A Low Cost Low Bandwidth Real-Time Virtual Classroom System for Distance Learning

Patrika Mondal[1], Swagato Misra[1], Iti Saha Misra[2]
[1]School of Mobile Computing and Communication, Jadavpur University Salt Lake Campus, Kolkata-700098, India
[2]Electronics and Telecommunication Engineering Department, Jadavpur University Kolkata-700032, India
pmpatrimn@gmail.com, swgtmsr@yahoo.co.in, iti@etce.jdvu.ac.in, itisahamisra@yahoo.co.in

***Abstract*—Virtual classroom teaching or E-learning is one of the best solutions for erasing the curse of the illiteracy of a large population in many developing countries. Most of the E-learning or virtual classroom teaching tools demand high requirement of system resources because live video streaming consumes high bandwidth resulting huge costs. The major challenge of the virtual classroom teaching environment is to design a low cost low bandwidth application. In this paper we propose an internet based solution where only voice is streamed over the network using UDP protocol. Teacher and students establish a TCP connection to transfer the visual aid which is encoded properly to protect Intellectual property. The teacher solely controls the visual aids. Control events of the visual aids are captured by the application and very small sized corresponding messages are transferred to all the students where by recognizing the messages appropriate events are invoked to reflect the same event as the teacher end. So the major traffic for this application is voice packets and some small sized control messages which require considerably low bandwidth.**

***Keywords*—Virtual interactive classroom, low-cost low-bandwidth, remote learning system.**

I. Introduction

Advances in technologies such as real time streaming video, virtual learning environment has added a new dimension in modern education system. It allows teachers and student to aware each other in different location and to undertake many of the teaching learning activities of physical class environment through real-time communication. In many remote places in developing countries including India, quality teaching is the hindrance for the proper learning mechanism because of the lack of efficient teachers for serving the large population. Imagine a teacher in one university delivering a lecture and students in another campus can follow that real time class. In a city 5000 km away a student is using on-demand lecture to take part in the same course delivered online. Not only that, a physically disable person or a student recovering from an operation watches a live lecture without being present at the classroom.

Real time virtual classroom applications which are available in the market such as WebEx [8], Learning Activity Management System (LAMS) [13], NetMeeting [9], Macromedia Breeze [11], ConferenceXP [14] etc have some problems when system resources are the main constraint. Firstly, compared with traditional textual applications, streaming video applications usually require much higher bandwidth. A typical piece of 25 second 320x240 QuickTime movies could take 2.3MB, which is equivalent to about 1000 screens of textual data. Secondly, most streaming video applications require the real-time traffic. Audio and video data must be played back continuously at the rate they are sampled. If the data does not arrive in time, the playing back process will stop and human ears and eyes can easily pick up the artifact. Thirdly, video data stream is usually bursty. Just increasing the bandwidth will not solve the burstiness problem. Contrary to the high bandwidth, to serve the large number of underprivileged people in remote places of many developing countries, networks are shared by thousands and millions of users, and have limited bandwidth, unpredictable delay and availability. Solving these conflicts is a challenge video streaming based virtual learning systems must face.

It is obvious that voice transmission takes much lesser bandwidth than transmitting a video file. In this paper we have implemented a virtual classroom system where visual aids are preloaded at student endpoints encoded appropriately to protect Intellectual property and only voice is streamed over the network using UDP protocol. As teacher can only able to control the visual aids, all the control events to control the visual aids will be captured by the application and corresponding very small sized messages are transmitted from the central node or teacher end using TCP protocol and then by recognizing the messages appropriate events will be invoked at the student ends. Moreover, during question answer session both ways voice communications will be possible between the teacher and participants.

II. A DESIGN FRAMEWORK FOR VIRTUAL CLASSROOM APPLICATION

There are two main components in the proposed design framework for the virtual classroom application such as 1) shared visual aid module and 2) voice streaming module. In the first module the central node or the teacher node controls the shared visual aids and the same will be reflected at student ends. In the second module the voice packets are streamed over the network in both ways. We use the term

978-1-4799-1095-3/13/$31.00 ©2013 IEEE

presenter and participant instead of teacher and student respectively for the rest of the paper.

