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Videoconferencing Procurement and Usage Guide

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ABSTRACT

This report presents a brief history, technical discussion, and the processes that are required in order to evaluate the need for a videoconferencing system. This report provides guidance for the evaluation, selection, purchase, installation, and use of various options and system types. Communication and physical requirements are discussed with respect to each of the most common systems that are currently available. Requirements are provided for personnel training and site preparation.

KEYWORDS

Audio; Conference; Interactive; Remote; Video; Videoconference; Visual

Certain trade names and company products are mentioned in the text or identified. In no case does such identification imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the products are necessarily the best available for the purpose.

EXECUTIVE SUMMARY

This report may be used as a guide for government agencies considering or planning the use of videoconferencing. A technical description, cost and benefits analysis, and procurement and implementation guidance of videoconferencing are presented. Videoconferencing is a viable means of providing quality, interactive, remote communication. Videoconferencing is a cost effective means of conducting project meetings, conducting training sessions, and providing real-time customer assistance. This report does not recommend a particular vendor, type of equipment, or technical approach.

Each section of this document addresses commonly asked questions concerning videoconferencing. The questions which are discussed are:

(1) What is videoconferencing?
(2) Do I want to buy a videoconferencing system?
(3) What system do I want to buy?
(4) How do I intelligently use what I have bought?
(5) What strategy should I use to install the system I have bought?

This report contains a short tutorial on videoconferencing systems. There is also a discussion of the current state of applicable standards and how these standards affect the utility of many of the available videoconferencing systems.

Each of the available major videoconferencing system types are described: large fixed systems, mobile systems, and desktop systems. Comparisons are made based on the systems' strengths and weaknesses.

Videoconferencing is a currently viable and cost effective method of conducting meetings. As new capabilities are introduced, videoconferencing will become a progressively more powerful and effective business tool. These capabilities will include whiteboarding, application sharing, and computer sharing. Standards-making organizations are expected to enhance existing standards to include these additional capabilities over the next few years.

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1. INTRODUCTION

This report may be used as a guide for government agencies considering or planning the use of videoconferencing. A technical description, cost and benefits analysis, and procurement and implementation guidance of videoconferencing are presented. Videoconferencing is a viable means of providing quality interactive remote communication. Videoconferencing is also a cost effective means of conducting project meetings, conducting training sessions, and providing real-time customer assistance. This report does not recommend a particular vendor, type of equipment, or technical approach.

This report provides answers to a series of questions. Each section addresses a different question. Section 2 answers the question: what is videoconferencing? Section 3 answers the question: do I want to buy a videoconferencing system? Section 4 answers the question: what system do I want to buy? Section 5 answers the question: how do I intelligently use what I have bought? Section 6 answers the question: what strategy should I use to install the system I have bought?

2. DEFINITION AND STATUS OF VIDEOCONFERENCING

When considering the purchase of a videoconferencing system, it is necessary to understand what it is, what it does, how it is used, and how it can relate to the purchaser. The following sections address these issues and take some of the guesswork out of the development of the requirements necessary for the purchase of a system.

2.1 Definition

Videoconferencing is a process whereby two or more people can communicate interactively both visually and audibly from remote locations in real time. Videoconferencing can be used to conduct meetings of business groups located in different cities, to teach students who are not physically located in the same location, and to allow remotely located people to work together to perform complex technical tasks.

2.2 History of Videoconferencing

During the 1970's, a small number of firms used videoconferencing. For the most part, videoconferencing systems were collections of readily available, consumer related, audio and video equipment which were interconnected to satisfy individual business requirements. A few years later, several vendors began to market point-to-point systems which used dedicated transmission media and which consisted of more general audio and video electronics systems. A larger market began to emerge as interest increased and as the benefits to be gained through the use of

videoconferencing became more apparent. By the mid 1980's, several firms began to support a more focused market by designing and producing equipment specifically for videoconferencing use. This equipment took advantage of the availability of reduced bandwidth transmission capability through the use of audio and video digital compression techniques. Today, many types of equipment are available to support a wide variety of videoconferencing applications. These equipment types range from simple desktop systems to large complex systems more suited to theater applications. The videoconferencing market is expanding so rapidly that the range of current videoconferencing usage is limited only by the imagination of the designer and user.

2.3 Communications Primer

When considering the use of videoconferencing equipment for a particular application, a knowledge of some of the communications requirements (e.g., bandwidth, pixel, and frame) associated with the desired application is necessary. Although most vendor equipment will support several bandwidth choices, the bandwidth chosen for any specific use is extremely important with respect to the final perceived quality of the conference. The bandwidth selected will depend on the choices offered by public data networks and the user's budget. In order to understand how to choose the bandwidth desired for a particular conference, a short discussion of the issues relating to bandwidth usage is prescribed.

A pixel is a single illuminated point on the screen and is the basic element that creates a picture on a computer monitor. On a television screen, a row of pixels is converted to an analog picture line and displayed across the screen. The greater the number of pixels, the better the quality of the picture. Each pixel requires 24 bits to represent full color and must be refreshed at least 15 times per second to provide acceptable motion handling.

A standard video static picture (or frame) consists of 368 horizontal pixels on each of 525 lines, of which 480 lines are visible. The extra non-visible lines are used for additional services and options such as closed captions. For normal television, each frame is transmitted at a rate of 30 frames per second (fps). A broadcast-quality analog video signal converted to digital, requires approximately 90 megabits per second (Mbps) of transmission bandwidth. This large capacity is not only expensive but is not normally available in most locations. As a result, most videoconferencing signals are converted to a compressed digital signal prior to transmission. After transmission, the signals are decompressed and converted to analog prior to presentation to the viewer. The device that is used to accomplish the compression and decompression is commonly called a "codec" (coder-decoder). In addition to compression techniques, the screen resolution (i.e., the total number of viewable pixels times (x) the lines on a

screen) is reduced for most videoconferencing applications. The most common videoconferencing resolutions used are:

1. full common intermediate format (FCIF or Full CIF), which is 352 pixels x 288 lines; and

2. quarter common intermediate format (QCIF or Quarter CIF), which is 176 pixels x 144 lines.

As a comparison, a standard 1/2 inch Video Home System (VHS) has a resolution of 256 pixels x 240 lines. This lies on the high bandwidth side between QCIF and FCIF. Figure 1 depicts the relationship of the various resolutions described above.

