APPLICATION OF CU-SeeMe^{TM} INTERNET-BASED VIDEOCONFERENCING FOR HIGH ENERGY PHYSICS[1]

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Internet-based videoconferencing is becoming an important tool for world-wide collaboration in high energy physics. The CU-SeeMe^{TM} program offered the first personal computer-based desktop package for Macintosh and Windows machines, and some UNIX nv/vat compatibility is available through the use of reflectors. CU-SeeMe is being used by the BaBar and Beijing Spectrometer collaborations to netcast plenary talks, small group meetings between multiple sites, and for point to point communications. Networking is a crucial element in the use of this technology. Experiences with an experimental network of CU-SeeMe reflectors at SLAC, CERN and ESnet are discussed. Slide presentation options, including a hybrid solution using the World Wide Web are described, and tips for perspective netcasters are reviewed.

1 Introduction

Internet-based videoconferencing has joined the telephone and ISDN-based conferencing as a tool that high energy physicists use to communicate at a distance. CU-SeeMe^{TM} was the first Internet-based package for desktop computers, and many of its features make it suitable for high energy physics use. CU-SeeMe clients are available for both Macs and PCs, and there is limited interoperability with UNIX nv/vat clients. Both freeware and inexpensive commercial CU-SeeMe clients software can be used. No specialized skills are needed for installation. An inexpensive Connectix QuickCam[2] provides a

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[2] http://www.connectix.com/

desktop/laptop video option for a typical PC or Mac which is ordinarily not configured for video inputs. If a Mac or PC is equipped with AV hardware, a camcorder or video camera may be used. Systems without a camera can still receive audio and video, but will only transmit audio.

2 Cornell (Freeware) and White Pine (Commercial) Versions

CU-SeeMe was first conceived of in 1992 at Cornell University by Dick Cogger who headed the development team. [3] Tim Dorcey coded the first working versions. Their goal was to get desktop conferencing going as quickly as possible using available Mac hardware. They soon attracted support from the US National Science Foundation and the interest of the Global SchoolHouse [4] . Global SchoolHouse used CU-SeeMe to connect school kids to each other and to interesting people around the world. When Charley Kline contributed his Maven audio software to the project, audio-visual conferencing had arrived. The Cornell version of CU-SeeMe will continue to be made available as freeware [5] . It is supported by an active user community [6] and WWW pages created by volunteers. [7] In 1995, CU-SeeMe was licensed to White Pine Software for commercialization. White Pine has developed a backward compatible Enhanced CU-SeeMe client [8] which has additional features and technical support.

3 Description of CU-SeeMe Clients

3.1 Networking

CU-SeeMe and most other Voice Over Net (VON) packages transmit UDP packets over an IP network such as the Internet. UDP differs from TCP in

[3] Michael Sattler, Internet TV with CU-SeeMe, ISBN 1-57521-006-1, Sams.net Publishing, Indianapolis, IN, 1995
[4] http://www.gsn.org/
[5] Cornell University's CU-SeeMe Page, http://cu-seeme.cornell.edu/Welcome.html
[6] CU-SeeMe-L Listserver, http://cu-seeme.cornell.edu/listinfo.html
CU-SeeMe Listserver Archives,
http://www.indstate.edu/CU-SeeMe/all_archives.html
[7] http://www.indstate.edu/msattler/sci-tech/comp/CU-SeeMe/index.html
http://www.aye.net/Cu-SeeMeFolder/CuSeeMeGuideINDX.html
http://cu-seeme.cornell.edu/ WCW/
http://cu-seeme.cornell.edu/ WCW/cuguide.htm
http://www.applink.net/win/connect.htm
[8] http://www.wpine.com/

that if a packet does not reach its destination, no attempt is made to re-transmit it. CU-SeeMe uses UDP ports 7648 - 7652. Client bandwidth caps for transmission and reception are typical set to 80 kbits/s for use on the Internet, however this in only by convention. For local ethernet connections or connections over a high performance Internet segment, users can allow a higher bandwidth to increase the frame rate. When modem connections are used, lower bandwidth caps are needed. The usability of a modem connection is highly variable and largely depends on the quality of service delivered by the Internet Service Provider.

