of the environments regarding several criteria. These criteria follow the structure of the Chapter 2.

The first and second tables present educational criterias for the evaluation of the environments.

- Session Profile: It represents the ability to define the parameters of a session in advance to lower manipulation during the synchronous collaboration phase;
- Scheduling: It represents the ability to define schedule activities;
- Record, Archive: It represents the ability to record and archive documents and audio files used during a session;
- Educational Roles: It represents the ability to attribute educational roles to the users in order to manage them according to their role;
- User Profile: It represents the ability to support personal information of the user for information or adaptation purposes;
- Rights on Tools: It represents the ability to avoid all the users having the same rights in the manipulation of the tools;
- Chairman Control: It represents the ability to give a specific user rights to control the collaboration parameters of other participants (e.g. changing rights of the tools, stopping audio communication);
- Meeting: It represents the ability to perform activities where communication is oriented from any user to all the users;
- Lecture Conference: It represents the ability to perform activity where communication is mainly directed from one user to the others;
- Other Style: It represents the ability to support style of communication different from the Meeting and Lecture style;
- Questions, Hand Raising: It represents the ability to manage the notification and the treatment of question during a synchronous activity;
- Others: It represents the ability to support dynamic collaboration protocols during the synchronous phase of the activity;
- Advanced List of Users: It represents the ability to present detailed information about the users joining an activity;
- Others: It represents the ability to present information supporting environmental awareness (e.g. users are tired);

The third and fourth tables present distributed system criterias for the evaluation of the environments.

- Web Access: It represents the ability to access the environment from a web browser;
- Firewall NAT: It represents the ability to connect a client to the environment behind a firewall or a Network Address Translation system;
- OS Support: It represents the ability of kind for different Operating Systems;
- PDA Support: It represents the ability to connect to the environment from limited capability devices (mainly PDA);
- Location Transparency: It represents the ability to use the system from any location with the best services possible (e.g. distributed servers around the world, time adjustement according to the time zones);
- Failure Transparency: It represents the ability to recover and hide failure (e.g. automatic reboot of the system, redundancy of the servers);
- Authentification: It represents the ability to Authentify users joinning an activity (e.g. use of a passwrod to access the session or to authentify the user);
- Encryption: It represents the ability to secure communications.

The fifth and sixth tables present tool criterias for the evaluation of the environments.

- Audio: It represents the ability to support audio communication in one or several transport technology;
- Video: It represents the ability to support video communication in one or several transport technology;
- Chat: It represents the ability to support text based communication and the functionalities associated with this tool;
- Whiteboard: It represents the ability to share documents and put annotation over them and the functionalities associated with the tool (e.g. import of serveral type of documents, specific markers);
- VideoStreamer: It represents the ability to share a video document in an optimized way (independant from application sharing);
- Application Sharing: It represents the ability to share an application and the functionalities provided with the application (e.g. rights on the application sharing, sharing only a region of the computer);
- Other: It represents the ability to support other type of Multi User Application (e.g. 3D Modelization Application, Collaborative Browsers, Experimental Settings);
- Virtual Reality: It represents the ability to support 3D representation of the communication environment;
- File Sharing: It represents the ability to share files between the users;

When an environment does not provide the evaluated criteria, a "-" sign is put in the corresponding box. When the environment provide the criteria, a "+" sign is put in the box. When, it was not possible to get the information regarding the environment, the box is left blank. Additional "+" and "-" signs are added when the environment fill in the criteria and provide better support than other environments.

Name	*Preparation and Review*			*Differentiation and Control of the Users*			
	Session Profile	*Scheduling*	*Record Archive*	*Educational Roles*	*User Profile*	*Rights on Tools*	*Chairman Control*
VRVS	+	+	-	-	+	+	
ISABEL	+	-	+	-			++
Platine 1.0	+	-	-	-	-	+	+
Platine 3.0	++	-	-	+	-	++	++
TANGO	+		+	-	-		+
TELUQ LVP						+	+
Webex	+	++	+	-	+	+	+
LiveMeeting	+	++	+		+	+	+
Elluminate	+	+	++			+	++
Maratech			+			+	+
WorkSpace3D				-	-	+	

Name	*Orientation of the Communication*			*Dynamic Collaboration*		*Awareness Support*	
	Meeting	*Lecture, Conference*	*Other Style*	*Questions*	*Others*	*Advanced List of Users*	*Others*
VRVS	+	+	-	-	-	++	-
ISABEL	+	++	++	+	+	+	-
Platine 1.0	+	+	+	-	+	-	-
Platine 3.0	+	+	++	-	++	++	+
TANGO	+	-	-			+	
TELUQ LVP				+	+	+	
Webex	++		+		+	++	+
LiveMeeting	+	+		+	+	+	+
Elluminate	+	+		+	+	++	++
Maratech	+					+	+
WorkSpace 3D	+	-	-	+	-	+	++

Name	*Access*				*Transparency*	
	Web Access	*Firewall NAT*	*OS Support*	*PDA Support*	*Location*	*Failure*
VRVS	++	++	++	+	++	+
ISABEL	−		−	-	+	
PLATINE 1.0	-	-	+	-	+	-
PLATINE 3.0	+	+	++	+	+	-
TANGO	++	+	++	-	+	
TELUQ LVP				-	+	
WEBEX	++	++	++	-	++	+
LIVEMEETING	+		-	-	++	
Elluminate	+	++	++	-	+	+
Maratech	+	+	+	-	+	
WorkSpace3D	+	++	−		+	-

Name	*Load Scalability*	*Independent*	*Security*	
			Authentification	*Encryption*
VRVS	+	−	+	-
ISABEL	+	+	+	-
PLATINE 1.0		++	+	-
PLATINE 3.0		++	+	-
TANGO	+		+	
TELUQ LVP				
WEBEX	+	+	+	+
LIVEMEETING	+	-	+	
Elluminate	+	+	+	+
Maratech	+		+	+
WorkSpace 3D	-	+	+	+

Name	*Direct Communication Tools*			*Document Sharing Tools*	
	Audio	*Video*	*Chat*	*Whiteboard*	*Video Streamer*
VRVS	++	++	+	-	+
ISABEL	+	+	+	+	
PLATINE 1.0	+	+	+	+	
PLATINE 3.0	++	++	+	++	
TANGO	+	+	+		
TELUQ LVP	+	+	+	+	+
WEBEX	+	+	+	++	
LIVEMEETING		+	+	+	
Elluminate	+	+	++	+	
Maratech	+	+	+	+	
WorkSpace3D	+	+	+	+	