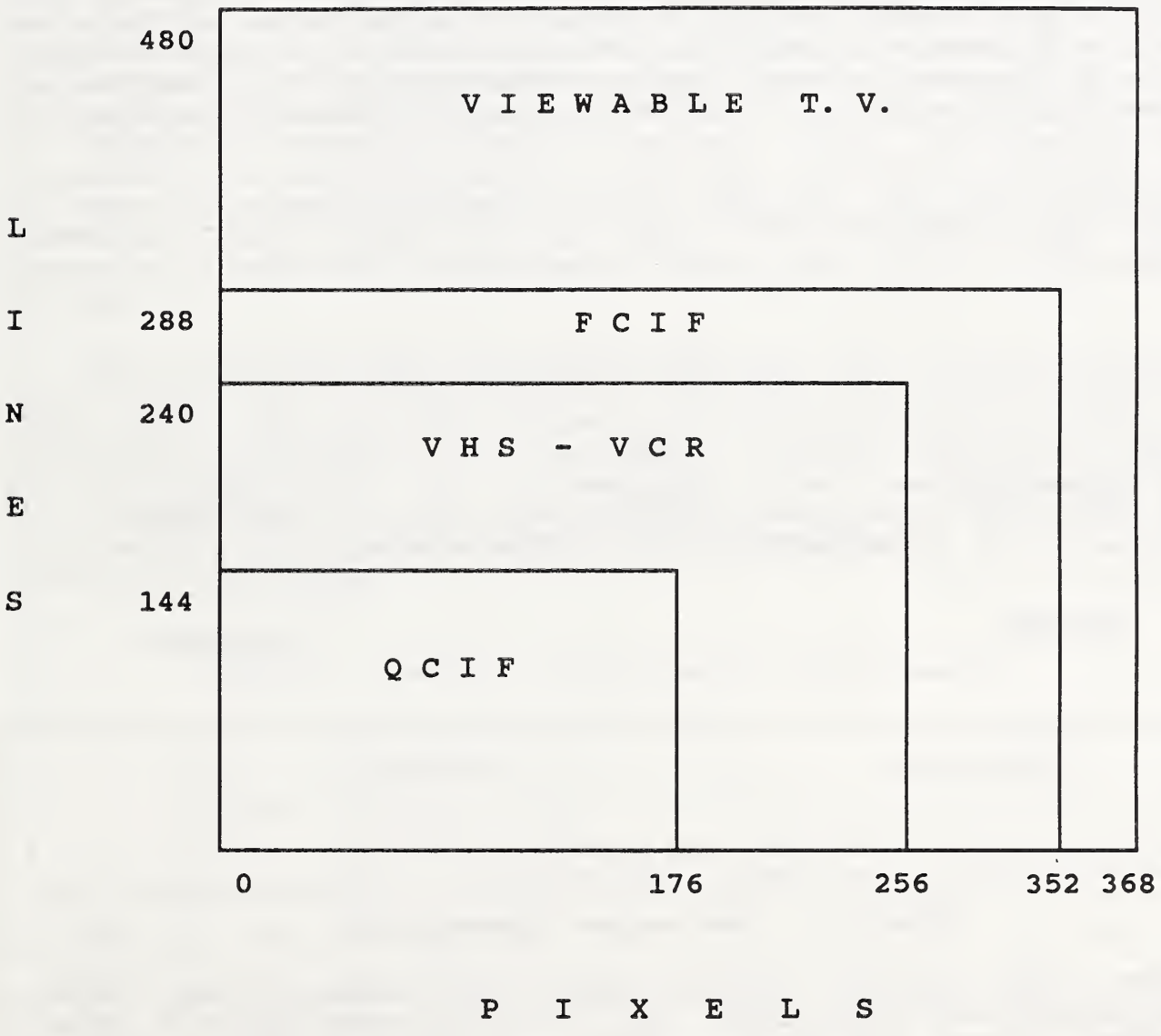

Figure 1. Relative Viewable Resolutions.

The resolutions depicted in Figure 1 do not account for the fact that some information is always lost during the process of converting and reconverting a signal from analog to digital to analog.

Since an FCIF video requires a transmission rate of about 36 megabits per second, the transmission cost would be prohibitive. For this reason, videoconferencing employs video compression to achieve acceptable performance. Participants in a videoconference generally are nearly stationary because they are involved in discussion. This lack of motion is beneficial because a large part of the picture is static from frame to frame and only those pixels that change must be transmitted for each frame. Compression techniques, which can achieve compression ratios of up to 800 to one, permit videoconferencing to operate at rates as low as 112 kilobits per second (Kbps). Thus, videoconferencing may be effectively conducted using two switched 56 Kbps telephone lines. Figure 2 illustrates the one-way transmission of a compressed picture from a sender to a receiver; however, videoconferencing is full duplex.

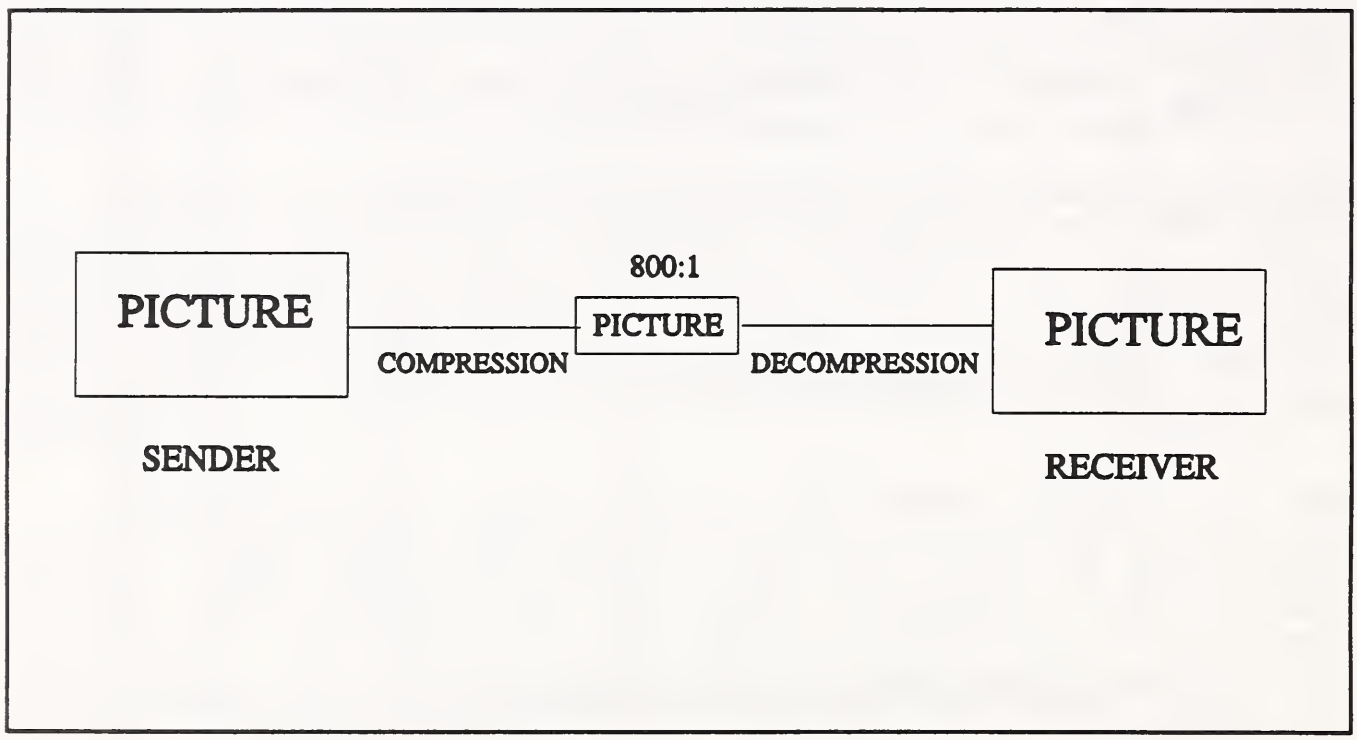

Figure 2. Compressed Transmission.

Vendors will offer 56,000 bits per second (56 Kbps) videoconferencing with QCIF, but this is essentially a video telephone. Full videoconferencing, using a 20 inch or larger monitor, starts with FCIF resolution and 112 Kbps bandwidth. QCIF resolution is adequate for use with a PC window. Most compression algorithms break the picture down into groups of pixels and lines.

These groups are often called tiles. The amount of motion which is occurring within the area described by a particular tile is often used in the process of motion prediction and compensation.

In order to reduce the bandwidth requirements further, the transmission rate of most videoconference sessions is reduced to between 8 and 15 fps. As the transmission rate is reduced, viewed motion tends to become disjointed.

Quality is often defined as a function of both resolution and transmission rate. As resolution is decreased, the picture becomes blurred; and, as transmission rate is decreased, the ability to see motion is decreased. Obviously, with only a given amount of bandwidth available (or affordable), tradeoffs must be made. A high quality telephone connection has a bandwidth of 56 Kbps; bandwidth is available in multiples of 56 Kbps with multiple lines. Videoconferencing systems will usually only permit a maximum of two switched 56 Kbps lines per system, for a combined transmission rate of 112 Kbps. Higher transmission rates, however, require the use of Integrated Services Digital Network (ISDN), which provides transmission rates in multiples of 64 Kbps; therefore, 128 Kbps and 384 Kbps are common videoconferencing choices. An ISDN Basic Rate Interface (BRI) line is 128 Kbps. Of course, any other transmission rate may be purchased, usually as a part of some other service.

The normal minimum acceptable bandwidth for videoconferencing is 112 Kbps. This choice yields acceptable voice, reasonably good video resolution, but only minimally acceptable motion quality. A bandwidth of 384 Kbps is the lower limit of Cable Television (CATV) and will result in a very good overall video reception. Table 1 depicts some of the most common choices along with the bandwidth requirements and the number of 56 Kbps circuits or 64 Kbps channels associated with each.

Table 1. Nominal Transmission Requirements.

	Uncompressed			Compressed	
	Lines	Pixels	10^6 Pixels/sec (30 fps)	Number of 64 (56) K Channels	10^3 Hz Transmission Rate
CATV	480	368	5.3	>= 6	>= 384
FCIF	288	352	3.0	4 - 6	236 - 384
VHS	240	256	1.8	2 - 4	112 - 256
QCIF	144	176	0.8	1 - 2	56 - 112/128

The audio component of the transmission also consumes bandwidth. The audio bandwidth which is normally considered is in the analog frequency range of 50 Hz to 7 kHz. This maps into a digitally transmitted bandwidth of approximately 16, 24, 48, 56, or 64 Kbps depending upon the desired audio quality and whether or not the conference is in stereo.