3.2 Video

The video codecs common to both free and commercial CU-SeeMe clients and nv use a 4-bit greyscale. Two window sizes are available: standard (160 x 120 pixels) and high resolution (320 x 240 pixels). High resolution CU-SeeMe windows are slightly lower in resolution than the H.320 mode of ISDN-based conferencing common to Picture-Tel and V-Tel (352 x 288 pixels). Once the video image has been decimated, the codec divides the image into 8 x 8 pixel squares, and an update is transmitted only if a square differs sufficiently from the previous frame. If so, a lossless compression algorithm for transmitting the differences is used which achieves about a 40% compression.[9] With standard resolution and an 80 kbit/s connection, CU-SeeMe will deliver a typical talking head at 1.5 to 4 frames per second.

White Pine's Enhanced CU-SeeMe comes with a Crystal Net SFM Video Codec[10] that provides for standard size window in color. The color codec uses approximately the same bandwidth as the standard greyscale codec, but it uses a proprietary compression algorithm. The color is a pleasant feature, but the fuzziness of the picture makes it less suitable than the greyscale codecs for slide presentation.

3.3 Audio

CU-SeeMe supports full duplex sound, although older PC sound cards are sometimes half duplex. Two audio codecs are common to all CU-SeeMe clients: Delta-mod (16 kbits/s) and Intel DVI (32kbits/s). All Mac clients support Mu-law (64 kbits/s). White Pine's Enhanced CU-SeeMe also supports two lower bandwidth codecs, DigiTalk (8.5 kbits/s) and Voxware (2.4 kbits/s)

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[9] Tim Dorcey, CU-SeeMe Desktop VideoConferencing Software, Connexions, Volume 9, No.3, March 1995 (http://cu-seeme.cornell.edu/DorceyConnexions.html)
[10] http://www.crystalnet.com/

which are particularly interesting for modem connections. Clients can transmit sound in increments of 50 ms or 100 ms at a time. UNIX vat clients can use Intel DVI or Mu-law codecs talk to converse with CU-SeeMe clients via a CU-SeeMe reflector. The single codec common to both CU-SeeMe platforms, Cornell and White Pine clients, and vat is Intel DVI. Users have two choices for transmitting. 'Push To Talk' mode activates their microphone only when a button is depressed. Voice-Activated (vox) mode transmits when the sound picked up by the microphone exceeds a user-controlled threshold. Echoing is reduced by switching to a higher threshold when sound from the network is playing from the computers local speakers. It works best when there is a reasonable separation between the microphone and speakers. Some users find a headset with a built in microphone convenient. Audio is more sensitive to network conditions than video. Packet loss doesn't become noticeable until it rises to between 5 and 10 %. From 10 to 20 % packet loss, the sound interruptions become increasingly annoying, and eventually unusable.

3.4 Other Features

CU-SeeMe clients feature a chat window for exchanging typed information. This is a useful way to exchange information during a presentation without interrupting the audio. It comes in handy when there is an inadvertent audio codec mismatch. A participant window displays a list of all parties connected to the conference, and a diagnostic can be displayed to show the packet loss for each connection. Connections can be initiated by entering the IP number to call directly, or via a nickname or phone book entry. White Pine's Enhanced CU-SeeMe can be set up as a WWW helper application to initiate calls by clicking on an WWW link, and it initiates an 'accept call?' dialogue when a remote client attempts to connect to it. Enhanced CU-SeeMe is sold in a bundle with WhitePineBoard which allows clients to share text and graphics. It works best on high bandwidth connections. Supported document formats are BMP, EPS, GIF, PCX, PICT, TGA, TXT, TIF, WMF for PC's and PICT, PICT2, Text, Scrapbook for Macs.

4 Conference types

4.1 Client to Client

Two CU-SeeMe clients may connect directly to each other. This is often useful as a substitute for long distance or intercontinental telephone calls. As with a telephone, either party can place or end the call.

4.2 *Single Reflector*

When more than two parties wish to communicate, a UNIX or Windows NT-based reflector is used. Each client connected to the reflector sees and hears each of the other parties connected. UNIX nv and vat clients may also connect to a reflector using ports determined by the reflector operator. The operator may choose to restrict the number of parties that can connect, but bandwidth imposes a practical restriction. As the number of windows increases, the frame rate drops. A single reflector can support several simultaneous conferences. Both freeware Cornell and proprietary White Pine reflectors are available. The Cornell version 4.03 reflector is generally adequate for single reflector operation as a public high energy physics reflector. Mac and PC clients can connect using the freeware audio and video codecs, but there are endian problems with nv/vat connections with some platforms. White Pine has addressed the endian problem, and has better options for fine tuning the properties of multiple conferences. A White Pine reflector conference may be password protected. Usage can be restricted by conference by conference, and it can be monitored for billing purposes.

