Technical Note: Hardware and Software Requirements for Tango Interactive Virtual Classroom.

Typical arrangements of Virtual Classrooms

In practical applications of Interactive Synchronous Distance Learning, we usually deal with a small number of typical network topologies. The two most basic arrangements are**: instructor to a classroom** and **instructor to a group of geographically dispersed students**. Arrangements that are more complex may include a combination of the two basic topologies and, possibly, a local classroom from which the instructor delivers the class to both local and remote students.

In the following, we will discuss the two basic arrangements in detail and provide general guidelines for setting up more complex distance learning topologies.

Figure 1 (right) shows the typical "instructor to a classroom" set-up. In this topology, the instructor delivers the class to a group of students gathered in one computerized classroom at a remote location. There is no limit on a distance between the instructor and students locations.   Tango Interactive Virtual Classroom requires network connectivity between both locations, using either public Internet or a Virtual Private Network.

1. Multicast versus Unicast on today's Internet

Before we go any further with explanation of different network topologies for ISDL, it is necessary to explain the role and status of multicast transmission on today's packet switched networks.

Tango Interactive Virtual Classroom provides a voice over IP application. Actually, both audio and video are supported. These multimedia streams are being sent from the instructor to students. Delivery of the audio and video streams can be organized in one of two ways: either a separate stream is sent from the instructor workstation to each student's using the primary IP address of the student's machine, or just one multimedia stream is sent from the professor's workstation to a class D (multicast) address to which all students workstations listen. Technically, the later solution is superior.
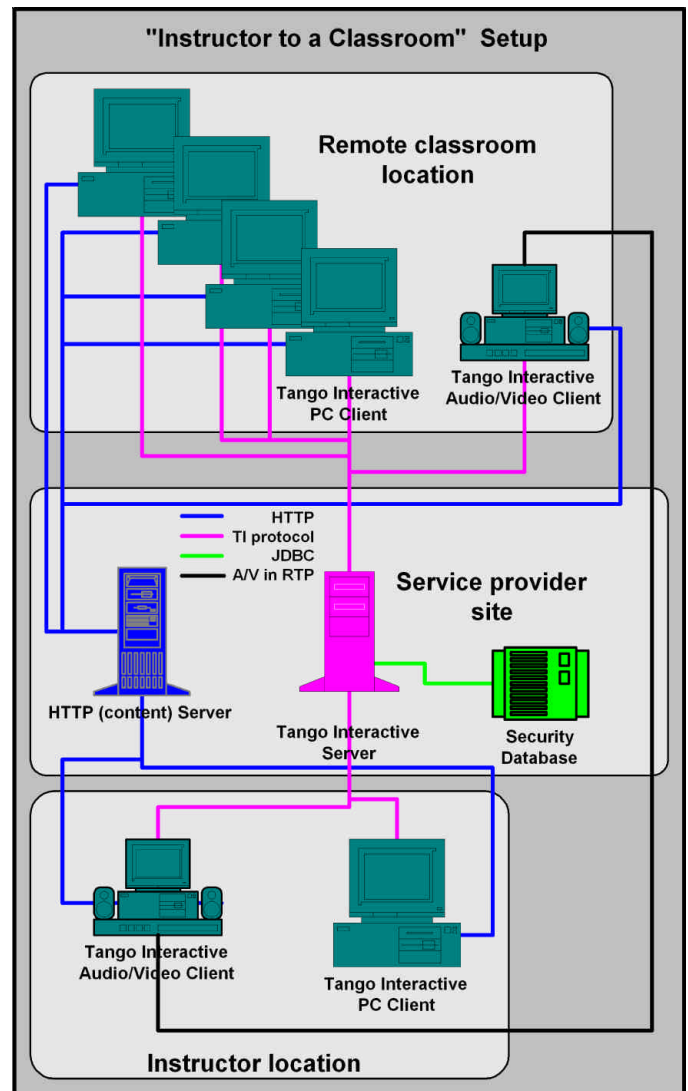

Figure 1: "Instructor to the classroom" setup

The problem is that, on the today's Internet, the support for multicast is very incomplete. Many ISPs offer no multicast, and, even on academic campuses, the coverage is far from universal. It is always possible to join the MBone by setting up multicast tunnels, but this

is a relatively complex operation, which significantly increases the cost of the customers network support.