Name	*Multi User Applications*		*Other*	
	Application Sharing	*Other*	*Virtual Reality*	*File Sharing*
VRVS	++		-	-
ISABEL	++		-	
PLATINE 1.0	++		-	-
PLATINE 3.0	++	+	-	-
TANGO			-	
TELUQ LVP	+	++	-	+
WEBEX	+	+	-	+
LIVEMEETING	+	+		
Elluminate	+			
Maratech	+			
WorkSpace 3D	+	++	+++	+

Appendix B
Evaluation Questionnaire of the Multipoints Experiment

Quality evaluation questionnaire

Thank you for having followed this e-learning lesson, to evaluate quality of the system and to have some drawback from this experiment. We would like to ask you some question. They are divided into 5 sections: audio, video, slides/whiteboard, interactivity and whole system quality. Please answer the best you can and feel free to had any comments

B.0.0.3 Technical questions

Audio During communication you may have heard that the sound interrupted for very short period of time, like when you use a cell phone and the quality is bad. Let's call this interruption "cuts"

Question 1: Do you think the number of audio cuts was (pick one):

(too many) (a lot) (a few) (very few) (no cut at all)

Question 2: Compared to a cell phone, do you think the quality of communication was (pick one):

(a lot worse) (worse) (same) (better) (a lot better)

Question 3: Compared to a traditional lecture, how much concentration is required to understand the e-learning lecture (pick one):

(more) (a bit more) (the same) (a bit less) (fewer)

Question 4: How tiring is it to follow the audio comments of the professor (pick one):

(very tiring) (tiring) (a bit tiring) (not tiring)

Question 5: How would you rate the quality of audio communication on a scale from 0 to 10 (use the whole scale please)?

(0) Means you didn't understand anything.

(10) Means that the quality was as good as if the professor was in the same room.

(Less than 5) means that you think the quality was too bad to be able to concentrate on the lecture).

Video Question 6: Do you think the video was smooth enough (pick one):

(not at all) (not so much) (enough) (smooth) (very smooth)

Question 7: Do you think video deformations were (pick one):

(too much) (a lot) (few) (very few) (inexistent)

Question 8: Do you think picture deformations were disturbing concentration (pick one):

(yes a lot) (yes) (yes, just a bit) (no, not much) (no, not at all)

Question 9: Compared with streaming video available on the Internet, do you think the quality was (pick one):

(a lot worse) (worse) (same) (better) (a lot better)

Question 10: How would you rate the quality of video on a scale from 0 to 10?

(0) Means you didn't see any picture.

(10) Means that the quality was as good as if the professor was in the same room.

(Less than 5) means that you think the quality was too bad to be able to concentrate on the lecture).

B.0.0.4 Interactivity

Delay Influence Question 11: Did you felt any delay?

(a lot) (a little) (almost no) (not at all)

If you answered that you felt some delay, please answer the question 10 to 14

Question 12: Do you think delay during dialogue was disturbing (pick one):

(very disturbing) (disturbing) (a bit disturbing) (not disturbing)

Question 13: If delay is considered at least a bit disturbing, which element was the most penalized (pick one)?

(audio in lecture) (video in lecture) (slides in lectures)

(audio in dialogue) (video in dialogue)

Question 14: Do you think shorter delay would improve interactivity (pick one):

(not at all) (not much) (a bit) (really) (really a lot)

Question 15: How would you rate interactivity (regards to delay) during dialogue, (scale from 0 to 10)?

(0) Means no interactivity.

(10) Same interactivity as if the professor was in the classroom?

Slides/Whiteboard Question 16: Do you think slides were easy to read and understand (pick one):

(not at all) (not much) (yes) (clear) (very clear)

Question 17: Do you think comments and slides were well synchronized (pick one):

(not at all) (not much) (yes) (perfectly)

Question 18: Do you think use of slides help to make lesson more clear than use of chalk/blackboard (pick one):

(not at all) (not) (same) (a bit) (a lot)

Question 19: How would you rate the quality of slide presentation on a scale from 0 to 10?

(0) Means slides were useless.

(10) Means slides were displayed perfectly and lesson well organized.

Organization Question 20: Do you think window organization is adequate (pick one)

(not at all) (not adequate) (not much) (adequate) (perfect)

Question 21: Do you think the different elements (audio, video...) were enough to recreate classroom environment and allow learning (pick one):

(not at all) (not enough) (quite enough) (enough)

If no, can you explain what was references were missing? Do you have any idea how those references can be reproduced?

Question 22: Do you think learning with such an environment is more difficult than in a traditional classroom (pick one):

(a lot) (a bit) (the same) (a bit easier) (really easier)

Question 23: How would you rate interactivity of the whiteboard during lectures, (scale from 0 to 10)?

(0) Means no interactivity.

(10) Same interactivity as if the professor was in the classroom?

Media compare To try to compare different media used and identify the ones that have the most important impact on the learning process, we would like to ask you to compare them:

Question 24: On a scale from 0 to 10, how would you rate, compare to other media, the impact of :

Audio quality : (1) (2) (3) (4) (5) (6) (7) (8) (9) (10)

Video quality: (1) (2) (3) (4) (5) (6) (7) (8) (9) (10)

Delay value: (1) (2) (3) (4) (5) (6) (7) (8) (9) (10)

Slides presentation: (1) (2) (3) (4) (5) (6) (7) (8) (9) (10)

Lesson organization: (1) (2) (3) (4) (5) (6) (7) (8) (9) (10)

Overall quality Question 25: Do you think the overall quality of the system is good enough to learn anything (pick one):

(not at all) (not enough) (quite enough) (good enough) (very good)

Question 26: Do you think the system was well balanced (pick one):

(not at all) (not much) (well) (very well)

1. Question 27:If you have answered that the systems was unbalanced or if you have your opinion, explain what should be given more importance?

- Audio Communication (a little) (average) (a lot)
- Video Communication (a little) (average) (a lot)
- Network Delay (a little) (average) (a lot)
- Presentation of slides (a little) (average) (a lot)
- Organization of the lecture (a little) (average) (a lot)

Question 28: How would you rate the communication quality of this system on a scale from 0 to 10?
(0) No communication is possible
(10) Real situation communication
Question 29: How would you rate the learning quality of the system on a scale from 0 to 10?
(0) Means the lecture was as efficient as if the professor would have been absent?
(10) Means the lecture was very efficient
How would you qualify this experience: interesting, funny, gadget, disturbing...?