Other functions such as camera control and location selection require the use of additional bandwidth. In general, this additional bandwidth use is minor.

2.4 State-of-the-Art

This section provides an overview of the current status of various products, services, and issues related to videoconferencing and descriptions and definitions necessary for properly evaluating a system prior to its purchase.

2.4.1 Videoconferencing Services

Videoconferencing involves the transmission of synchronous audio and video and other data between remote conferencing sites. There are three types of videoconferencing systems:

- large fixed systems
- mobile systems, and
- desktop systems.

The basic features of videoconferencing are available on all three systems. They provide for the transmission of audio and visual information and the display of the picture on one or two television screens. The systems are distinguished primarily by audio and video quality, size, intended audience, and auxiliary inputs and outputs. A significant amount of overlap exists in services provided by the fixed and mobile systems. This overlap is to be expected as these are the traditional multi-user systems and are intended to cover the great variety of user videoconferencing requirements.

The large, or fixed, system is a cabinet system consisting of one or two 20-inch to 46-inch monitors, a high quality zoom and pan camera, and a high performance audio system. This system requires a dedicated room and is useful for conferences with a large number of attendees (six or eight would be common, but larger numbers could be accommodated). It can also be used as a classroom system or as a showcase facility. This system will permit a vendor's full range of input or output devices to be attached, such as a Video Cassette Recorder (VCR) or a second telephone. It will support all of the transmission rates that a vendor supports rather than a subset, as is usually the case with mobile or desktop systems.

A mobile system is mounted on an optional cart and consists of one or two 20- to 35-inch monitors, an attached zoom and pan

camera, and an audio system. The mobile system can be moved from room to room and used where ever the necessary communications exist. This system is suited for offices and can be stored elsewhere when not in use. It is generally used by a few participants and could comfortably be used by a single participant. This system will support some, but perhaps not all, of the input and output devices and transmission rates supported by the large system. This is a very functional system and often provides the same audio and video quality as the large system.

The desktop system, the newest member of the videoconferencing family, is designed as an add-on to a base computer system, such as a Personal Computer (PC) or workstation. This system allows the full use of the base system while adding both basic and advanced videoconferencing capabilities. The advanced features, which require computer based systems, permit the display and interaction of computer generated data. The desktop system, however, limits the use of the videoconferencing to the owner of the PC/workstation, making this a personal videoconferencing system. The desktop system uses a "window" as a viewing area. This window is a smaller screen size and provides a lower picture quality, although it is meant to be viewed close-up. The camera is a small mobile unit that can also be used to view documents. This system will support some additional input and output devices and usually supports only the lower transmission rates.

Desktop systems add a new facet to videoconferencing. They make possible a face-to-face collaboration among users of workstations/PCs who are physically separated. These systems benefit greatly by using a "whiteboard" that permits application and system sharing. Whiteboarding provides the capability of drawing on a screen, overlaying information that has been previously displayed. A second new application of videoconferencing is the ability of a user or developer to "talk to the expert." When a user, such as a taxpayer in an Internal Revenue Service (IRS) field office, needs expert assistance, this system will allow both the user and the user's documents to be accessible by the expert. These systems, which are new to the market and are provided on the ubiquitous PC, will create an expanding market as its capabilities are discovered and expanded. Desktop systems are also available for use on the Macintosh and UNIX systems.

Desktop systems can also use a Local Area Network (LAN) as a videoconferencing media. The use of a LAN is an added benefit of the desktop system even though it is limited to point-to-point communication and only provides a productivity gain for one person. Desktop systems are too expensive at this time to be used only as a local videoconferencing system.

2.4.2 Videoconferencing Standards

The former International Telegraph and Telephone Consultative Committee (CCITT), now known as the International Telecommunications Union (ITU), has defined a series of Recommendations that are collectively called the "px64" or H.320 series of Recommendations (these and related recommendations are specified in [1-14]). The name is appropriate because the transmission rate is a multiple of 64 Kbps (56 Kbps may be used where 64 Kbps is not available) and the allowable values of "p" are 1, 2, 3, 4, 6, 8, 12, 18, 23, 24, and 30. Vendors will support most of these speeds (30 is the least supported speed), but not in all models. To get a specific speed users may be limited to a particular vendor model. The most popular speeds, in order of use, are 128, 384, 768 and 1536 Kbps ("p" values of 2, 6, 12, and 24). Federal Information Processing (FIPS) publication 178 [15] adopts ITU Recommendations H.221, H.230, H.242, H.261, and H.320 as a federal standard. The px64 standard is, or soon will be, implemented by all of the major videoconferencing vendors. This standard is still under development and new features, such as far-end camera control, are being studied for inclusion. With the speed with which new capabilities are being added to products, the standards bodies will be producing upwardly compatible versions of the standard for a long time.

The px64 standard defines how to compress and transmit the video and audio data. Given low bandwidth availability, high compression rates are necessary to limit the amount of data sent. This requires that only changed data be sent instead of the full picture. The standard does not define how transmitted picture data are generated. This allows the vendors to differentiate their products by sophisticated pre-processing and/or post-processing techniques. Pre- and post-processing is an art as well as a science. Because the techniques are hard to implement and produce only subjective visual improvements, they will be difficult to standardize. Pre-processing, the more prevalent technique, attempts to filter out difficult-to-code information that is unimportant to picture quality. A curious artifact of pre-processing is that systems which pre-process the information can improve the picture quality of the far-end system provided by a different vendor even if that vendor's system does not implement the same service. Pre-processing, although implemented by many vendors, is unlikely to be available in a multi-vendor environment unless there are guarantees that the service will be reciprocal. Post-processing, which attempts to compensate for high distortion levels, will be used by any vendor that implements post-processing.

The px64 standard defines two video resolutions, FCIF and QCIF. FCIF provides a better resolution than either VHS or QCIF and is more than adequate for most videoconferencing applications. FCIF provides a total of about 101 Kbits of resolution and must be refreshed at least 15 times per second (fps) for each color. A

coding technique (Discrete Cosine Transforms) is used to compress the required bandwidth so that a smaller bandwidth line may be used. This technique, which was developed by the vendors, partitions the screen into "tiles" and sends only change data for each tile. This technique is transparent to the user. The tiles only become visible when there is too much motion and tile blurring occurs.

The px64 standard also specifies a means of sending a single picture, usually shown on a second monitor, called freeze-frame graphics. This is defined by the ITU in Appendix D and requires that audio continue to be sent, but the video can be frozen while the graphics frame is being sent. After the graphic is sent, the normal picture continues. The single picture is sent at twice the FCIF resolution.

There are three ITU Recommendations that provide for audio coding: Recommendation G.711 is a 64 Kbps code providing a 3.1 kHz voice signal, Recommendation G.728 is a 16 Kbps code providing a 3.1 kHz voice signal, and Recommendation G.722 is a 64 Kbps code providing a 7 kHz voice signal. The audio (i.e., 3.1 or 7 kHz) is an analog signal and the encoding is digital (i.e., 16 or 64 Kbps). Recommendation G.728 is usually implemented with 112/128 Kbps communications since it only uses 16 Kbps of bandwidth. Recommendation G.722 is usually implemented with 384 Kbps and above communications since it provides the highest quality audio. Recommendation G.711 is only used if Recommendations G.722 and G.728 are not supported by one of the end systems. These recommendations are summarized in Table 2.

Table 2. Audio Coding Recommendations.

ITU Recommendation	Audio Transmission Bandwidth	Analog Signal Frequency	Used with Transmission Bandwidth
G.711	64 Kbps	3.1 kHz	if G.722 and G.728 unavailable
G.728	16 Kbps	3.1 kHz	112/128 Kbps
G.722	64 Kbps	7 kHz	>= 256 Kbps

Recommendation G.722 requires too much bandwidth to be used at 112/128 Kbps, but users want the higher quality audio at the lowest transmission rate that will not seriously impact the video. A bandwidth trade-off that vendors make is to switch from Recommendation G.728 to Recommendation G.722 when the available bandwidth is 256 Kbps (due to availability, the switch usually

occurs at 384 Kbps). There is work underway to standardize a 7 kHz audio coding algorithm at 32 Kbps and lower speeds.

The px64 standard does not specify the source or the final destination of the audio or visual data that is transmitted; therefore, the px64 standard permits both two-party and multiparty videoconferencing among different vendors.