The multicast technology has been popular with large, technically savvy universities and with certain DOD agencies. Our recent studies show that even at the technically capable organizations the cost of maintaining the MBone connection is so high that many of the current multicast technology users switch to the less expensive unicast methodology. This transition is stimulated by the improving bandwidth and stability of the Internet backbone.

Tango Interactive Virtual Classroom has been designed around the concept of inexpensive, commodity based technology. Consequently, given the problems with multicast availability the default transmission method for BuenaVista, our video Figure 2: "Instructor to a Classroom" setup for TIVC and voice over IP application, uses unicast. Multicast support is only available as a custom solution upon explicit request. This trade-off imposes certain limitations on system scalability, and it has an impact on the recommended Virtual Classroom configuration.

2. "Instructor to a Classroom" setup

In the simplest case, "Instructor to a Classroom" setup involves the instructor workstation at one location and a number of PCs or Unix workstations installed in one physical classroom at a remote location (Figure 1). With such an arrangement, it is not necessary for students in the classroom to receive separate audio and video streams. A combination that we have successfully tested at many locations consists of a dedicated audio and video workstation, connected to a large screen display of any kind and to an acoustic amplifier or simply to a set of good quality, amplified loudspeakers. The large display is used to show the real-time video of the instructor, and the loudspeakers are transmitting Instructor's voice. To ensure interactivity, the Instructor can activate the full track audio-video agent on each student's workstation, so that the students can freely ask questions using audio channel. If the student's workstation is equipped with video camera, student's video will be shown on the large screen too.

In situations where high system availability is critical, we recommend that at least one of the students' workstations is set up so that it can be quickly turned into the audio-video workstation. A simple switching device or a projector with double, selectable input could easily accomplish this.

Recommended configurations for the audio/video and student workstations are discussed in the section "Configuration of the workstations".
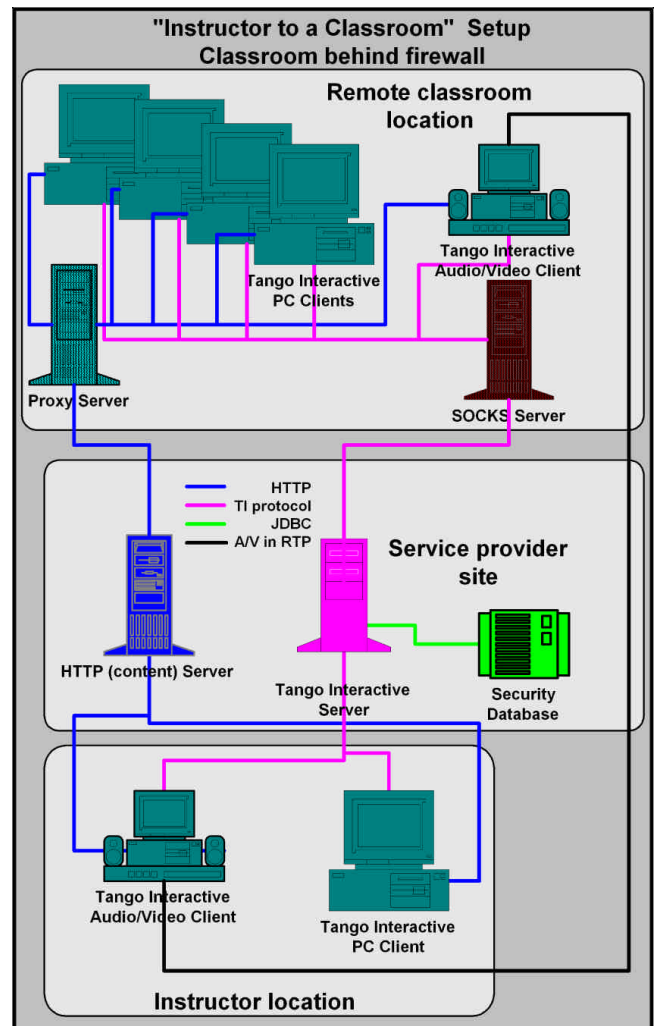
3. Classroom behind firewall

Figure 2: Virtual Classroom behind firewall

A classroom used to receive ISDL classes may be a part of corporate Intranet and it may be placed behind firewall. Tango Interactive supports such network configuration. To receive classes delivered from outside of the firewall, the receiving site must provide two proxy servers: a standard HTTP proxy (e.g., Netscape Proxy Server) and a SOCKS4 proxy. The requested configuration is displayed on Fig. 2.