If you have any opinion about the good or bad point of this environment, please let us know.

Please try to list good and bad parts of this experiment.

Please feel free to add any comments or remarks about this experience, way to improve it...

Thank you very much for your collaboration

Appendix C

Evaluation Questionnaire of the Two Points Experiment

Quality evaluation questionnaire

Thank you for having followed this e-learning lesson, to evaluate quality of the system and to have some drawback from this experiment. We would like to ask you some question. They are divided into 5 sections: audio, video, slides/whiteboard, cpmmunication and whole system quality. Please answer the best you can and feel free to had any comments

C.0.0.5 Technical questions

Audio During communication you may have heard that the sound interrupted for very short period of time, like when you use a cell phone and the quality is bad. Let's call this interruption "cuts"

Question 1: Do you think the number of cuts is (pick one):
a lot average few
(1) (2) (3) (4) (5)

Question 2: How much extra concentration is required to understand the e-learning lecture (pick one):
more same less
(1) (2) (3) (4) (5)

Question 3: How tiring is it to follow the audio comments of the professor (pick one):
tiring not tiring
(1) (2) (3) (4) (5)

Question 4: How would you rate the quality of audio communication on a scale from 0 to 10 (use the whole scale please)?
(0) Means you didn't understand anything.
(10) Means that the quality was as good as if the professor was in the same room.
(Less than 5) means audio quality was too bad for learning.

Video Question 5: Do you think the video was smooth enough (pick one):
not smooth smooth
(1) (2) (3) (4) (5)

Question 6: Do you think video deformations were (pick one):
many few
(1) (2) (3) (4) (5)

Question 7: Do you think picture deformations were disturbing concentration (pick one):
disturbing not disturbing
(1) (2) (3) (4) (5)

Question 8: Is video resolution good enough?
not enough enough
(1) (2) (3) (4) (5)

Question 9: How would you rate the quality of video on a scale from 0 to 10?
(0) Means you didn't see any picture.

(10) Means that the quality was as good as if the professor was in the same room.

(Less than 5) means video quality was too bad for learning.

C.0.0.6 Interactivity

Delay Influence Question 10: Did you felt any delay?

yes no

(1) (2) (3) (4) (5)

If you answered that you felt some delay, please answer the question 11 to 13

Question 11: Do you think delay during lecture was (pick one):

disturbing not disturbing

(1) (2) (3) (4) (5)

Question 12: If delay is considered at least a bit disturbing, which element is the most penalized (pick one)?

(audio in lecture) (video in lecture) (slides in lectures)

(audio in dialogue) (video in dialogue)

Question 13: How would you rate interactivity (regards to delay) during dialogue, (scale from 0 to 10)?

(0) Means delay infinite.

(10) No delay as if the professor was in the classroom.

(Less than 5) means delay is too bad for learning.

Slides/Whiteboard Question 14: Do you think slides were easy to read and understand (pick one):

difficult easy

(1) (2) (3) (4) (5)

Question 15: Do you think comments and slides were well synchronized (pick one):

no yes

(1) (2) (3) (4) (5)

Question 16: In traditionnal lesson, you can see the teacher and the whiteboard at the same time. in this system, whiteboard and professor video are transmitted separetly. Do you think it is?:

bad good

(1) (2) (3) (4) (5)

Question 17: How would you rate the quality of slide presentation on a scale from 0 to 10?

(0) Means slides were useless.

(10) Means slides were displayed perfectly and easy to read.

(Less than 5) means that slides presentation is too bad for learning.

Organization Question 18: Do you think the different elements (audio, video...) were enough to recreate classroom environment and allow learning (pick one):

not enough enough

(1) (2) (3) (4) (5)

If no, can you explain what was references were missing? Do you have any idea how those references can be reproduced?

Question 19: Do you think the display on the wall was big enough?

not enough big enough

(1) (2) (3) (4) (5)

Question 20: What do you think of the size of:

small big

Whiteboard (1) (2) (3) (4) (5)

Video (1) (2) (3) (4) (5)

Question 21: Will you mind if there was no video at all?

yes no

(1) (2) (3) (4) (5)

Question 22: How would you rate organization during lectures, (scale from 0 to 10)?

(0) Means organization is really bad.

(10) Means organization is very good.

(Less than 5) means organization is too bad for learning.

Media compare To try to compare different media used and identify the ones that have the most important impact on the learning process, we would like to ask you to compare them:

Question 23: On a scale from 0 to 10, how would you rate, compare to other media, the impact of :

Audio quality : (1) (2) (3) (4) (5) (6) (7) (8) (9) (10)

Video quality: (1) (2) (3) (4) (5) (6) (7) (8) (9) (10)

Delay value: (1) (2) (3) (4) (5) (6) (7) (8) (9) (10)

Slides presentation: (1) (2) (3) (4) (5) (6) (7) (8) (9) (10)

Communication: (1) (2) (3) (4) (5) (6) (7) (8) (9) (10)

Overall quality Question 24: Do you think the overall quality of the system is good enough to learn anything (pick one):

not enough good enough

(1) (2) (3) (4) (5)

Question 25: Do you think learning with such an environment is more difficult than in a traditional classroom (pick one):

yes no

(1) (2) (3) (4) (5)

Question 26: According to you, which and how much elements should be improved?

a bit a lot

audio (1) (2) (3)

video (1) (2) (3)

delay (1) (2) (3)

slides (1) (2) (3)

organization (1) (2) (3)

Question 27: If you have the opportunity to follow a lesson anywhere with such a system instead of going to the university, will you use it?

never always

(1) (2) (3) (4) (5)

Question 28: How would you rate the communication quality of this system on a scale from 0 to 10?

(0) No communication is possible.

(10) Real situation communication.

(Less than 5) means communication is not sufficient.

Question 29: How would you rate the learning quality of the system on a scale from 0 to 10?

(0) Means the lecture was as efficient as if the professor would have been absent?

(10) Means the lecture was very efficient

(Less than 5) means this system is too bad for learning.

How would you qualify this experience: interesting, funny, gadget, disturbing…?

Please try to list good and bad parts of this experiment.

Please feel free to add any comments or remarks about this experience, way to improve it...

Thank you very much for your collaboration

Appendix D

XML representation of the CCMS model

This Annex presents the XML schemas files of the elements of the model. For each type of element, one or more XML sample files are presented.