2.4.3 Vendor Proprietary Enhancements

Vendors support both the H.320 series of Recommendations, with enhancements, and their own proprietary algorithms. The situation seems to be that, if the systems providing the videoconferencing service are the same, vendors will use their proprietary algorithms; otherwise, the service will be based on the H.320 series of Recommendations. Use of the H.320 series of Recommendations can occur, however, even if the vendors are the same on both ends. Vendors differentiate their products by the different peripherals they permit, by their enhanced processing algorithms, and by the additional functions they can provide. The devices, enhancements, and features discussed here are available from more than one vendor. Features that are not yet available or are available from only a limited number of vendors are discussed in Section 2.4.5.

Even within videoconferencing products of the same type, vendors support a wide variety of additional devices to facilitate conferencing productivity. Additional devices include:

- dual monitors,
- 35 millimeter (mm) slides,
- stereo quality speakers,
- additional microphones,
- additional telephones,
- auxiliary input,
- a second camera, and
- an easy-to-use control panel.

A second monitor permits freeze frame graphics to be displayed and annotated (annotation is usually implemented using a pen and tablet or mouse and keyboard) while the videoconference continues. A second monitor also facilitates the use of the devices mentioned above. Without a second monitor, the user would need to use picture-in-picture (PIP) to view the remote end and the freeze frame graphics. A slide converter can be used to send a slide show from a standard carousel. Audio power and clarity can be enhanced with stereo quality speakers. This is important in a larger room or class setting. Additional microphones permit either a mobile speaker or more than one speaker. An additional telephone allows another person to participate in the audio part of the conference. A second camera allows a user to switch the remote view to a document or other separate object.

All vendors provide a control panel for each system. The control panel is the means by which a user controls all capabilities of the local system and, where possible, the remote end. Control panels vary from vendor to vendor, but all are easy to learn to use and control functions are clearly marked. The more complicated control functions use on-screen menus to provide assistance.

Vendors enhance both the audio and the video by use of proprietary algorithms and either pre- or post-processing (usually both forms of processing). The proprietary algorithms use sophisticated motion smoothing and prediction techniques to produce the most appealing visual display. The audio is enhanced by increasing tone quality while at the same time reducing bandwidth. Echo cancellation is the primary means of increasing tone quality. High quality 7 kHz audio can be sent using as little as 24 Kbps bandwidth.

In response to users needs, and to differentiate their products, vendors support proprietary features in their equipment. Among the proprietary features supported by vendors are:

- far end camera control
- remote diagnostics,
- call set-up,
- connection control, and
- Data Encryption Standard (DES) [16-18], encryption.

Far end camera control allows a pan and zoom camera to be controlled from a remote site. The controls supported include pan, zoom, switch to preset position, and focus. These features allow a remote controller great flexibility in selecting the picture to be seen. The near-end site can prohibit the far-end from controlling the near-end camera. The zoom implies both zoom-in and zoom-out capability. Preset positions cause the camera to switch to a predetermined, but changeable, position and to auto-focus at that position. Most cameras are auto-focus, but sometimes the viewer needs to be able to control the focus. Remote diagnostics permit the testing of the quality of a videoconference while the conference is in progress. The diagnostics allow problems to be quickly detected and corrected. Call set-up permits a site to pre-select a number of remote sites for videoconferencing and pre-program information about those sites into the local system to expedite a call. Connection control allows the connection parameters to be modified to enhance the conference. Typically, these parameters would control functions such as lip synchronization. Encryption, i.e., DES, provides communications security.

2.4.4 Supporting Network Infrastructure

The primary means of videoconferencing transmission is the telephone service. The stated minimum transmission rate necessary

to support videoconferencing is 56 Kbps, although a rate of 112 Kbps is the preferred minimum. Plain Old Telephone Service (POTS), the telephone on every desk, cannot support a 56 Kbps transmission rate. A special telephone service called switched service is required. A user may purchase a line providing transmission rates of 56 Kbps (switched 56), 64 Kbps, 1.544 Mbps (T1), or a fraction of T1 called fractional T1. The usual fractional T1 transmission rates are 768 Kbps, 384 Kbps, 256 Kbps, and 128 Kbps. These rates are multiples of 64 Kbps and not quotients of 1.544 Mbps because a T1 line has overhead that is not included in the fractions. Fractional T1 provides a way for users to purchase only the transmission rate that they require. Switched 56 and fractional T1 are available nearly everywhere in the United States, while 64 Kbps has limited availability. To achieve a transmission rate of 112 Kbps a user will usually purchase two switched 56 lines and use them in tandem. For greater transmission rates, a fractional T1 service is used. Thus, the primary means of videoconferencing transmission is two switched 56 lines or a fractional T1 line, usually at 384 Kbps or 768 Kbps.

ISDN is a newer service offered by the telephony providers. At this time, the BRI of 128 Kbps is available in limited geographic areas. Although the Primary Rate Interface (PRI), which will support much higher transmission rates, is currently available for users of the Federal Telecommunications System (FTS2000), PRI is less widely available than BRI for general use and will not be generally available for several years. Customers are encouraged to use the BRI and its attendant services now and step up to the PRI when it becomes available. To use ISDN, the service must be available at the user's site and at all remote sites. Most videoconferencing vendors support the BRI now.

A serious problem with all switched services (including ISDN) offered by the various providers is that they are not interconnected, unless specifically requested by a user for a particular time and duration. Thus, for a user on provider A to connect to a user on provider B, one of them must have scheduled (and paid for) a connection of the two telephony lines. This is not true for the POTS, because full connection has been mandated by law.

Recently LAN-based videoconferencing systems have become available. The use of an Ethernet-like LAN for transmitting videoconferencing is limited because of the required bandwidth. For example approximately 512 Kbps is necessary to provide the same capability as an ISDN BRI. This is due to the synchronous nature of a LAN and the overhead incurred by the link, network, and transport layer protocols. Figure 3 shows how a LAN based videoconferencing system is interconnected to all other systems connected to the LAN and, via the telephone system, to other Wide Area Network (WAN) systems.

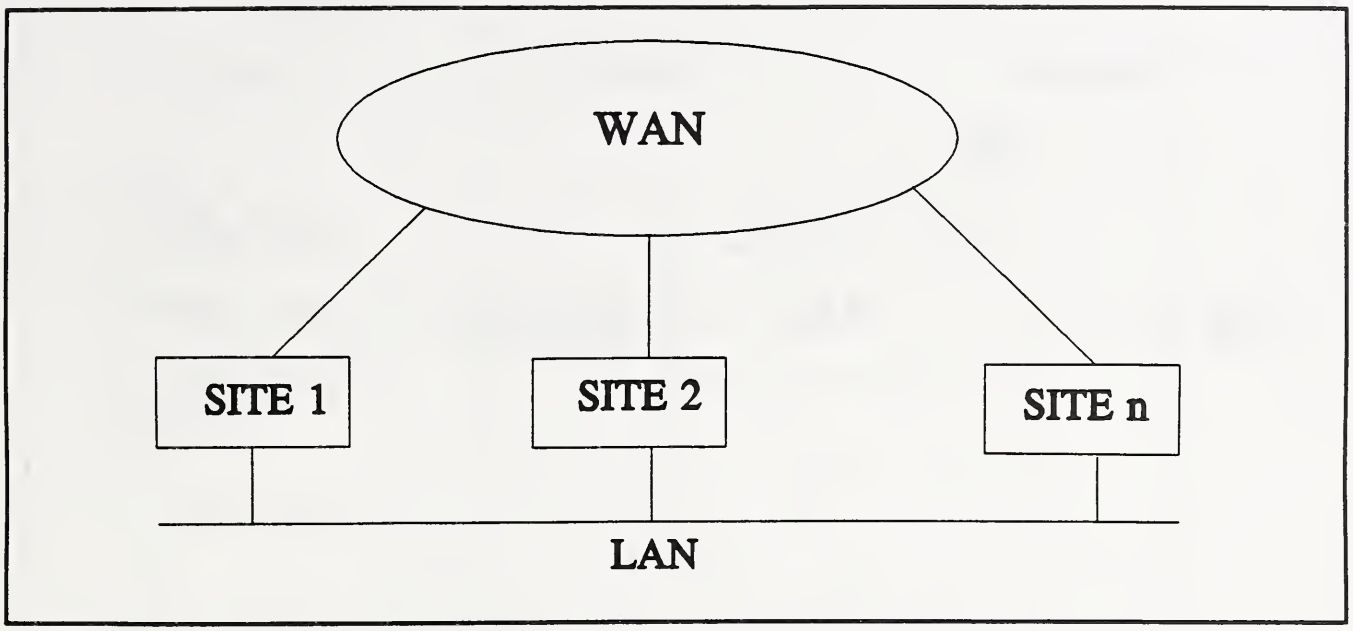

Figure 3. LAN-Based Connectivity.