4.3 *Blind Carbon Copy Reflector Networks*

Reflectors can be daisy-chained or fanned out in a Blind Carbon Copy (BCC) network in which a feed from one or more clients is forwarded from the primary reflector to the secondaries. This configuration is useful for netcasting an event such as a big meeting. Typically, only the clients covering the event are allowed to transmit to the primary. All other clients, whether connecting to the primary or secondary reflectors are permitted to receive but not transmit. Both Cornell and White Pine reflectors work in BCC networks, but the same caveats apply as for standalone Cornell reflectors.

4.4 *Unicast and Multicast Reflector Networks*

Two reflectors can be peered using a unicast connection, and unicast reflectors may be daisy-chained or fanned out as long as there are no closed loops. Two or more reflectors may also be peered with a multicast connection. When CU-SeeMe clients connect to a conference that is shared by peered reflectors, they see all clients connected to that conference on any of the reflectors. The White Pine reflector is recommended for unicast and multicast as the Cornell code has bugs and usually does not work correctly.

5 Reflectors as a Network Routing Tool

Individual users have little direct control over the routing between two IP addresses, however connecting to reflector can sometimes select a more favorable route. Consider clients at two US universities which route to each other via a congested public network. If the clients at the universities aimed for a reflector at an Energy Sciences Network (ESnet) site such as SLAC instead of each other, they might route via the public network to a nearby ESnet site, and then along ESnet for the remainder of the route to the reflector. Since ESnet performs substantially better than the public network, the CU-SeeMe connection between the universities is likely to improve. This is the case for U.T. Dallas which picks up ESnet to SLAC 'nearby' at the Fusion Research Lab in Austin. Another example occurred during a recent BaBar netcast, when a direct CU-SeeMe feed from SLAC to the UK was unusable, but the feed through a reflector at CERN was fine[11]. On the other hand, German universities have a decent connection to CERN, but a better connection to ESnet sites in the US. A CU–SeeMe network for the BaBar collaboration might unicast reflectors from DESY to SLAC to CERN. The DESY reflector would serve German clients, SLAC would serve North American clients, and CERN would serve clients in the UK, Italy, France, and other European countries. A more heavily used network, perhaps serving the entire European and US high energy physics communities might be configured with a multicast network across the US at ESnet sites such as SLAC, Fermilab, and the Princeton Plasma Physics Lab. From Princeton, two unicast connections would serve DESY and CERN. CERN in turn would fan out the network with unicast connections to central reflector sites in Italy, France, the UK., and other European member states. The point is to design a reflector network to achieve the lowest packet loss and while conserving bandwidth using unicast or multicast connections along the best available route.

6 The CU-SeeMe Learning Curve

6.1 Installation

Within BaBar and BES, most users do not need help downloading and installing CU-SeeMe clients from the network, or installing from clients from White Pine disks. Most Mac users prefer to use the free Cornell client which works well. When there has been a configuration problem on a Mac, it is usually due to an old or missing version of the Sound Manager or QuickTime

[11] Alan Flavell, personal communication.

extensions. Occasionally, a new user will forget to turn off virtual memory or Connectix RamDoubler, but most high energy physics Macs seem to come with sufficient memory and/or savvy owners. The incidence of these problems among HEP users is much lower than in the non-HEP CU-SeeMe community. The Cornell PC client is not as stable as its Mac counterpart, and most BaBar and BES PC users end up using White Pine Enhanced CU-SeeMe clients. Installing a PC client requires a cuseeme.ini file, but this has not proved troublesome for HEP users after consulting White Pine documentation. Most HEP PC's are recent enough to include full duplex sound boards, and most users have sidestepped video capture board compatibility problems by using a Connectix Quickcam which does not require a video board. High energy physicists appear to have a much easier time installing Connectix QuickCam than the general public.

6.2 Using Clients

Most high energy physicists can figure out how to make connections without help. Occasionally, a reminder is needed when a meeting occurs on a conference id that is not the default. When using the limited bandwidth (64 kbits/s) connection from IHEP in Beijing, physicists had little trouble following instructions on a web page showing how to restrict their transmit and receive rates.

The most challenging problem for new users is positioning a microphone correctly and adjusting its gain. Voice activated audio works well when the input gain and thresholds are set correctly, but the GUI for this feature could be improved. Some users never master it, or simply prefer push to talk. As in ISDN/H.320 multipoint conferences, users quickly learn to mute their microphones to avoid interrupting a presentation.