D.0.0.7 Variable

Schema <?xml version=”1.0” encoding=”UTF-8”?>
<xs:schema xmlns:xs=”http://www.w3.org/2001/XMLSchema”
elementFormDefault=”qualified” attributeFormDefault=”unqualified”>
<xs:element name=”variable”>
<xs:complexType mixed=”true”>
<xs:sequence>
<xs:element name=”default” minOccurs=”0”/>
<xs:element name=”possiblevalue” minOccurs=”0” maxOccurs=”unbounded”/>
<xs:element name=”instantiationinterface” type=”xs:anyType” minOccurs=”0” maxOccurs=”unbounded”/>
<xs:element ref=”variable” minOccurs=”0” maxOccurs=”unbounded”/>
< /xs:sequence>
<xs:attribute name=”variableref” use=”required”/>
<xs:attribute name=”name” type=”xs:string” use=”required”/>
<xs:attribute name=”type” type=”authorizedtypes”/>
< /xs:complexType>
< /xs:element>
<xs:simpleType name=”authorizedtypes”>
<xs:restriction base=”xs:string”>
<xs:enumeration value=”string”/>
<xs:enumeration value=”shortInteger”/>
<xs:enumeration value=”date”/>
< /xs:restriction>
< /xs:simpleType>
<xs:element name=”publicvariable”>
<xs:complexType>
<xs:sequence>
<xs:element name=”variableref”/>
<xs:element name=”default” minOccurs=”0”/>
<xs:element name=”possiblevalue” minOccurs=”0” maxOccurs=”unbounded”>
<xs:complexType>
<xs:sequence>
<xs:element name=”value”/>
<xs:element name=”representation”/>
< /xs:sequence>
< /xs:complexType>

< /xs:element>
<xs:element name=”instantiationinterface” type=”xs:anyType” minOccurs=”0” maxOccurs=”unbounded”/>
<xs:element ref=”publicvariable” minOccurs=”0” maxOccurs=”unbounded”/>
< /xs:sequence>
< /xs:complexType>
< /xs:element>
< /xs:schema>

D.0.0.8 Sample XML files

6 variables are presented.

Username

<?xml version=”1.0” encoding=”UTF-8”?>
<variable xmlns:xsi=”Variable.xsd” name=”username” variableref=”uname” type=”string”/>

UserinCharge

<?xml version=”1.0” encoding=”UTF-8”?>
<variable xmlns:xsi=”Variable.xsd” name=”userincharge” variableref=”userincharge”>draymond</variable>

BitPerSample

< /?xml version=”1.0” encoding=”UTF-8”?>
<variable xmlns:xsi=”Variable.xsd” name=”bitpersample” variableref=”test” type=”shortInteger”>
<default>8</default>
<possiblevalue>8</possiblevalue>
<possiblevalue>16</possiblevalue>
<possiblevalue>24</possiblevalue>
<instantiationinterface/>
< /variable>

Frequency

<?xml version=”1.0” encoding=”UTF-8”?>
<variable xmlns:xsi=”Variable.xsd” name=”frequency” variableref=”freq”>
<default>8000</default>
<possiblevalue>8000</possiblevalue>
<possiblevalue>12000</possiblevalue>
<possiblevalue>24000</possiblevalue>
<instantiationinterface/>
< /variable>

Date

<?xml version=”1.0” encoding=”UTF-8”?>
<variable xmlns:xsi=”Variable.xsd” type=”date” name=”date” variableref=”date”>
2005-10-09
< /variable>

Admininfo

<?xml version=”1.0” encoding=”UTF-8”?>
<variable xmlns:xsi=”Variable.xsd” name=”administrationinfo” variableref=”admininfo”>
<variable type=”date” name=”date” variableref=”date”>2005-11-09</variable>
<variable name=”userincharge” variableref=”userincharge”>draymond</variable>
< /variable>

D.0.0.9 User

Schema <?xml version=”1.0” encoding=”UTF-8”?>
<xs:schema xmlns:xs=”http://www.w3.org/2001/XMLSchema” elementFormDefault=”qualified” attributeFormDefault=”unqualified”>
<xs:include schemaLocation=”Variable.xsd”/>
<xs:element name=”user”>
<xs:complexType>
<xs:sequence>
<xs:element ref=”variable” minOccurs=”0” maxOccurs=”unbounded”/>
< /xs:sequence>
<xs:attribute name=”ref” use=”required”/>
<xs:attribute name=”name” type=”xs:string” use=”required”/>
< /xs:complexType>
< /xs:element>
< /xs:schema>

Sample XML files 2 users are presented.
David < /?xml version=”1.0” encoding=”UTF-8”?>
<user xmlns:xsi=”User.xsd” ref=”draymond” name=”raymond”>
<variable name=”username” variableref=”uname” type=”string”>
< /variable>
<variable name=”age” variableref=”age” type=”shortInteger”>
< /variable>
< /user>
Kenji <?xml version=”1.0” encoding=”UTF-8”?>
<user xmlns:xsi=”User.xsd” name=”kenji” ref=”matsuura”>
<variable name=”username” variableref=”uname” type=”string”>
< /variable>
<variable name=”age” variableref=”age” type=”shortInteger”>
< /variable>
< /user>

D.0.0.10 Learning Profiles

Schema <?xml version=”1.0” encoding=”UTF-8”?>
<xs:schema xmlns:xs=”http://www.w3.org/2001/XMLSchema” elementFormDefault=”qualified” attributeFormDefault=”unqualified”>
<xs:include schemaLocation=”Variable.xsd”/>
<xs:element name=”LearningProfile”>
<xs:complexType>
<xs:sequence>
<xs:element name=”userref” minOccurs=”0” maxOccurs=”unbounded”/>
<xs:element name=”profileref” minOccurs=”0” maxOccurs=”unbounded”/>
<xs:element ref=”variable” minOccurs=”0” maxOccurs=”unbounded”/>
< /xs:sequence>
<xs:attribute name=”profileref” type=”xs:anyURI” use=”required”/>
<xs:attribute name=”name” type=”xs:string” use=”required”/>
< /xs:complexType>
< /xs:element>
< /xs:schema>

Sample XML File 1 learning profile is presented. It is the student learning profile.