The capability of a LAN to transmit to all connected stations at once makes a class or a video broadcast (e.g., a press conference) an excellent candidate for LAN videoconferencing. This broadcast capability can be extended to a large packet-switched network, such as the Internet, in order to provide a nation-wide broadcast service.

There are two types of videoconferencing: point-to-point and multiparty. Point-to-point is the full-duplex connection of two sites. Multiparty conferencing works the same as point-to-point except that bridging is used to connect all the sites. Bridging is the hardware/software necessary to connect multiple sites and to decide who views and hears what at each remote site. Audio must also be controlled since only one audio source can be received at a time. The audio source can be any site and may be different from the video source. This is usually on a first-come first-serve basis. Bridging must be provided either by the user or the carriers. Figure 4 shows how bridging effects connectivity in a multiparty videoconference and the how the placement of the bridge can have dramatic cost consequences by reducing the required number of long distance connections.

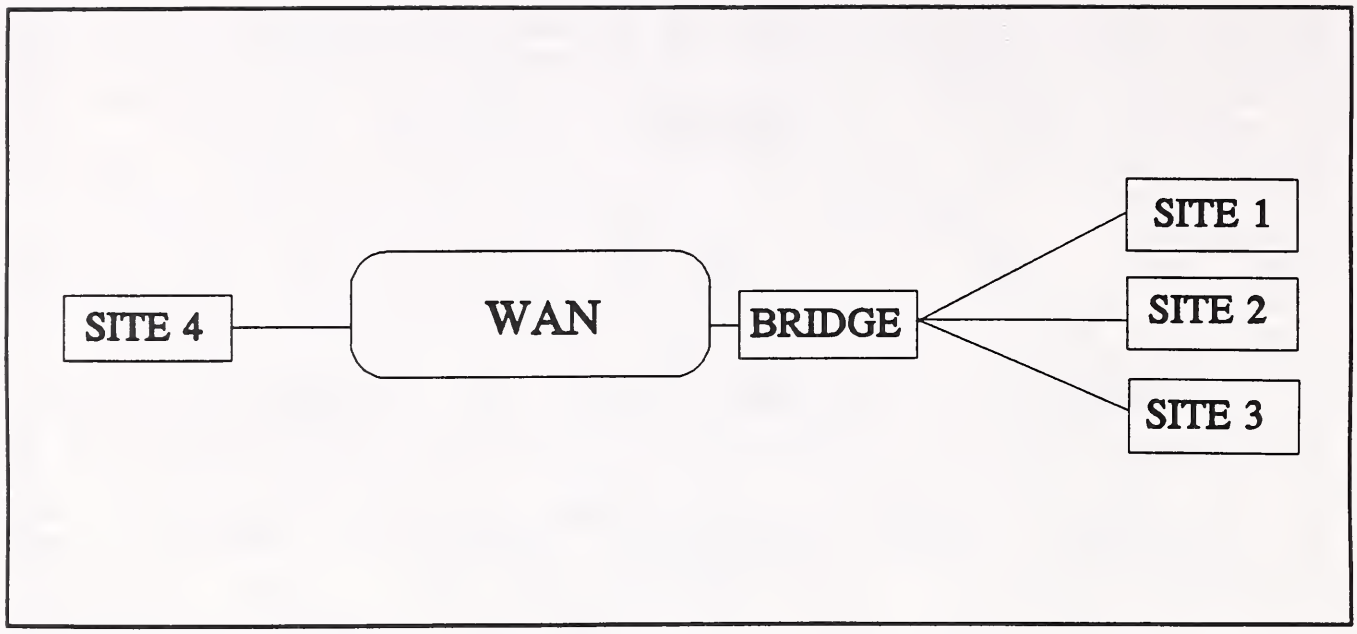

Figure 4. Multiparty Bridging.

2.4.5 New Products

Videoconferencing is in the midst of a dramatic change in both the services and the means of communication provided. The traditional use is one in which two or more sites are connected via telephone lines. Still the most prevalent means of videoconferencing, the "talking heads" model of videoconferencing, will continue to form the basis of more advanced conferencing technologies. Three videoconferencing developments which will be explosive forces driving videoconferencing to new uses and will greatly expand the market are:

- computer conferencing,
- video messaging, and
- high speed LANs.

New advanced services that comprise computer conferencing have already started to arrive and include:

- whiteboard,
- file transfer,
- file sharing,
- application sharing, and
- computer sharing.

All of these services require that both end systems be computer systems with disk storage, since the services all work with files.

A whiteboard is an area of the screen on which computer-generated output and user annotations, both text and graphics, from either the local or the remote site are displayed. An example use of a whiteboard is shown in Figure 5.

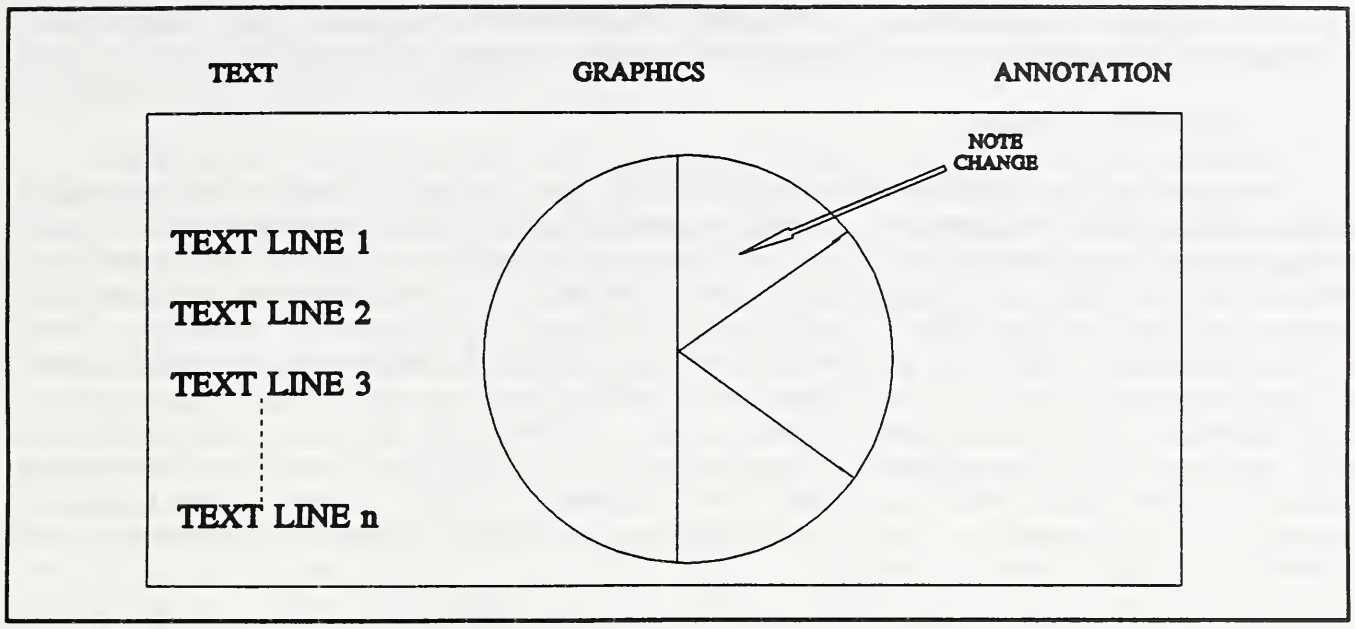

Figure 5. Use of Whiteboard.

File transfer allows a file to be transferred to a remote system for processing. File sharing means that either end can call up a data file that users at both ends can view. File sharing allows users to mark up an object before saving it at either or both end systems. Application sharing means that one system can run an application on the other system and both systems can view the results. Computer sharing means that one system, e.g., system A, can control the other system, e.g., system B, and that system A can execute any command on system B that system B is capable of executing, with the results being viewed by both systems. These capabilities are not currently available on all vendor products but are expected in the near future. These services are collectively called "computer conferencing" and are predicted to be the most demanded videoconferencing service.

Another new service is video messaging. This allows a user to send to a recipient a message that consists of audio, video, and graphic images. This multi-media message, which allows recipients to examine graphs and pictures with audio and visual explanations, is an extension of existing capabilities.

