

## **Innovative Uses of Teleconferencing Technologies for BME Education**

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### **Abstract**

The opportunities for use of teleconferencing as a teaching tool have changed dramatically in the last few years, and more change is anticipated. The driving factor has been the introduction of a set of strong international teleconferencing standards that have had the byproduct of dramatically reduced prices, enhanced interoperability, and the addition of LAN-based solutions. CUA, as part of ongoing initiatives in telehealth and telerehabilitation, has been using and evaluating a broad range of teleconferencing technologies, including systems that communicate through ISDN, LAN, and regular telephone. Technically, there are three core aspects to such evaluation: video, audio, and data-sharing. Data-sharing includes tools for sharing files, a whiteboard, and applications (e.g., PowerPoint, Matlab). The latter includes the possibility of a shared mouse or keyboard, and to date this capability has been underutilized by the academic community. Taken together, these technologies open the way for minimizing the barrier of distance between students and instructors.

Keywords: Distance learning, Internet, teleconferencing, video-conferencing

### **1. Introduction**

The accelerating advancements in computing technologies have resulted in high-powered, low cost tools useful for augmenting traditional teaching practices. These tools may also be highly applicable in non-traditional teaching environments such as distance learning for increasing instructor-student interaction. Innovative uses of the World Wide Web (i.e. Internet), Web-based bulletin boards, and EMAIL have been reported by Morse<sup>1, 2</sup> and others.<sup>3</sup> These tools provide a means for disseminating information from instructor to students and also for facilitating communication among students outside of the classroom. However, as those who have tried these techniques will confirm, they are cumbersome to use and often can be incredibly time consuming. Regular maintenance and updating of course websites can often become an overwhelming task and a task for which many faculty do not have time or interest. Other barriers to use of these technologies may include lack of knowledge in website design and development. Additionally, instructor response to questions posted on online course bulletin boards or EMAIL (i.e. text-based, “virtual” office hours) are inefficient, time-consuming avenues for communication with students and lack real-time interaction between parties.

The department of biomedical engineering (BE) at The Catholic University of America (CUA), as part of on-going research efforts in telehealth and telerehabilitation, is investigating creative uses of teleconferencing solutions for enhancing educational opportunities for our students. We are currently performing quantitative evaluation of teleconferencing systems which utilize “plain-old” telephone services (POTS), integrated services digital network (ISDN), and local area networks (LAN) to determine their suitability for telehealth and distance learning applications.

This paper reports on our experiences with a variety of approaches, and various combinations of audio, data and video. These include a student taking a class from 1000 miles away, an instructor teaching a class from another continent, and guest lecturers from other states. It also includes remote office hours and student-to-student communication across distance. Each situation requires different tools and approaches, and in this paper we address both the technical and instructional aspects of reaching solutions, with special emphasis on cost-effective approaches that we feel can enable effective learning. We believe that real-time two-way communication (i.e. teleconferencing) with students using multimedia technologies (i.e. audio, video, and data sharing) may present a more efficient means of facilitating learning outside of traditional environments and may be instrumental in overcoming several barriers to distance learning. It can also be used as an interactive supplement for courses that also include asynchronous learning approaches.

## **2. Technological Discussion**

We will first discuss several key technological issues relating to teleconferencing systems. These include international standards, bandwidth, and finally, commercially available products. For effective use of these systems, the reader should appreciate these issues and understand the tradeoffs, strengths, and weaknesses of the various commercial products available.

### **2.1 Standards**

A wide variety of teleconferencing systems are available on the market possessing a range of interactive capabilities. These fall into two major categories: (1) systems utilizing dedicated point-to-point connections (e.g., regular telephone or ISDN lines) and (2) those using the Internet Protocol (IP). The recent plethora of products available in each of these categories has been, in large, a result of the formation of strong technological standards set forth by the International Telecommunications Union (ITU) and widely accepted by manufacturers of teleconferencing systems. Regular telephone based systems, often referred to as Plain-Old-Telephone-Services or POTS, follow the ITU’s H.324 standard governing video, audio, and data transfer across copper wires. The more recent IP-based systems follow the ITU’s H.323 standard for packet-based information transfer. The classic approach for more traditional, higher-end systems is the ITU’s H.320 standard, which details how information is to be transferred for dedicated ISDN and T1 connections.

Two major implications result from the establishment of widely accepted standards. First and foremost, these standards provide a guideline around which manufacturers design their products.