<?xml version="1.0" encoding="UTF-8"?>
<LearningProfile xmlns:xsi="LearningProfile.xsd" profileref="student" name="Student">
<userref/>
<variable type="string" name="Description" variableref="description">
profile is used to manage users taking part in the activity as student
< /variable>
< /LearningProfile>

D.0.0.11 Link

Schema <?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
elementFormDefault="qualified" attributeFormDefault="unqualified">
<xs:include schemaLocation="Variable.xsd"/>
<xs:group name="endpoint">
<xs:sequence>
<xs:element name="userref" minOccurs="0" maxOccurs="unbounded"/>
<xs:element name="profileref" minOccurs="0" maxOccurs="unbounded"/>
< /xs:sequence>
< /xs:group>
<xs:element name="link">
<xs:complexType>
<xs:sequence>
<xs:element name="source">
<xs:complexType>
<xs:group ref="endpoint"/>
< /xs:complexType>
< /xs:element>
<xs:element name="destination">
<xs:complexType>
<xs:group ref="endpoint"/>
< /xs:complexType>
< /xs:element>
<xs:element name="invocation" minOccurs="0">
<xs:annotation>
<xs:documentation>Rules for the invocation of temporary links</xs:documentation>
< /xs:annotation>
<xs:complexType>
<xs:sequence>
<xs:element name="source">
<xs:complexType>
<xs:group ref="endpoint"/>
< /xs:complexType>
< /xs:element>
<xs:element name="invocationrights"/>
< /xs:sequence>
< /xs:complexType>
< /xs:element>
<xs:element ref="variable" minOccurs="0" maxOccurs="unbounded"/>
< /xs:sequence>
<xs:attribute name="linkref" type="xs:ID" use="required"/>

```
<xs:attribute name=”name” type=”xs:string” use=”required”/>
< /xs:complexType>
< /xs:element>
< /xs:schema>
```

Sample XML file 1 link is presented. It is the audio link

```
<?xml version=”1.0” encoding=”UTF-8”?>
<link xmlns:xsi=”Link.xsd” linkref=”audiolnk” name=”audiolink”>
<source>
<userref>draymond</userref>
< /source>
<destination>
<userref>matsuura</userref>
< /destination>
<variable name=”bitpersample” variableref=”test” type=”shortInteger”>
<default>8</default>
<possiblevalue>8</possiblevalue>
<possiblevalue>16</possiblevalue>
<possiblevalue>24</possiblevalue>
<instantiationinterface/>
< /variable>
<variable name=”frequency” variableref=”freq”>
<default>8000</default>
<possiblevalue>8000</possiblevalue>
<possiblevalue>12000</possiblevalue>
<possiblevalue>24000</possiblevalue>
<instantiationinterface/>
< /variable>
< /link>
```

D.0.0.12 Tool

Schema <?xml version=”1.0” encoding=”UTF-8”?>

```
<xs:schema xmlns:xs=”http://www.w3.org/2001/XMLSchema”
elementFormDefault=”qualified” attributeFormDefault=”unqualified”>
<xs:include schemaLocation=”Link.xsd”/>
<xs:element name=”tool”>
<xs:complexType>
<xs:sequence>
<xs:element ref=”link” maxOccurs=”unbounded”/>
<xs:element ref=”variable” minOccurs=”0” maxOccurs=”unbounded”/>
< /xs:sequence>
<xs:attribute name=”toolref” type=”xs:anyURI” use=”required”/>
<xs:attribute name=”name” type=”xs:string” use=”required”/>
<xs:attribute name=”type” type=”tooltype” default=”group”/>
< /xs:complexType>
< /xs:element>
<xs:simpleType name=”tooltype”>
<xs:restriction base=”xs:string”>
<xs:enumeration value=”group”/>
<xs:enumeration value=”personal”/>
< /xs:restriction>
```

< /xs:simpleType>
< /xs:schema>

Sample XML file 1 tool is presented. It is the Videoconferencing tool

<?xml version=”1.0” encoding=”UTF-8”?>
<tool xmlns:xsi=”Tool.xsd” toolref=”jvisio” name=”videoconferencing”>
<link linkref=”audiolnk” name=”audiolink”>
<source>
<userref>draymond</userref>
< /source>
<destination>
<userref>matsuura</userref>
< /destination>
<variable name=”bitpersample” variableref=”test” type=”shortInteger”>
<default>8</default>
<possiblevalue>8</possiblevalue>
<possiblevalue>16</possiblevalue>
<possiblevalue>24</possiblevalue>
<instantiationinterface/>
< /variable>
<variable name=”frequency” variableref=”freq”>
<default>8000</default>
<possiblevalue>8000</possiblevalue>
<possiblevalue>12000</possiblevalue>
<possiblevalue>24000</possiblevalue>
<instantiationinterface/>
< /variable>
< /link>
< /tool>

D.0.0.13 Learning Activity

Schema

<?xml version=”1.0” encoding=”UTF-8”?>
<xs:schema xmlns:xs=”http://www.w3.org/2001/XMLSchema”
xmlns=”http://emulator.is.tokushima-u.ac.jp”
targetNamespace=”http://emulator.is.tokushima-u.ac.jp”
elementFormDefault=”qualified” attributeFormDefault=”unqualified”>
<xs:include schemaLocation=”Variable.xsd”/>
<xs:include schemaLocation=”Tool.xsd”/>
<xs:include schemaLocation=”LearningProfile.xsd”/>
<xs:include schemaLocation=”User.xsd”/>
<xs:element name=”activitytype”>
<xs:complexType>
<xs:sequence>
<xs:element ref=”variable” minOccurs=”0” maxOccurs=”unbounded”/>
<xs:element ref=”user” minOccurs=”0” maxOccurs=”unbounded”/>
<xs:element ref=”LearningProfile” minOccurs=”0” maxOccurs=”unbounded”/>
<xs:element ref=”tool” minOccurs=”0” maxOccurs=”unbounded”/>
< /xs:sequence>
<xs:attribute name=”activityref” use=”required”/>
<xs:attribute name=”name” type=”xs:string” use=”required”/>
< /xs:complexType>

```
< /xs:element>
< /xs:schema>
```