The use of a LAN as the transmission medium, when used in conjunction with WAN connectivity, is spawning a new market for videoconferencing. Using a LAN for videoconferencing, there is never a need to schedule or make a reservation and there is no transmission charge. Primarily one-to-one communications, LAN-based videoconferencing is the most natural and free-form of any type of videoconferencing. Although there are a few LAN products on the market at this time, the technology needed to make this

market thrive includes a high bandwidth capability not yet currently available, but expected in the near future.

2.4.6 Related Issues

Compression ratios of 800 to one can be achieved only if the compression is "lossy." Lossy means that the compression and decompression processes do not transfer all of the information contained in the original picture. What is lost is manifested in static picture quality, motion handling, and frame rate. The static picture quality loss is not significant and quality improves only moderately with increased transmission speed. For example, a significant increase in speed, e.g., from 128 Kbps to 384 Kbps, will not produce a drastic improvement in picture quality because the picture quality is good to start with. The additional bandwidth is used to improve motion handling and to maintain a constant frame rate.

There are three interlocking factors that comprise perceived picture quality for lossy videoconferencing systems. These factors are:

- resolution,
- motion handling, and
- frame rate.

The resolution for px64 based systems is either FCIF or QCIF. Since there are four times the number of pixels displayed in a FCIF as in a QCIF picture, the FCIF picture has better resolution and is the resolution preferred by most people.

Motion handling is a serious issue because all of the data required to replenish a full screen cannot be sent in each frame. The picture is decomposed into segments and only the change data for a segment is sent. High compression ratios enable the sending of change data, but the limitations of data compression become apparent when the amount of change data saturates the available bandwidth. In that case, the picture becomes blurred until the motion slows sufficiently to allow the changes to catch up. Blurring will only occur where there is motion and the blurring of one segment will not affect other segments. Thus, if someone waves a hand, only the hand will be blurred. Video conferencing vendors allow for a number of transmission rates, from 112 Kbps to 1.544 Mbps, in order to accommodate the variety of user needs for both motion handling and picture quality.

There are other problems with motion handling to which users must adjust. Motion, in addition to blurring the picture, also produces a slight jerking appearance. Independent of bandwidth, there is a delay induced into the system when compressing and decompressing the video. This delay, which also affects lip synchronization, is noticeable when participants at a remote site hesitate before responding. Real time codec chips, now becoming

available, will alleviate the delay problem. Both the jerking and delay problems will become less noticeable as users become more adjusted to videoconferencing.

The last factor influencing picture quality is the number of frames per second (fps). At 112 Kbps, a maximum frame rate of 15 fps is used and at 384 Kbps, a maximum rate of 30 fps is used. When there are only small changes in the picture, the changes can be handled smoothly. As the changes increase, the amount of data that must be transmitted to maintain the frame rate and picture resolution increases until the transmission rate is reached. At that point the system can either reduce the frame rate or permit blurring to occur. Vendors can use a varying frame rate to maintain a clear picture. When there is a significant amount of motion, the picture can deteriorate into a series of still frames. Not all vendors allow the frame rate to vary, so that the user need not adjust to varying rates but will, instead, become used to one fixed rate. The blurring can be very bothersome to view until the motion slows. The different ways of handling frame speed and blurring can cause users some minor adjustment if systems are switched.

The amount of acceptable loss is dependent upon the user's application. For example, a medical diagnostic evaluation may require a T1 line for maximum picture quality at all times. For most applications, a lower bandwidth of 128 Kbps or 384 Kbps is acceptable. These low data rates can produce an acceptable videoconferencing service and are justified both economically and qualitatively.

Multiparty videoconferencing involves the additional problems of scheduling (people, equipment, and carriers), usage accounting, network control, and deciding what video to display on each site. Vendors have proprietary software to handle these problems, but each solution is different. The most annoying problem is the necessity of scheduling with the telephony providers when communicating systems are connected to different providers. The provider interconnection should be transparent to the user; this is not the case at this time.

A major issue in videoconferencing is how the standards can keep up with the rapid changes in the capabilities of videoconferencing. These capabilities include video messaging, whiteboarding, file transfer, file sharing, application sharing, and computer sharing, and additional capabilities are on the way. The changes are occurring at such a rapid rate that the slow moving standards organizations could be left far behind. This void will be filled by <u>de facto</u> standards, set by a vendor or group of vendors with the largest market share. This could fracture the industry into using several competing, non-interoperable standards. Users of different vendor's equipment, who wish to interoperate, would be faced with a technically difficult and expansive task. To

avoid this outcome, vendors must show the same foresight that produced the H.320 Recommendation and quickly introduce into the standards bodies their proprietary solutions that are now entering the market.

2.5 Advances in the State-of-the-Art

Videoconferencing products will follow the general trend of the electronics industry, that is, more capability for less price. Some of the changes will be minimal, some will be substantial; but the sum will be dramatic. The factors influencing change are:

- transmission rates,
- electronic advances,
- new compression algorithms,
- new functionality,
- use of computers to provide videoconferencing, and
- use of higher-speed LAN media.

Two new technological developments that affect transmission rates will influence the market in the next few years. The first is the availability of higher speed modems and the second is the arrival of higher speed transmission methods. The new modems will support a transmission rate of 28.8 Kbps, with two or three times that rate using compression built into the modem. The modem compression will be limited when used with videoconferencing because videoconferencing data is already binary. The modems will enable minimal videoconferencing on a single POTS line and will enable the low, and less expensive, end of videoconferencing market to grow. The new transmission methods (e.g., Broadband ISDN (B-ISDN), Synchronous Transfer Mode (ATM), and Fast Ethernet) will enable the use of higher speed connections, and provide better quality audio and video. Advances in transmission speed will have the greatest positive impact on videoconferencing, but these advances will not arrive as quickly as the other changes. While waiting for the higher speed methods to arrive, videoconferencing can be done over existing technology such as X.25 [19] or frame relay. Currently, however, these methods do not seem to have any benefit over telephony and they are more expensive.

Electronic advances will greatly speed up the computational capability of the equipment that encodes and decodes the signal and performs pre- and post-processing. The biggest benefit will be the ability to encode and decode the video in real time. This would nearly eliminate the noticeable delay in current systems.

New algorithms for compressing data and improvements to existing algorithms will also improve videoconferencing services. Audio will probably be the first beneficiary of new algorithms as vendors propose 7 kHz audio at 24 Kbps and echo suppression. Additional improvements will come later.

Recently, vendors have been offering computer functions (such as whiteboarding, application sharing, and computer sharing), as part of their videoconferencing products. These functions are currently based primarily on the use of PCs to perform videoconferencing. In the future, the functions will be expanded and will be better integrated across multiple platforms. This will, of course, require that some means be found of providing interoperability among systems built by different vendors for different computer systems.

The use of computers as the platform for videoconferencing is a relatively recent development. The computer will allow the new functionality mentioned above, permit videoconferencing functionality to be updated by software, enable computer access to the remote system, and allow the videoconferencing system to function as a computer when videoconferencing is not in use. The predominant class of computer used currently is the PC. It is expected that additional videoconferencing vendors and computer manufacturers will soon enter the market or expand existing product lines.

The connection of PCs and workstations as videoconferencing platforms on LANs will expand the functionality of videoconferencing in at least three areas. The first area is peer to peer conferencing, which will increase the need for high speed LANs. The second area is multiparty conferencing, which needs high speed LANs even more than peer to peer conferencing. An application of multiparty conferencing that will be among the first to appear is broadcast video. This can be implemented quickly and inexpensively. In broadcast video, there is no need for a camera at a receiving system because this is a one way service. The third area of expansion is network conferencing. Network conferencing allows a conferee to use any facility connected to a remote system. Any device or service (e.g., printer, fax, or electronic mail) on the network is available to all parties. The arrival of high speed LANs will make the network a valuable asset to a video conferee.

For the user, the new functionality and high speed networks that are now entering the market will lead to new and improved services as vendors and users find new ways to communicate. Thus, the future of videoconferencing is very promising.

2.6 Economic Considerations

Many of the direct costs associated with the purchase of a videoconferencing system will be offset by the benefits derived through its use. This section describes many of the costs and benefits which must be considered when purchasing a system.

2.6.1 Costs

Videoconferencing, like any other productivity tool, requires economic justification. The economic justification should include the savings resulting from reduced expenditures in other forms of communications such as reduced travel and telephone usage. The costs associated with videoconferencing can be broken into four basic categories:

- equipment,
- installation,
- continuing fixed, and
- continuing variable.