The HTTP proxy server channels all TI VC traffic, including Session Manager and application code download, as well as all HTTP data traffic created by TI VC application modules. Installation of the HTTP proxy server may be beneficial even if there is no firewall involved. A proxy server local to the classroom can significantly improve system performance, especially on slow networks.

To channel the HTTP traffic through proxy server, all browsers used in the Virtual Classroom must be pointed to the proxy server. The exact method of configuration depends on the browser and on the general site proxy configuration policy.

In addition to the HTTP network traffic, the TI VC system needs a connection to the TI class server. Since TI uses proprietary and application-dependent communication protocol, the system needs a SOCKS proxy server to traverse firewall. At present, TI requires SOCKS4 protocol. Most SOCKS5 proxy servers support version 4 of the protocol as well.

TI system uses browser SOCKS setup and it does not need separate configuration. TI plug-in knows how to retrieve browser's SOCKS proxy protocol setup.

Current version of TI VC does not support SOCKS protocol for BuenaVista. We expect that this feature will be added in version 2.1. BuenaVista proxying will require a proxy server supporting SOCKS version 5.

Netscape Proxy Server supports both HTTP and SOCKS4/5 protocols. In general, TI VC should work with any HTTP and SOCKS proxy.

4. "Instructor to a group of geographically dispersed students" setup

This setup is fundamentally different. The students, instead of being gathered in one of few classrooms, are attending the class from individual workstations located at random places. They may access the class via a dial-up link or cable modem provided by ISP or via a corporate or campus link to Internet.

The basic problem with this approach is scalability of audio/video. Obviously, audio (and, optionally, video) stream must be delivered to the workstation of each class participant. At present, use of multicast for such class arrangement is out of question: there is practically no support for multicast by the ISPs. Geographically dispersed users, having no benefit of the technical support usually available in institutional virtual classrooms, impose special demands on the ISDL software and Virtual Classroom support personnel. Construction of multicast tunnels is way beyond technical capabilities of such users.

There is a technical limit on the number of users that be concurrently supported in such configuration. The unicast mode (see below) of BuenaVista creates performance and bandwidth problems on the instructor workstation. The practical limit for a number of class recipients in the "dispersed" is ~20 for strictly one-way audio. For fully interactive two-way audio, the maximal number of users is around eight. These numbers can
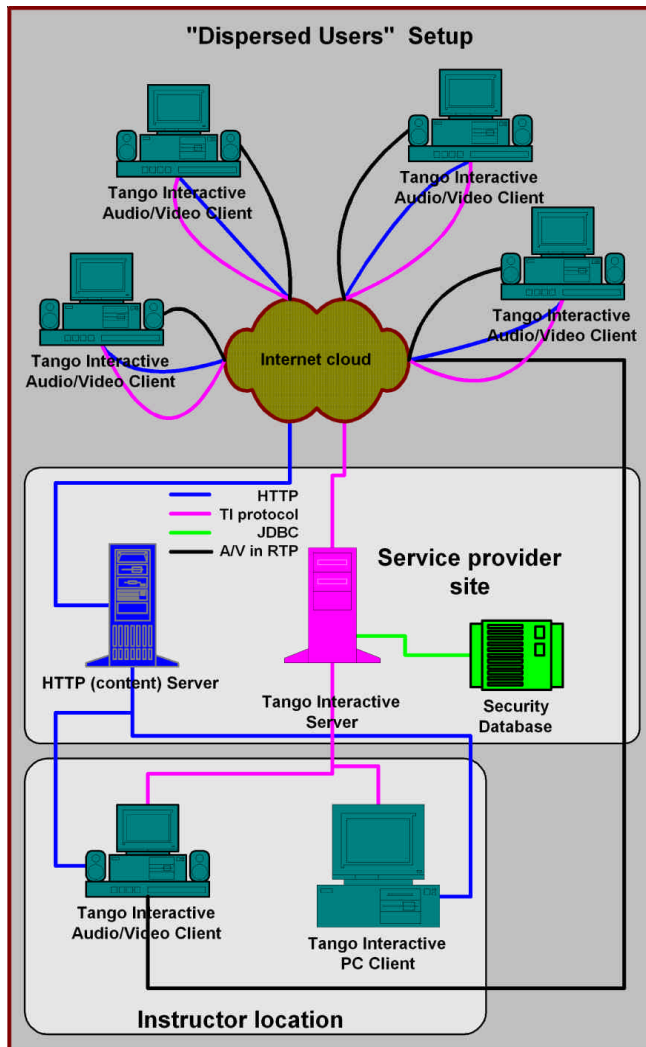