Sample XML file 1 learning activity is presented.

```
<?xml version=”1.0” encoding=”UTF-8”?>
<activitytype xmlns=”http://emulator.is.tokushima-u.ac.jp”
xmlns:xsi=”http://www.w3.org/2001/XMLSchema-instance”
xsi:schemaLocation=”ActivityTypeSchema.xsd”
activityref=”activity01” name=”sample”>
<variable name=”administrationinfo” variableref=”admininfo”>
<variable type=”date” name=”date” variableref=”date”>2005-11-09</variable>
<variable name=”userincharge” variableref=”userincharge”>draymond</variable>
< /variable>
<user ref=”draymond” name=”raymond”>
<variable name=”username” variableref=”uname” type=”string”>Raymond</variable>
<variable name=”age” variableref=”age” type=”shortInteger”>26</variable>
< /user>
<user name=”kenji” ref=”matsuura”>
<variable name=”username” variableref=”uname” type=”string”>Matsuura</variable>
<variable name=”age” variableref=”age” type=”shortInteger”>32</variable>
< /user>
<LearningProfile profileref=”student” name=”Student”>
<userref>draymond</userref>
<variable type=”string” name=”Description” variableref=”description”>This profile is used to
manage users taking part in the activity as student</variable>
< /LearningProfile>
<tool toolref=”jvisio” name=”videoconferencing”>
<link linkref=”audiolnk” name=”audiolink”>
<source>
<userref>matsuura</userref>
< /source>
<destination>
<profileref>student</profileref>
< /destination>
<variable name=”bitpersample” variableref=”test” type=”shortInteger”>
<default>8</default>
<possiblevalue>8</possiblevalue>
<possiblevalue>16</possiblevalue>
<possiblevalue>24</possiblevalue>
<instantiationinterface/>
< /variable>
<variable name=”frequency” variableref=”freq”>
<default>8000</default>
<possiblevalue>8000</possiblevalue>
<possiblevalue>12000</possiblevalue>
<possiblevalue>24000</possiblevalue>
<instantiationinterface/>
< /variable>
< /link>
< /tool>
< /activitytype>
```

Appendix E

WebPages Supporting the representation of the model

The WebPages supporting the model are reprocude in this appendix. The first capture present the welcome page in Japanese. The welcome page in English has been inserted directly in the chapter 5.

The second capture represent the page presented when clicked on the videoconferencing picture on the left frame of the English page.

The third capture present the information that was presented when clicked on the student picture on the left frame of the English page.