It is slightly more complicated for UNIX nv/vat clients to join a CU-SeeMe reflector-based conference. Nv needs to be configured in a different manner from MBone netcasts. Nv and vat need to specify the conference id and the UDP port to use, but the syntax is slightly different for each application. A solution that has worked for BaBar is to publicize the command line syntax on a WWW page and in emails before a meeting. The nv syntax is:

```
      nv -encoding cuseeme -recvGrey -xmitGrey IP_address port conf_ID
e.g.  nv -encoding cuseeme -recvGrey -xmitGrey cuseeme.slac.stanford.edu 4444 1
```

Due to a small incompatibility between nv and CU-SeeMe, an nv client will not start receiving until it starts transmitting. The command line syntax for vat is:

```
       vat -f dvi4 reflector-name/port-number
e.g.   vat -f dvi4 cuseeme.slac.stanford.edu/3456
```

7 Presentions for CU-SeeMe Videoconferences

Slide presentation is one of the most difficult aspects of Internet videoconferencing. An old standby is to fax slides in advance to all sites, however as the number of parties increases, the overhead grows combinatorially. US BES users found it more convenient to produce simple WWW sites to present slides. Ubiquitous PAW graphs are easily saved in postscript files and converted to GIF format. A winning combination is to link GIF files for WWW presentation during the videoconference but to include a link to the postscript version that produces a higher quality printed copy.

White Pine's presentation solution, WhitePineBoard, only works when White clients and reflectors are used, when the network connection to all parties is close to ideal, and when the presenter can control the computer. When a presentation also has a local audience, and LCD panel or a large monitor would be needed. These conditions rarely present themselves, however lower tech solutions are effective.

A native CU-SeeMe solution is to transmit high resolution CU-SeeMe images. When the presenter is in front of the computer, a document camera is useful. Should an AV Mac/PC and/or a document camera not be available, a document camera can be jury rigged for a non-AV Mac using a Color QuickCam. A Color QuickCam is better for this than a greyscale QuickCam because it can be focused. When a presenter is showing overheads to a local audience, a video camera can be used to capture the projected screen image. The camera should be mounted on a tripod, and should be attended for best results. If the presenter is far from the videocamera and computer it is difficult to capture the presenter"s voice. A microphone with a long cable, or a sound system becomes necessary. For BaBar plenary meetings, SLAC hires a professional video production crew to record the meeting. The video producers sends the computer the same feed being recorded to tape which can be a view of the overhead screen, the presenter, or the audience. Audio is relayed from a radio mike to the house sound system and a copy is delivered to the netcast computer. CU-SeeMe, like ISDN/H.320, works best when the camera is stable and the slide being presented is not jiggled.

8 Tips for Producing Netcasts

Producing a netcast of a meeting is similar to doing live radio or television. If something goes wrong, the audience knows about it. A complete system test is highly recommended at least a day in advance. Once the system is configured, a 'do not touch' sign is a good idea. A recent netcast from SLAC was messed up when, unbeknownst to the production team, the equipment was reconfigured after the system test to duplicate a video tape. If possible, a second Mac or PC at netcast central is a useful diagnostic for an 'air check' of signal quality at each reflector. Live netcasts across time zones can interfere with the viewers sleep patterns. For two way, small group meetings, there is no alternative, but meeting netcasts can be transmitted live or tape-delayed.

In BaBar, it has proven impossible to obtain a copy of speakers' transparencies before a netcast. Fortunately, network improvements in the past year now permit the delivery of high resolution windows across the Atlantic. Overhead transparencies are collected after the meeting, scanned, and placed on the WWW for the rebroadcast. Slide scanning can be quite painful if the scanning is done manually. A slide scanner with an automatic feeder is highly recommended. It is fastest to scan at a resolution that produces the desired screen image size directly. For example, WWW browsers typically display GIFs at 72 dpi, so scanning an image at 50 dpi would result in an image that is 69% of the original size when viewed on the web. To reduce download times, GIFs can be saved with fewer bits per pixels. A 4 bit/pixel greyscale is usually adequate. The only editing that needs to be done manually is to orient landscape and portrait images. The WWW pages that display the meeting slides should be set up in advance. When the GIFs of slides are produced and ftp'ed to the WWW server, and chmod'ed, the job is finished.

It helps to keep the reflector network as simple as possible while still routing the signal along the best route. Early BaBar netcasts used an unnecessarily complex BCC network which proved difficult to maintain centrally. In general, a reflector should be added only when several users at a site are connecting, or to achieve a specific routing goal. Within the US, ESnet loading is not yet a significant concern. Most internal networks used for HEP in European countries, and those countries connections to CERN are in good shape as well.