Figure 3: "Dispersed Users" Setup of TIVC

be a little higher if high-end workstations are used and the network bandwidth is very good (T1 range).

Connectivity requirements for dispersed users are discussed below in the section "Protocols and bandwidth".

5. Mixed configurations

In real-life applications, we often encounter situations where all three of the network topologies discussed above are intermixed. TIVC permits such configurations. It is possible to have a number of Virtual Classrooms of line, some of them connecting via firewall, along with a number of individual, "dispersed" users. TIVC has been successfully used in such situations. The legitimate question is, then, how many classrooms and individual; students can TIVC concurrently support?

3

There is no exact answer to this question, as scalability limits depend on both hardware and software. Faster machines used as servers and clients will push the numbers higher. Remember, please, that TIVC has been designed to support interactive synchronous distance learning. The number of students in the classroom is limited by the very nature of the process. Above certain limit, the interactive class becomes a broadcast.

The most stringent limitation is imposed by the audio/video agent. The system will support up to 25 audio/video channels. (TIVC floor control got BuenaVista uses one-to-many concept of audio/video transmission. This means that at any given time, there is only one speaker addressing entire class or breakout group. The instructor is in control of who can send audio and video). Using "Instructor to a classroom" topology, or a mixture of different topologies, TIVC can easily support up to a hundred of concurrent students. For "dispersed users" topology, number of concurrent users is imposed by BuenaVista.

Protocols and bandwidth

The session setup and message passing protocol used internally by Tango Interactive is using TCP as transport layer. Data transfer from the HTTP servers is also using TCP.

Bandwidth requirements for the TI protocol are negligible. The system has been successfully tested over wireless 9.6 kbps links, as well as over the marginal networks with packet loss as high as 60%. No problems other than slow response were observed.

Bandwidth requirements for the date transfer from HTTP servers are strictly application-dependent. Our courseware management system offers multiple versions of the class visuals, from large images to simplified HTML. It is possible to adjust quality of the visuals to network conditions, to improve system performance. Another solution for slow networks is installation of a proxy server for HTTP protocol (see section below about "classroom behind firewall"). This solution will ensure smooth operation of the TI framework even on extremely bad networks.

Audio and video over IP is somewhat more demanding. BuenaVista application uses TCP for internal communication and UDP (more precisely, RTP) for media transport. Although BuenaVista can produce high-quality, high bandwidth data streams on LANs, it is also equipped to deliver audio and video over slow connections. The GSM audio nominally requires only 13 kbps per audio stream. Since BuenaVista suppresses transmission of silence if properly set up, the effective audio stream for a typical class requires approx. 10 kbps. A useful video stream using our

H.263 encoder can be tuned to ~12 kbps. Video stream transmission is always optional.