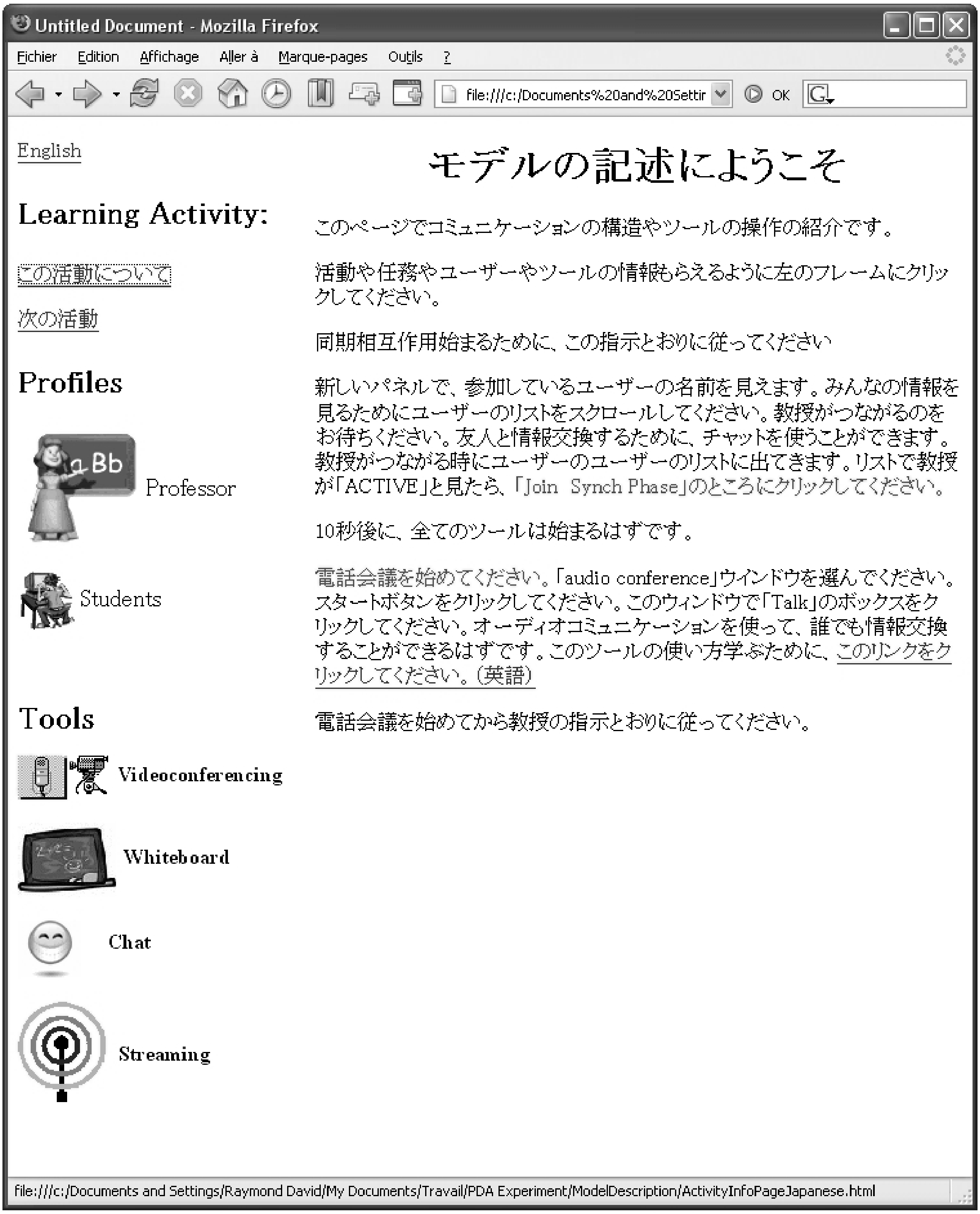

Figure 60: Japanese Welcome Page

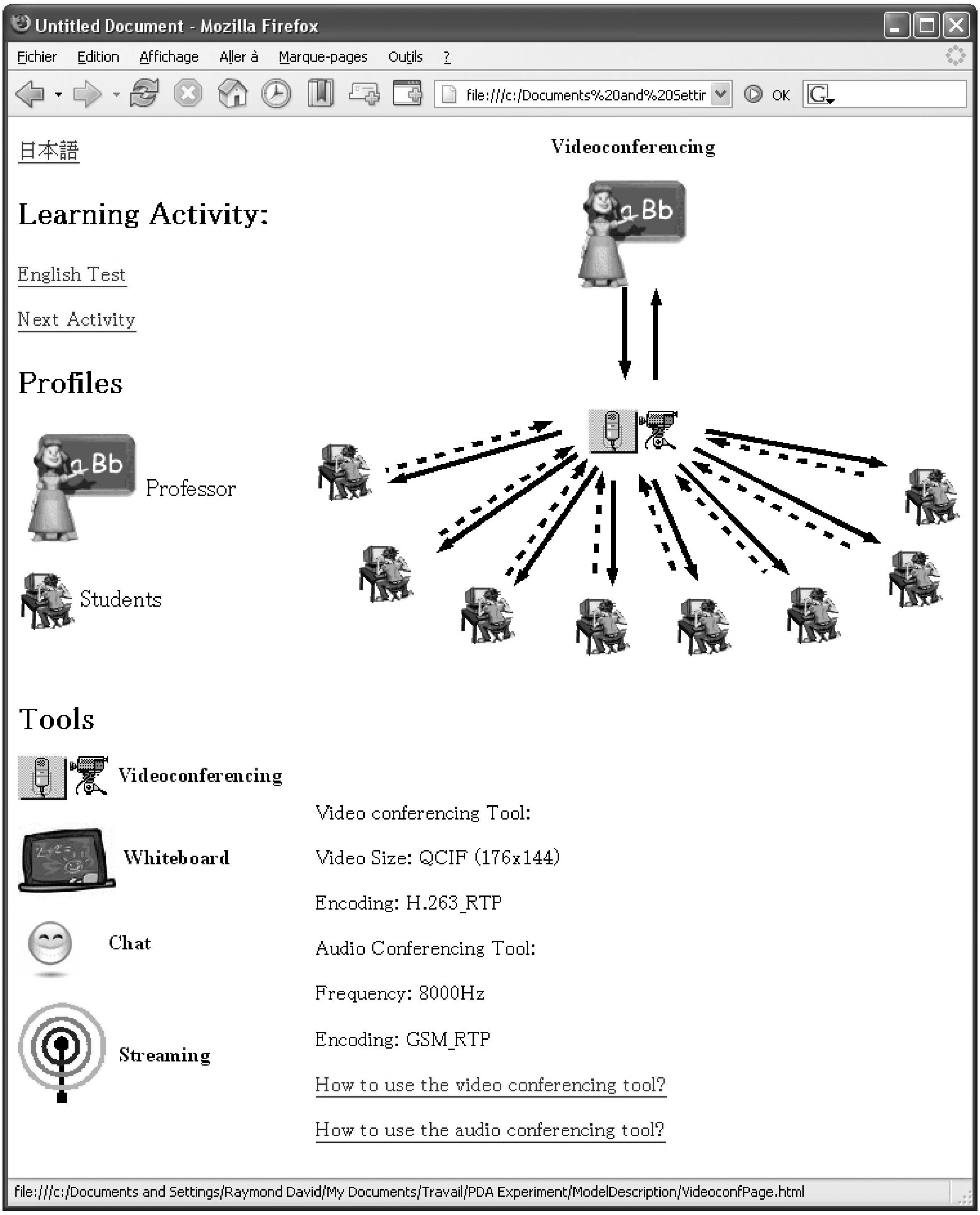

Figure 61: English Video and Audio conferencing Tool Page

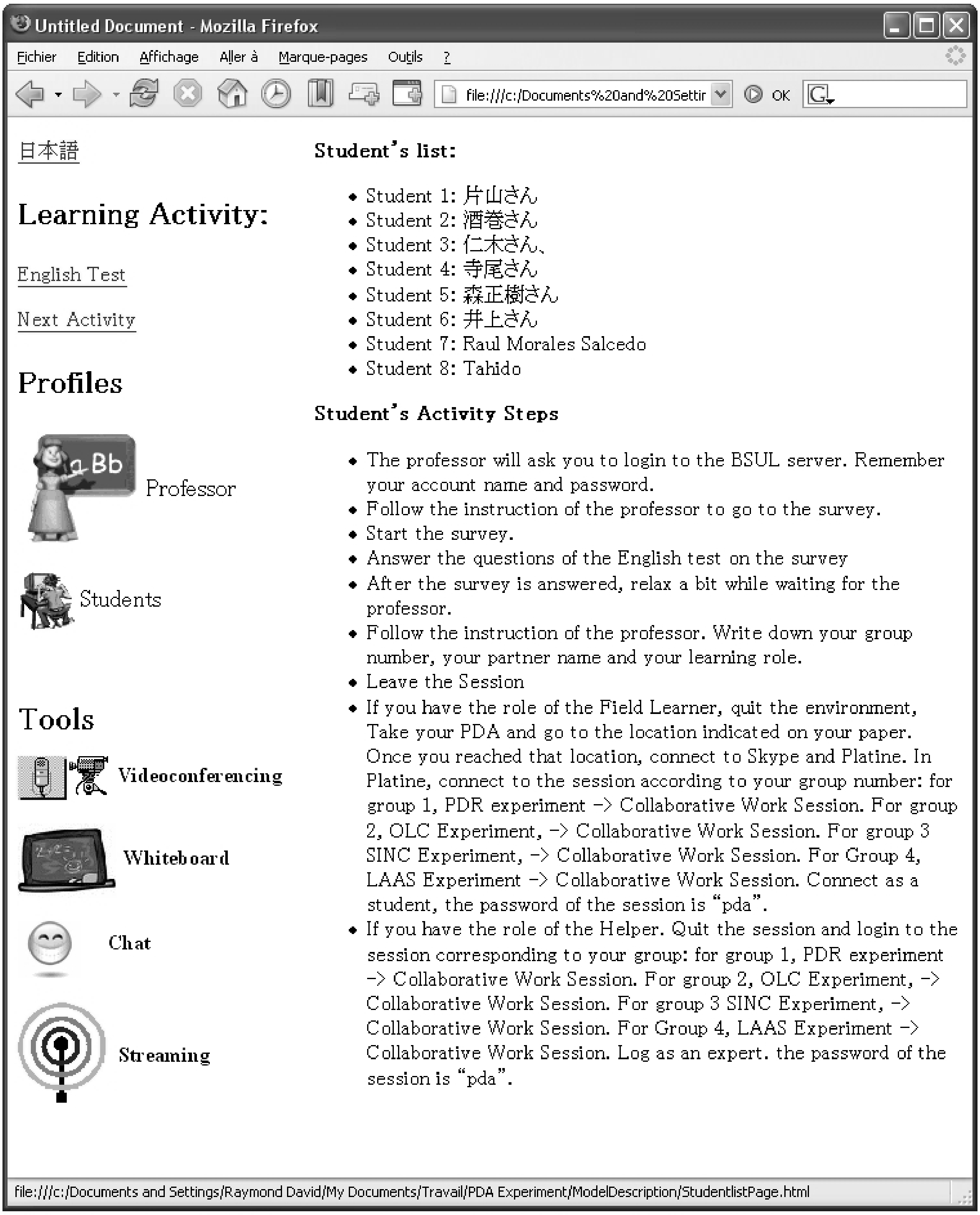

Figure 62: English Student Profile Info Page

Appendix F
Evaluation Questionnaire of the Experiments of Chapter 5

Pre Test Have you ever used a PDA?
(yes) (no)
Have you ever used videoconferencing or Instant Messenging software?
(yes) (no)