Specifically, these standards provide a framework addressing information transfer and processing by each teleconferencing system. By following the basic guidelines set forth by each standard (i.e. H.320, H.323, and H.324), the manufacturer can be assured that systems developed by them may inter-operate with systems built by others. However, the establishment of standards do not preclude the manufacturer of teleconferencing systems from exceeding the capabilities (i.e. transmission speeds, COMpression/DECompression algorithms or CODECs, etc.) called for by the applicable ITU standard. In the telehealth setting, interoperability has been a key issue as it is highly common that different telehealth networks often utilize different teleconferencing technologies.

The second major implication of widely accepted standards has been the reduction in the cost of many teleconferencing systems. Whereas a five years ago unit cost was in the range of one hundred thousand for higher-end systems and several thousand dollars for lower-end systems, it is not unlikely for comparable present systems to cost an order of magnitude less. The key area where there is a direct correlation between standards and cost reduction is in the area of IP-based telephony. Here, standards have enabled the utilization of off-the-shelf, mass-market, low-cost products such as PC cameras, video and sound cards, and a multitude of computer software programs to be used for teleconferencing. In the IP arena where a LAN is already in place (e.g., the typical university setting), the only additional cost for interactive teleconferencing may be the purchase of an external video camera (as other components are either built into most PC systems or can be obtained without cost).

## **2.2 Bandwidth**

When discussing teleconferencing, the question of bandwidth inevitably arises. How much is needed? How is performance affected by bandwidth availability? What are the trade-offs? Bandwidth is a commonly used term referring to the size of the “pipe” available for information transfer. The bandwidth available with the wide variety of products on the market range from 33 kilo-bits per second (kbps) up to 100 mega-bits per second (Mbps). At most academic institutions, POTS and LANs (or WANs) may already be immediately available with no additional cost. At most institutions, ISDN may present extra monthly charges and may be unsuitable for regular use.

Systems transferring information over copper telephone wires (i.e. POTS, computer modems) have the maximum capability of transferring 64 kbps. The ITU H.324 standard calls for a maximum information transfer rate of 33.6 kbps for POTS-based teleconferencing systems. In reality, performance varies greatly between 21-33 kbps depending mainly on the quality available telephone lines. Standard ISDN is capable of transferring up to 128 kbps by using the equivalent of two parallel connected telephone lines. For quality teleconferencing, it is not uncommon to used 3 lines of ISDN giving the capability for transferring up to 384 kbps. Recently available in select regions of the United States is the cable modem. These systems use coaxial lines for receiving information from the “outside” world. Theoretically, coaxial cable may provide up to 16 Mbps of bandwidth, but is usually shared among subscribers to the service. Usual service by cable modem providers specify an incoming information transfer rate of approximately 500 kbps.

Bandwidth for IP-based systems has an even greater range of possibilities. Long-distance, modem-to-modem communication using POTS is limited to the capabilities of copper wires with most recent computers equipped with 56 kbps modems. Telephone carriers (e.g. Bell Atlantic) have recently begun offering, on a limited basis only in select areas, a new service called Asynchronous Digital Subscriber Line or ADSL. ADSL modems are capable of sending between 500 kbps and up to 1.5 Mbps depending on service type purchased. Lastly, most academic institutions use local area networks (LANs) for connecting student, faculty and staff computers. Most LANs transfer data between computers at a rate varying from 10 Mbps up to 100 Mbps, though of course this bandwidth may be shared by many users.

As part of our telehealth initiatives at CUA, a current project investigates the performance of various POTS, <sup>4</sup> IP, <sup>5</sup> and LAN-based teleconferencing <sup>5</sup> systems. As expected, preliminary results have shown a strong correlation between image quality and bandwidth availability. However, it was interesting to note that there was also a wide variation in performance (i.e. video transmission rates, image resolution, image quality, etc) of the various systems even at comparable bandwidth rates. <sup>4</sup>

### 2.3 Teleconferencing Systems

As before, discussion of the various teleconferencing packages can most easily be done by dividing the conversation into two categories: (1) POTS-based systems and (2) IP-based systems.