Equipment costs will vary depending on the type of conference supported (e.g., desktop, multiparty), bandwidths supported, and equipment features. Typical equipment costs can be as low as $2500 for a LAN-based desktop system, to several tens of thousands of dollars for a large, fixed multi-screen system with many features. As potentially supported features are increased, initial equipment costs can be expected to increase. A reasonable idea of the future intended use and requirements of the videoconferencing equipment is necessary for an accurate economic justification. Supporting items such as tables, chairs, and other facility furnishings should be included as part of the cost.

Installation costs can consist of such items as:

- training,
- facility preparation,
- LAN or communication signal carrier selection, and
- connection.

Training may be required in order for a systems manager to fully understand all of the processes necessary in order to set up a fully successful videoconferencing facility. The costs associated with this initial training may not be trivial. In a larger facility which utilizes advanced videoconferencing features, a thorough familiarity of the technical interactions of each component of the system is necessary. These technical interactions must be considered during the facility planning and installation phases. Facility preparation can consist of such items as room layout planning and interior design as well as lighting and acoustical materials installation. Estimates should be made for the average and maximum number of participants in a videoconference. The location and requirements for electrical and video control circuits should be considered when deciding on the final facility layout. Installation of the proper connections for the communication bandwidths desired should be discussed with the communications company during the early planning stages. Equipment installation for larger systems will sometimes be handled by the equipment vendor as part of the original equipment purchase support agreement.

Continuing fixed costs consist of recurring costs for such items as equipment lease fees, maintenance or service contracts, communication line access charges, facility rental or usage charges, periodic overhead or depreciation. These charges consist of all costs relating to the videoconferencing facility whether or not it is actually used. These costs can be a significant part of the overall cost of providing the facility.

Continuing variable costs are those costs that are directly related to the actual use of the facility. These costs can normally be assessed on a per-conference basis. They consist of communications set-up, connect and call charges, and any required personnel support. The users of the facility will require training to use the equipment properly.

2.6.2 Benefits

The usual cost benefits associated with videoconferencing (e.g., reduced travel and per-diem and reduced individual use of the telephone) are only a small part of the benefits that can be expected. Some of the benefits are not always readily apparent. More efficient meetings, additional personnel time on the job, increased face-to-face participation of essential staff in meetings, and earlier discussion and resolution of project problem areas all contribute to a project that is run more efficiently and effectively. Personnel schedules are not as likely to be disrupted due to project related travel. The work environment is improved by placing more employees in the meeting loop and by providing project-employee interaction.

The use of videoconferencing in daily communication can result in additional benefits, some of which are not easily obtainable through the use of other technologies. During most multi-disciplined projects, face-to-face meetings are a necessity. This is due to the high degree of interaction required when documents are exchanged and analyzed, when recommendations are developed and discussed, and when conclusions are finalized. Once the necessity for a meeting is determined, in order for the project to produce an output that is both timely and of a high quality, the meeting must occur promptly. Timely consultation with the project sponsor (or customer) is also essential. Videoconferencing is an effective and economical alternative to frequent face-to-face meetings between project team members whose work places are at different geographical locations.

Often facial expressions during a conversation indicate a mood or opinion about a subject that is not conveyed verbally. Visual communications are key to determining the true feelings and opinions of many individuals. The ability to perceive the apparent feelings of the person or persons with whom one is communicating is an essential element in conducting any business endeavor. These

visual expressions cannot be detected during a telephone discussion.

The ability to look at (and possibly annotate) text and/or graphic information while simultaneously in audio and visual contact with a remote user is not available with other conferencing systems. The ability to carry on an interactive visual session with a remote user is a unique feature of videoconferencing.

Scheduling of meetings between personnel from organizations at different physical locations can sometimes be difficult and inconvenient. In many cases, the time spent in commuting and attending the meeting represents a business hardship and is at the expense of other organizational commitments. The scheduling of a videoconference is often as easy as making a telephone call and requires minimal schedule disruption on the part of the participants. In the case where the participants are involved in a PC-based conference, the scheduling procedures are generally trivial.

Since most required resources are available at the office of videoconference participants, very little time is wasted in retrieving forgotten materials or setting up telephone contact with the expert who did not make the trip. More time can be spent in actual productive business communication. In addition, personal rapport is established between project participants at an early stage and is enhanced throughout the life of the project. Videoconferencing does not, however, offer the social opportunities that are often associated with a meeting where business is often carried out. The one-to-one and impromptu nature of desktop videoconferencing is as close to a social setting as it is possible to achieve with videoconferencing.

3. VIDEOCONFERENCING PROCUREMENT DECISION FACTORS

The purpose of this section is to identify the factors that should influence the decision of whether or not to purchase videoconferencing equipment. There are two areas that need to be considered in this decision: the benefits derived from the use of videoconferencing and the ability of the organization to modify its operations to take advantage of those benefits. Section 3.1 provides a statement of benefits, an example of use, and a question or information the organization can use to help determine the usefulness of the benefit. For each reason for using videoconferencing the organization must ask if and to what extent that reason applies to the organization. Section 3.2 describes changes in an organization's method of operation along with a reason for each change. Videoconferencing should be employed only if an organization is willing to make the necessary changes. There are also times when the use of videoconferencing will not be beneficial, and those conditions are stated in Section 3.3.

3.1 Benefits in the Use of Videoconferencing

There are at least three major categories of benefits an organization can receive from using videoconferencing. These are:

- an effective and efficient means of interactive communication,
- cost and time savings, and
- increased productivity.

There are situations when time is critical and visual interaction is necessary and the use of other communications means (such as the telephone) is inadequate. An example of this is remote medical diagnosis. A patient can be examined while x-rays and other data are sent to a medical expert at a remote facility for an on-line diagnosis. Currently, this is being successfully done. A more frequent occurrence is a delay in a project caused by waiting for a meeting. A survey would help an organization determine how often these time critical situations occur and how great is the adverse impact on the project.

The second category of videoconferencing benefits is the most publicized: the elimination of travel and the saving of time. Meeting participants will feel more comfortable in their own surroundings with support staff and material close at hand. The number of meetings will increase with videoconferencing, because they can be scheduled and attended on short notice and with a minimum of inconvenience. This reason should not be overstated since not all travel will be eliminated. Information on the cost and the number of trips before the use of videoconferencing is available to an organization. This cost is the theoretical maximum savings and the actual savings will be less.

The third category is the most difficult to measure. Productivity will increase with use of videoconferencing because meetings can be scheduled when needed and requisite resources can be brought to the meeting. This will enable timely answers to problems instead of waiting for a convenient meeting time. Videoconferencing can also facilitate the introduction of new capabilities into an organization, such as a service desk which will enable a user to request a service or to explain a problem using supporting visual material. The user can then immediately receive assistance from the remotely located expert. Providing a videoconferencing service desk which allows users to talk face-to-face with government representatives can also be a clever public relations move as well as an efficient way of conducting business. The productivity gains and benefits that an organization can expect to achieve from using videoconferencing can be determined by examining how similar organizations use and benefit from videoconferencing.

3.2 Modifications to Current Operations

Once videoconferencing is available in an organization management should publish guidelines which encourage the use of the new technology. Benefits cannot be gained unless the equipment is used.

Meetings can be more frequent and more informal, held on shorter notice, held when needed, and held in spite of the availability of all interested parties. Videoconferencing can be used successfully to conduct formal meetings that require significant advance preparation at which important decisions are reached by the highest level of management. The frequency and structure of meetings and the level of intimacy are the elements that will change. Currently, management schedules meetings and selects the personnel to attend those meetings. With videoconferencing, the decision-making process will become more decentralized. Those who want a meeting will decide when it is held and who should participate.

Management should expect different results from meetings using videoconferencing. Meetings not conducted using videoconferencing are generally carefully scheduled, formal, and costly; videoconferencing meetings, however, are more likely to be informal, casually scheduled, and inexpensive. Videoconferencing will produce more timely results and reports.

Management will need to share authority with potential attendees over who will attend a meeting. The personnel that should attend a meeting are no longer limited to those with travel money. Those who have business to conduct or views to be contributed will attend the meetings.

3.3 When Not to Use Videoconferencing

There are situations when videoconferencing is not the most beneficial means of communication. Videoconferencing can provide an interactive communications service in situations in which what is seen is as important as what is heard. Many communication needs, such as those that are non-visual or those that are not interactive, can be adequately satisfied by less expensive means. Telephone is a non-visual interactive means of communication that still satisfies most data communications needs. Telephone service is universal and inexpensive. The telephone also permits three modes of communication (casual, anonymous, and less attentive) that videoconferencing does not.