A. Client/Server Sequential process for connection establishment

There are four sequential steps to establish a connection between presenter and participant ends as shown in Fig.1. The connection establishment process follows simple client server architecture [4]. First, the presenter node or server listens to a specific port for the TCP connection with participants or clients. Second, the clients send connection request massage to the socket address of the server. Third, Server accepts the requests from clients and updates the student count of attending the class and also sends an acknowledgement to all the participants. Lastly for voice communication all the participants listen to their specific port and server sends the connection request to all the participants to open the voice connection.

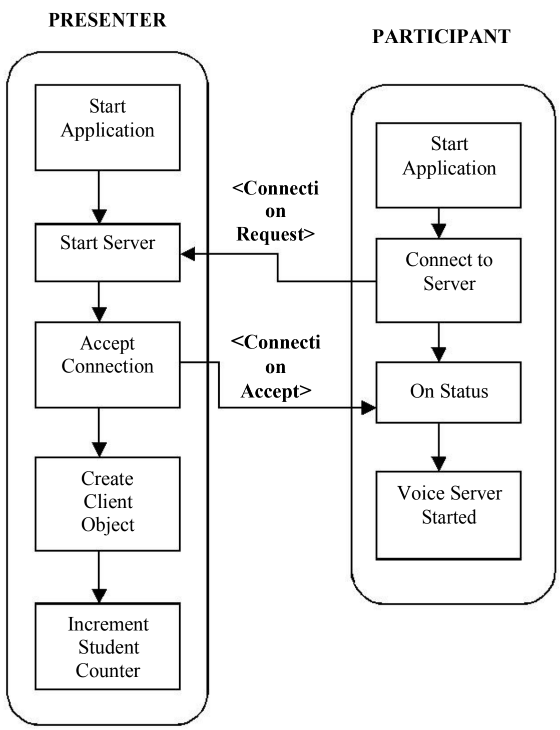

Fig .1. Connection establishment steps between teacher and student.

B. Collaborative functions for lecturer and learner in a virtual interactive classroom

1) Transmitting and receiving file function: After establishing TCP connection with all the participants, the study material encoded appropriately to protect Intellectual property and a message, named *<FILE>*,shown in Fig.2 to indicate that a file has been sent are transmitted to all the participants. All connected students waiting for some data to arrive at particular socket accept the study material sent by the presenter and the message.

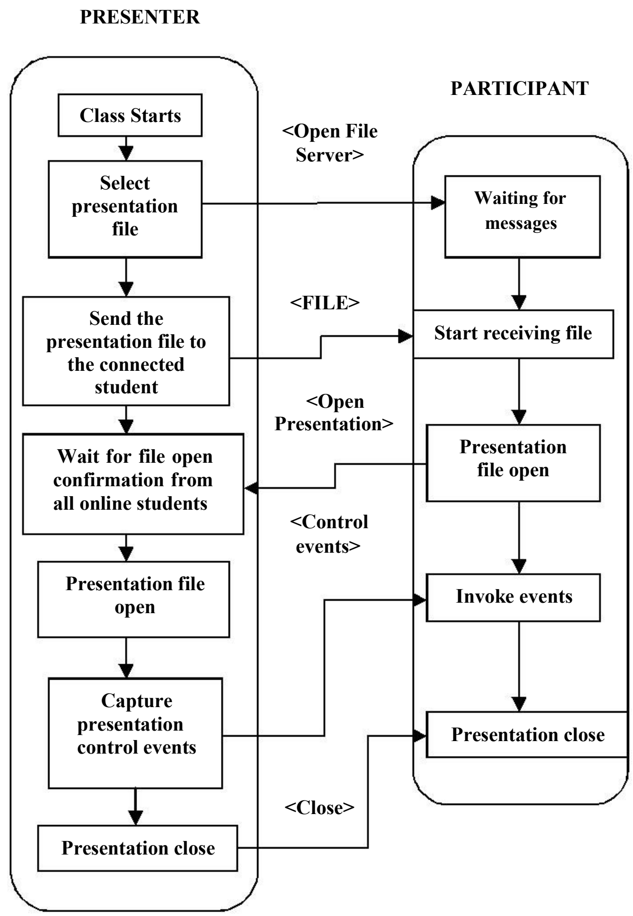

Fig. 2. Sequential steps of teacher and student in a Virtual interactive classroom.