Does it mean that TI VC users can connect to classes via modems? The answer is: yes, if they have a 56 kbps modem and if their ISP provides decent service. Please, remember that 56 kbps modem bandwidth is a myth. Typically, a "good" connection to an ISP will provide 41-44 kbps downstream, upstream bandwidth is always limited to 33.6 kbps. Assuming the best possible connection, it is usually possible to receive TI VC classes with audio only. Video reception on such links is not practical. The minimal home link bandwidth necessary to receive audio, video, visuals, an to participate in other TI VC sessions without interruptions of the audio stream is ~80 kbps and hence requires an ISDN link or better (cable modem. ASDL, etc.)

Since the default transmission method used by BuenaVista is unicast, the outgoing link from the teacher site must support N times he average A/V bandwidth for audio/video streams alone. In practice, the instructor site requires at least T1 connectivity.

Configuration of the workstations

All recommendations in this section are supposed to provide the reader with reliable information on how to configure the system to obtain satisfactory performance. These are not "minimum system configurations" as practiced by many software vendors.

TIVC will run on much weaker workstations, including such outdated platforms as 166 MHz Pentium machines, but the performances will not be acceptable except for a system demonstration. All listed configurations ensure excellent system performance, necessary for delivery of high-quality ISDL classes.

1. Audio/video workstation

Platforms: At present, Tango Interactive Virtual Classroom supports two platforms as audio video workstations. One of the platforms is an SGI O2 workstation running IRIX 6.5. A standard, vendor-recommended configuration of this platform is adequate for TIVC applications. The O2 workstations come, per default, with a camera, an A/V module, and 128MB of RAM.

Another option is a PC with Windows NT operation system. Hardware specification for a PC-based audio video platform is provided in the table above.

We discourage use of Windows 95/98 as the operating system for TIVC. The system will work, but stability may be less than perfect. This is due to the poor performance of the Windows 95/98 under heavy load, caused by inherently weak process management in the non-preemptive environment.

4

Recommended configuration of the Virtual Classroom Audio-Video workstation	
Operating system	Windows NT Workstation (preferred) or 98 (marginally acceptable, discouraged). Windows 95 is not supported.
CPU	450 MHz Pentium III or faster
Memory	128 MB DRAM
Storage	8 GB or more (can be IDE or ATA), CD-ROM drive
Graphics card	1152x864 True Color or better
Projector	Capable of handling 1152x864 resolution of the graphics card
Network	Ethernet 10/100 Mbps

Video capture device	• Winnov PCI Videum Conference Pro kit (includes camera and audio capture)
	• Panasonic EggCam
	• Recent (1998 or newer) Intel Smart Video Recorder III and a compatible camera, preferably with SVHS output
	• Other cards built around Brooktree chipset (See Appendix A)
	• Deprecated configurations:
	  o Parallel port cameras
	  o USB port cameras if Windows NT is used

Audio device	Unnecessary if Winnov Videum Conference Pro is installed; Otherwise Soundblaster 64 (MUST have full-duplex-enabled device driver)
Microphone	Headset-integrated. Recommended: VXI Parrott 10-3. Important: use of any camera built-in microphones is unacceptable!
Audio output	Professional amplifier or good quality amplified speakers. Equalizer or tone control highly recommended
Echo canceller (optional but useful)	Biamp System's VC 3000 Voicecrafter

Backup: In the classroom setup, two workstations with this configuration are recommended, one of them acting as a backup. A mix of an IRIX and a PC workstations is acceptable.

Video capture cards: Current market for the PC video capture cards is very crowded. All products are touted as "high-quality" videoconferencing devices. Unfortunately, the reality is very different. Only a handful of products is useful for professional applications. We strongly recommend that only certified solutions be used with TIVC. BuenaVista may or may not work with other cards/cameras. In any case, we will not support or troubleshoot unstable, buggy, or incompatible drivers coming with audio or video capture solutions not on our certified devices list. Use of such devices is entirely on the end-user risk.

Microphones: For good audio quality, special attention must be paid to choice of microphones. Many cameras, even the certified ones, come with a built-in microphone. Built-in microphones are entirely unsuit able for multi-party conferencing. Don't use them! They are all low-quality, highly sensitive, omni-directional devices. They are great in picking up and

transmitting ambient and background noise, dramatically lowering signal-to-noise ratio. Digitization of a poor quality audio signal tends to make things worse. One open camera mike in the conference can effectively disturb all conference participants. The only acceptable solution is a good quality, unidirectional, head-worn microphone, preferably equipped with ambient noise suppression via a built-in DSP.