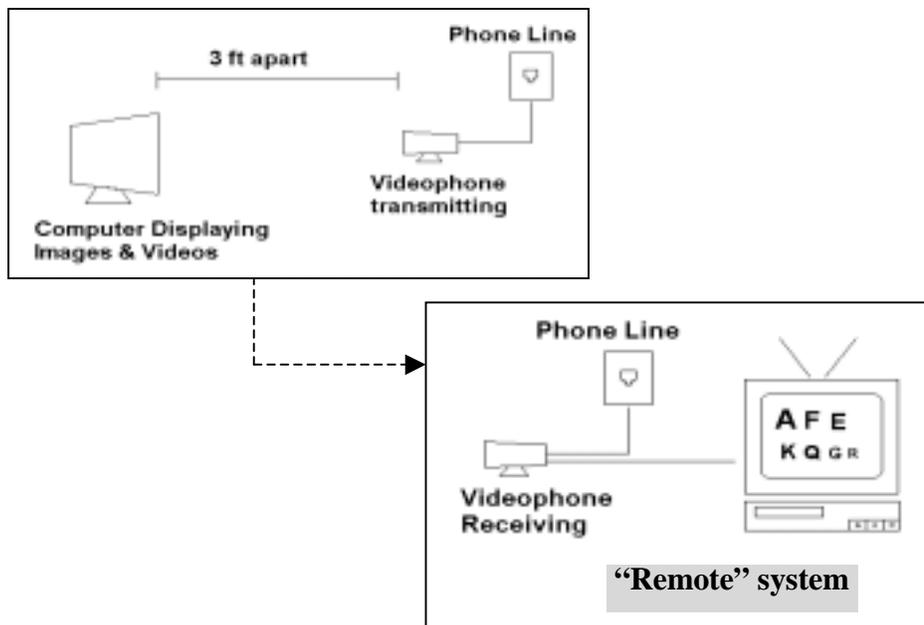


Figure 1: Schematic of typical POTS-based teleconferencing connection (using set-top box with external display module (i.e. television, computer, etc)).

### 2.3.1 POTS-based Systems

There are several POTS-based systems available on the market for teleconferencing use. A schematic for teleconferencing systems using POTS is shown in Figure 1. For practical reasons, we decided to focus our attention on low-cost, mass-market units available for approximately \$1000 or less. The most commonly available systems in this price range were made by 8x8 Inc. (Santa Clara, CA), C-Phone Corp. (Wilmington, NC), InnoMedia Inc. (San Jose, CA), and Panasonic Corp (see Figure 2a).



(a)



(b)



(c)

Figure 2: (a) Teleconferencing units. InfoView (InnoMedia Inc; top left), DS-324 Pro with external camera (C-Phone Corp; top right), DS-324 basic (C-Phone, front right), VC 105 set-top (8x8 Inc, front left), and VictPro (Panasonic Inc, center). (b) Close-up of VictPro by Panasonic with integrated phone, camera, and display screen. (c) Sample display of set-top systems (here for the Infoview system).

As shown in Figure 1, most systems have internally imbedded modems and connect directly to standard telephone lines. Some systems such as the DS-324 by C-Phone Corp. use an external

remote control infrared (IR) module similar to those controlling televisions and VCRs in order to navigate the built-in software menus for setting up the systems. Others such as those by 8x8 Inc. and InnoMedia Inc. connect directly to standard touch-tone telephones and use the tones to navigate the various on-board software menus. To reduce cost, most systems (Figure 2a) are set-top boxes consisting of the camera and modem that connect directly to standard low-cost video displays (i.e. TVs) via video and audio RCA jacks. Some systems such as the VictPro by Panasonic (see Figure 2b) and the VC150 by 8x8 Inc. fully integrate camera, modem, and display all into one unit for ease of set-up and use.

Figures 2b and 2c show a typical videoconference between two POTS-based systems.

Preliminary testing reveals that typical connect rates between systems range from 21-33 kbps.<sup>4</sup> Temporal video transfer rates range between 3 to 15 frames per second (fps) with the tradeoff being image quality at higher frame rates. For optimal temporal performance and image quality, we found that video transfer rates using these systems should be between 5-8 fps. Audio quality was qualitatively comparable to standard telephone quality.

### **2.3.2 IP-based Packages**

Currently, there are several dozens of IP-based teleconferencing packages available with widely varying capabilities. The size of this cadre of products is expanding exponentially with each passing day. These products (currently) require the use of a personal computer connected to the Internet (via modem or LAN) equipped with a sound card with microphone and speakers, PC video camera and video card, and necessary software. The appeal of IP-based telephony is that at academic institutions it is usually “free” to the user. Access to the Internet is readily available as are high-powered computing systems possessing necessary equipment. If a video camera is not already available, one can be found for less than \$30. The only missing component then is software.