2) *Opening of the file function*: After receiving *<FILE>* message respective file open event is invoked at all the connected participants and a message is sent to the presenter acknowledging the file has been received. After receiving acknowledgement messages from all the participants the presenter can confirm that presentation file has been opened in all the participant ends. The presenter can now start delivering the lecture.

3) Invoking the control events at student ends: There are many control functions in any presentation file such as navigate the slides back and forward by keystroke or mouse click, mark the particular area of a slide by pen-control, move the mouse cursor in the slide area and so on. The novelty of this paper is whenever a control event is occurred at the presentation file of the presenter end that control event is captured and a message indicating the type of the control event is transmitted over the network to all the participant ends. For example we have transmitted *<Next>* and *<Previous>* for right and left keystroke event respectively in visual aid area. Similarly for mouse move the x-y position of the mouse cursor is sent. At the participant end the application recognizes the corresponding control event by receiving the message. The control event is then invoked in presentation file to reflect same effect as the presenter end.

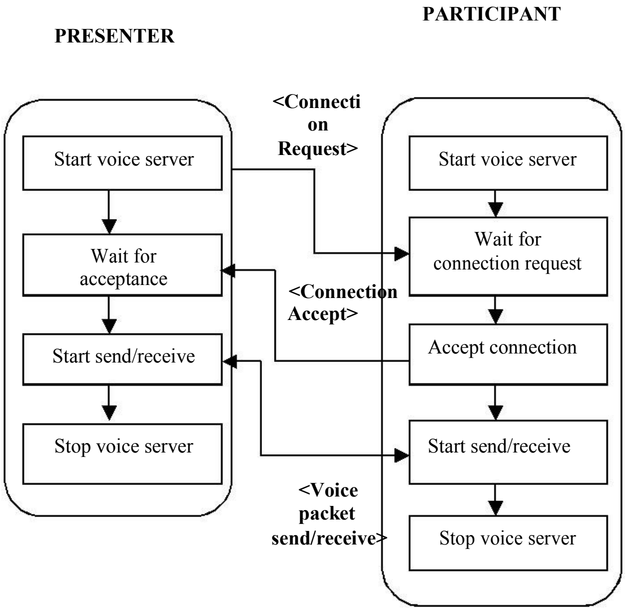

Fig .3. Connection establishment steps between voice server of teacher and student

4) *Voice communication function:* An UDP connection is established between presenter and participant ends for voice communication. At the presenter end voice is captured by the microphone and the packetized voice is sent over UDP protocol. There is also a provision in our application for encoding the voice packets by a voice codec, G.711 [10]. In the interactive session voice packets are streamed from participant to presenter end so that both way communications are possible. The flow chart of above stated steps are depicted in the Fig.2 and Fig.3.

III. SUPPORTING TECHNOLOGY

C#, an integral component of Windows that includes a virtual execution system called the common language runtime (CLR) and a unified set of class libraries was developed by Microsoft within its .NET initiative. We have opted for this technology for the implementation of this project mainly because of two reasons. Firstly, as our application needs to handle the control function of windows presentation file, C# provides powerful features of interaction with other windows software such as COM objects or native Win32 DLLs, called *Interop* [5].We have used two Interop DLLs namely *Interop.Microsoft.office.core* and *Interop.Microsoft.office.Intero.powerpoint*. Secondly, to intercept the control events such as mouse actions and keystrokes we need to implement a procedure called *hook procedure* [5]. A hook procedure can act on each event it receives, and then modify or discard the event. An application implements hooks by creating a callback function. When Windows processes a hookable event, such as mouse movement it calls this callback function, which the hooking application handles accordingly. We have used two free open source DLLs, *SystemHookCore* [6] and *Kennedy.Managedhooks* [6] to serve the purpose.