Headphones vs. speakers: For individual student workstations, and for the "dispersed" users receiving individual audio streams, no loudspeakers should be used. Instead, the audio should be received via headphones. The best choice is a set of headphones with integrated microphone.

Echo cancellation: A useful addition to the virtual classroom setup is an echo canceller. In the absence

of such a device, the audio played by speakers can be picked up by the microphone and transmitted back to the sender. Since voices over IP applications always have noticeable delay, related to various buffers in he system, the "echo" transmission is extremely annoying for the audio sender and disturbing to other receivers. If the audio stream is played back in the classroom using speakers, the classroom microphone must be turned off unless in use. This somewhat lowers interactivity. An echo canceller (listed in the table above) helps to alleviate this problem. With echo canceller installed, it is possible for each student to use classroom microphone at any time to ask a question.

Audio equipment quality: The general rule for classroom equipment is this: since good audio

quality is critical for reception of the class, don't settle for cheapest available audio components, usually offered with computers. Only professional class devices should be used in the classroom.

Classroom video: With just one audio/video workstation in the classroom, instructor's video is shown via a projection device. Many computer screen projectors only handle low screen resolutions, such as 800x600. The projector used in the virtual classroom should match resolution of the graphics card installed in the audio/video workstation. Since this workstation can also be used to show certain specialized visuals, the minimal acceptable screen resolution is 1152x864 in TrueColor.

2. Student workstations

Recommended configuration of the Virtual Classroom student workstation	
Operating system	Windows NT Workstation (preferred) or Windows98 (marginally acceptable). Windows 95 is not supported (see Appendix B).
CPU	400 MHz Pentium II or faster
Memory	128 MB DRAM
Storage	8 GB or more (can be IDE or ATA), CD-ROM drive, floppy disk
Graphics card	1152x864 True Color or better
Network	Ethernet 10/100 Mbps

Video capture device (optional but useful if high interactivity is required)	• Winnov PCI Videum Conference Pro kit (includes camera and audio capture)
	• Panasonic EggCam
	• Recent (1998 or newer) Intel Smart Video Recorder III and a compatible camera, preferably with SVHS output
	• Other cards built around Brooktree chipset (See Appendix A)
	• Deprecated configurations:
	  o Parallel port cameras
	  o USB port cameras if Windows NT is used

Audio device	Unnecessary if Winnov Videum Conference Pro is installed; Otherwise Soundblaster 64 (MUST have full-duplex-enabled device driver)
Microphone	Headset-integrated. Recommended: VXI Parrott 10-3. Important: use of any camera-integrated microphones is unacceptable!
Audio output	Headphones, recommended: VXI Parrott 10-3. Speakers should NOT be used!

The table above lists the recommended configuration of the student's workstation in the Virtual Classroom. The preferred platform is PC-based.

Other supported platforms include Linux, IRIX 6.5, and Solaris 2.6 machines. At present, there is no audio/video support for Linux and Solaris. In general,

system performance on Unix machines isn't as good as on Wintel platforms.

We discourage use of Windows 95/98 as the operating system for TIVC. The system will work, but stability may be less than perfect. This is due to the poor performance of the Windows 95/98 under heavy

load, caused by inherently weak process management in the non-preemptive environment.

For "dispersed students", we recommend identical configuration, with two exceptions:

- A Pentium III based machine is preferable if the student wishes to receive both audio and video. In general, workstations on slower net-work links should have faster CPUs, to make up for the more complex audio/video codecs used for higher media compression.