F.0.0.14 Technical Evaluation

Human-Computer Interface: Tablet PC Writing System Question 1: Is the stylus system convenient for writing messages on the Chat?
(not Convenient) (Convenient)
(1) (2) (3) (4) (5)
Question 2: Is the stylus system convenient for drawing elements on the whiteboard? (no - yes)
(not convenient) (Convenient)
(1) (2) (3) (4) (5)

Influence of the network and system Delay
Question 3: Did you felt any delay during the communication?
(A lot) (Not at all)
(1) (2) (3) (4) (5)
Question 4: Do you think the reaction time of the system is disturbing?
(A lot) (Not at all)
(1) (2) (3) (4) (5)
Audio Quality
Question 5: How would you rate the audio quality?
(Bad) (Good)
(1) (2) (3) (4) (5)
Video Quality
Question 6: How would you rate the video quality?
(Bad) (Good)
(1) (2) (3) (4) (5)

F.0.0.15 Evaluation of the Tools

Chat Question 7: Do you consider the chat was easy to use in this experiment?
(Not Easy) (Easy)
(1) (2) (3) (4) (5)
Question 8: Do you consider the chat was useful in this experiment?
(Not Useful) (Useful)
(1) (2) (3) (4) (5)

Whiteboard Question 9: Do you consider the whiteboard was easy to use in this experiment?
(Not Easy) (Easy)
(1) (2) (3) (4) (5)
Question 10: Do you consider the whiteboard was useful in this experiment?
(Not Useful) (Useful)
(1) (2) (3) (4) (5)

Videoconferencing Question 11: Do you consider the audio and video conference was easy to use in this experiment?
(Not Easy) (Easy)
(1) (2) (3) (4) (5)
Question 12: Do you consider the audio communication was useful in this experiment?
(Not Useful) (Useful)
(1) (2) (3) (4) (5)
Question 13: Do you consider the video communication was useful in this experiment?
(Not Useful) (Useful)
(1) (2) (3) (4) (5)

Streaming (During the English Test) Question 14: Do you think the streamer was easy to use in this experimentH
(Not Easy) (Easy)
(1) (2) (3) (4) (5)
Question 15: How would you rate the quality of the media distributed with the streamer?
(Bad) (Good)
(1) (2) (3) (4) (5)

F.0.0.16 Organization

Access to the Sessions Question 16: Do you think the start of the Platine system is easy?
(Not Easy) (Easy)
(1) (2) (3) (4) (5)
Question 17: Do you think the selection and identification of the activity is easy?
(Not Easy) (Easy)
(1) (2) (3) (4) (5)
Question 18: Do you think starting the synchronous collaboration phase of the activity is easy?
(Not Easy) (Easy)
(1) (2) (3) (4) (5)
Question 19: Did you have any difficulties in using the system?
(A lot) (Not at all)
(1) (2) (3) (4) (5)

Synchronous Session State Display Question 20: Did you easily identify the users connected to the session?
(Not Easily) (Easily)
(1) (2) (3) (4) (5)
Question 21: Did you easily identify the role of each user?
(Not Easily) (Easily)
(1) (2) (3) (4) (5)
Question 22: Did you easily identify the tools used in the session?
(Not Easily) (Easily)
(1) (2) (3) (4) (5)

Question 23: Do you think the information displayed by the synchronous session state display contribute to make you feel part of a learning group?

(No, not at all) (Yes, definitely)

(1) (2) (3) (4) (5)

Question 24: Do you consider the session state display was useful in this experiment?

(Not Useful) (Useful)

(1) (2) (3) (4) (5)

Management of the Session Question 25: Do you think the system to switch between tools helped to manipulate the computer?

(No, not at all) (Yes, definitely)

(1) (2) (3) (4) (5)

Question 26: Do you think the system to switch between tools helped to focus your attention?

(No, not at all) (Yes, definitely)

(1) (2) (3) (4) (5)

Modelisation of the Activity Question 27: Do you think it was useful to have the display of the model organization of the activity?

(No, not at all) (Yes, definitely)

(1) (2) (3) (4) (5)

Question 28: Do you think, the model of the activity helped you to understand your role in the activity?

(No, not at all) (Yes, definitely)

(1) (2) (3) (4) (5)

Question 29: Do you think the model of the activity helped you to understand how you can communicate with the other users?

(No, not at all) (Yes, definitely)

(1) (2) (3) (4) (5)

Question 30: Do you think the model of the activity helped you to understand the rules of the communication?

(No, not at all) (Yes, definitely)

(1) (2) (3) (4) (5)

Question 31: Do you think the model of the activity helped you to access information about the lecture easily?

(No, not at all) (Yes, definitely)

(1) (2) (3) (4) (5)

F.0.0.17 Overall Quality

Organization of the Activity Question 32: Do you think the different element were (whiteboard, audio, . . .) were sufficient to recreate classroom environment and allow learning?

(No, not at all) (Yes, definitely)

(1) (2) (3) (4) (5)

Question 33: Do you think this system support well collaboration?

(No, not at all) (Yes, definitely)

(1) (2) (3) (4) (5)

Question 34: Do you think the overall quality was sufficient for collaboration?

(No, not at all) (Yes, definitely)

(1) (2) (3) (4) (5)

Learning Scenario Question 35: Did you find this activity interesting?

(No, not at all) (Yes, definitely)

(1) (2) (3) (4) (5)

Question 36: Do you think you improve your language skill with this activity?

(No, not at all) (Yes, definitely)

(1) (2) (3) (4) (5)

Question 37: If you had the opportunity to use such a system for learning from your house instead of going to the university, would you use it?

(No, not at all) (Yes, definitely)

(1) (2) (3) (4) (5)

F.0.0.18 Free Comments

How do you think the environment could be improved?

Please give as many comments as possible, about:

What you liked and didn't like.

The way you would like to use the system.

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