As there is a plethora of software products available on the market, the capabilities of a few commonly used teleconferencing packages (i.e. Conference Netscape, CU-SeeMe, Internet Phone by Intel, Internet Phone by VocalTec, NetMeeting, VDO Phone, and WebPhone) are summarized in Table 1. These packages provide real-time interaction communication between two parties (i.e. students and instructor) using several avenues. Standard with most of these packages are real-time audio and text-based chat capabilities. Additionally, all systems in Table 1, except for Conference Netscape, include video conferencing capabilities over IP connection. While possible, preliminary experience with these packages show that video over standard modem connections (i.e. <56 kbps) result in poor quality images, unreliable connection, and in some cases, interference with audio quality.

Another useful feature for interactive education are the interactive data-features associated with the T.120 standard. This includes the “white boarding” capability of these (and other) packages, which allows the user to write or draw diagrams on a “virtual” object-oriented whiteboard that can be instantaneously seen and edited by a remote user. Different packages use different techniques to handle the complex issue of cursor “control.”

An interesting feature in NetMeeting by Microsoft Corp. (Redmond, WA) that we believe has the most potential for distance learning and interactive education is the application sharing capabilities inherent in the Windows software package. (CU-SeeMe, Intel's Internet Phone, and VDOPhone use NetMeeting's application sharing modules in their packages.) Examples that we have successfully used range from office-oriented packages (e.g., Powerpoint, Word) to core engineering education packages (e.g., Matlab, AutoCAD, Labview).

Lastly, as one can observe from Table 1, the cost for these IP-based telephony packages is extremely low, usually less than \$100. Intel's InternetPhone product starts at \$69 and can cost up to \$154 with the purchase of an external camera. NetMeeting and Conference Netscape are available for free from their websites. In fact, newer versions of Internet Explorer (Microsoft Corp.) have NetMeeting imbedded within the browser.

Product	Conference Netscape	CU – SeeMe	Internet Phone 3.1 (Intel)	Internet Phone (VocalTec)	NetMeeting (Microsoft)	VDOPhone	WebPhone
Audio	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Video	No	Yes	Yes	Yes	Yes	Yes	Yes
Chat	Yes	Yes	Yes	Yes	Yes	Yes	Yes
White board	Yes	Yes	Yes	Yes	Yes	Yes	No
Application Sharing	No	Yes	Yes	No	Yes	Yes	No
Cost	FREE	\$69	\$69-154	\$50	FREE	\$69	\$50

Table 1: Comparison of widely used IP-based teleconferencing tools (costs as of Fall 1999).

### 3. Case Studies

#### 3.1 Tele-teaching/Distance learning

During the Spring of 1999, Nasreen Haideri, a doctoral student of one of us (JW), needed to be in Texas to fulfill some professional obligations but desired to take a course at CUA that was integrally tied to her dissertation topic (BE 517, Soft Computing for Biomonitoring and Biocontrols). She preferred not to pay ISDN line charges, and through her hospital work setting, had full access to a LAN. The solution turned out to be straightforward and cost-effective: we used the NetMeeting (H.323 standard) package to share Powerpoint presentations, share audio (2-way), and in some cases share video and a digital whiteboard. Generally, we found interactive video to be the least necessary since in this case the student already knew the instructor well, yet audio to be critical; thus normally she would freeze the video image to assure higher quality audio. The only difference was that when the remote student asked a question, there was a slight (under one half second) audio delay. Through shared access of the mouse pointer, she could also highlight parts of the slides, or edit a whiteboard -- ironically, these are

features that were not available to the students directly in the room. For this application only standard computer monitors were needed.

Also during the Spring of 1999, students within our BE 542 Home Care Technologies II: Product Evaluation course used NetMeeting-based conferencing to evaluate a wide variety of possible combinations of bandwidth (e.g., LAN-LAN, LAN-POTS, POTS-POTS) and goal-directed target applications (e.g., engineering educational packages) to help us get a better sense of the possibilities for using these tools. There was a sense that to be viable, students either need to use the tools within a university's LAN, or if outside of the university, the connection should be LAN-LAN.

During the Fall of 1999, we have had a new tenure-track faculty member whose H1B Visa was delayed, Chris Kirtley, M.D., Ph.D., teach our BE 528 Rehabilitation Engineering course from Hong Kong. This course of 11 students met from 6:30 - 9:10 PM, which was 7:30 - 10:10 AM in Hong Kong. There was a co-instructor on the CUA side, to help moderate the course. The strategy chosen in this class again focused on (usually remote desktop) data-sharing and audio, only here with the data-sharing primarily through the Web. This included the use of moving images, e.g. related to gait analysis. For this application a 35" computer monitor (Gateway Destination) was used for display. Next to this monitor was the H.320/H.323-compliant Polycom videoconferencing system (with its own 35" monitor, that could use the Destination monitor as its secondary monitor) that was at times used for other out-of-state guest lecturers. (This latter system is routinely used by our research team for ISDN videoconferencing (including Powerpoint presentations)).