- A dial-up adapter or cable modem replaces Ethernet card. For ISP link recommendation, consult "Protocols and bandwidth" section earlier in this document

3. Instructor workstation

Recommended configuration of the Virtual Classroom instructor workstation	
Operating system	Windows NT Workstation
CPU	Dual processor 450 MHz Pentium III or faster
Memory	256 MB DRAM
Storage	18 GB or more (can be IDE or ATA), CD-ROM drive
Graphics card	1200x1024 True Color minimum, 1600x1200 True Color recommended
Monitor	21 inch high-resolution, 85Hz scan frequency
Network	Ethernet 10/100 Mbps
Video capture device	- Winnov PCI Videum Conference Pro kit (includes camera and audio capture) - Panasonic EggCam - Recent (1998 or newer) Intel Smart Video Recorder III and a compatible camera, preferably with SVHS output - Other cards built around Brooktree chipset (See Appendix A) - Other video capture cards can be tried but we won't support or troubleshoot such configurations - Deprecated configurations: - Parallel port cameras - USB port cameras if Windows NT is used
Audio device	Unnecessary if Winnov Videum Conference Pro is installed; Otherwise Soundblaster 64 (MUST have full-duplex-enabled device driver)
Microphone	Headset-integrated. Recommended: VXI Parrott 10-3. Important: use of any camera-integrated microphones is unacceptable!
Audio output	Headphones, recommended: VXI Parrott 10-3. Speakers should NOT be used!
Echo canceller (optional but very useful)	Biamp System's VC 3000 Voicecrafter

Instructor workstation is a critical part of the system. This workstation consolidates features needed in the audio/video and student machines. Further, the instructor often needs to concurrently use a variety of application modules that allow system and class monitoring. This workstation must handle a dozen or more processes on top of the usual complement of system applications. High performance of this workstation is a key to high performance of the entire TIVC system.

Instructor workstation must run Windows NT or Windows 2000 operating system.

Due to the very high system load, we recommend that instructor workstation is a two CPU machine. This configuration allows the operating system to allocate very CPU intensive Video and audio encoding and transmission to one processor, leaving ample computing power to handle Java VM running the TIVC kernel.

If a two CPU machine is not available, we recommend that the instructor be provided with two separate machines (as in Fig. 1), one machine handling audio/video, and another running rest of the TIVC applications. TIVC system seamlessly handles such configuration.

Another critical aspect of the instructor machine is the high-res display unit. We recommend use of the 21 inch, high quality monitors with highest possible resolution. 1200x1024 resolution is a minimum, 1600x1200 screen allows the instructor to neatly arrange all needed software tools on the screen in one always visible layer.

All issues regarding audio gear quality discussed in the section "Audio/video workstation" apply to the instructor workstation as well. Echo canceller should be given serious consideration.

4. Software requirements

Each workstation participating in TIVC system should have the following software installed:

- Windows NT 4.0 with Service Pack 5
- Netscape Communicator 4.7
- Microsoft Office
- Microsoft Internet Explorer 5 including Net-Meeting 2.11
- VNC (Virtual Network Computing) server

The following additional 3rd party software has proven to be extremely useful for system troubleshooting by either end user support personnel or by WebWisdom.com engineers:

- TextPad (wonderful text editor for Windows)
- WinZip (popular file compression utility)
- FTP client
- FTP server (MS FTP server from Web Peer Services is acceptable)

5. Support issues

Delivery of ISDL classes requires technical support. The practice has proven that in the "Virtual Classroom " configuration there should be one technical support person per remote classroom location. Instructor site should have a teaching assistant on-line. Service provider should expect to have a technical person per each set of three concurrent ISDL classes.

TIVC provides out-of-band communication channels for support personnel.

Support personnel workstations should conform to the specification of the student workstation.

6. Issues not covered in this memo

This paper does not discuss issued related to the TIVC server and to the HTTP server(s) hosting TIVC system. These issues are addressed in a separate document "Hosting TI VC Service".

Appendix A

The following video capture cards use Brooktree/Rockwell Bt848 chipset:

- Intel Smart Video Recorder III
- Panasonic - Eggcam kit - includes a camera
- Hauppauge Computer Works - Wincast/TV
- Diamond Multimedia - SupraVideo Kit
- miro - miroMediaTV
- 3Com - Big Picture Kit - includes a camera (and a modem)
- Zoom Telephonics - VideoCam - includes video capture / modem board and camera
- Boca Research - VideoCommunication Suite - includes video capture / modem board and camera

It is usually possible to use Intel Smart Video Recorder III device driver with these cards.