IV. IMPLEMENTATION

A. Participants

Some students of Jadavpur University, India were recruited to participate in the virtual classroom on our internet application where the teacher and students used virtual interactive classroom for teaching and learning. We had also setup a test bed for a voice conference system where the presenter (speaker) and participants (listeners) were widely separated. The speaker controlled the presentation and delivered the speech; the same was reflected at the listener ends.

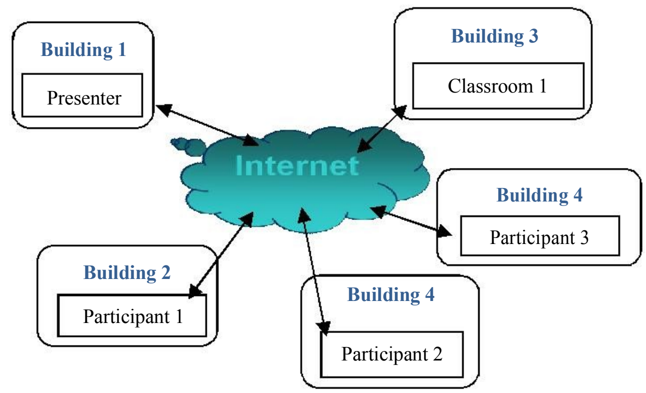

Fig.4. Test bed for the voice conference and distant presentation system

B. Virtual Interactive Classroom

We have installed the virtual classroom as internet application at the presenter and all the participant ends. The experiment has been set up and run on a windows platform with internet connection on in both presenter and participant ends which is shown in Fig.4. We have considered PowerPoint file for study material as it is the most popular way of teaching in our education system. In this virtual classroom application the presenter has the full authority to control the things such as presentation, audio presence by clicking on a menu item. When a participant runs the application a form will be opened which notifies that the presenter is available or not and a connect button which remains disable if the presenter is not running the application as shown in the Fig.5. The connect button of all the participants has been enabled after presenter runs the application. The presenter now knows the participant count which is displayed on the label of the form. The presenter clicks on a particular button to select the presentation file to send as shown in Fig.6.Figure7 shows all the connected participants send an acknowledgment to the presenter after opening of the presentation file at their ends. The presentation begins at the presenter end after receiving acknowledgment from all the participants. Similarly voice communication starts in both ways by clicking on open voice button as shown in Fig.6.

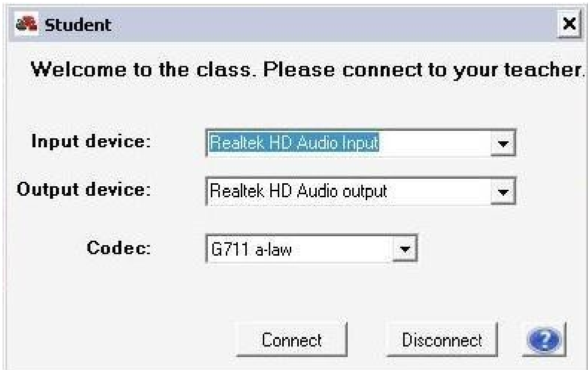

Fig.5.Screenshot of the opening form at the participant end

Fig.6. Screenshot of presentation and voice server open form at the presenter end

Fig.7. Screenshot of the acknowledgement of presentation opens at the presenter end

Figure8 shows the screenshot of a participant end where a student can see the marking at the slide which is actually done by pen control of presentation file by the presenter.