### **3.2 Remote Office Hours and Hybrid Approaches**

A useful future application, that ties especially to distance learning and to assignments that employ technical software packages, is remote office hours. While to date we have only employed this on an *ad hoc* basis, it is hypothesized that there are situations where remote office hours could even be more effective than face-to-face meetings -- especially where the primary focus is on the instructor and student using a computer package. This is because of the routine sharing of mouse and keyboard, complemented by interactive voice. A controlled study testing this hypothesis via a larger class (with multiple sections using different approaches) would be useful.

### **3.3 Telehealth Evaluation**

A unique series of courses taught by the Biomedical Engineering department at CUA entitled "Home Care Technologies" focuses on the applications of engineering and computing tools for home health care delivery and in-home rehabilitation. One module of the course required students to evaluate performance characteristics of NetMeeting by Microsoft Corp. and then to use the application sharing (i.e. shared mouse) capabilities of the program for telehealth related tasks.

This assignment was useful for students in developing quantitative, as well as qualitative, test protocols for product evaluation. Important parameters such as audio and video delays were assessed. Additionally, tests were conducted to evaluate the delay in data transmission (i.e. large data file) over LAN and modem lines:

- (1) without audio or video,
- (2) with only audio,
- (3) with only video, and
- (4) with audio and video present

Students also assessed the interaction and trade-offs in audio and video quality during each test case.

Using the campus LAN, temporal delays results showed audio and video delays to be on the order of approximately 400-500 ms. Data transfer times varied by almost 100% for test cases 1-4, ranging from 3.10, 4.29, 7.37, and 7.63 minutes, respectively, to transfer a 47 Mb file. Over telephone modem connected between 33-56 kbps, audio delays ranged from 1.6 to 3.24 seconds and video delays ranged between 5.6 to 30 seconds between image refresh depending on the image quality setting desired (fast video, medium, high quality). File transfer was not attempted over modem due to extremely lengthy transfer times expected.

During application sharing (i.e. shared mouse), users observed delays in cursor/mouse movement on the screen. Additionally, the presence of video competed with the application sharing and audio for bandwidth causing intermittent “jumpiness” in application performance and, at time, breakage of the audio stream. However, despite these minor performance glitches, the ability to perform application sharing provided a tremendous benefit for inter-user consultation.

The application-sharing component of NetMeeting was used in several scenarios by students. In one case, two parties at remote locations put together and presented a PowerPoint (Microsoft, Redmond, WA) presentation. Another test case involved students developing a website from remote locations by sharing Microsoft’s FrontPage program. Other telehealth scenarios involved used the application sharing capabilities for:

- (1) **Tele-health instruction:** teaching proper techniques for CPR, blood pressure measurement, etc. using audio, video, and application sharing (i.e. PowerPoint)
- (2) **Remote patient monitoring:** physiologic monitoring of blood pressure, temperature, etc. by sharing LabView (National Instruments, Austin, TX)
- (3) **Tele-therapy and telerehabilitation:** using a free-ware virtual reality (VR) software package, students were able to have a remote user control and navigate a VR environment that was observed by a “clinician” on a host computer.

Over high-speed connections (i.e. LAN), bandwidth was sufficient to perform most tasks. Using telephone modem connections, the limited bandwidth available (usually less than 56 kbps) presented problems in image quality, reliability of audio and video, and temporal delays during application sharing. Some applications with high computing requirements (i.e. virtual reality)

may require specialized computing capabilities (i.e. video capture cards, etc) on both host and remote computers in order to function properly.

#### **4. Conclusions**

Interactive teleconferencing tools provide exciting possibilities for use in engineering education. Decreased costs and increasing functional capabilities may potentially remove key barriers to access and utilization of these tools. The immediate challenge for educators is the creative implementation of these tools in traditional and distance learning environments. Key issues to be addressed for effective implementation are technical standards, bandwidth availability, and methods of utilization. For biomedical engineering education, the authors believe the capability of performing real-time audio, video, and application sharing present tremendous possibilities for interactive learning.

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