Publicity within BaBar has helped a CU-SeeMe demonstration project evolve into a tool that is known to most collaborators. A day or two before each meeting, an email with the netcast schedule and a URL for further information is sent to the entire collaboration. Several WWW pages have been written to help new users get started, and a videoconferencing email discussion group has been used to exchange news, developments and ideas.

9 How Well Does CU-SeeMe Work?

CU-SeeMe conferences works reasonably well for BES collaborators in the US. Most collaborators have been able to connect most of the time, although there have been periods of several months when collaborators with the poorest Internet connections (Hawaii and Colorado State) found connections to be unsatisfactory. Recent network upgrades have made their connections usable.

CU-SeeMe connections from the US to China were first established over IHEP's 64 kbits/s link during July, 1995. Network usage dropped from 11 PM to 7 AM Beijing time, and productive CU-SeeMe communications were possible. Later that summer, the first CU-SeeMe netcast of an HEP conference, the Lepton-Photon '95 symposium was attempted. The feed was tape delayed for the convenience of viewers and to allow the netcast to originate at IHEP. The Cornell reflector was used as the White Pine reflector was still under development. A BCC network was constructed from volunteer sites in the US, Japan, Great Brittain, and Norway. The routing did not make use of ESnet. Signal quality varied, but at times was usable. Since 1995, the IHEP network usage has increased greatly, making CU-SeeMe problematic. Currently, CU-SeeMe video works, but audio is unsatisfactory. CU-SeeMe video connections are accompanied by a telephone call or lots of typing in the chat window. A network upgrade to 128 kbits/s is expected in the near future.

Since April, 1996, plenary sessions from four BaBar collaboration meetings, three from SLAC and one from the Technishe Universitaet Dresden, have been netcast. The first netcast from SLAC used a White Pine 2.0 beta reflector release and turned up several bugs which are fixed in the current White Pine 2.1 release. Good signals were delivered to most US sites, and some European sites, and important lessons were learned about routing feeds. Subsequent netcasts delivered good CU-SeeMe feeds throughout the US and Europe.

Client to client usage within BaBar is hard to monitor but appears to be occurring. CU-SeeMe works well between U.T. Dallas and most BaBar sites and CERN. There have been two bizarre instances where audio was only established in one direction; the details have been forwarded to the development teams at White Pine and Cornell. Multiparty, transatlantic BaBar conferences using unicast reflectors are still under development. They tend to work when network conditions are good, but at other times audio does not make it through the reflectors when client to client connection succeed.

10 Hybrid Conferences.

Interest in Internet-based conferencing increased dramatically in BaBar when the lab stopped paying for BaBar teleconferencing. Some meetings that have traditionally used telephone conference calls have experimented with adding CU-SeeMe participants. So far, a crude interface using microphones in front of speakers has had only limited success. Audio levels have proven difficult to adjust. An electronic telephone patch to connect the telephone and CU-SeeMe inputs and outputs directly is being built.

At the other end of the spectrum, the SLAC V-Tel conferencing system can now feed an ISDN H.320 conference to CU-SeeMe and nv/vat clients, and the hardware is being assembled to feed the Internet clients back to the ISDN conference. Internet video will be treated as one of the local cameras at SLAC that can be selected by the SLAC user controlling the conference. Audio is more complicated. The Internet audio could be mixed with the SLAC microphones that feed the V-Tel unit, but then the conferees at SLAC would not hear it. If the Internet audio were just played aloud at SLAC, it would be picked up in some form by the V-Tel microphones, but the signal quality would probably be poor for remote ISDN participants. Some judicious mix will probably be needed to serve all parties. The sound feed for the Internet client will have to be a mix of the remote ISDN audio and the V-Tel microphones at SLAC. Some careful level and threshold setting may be necessary to avoid transmitting audio from the Internet client back to the sender via the V-Tel microphones at SLAC.

Bridges for telephone/Internet and ISDN/Internet conferences are far simpler when no local participants are present at the location of the bridge. Echoes are avoided because audio and inputs/outputs are directly exchanged, and Internet video would serve as a dedicated V-Tel video input. The telephone/Internet bridge is easiest to execute; it could be set up by any participant in the conference that had a second phone line, a phone patch, and an Internet client. An ISDN/Internet bridge could be set up in the same way if an ISDN site were willing to donate its equipment for a bridge, but only watch the proceedings. A better solution is to locate the ISDN/Internet bridge at the ESnet ISDN hub. ESnet is currently developing this capability. [12]

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[12] Craig Tenney, John LoSecco, personal communication

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