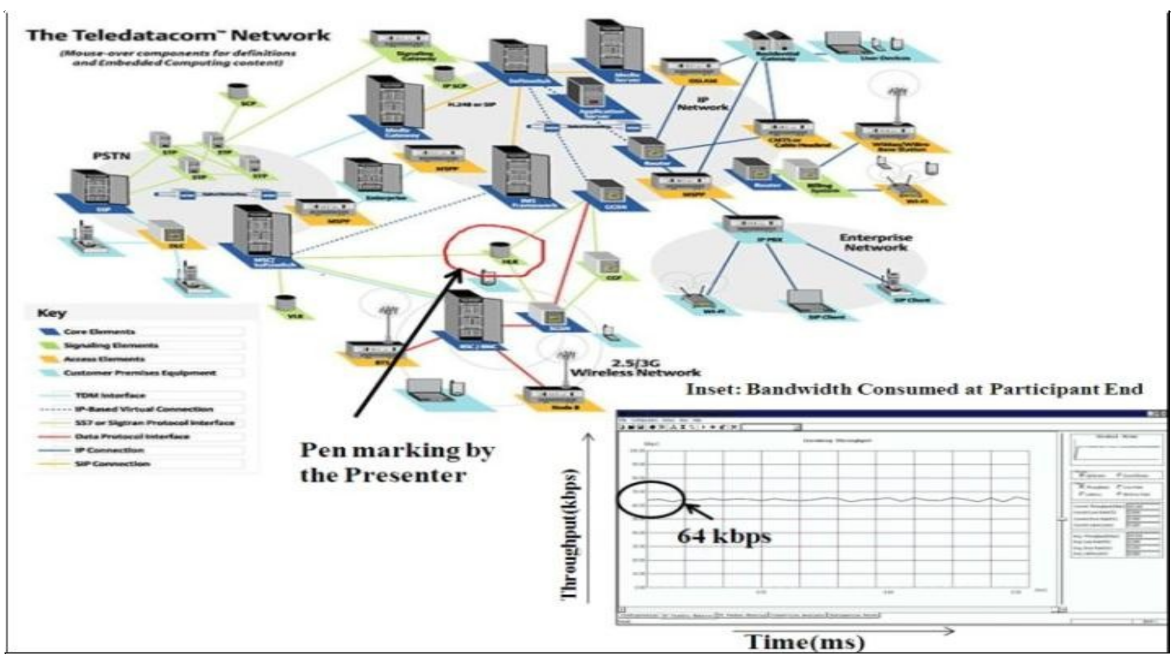

Fig.8. Screenshot of an opened presentation file and voice transmission at participant end

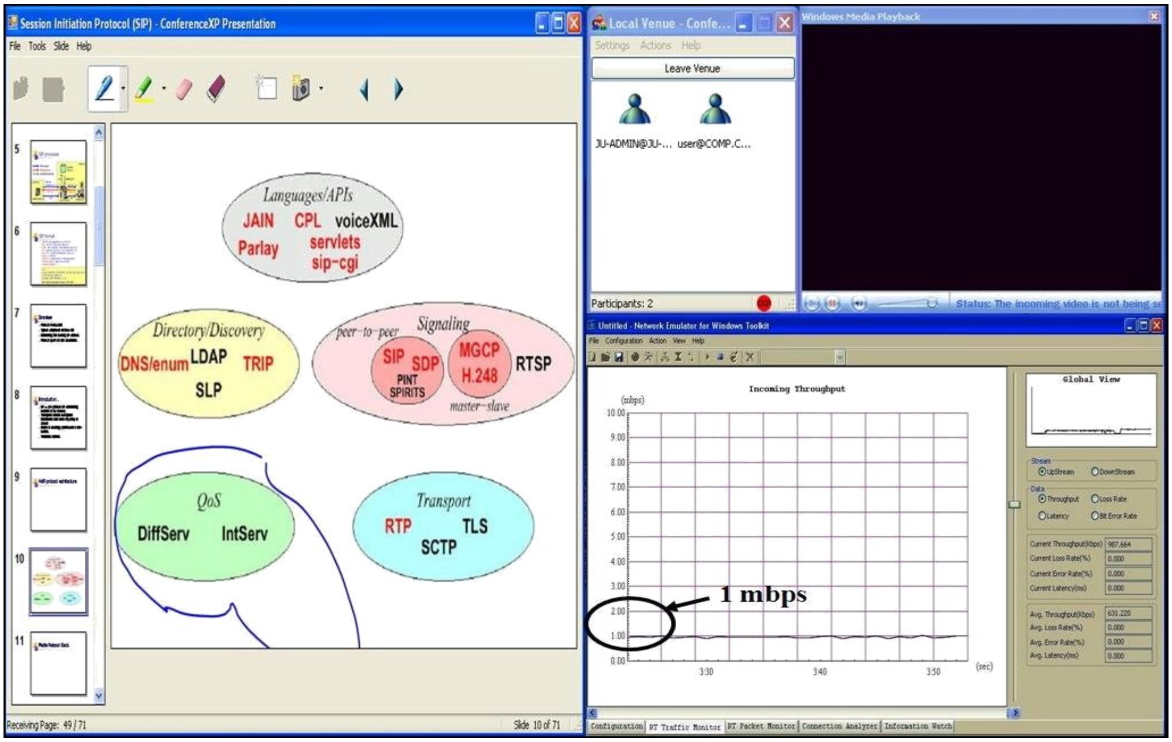

Fig.9.Screenshot of an open virtual classroom module of ConferenceXP with result of Network Emulator Toolkit

TABLE 1. BANDWIDTH REQUIREMENT FOR VIDEO (WEBEX)

Resolution	P2P Bandwidth(Kbps)	Remarks
90 p	0~120	Additional bandwidth may be consumed if severe packet loss is detected. This will compensate for lost packets.
180 p	120~360	Additional bandwidth may be consumed if severe packet loss is detected in order to compensate for lost packets.
360 p	360~1200	Actual resolutions include 360p, 432p, and 512p. Additional bandwidth may be consumed if severe packet loss is detected. This will compensate for lost packets.
729 p	1200 ~2000	Actual resolutions include 576p and 720p. Additional bandwidth may be consumed if severe packet loss is detected. This will compensate for lost packets.

TABLE 2. SUMMARY OF TEST RESULTS FOR VIDEO CONFERENCING (NETMEETING 3.0 RESOURCE KIT)

Scenario description	Average bandwidth (Kbps)	Bandwidth range (Kbps)
Windows 98 with small window and low-quality video	49	0-162
Windows NT 4.0 with small window and low-quality video	75	0-152
Windows 98 with medium window and medium-quality video	130	0-230
Windows NT 4.0 with medium window and medium-quality video	130	0-245
Windows 98 with large window and high-quality video	700	0-900
Windows NT 4.0 with large window and high-quality video	790	0-900

V. RESULTS AND DISCUSSIONS

We have used a network simulator tool, named Network Emulator Toolkit for Windows [12] for checking the bandwidth requirement at participant ends to claim that our application demands very low system resources. We have implemented a voice codec G.711 (MOS 4.1) [10] at both ends for voice communication. Figure 8 shows that only 64 kbps is enough for voice communication as well as controlling the presentation.

A screenshot of an application named, ConferenceXP [14], a product of Microsoft, where video is streamed over the network as well as transmission of presentation file, consumes bandwidth of nearly 1 mbps at the participant ends as shown in Fig. 9 for serving the same purpose as our application does.

We have also analyze the documentation of WebEx [8] and NetMeeting [9] ,which are very popular distance learning software as shown in Table 1 and Table 2. It is very clear that bandwidth requirement at the participant end in those applications is much higher than our application.

Our application is implemented in the University campus where we run this application in four different student ends and one teacher end as described in section IV. The users' feedback is collected for voice quality estimation by taking MOS as quality parameter. Figure10 shows that 43 percent and 32 percent users consider MOS as 3.75 and 3.7 respectively which are very close to MOS value 4, a standardize MOS value for good quality voice.

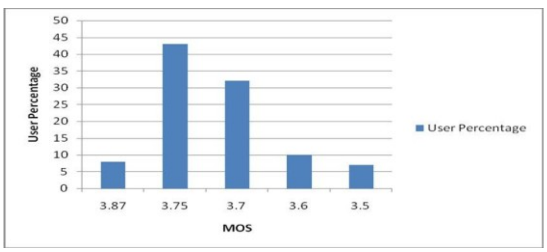

Fig.10.User percentage versus MOS for voice quality estimation

VI. CONCLUSION AND FUTURE WORK

In this article we have explored the potential of implementing a low cost low bandwidth Internet based remote virtual educational platform. In addition to the concept, the framework has been designed and implemented. As main network traffic for this application is voice packets the bandwidth requirement is very low. We have tested with a simulator, named Network Emulator Toolkit for Windows [12] a mere 64 kbps bandwidth is enough for good quality voice and control event message passing. So this virtual classroom application is an opportunity for students in rural areas as well as physically disabled students to study at home where system resource is the main constraint.

In the future research, based on the present study we intend to separate the presenter application and server application which will handle the connection establishment as well as session management with the participants. In our present solution the presenter node must have a public IP to connect with the participants and also the bandwidth requirement increases at presenter end as the number of participants increase. By implementing a server a presenter can deliver lecture from any private network with internet connection on and also above stated bandwidth problem can also be eliminated. We also plan to add a text chat system with it so that the participant with verbal disability can text their questions and also implement a video conferencing system to serve the hearing impaired students.

VII. ACKNOWLEDGEMENT

The authors deeply acknowledge the support from DST, Govt. of India for this work in the form of FIST 2007 Project on "Broadband Wireless Communications". Equal acknowledgement is accorded to IEEE SIGHT Project.

REFERENCES

[1] Premchaiswadi, W.; Tungkasthan, A.; Jongsawat, N.; , "Enhancing learning systems by using virtual interactive classrooms and web-based collaborative work," Education Engineering (EDUCON), 2010 IEEE , vol., no., pp.1531-1537, 14-16 April 2010

[2] Jiamao, L; Junjie, W; Ning, G.; "Several critical problems in a real-time interactive virtual classroom," Computer Supported Cooperative Work in Design, 2004. Proceedings. The 8th International Conference on , vol.1, no., pp. 631- 636 Vol.1, 26-28 May 2004

[3] Huang S; Hu H.; "Integrating Windows streaming media technologies into a virtual classroom environment," International Symposium on Multimedia Software Engineering, 2000. Proceedings

[4] Arcelli, F.; De Santo, M.; Chianese, A.; "Client-server architectures for distributed learning environments: a proposal," System Sciences, 1998. Proceedings of the Thirty-First Hawaii International Conference on, vol.7 , no., pp.395,403 vol.7, 6-9 Jan 1998

[5] (2013) The Microsoft developer Network. [Online]. Available: http://msdn.microsoft.com

[6] (2013) Code Project website. [Online]. Available: http://www.codeproject.com

[7] (2013) Stack Overflow website. [Online]. Available: http://stackoverflow.com

[8] (2012) The Cisco WebEx website. [Online]. Available: http://www.webex.co.in

[9] (2013) NetMeeting 3.0 Resource Kit home page Microsoft. [Online]. Available: http://technet.microsoft.com/en-us/library/cc767133.aspx (2008) The ITU website. [Online]. Available: http://www.itu.int/rec/T-REC-G.711

[10] (2008) The ITU website. [Online]. Available: http://www.itu.int/rec/T-REC-G.711

[11] (2013) Breeze Meeting homepage Adobe. [Online]. Available: http://www.adobe.com/resources/breeze/meeting

[12] (2013) NEWT support. [Online]. Available: http://research.microsoft.com

[13] (2009) The LAMS Foundation website. [Online]. Available: http://www.lamsfoundation.org

[14] (2013) ConferenceXP homepage Microsoft. [Online]. Available: http://research.microsoft.com/en us/projects/ConferenceXP