When the communication need not be interactive, the postal service, electronic mail, or facsimile are appropriate means of communication. Together these communication methods cover the non-visual communications range at far less cost than videoconferencing.

There may be a tendency to use videoconferencing, at first, for all remote communication. This is not a proper use of videoconferencing. This misuse will reduce the benefits gained by the use of videoconferencing and should be avoided.

4. PROCUREMENT CONSIDERATIONS

This section provides suggestions and guidance with respect to the procurement of a system to be used for videoconferencing. Several additional requirements, which will be needed as a result of the purchase of such a system, are discussed.

4.1 Services Provided by Videoconferencing Systems

The interoperability of the services provided by a videoconferencing system is determined, to some extent, by the degree to which the system conforms to recognized standards. In general, proprietary systems tend to offer a larger assortment of optional services; however, the offered services may be of little use when communicating with equipment which was built by a different manufacturer.

4.1.1 Standards

Most vendors offer systems that are at least partially based on standards. In general, implementations based on standards will guarantee at least a minimum amount of compatibility with other systems supporting the same standards. If one of the videoconferencing systems is not designed to operate in accordance with the standards supported by the others, then it is highly probable that the non-standard system will be unable to communicate with the others. To ensure compatibility, any videoconferencing system, which is being considered for purchase, must support the same standards as those systems with which it plans to interact.

4.1.2 Proprietary Systems

Practically all vendors have some form of proprietary system as one of their major products. Most of these systems, in addition to supporting their own proprietary standards, also support the H.320 Recommendation and other recommendations. This means that, in most cases, these systems will work with other vendors' systems, although not necessarily in an optimum fashion due to pre- and post-processing.

Some of the available videoconferencing systems support one or more additional data transport and display services. These services range from support for an attached fax machine to support for additional image transmissions. In most cases, during the time in which a supplemental transmission is taking place, a visual loss of quality on the main system will be noted. This loss is usually

minor and is a small tradeoff when considered within the overall scope of the total videoconference.

Most of these additional services are provided as optional vendor proprietary offerings and may not interoperate with other vendor systems. Some optional services may also require the purchase of additional bandwidth from the data transport carrier in order for the overall quality of the videoconference to be acceptable.

Each additional service should be evaluated for its expected benefit and cost with respect to the overall videoconferencing system under consideration.

4.2 Performance

Performance consists of several factors, some of which are subjective and all of which must be balanced by cost. Economic considerations constrain the user from requiring only the best performance and encourage the accurate specification of only the necessary factors. These factors include:

- resolution,
- audio quality,
- frames per second,
- picture quality,
- motion handling quality, and
- transmission rate.

The px64 standard defines two resolutions: QCIF and FCIF. QCIF, 176 x 144 pixel resolution, is appropriate for desktop systems where the screen size is small. For full size monitors, QCIF should only be used where resolution is not important. For most monitor-size systems, FCIF is the better choice.

Two factors distinguish audio quality: bandwidth availability and proprietary processing. The bandwidth is either 3.1 kHz or 7 kHz as specified in Recommendations G.728 and G.722, respectively. The transmission rate required is 16 Kbps for G.728 and 64 Kbps for G.722. Vendors can provide 7 kHz bandwidth with a 24 Kbps transmission rate, but currently only on proprietary products. On non-proprietary products, the use of 7 kHz voice grade bandwidth virtually necessitates a transmission rate greater than 112/128 Kbps. This voice band is usually used in conjunction with transmission rates of 384 Kbps and above. The vendor's proprietary processing provides echo cancellation and can be used with the px64 standard. This feature is independent of transmission rate and should be required, even though it is a vendor option, because it will noticeably improve the audio quality.

A vendor may either provide a constant frame rate or a frame rate which is adjusted downward to a minimum rate as motion increases. The maximum number of frames per second is usually 15

for 112/128 Kbps and 30 for 384 Kbps and above. The observable difference between constant frame rate and changing frame rate is subjective.

The picture quality will improve with increased speed, up to the limit imposed by the resolution. The picture quality is determined by the weakest link in the chain of events necessary to transmit a picture: camera quality, analog-to-digital conversion and digital-to-analog conversion. Picture quality and motion handling quality are used to determine if speeds greater than 384 Kbps are necessary. Picture quality and motion handling quality are both subjective. Most proprietary systems are slightly superior in these two areas and the choice of a proprietary system may influence the selection of a transmission rate.

Motion handling quality is directly related to transmission rate. Since a "lossy" compression is used, increased motion will cause blurring or tiling as defined in Section 2.3. The effects of blurring or tiling are reduced by an increased transmission rate. If there is too much blurring, the viewer is unable to continue watching the picture. Thus, the user must have some idea of the minimum level of clarity required of the system. There are some applications where the highest quality picture and motion handling are required. An example is a medical diagnostic system which requires the transmission rate provided by a T1 connection. Most videoconferencing needs, however, are satisfied by transmission rates of either 112/128 Kbps or 384 Kbps.

Transmission rate is the most important factor in performance. Transmission rate should be derived by determining what speed is required to meet the other performance criteria. Although there are eleven values for "p" in the px64 standard, there are only four widely used transmission rate values. These values are 112/128 Kbps, 384 Kbps, 768 Kbps, and T1 and these provide identifiable differences in performance. One BRI ISDN line or two switched 56 Kbps lines can provide a 112/128 Kbps transmission rate and define a channel interface to the telephony provider. Transmission rates of 384 Kbps and below are supported in most vendor products; higher transmission rates usually are only found in the top-of-the-line systems. The 768 Kbps transmission rate is half the highest available transmission rate and is a convenient fraction (1/2) of the T1 transmission rate. The T1 transmission rate of 1.544 Mbps is the highest commonly available transmission rate, although a transmission rate of up to 1.920 Mbps (p = 30) is supported by some vendors.

Some decisions are easy to make. For example, if high quality sound is required, then a speed of 384 Kbps is needed. Other decisions are much more subjective. The decision that will most often need to be made is whether to use a transmission rate of 112/128 Kbps or 384 Kbps since these two speeds will adequately

support many user needs. The trade-off here is between communications costs and motion handling.

4.3 Configuration

The three basic configurations of videoconferencing systems are fixed, mobile, and desktop. Each of these is designed to satisfy a different use or requirement. The choice of which configuration to purchase depends on the intended use of the end system.

A fixed system is designed to accommodate a large number of participants. It will usually be equipped with higher quality audio and video components and will probably be required to support a large number of auxiliary devices. All normal data transmission rates are usually expected to be supported. A fixed system will require a room in which it can be permanently installed. This type of system will be the most expensive.

A mobile system is designed to be transferred easily between multiple pre-wired locations. This system will generally provide service to a smaller audience and will provide a smaller selection of options and features. This type of system is an ideal choice for an organization desiring reasonable quality videoconferencing support for several groups located in different places within a small complex or local environment. A location could have one or more mobile systems in place of one fixed system. Note that each intended usage location must be pre-wired to accept any required telecommunication connections. If large conferences occur infrequently, then a number of smaller mobile systems is appropriate. Generally these mobile systems are intermediately priced.

A desktop system is normally a personal system utilizing a PC connected to either a LAN or a low bandwidth line. These are single user systems which are best suited to interactive task collaboration and one-to-one or one-to-many discussions. A desktop system is the least expensive of the videoconferencing configurations and will, therefore, be lacking in many of the features available with the more elaborate systems.

4.4 Session Configuration/Management

In order to schedule, to control network parameters, and to maintain adequate accounting records for the many varied features associated with a videoconference, it is often convenient and necessary to use some type of an automated system. Several vendors offer such systems as a feature associated with their videoconferencing equipment. In addition, some providers of telecommunications services also offer support in this area. It is strongly suggested that an automated configuration management system be purchased at the same time as the videoconferencing

system. This is especially important when ordering equipment other than desktop systems.

4.5 Installation

A decision must be made as to whether or not the equipment installation should be included in the original purchase. For large and/or complex systems, it is strongly recommended that the equipment vendor be responsible for the installation. This is especially important when purchasing a "first time" videoconferencing system. Any installation contract should contain provisions for ensuring that the proper telecommunication connections are in place prior to the delivery of the equipment.

4.6 Training

The original procurement should contain appropriate training provisions. These provisions will vary from classroom training to informal explanations depending on the type of equipment purchased and the experience of the users of the equipment. In any event, the vendor must be held responsible for the training of the users of the provided equipment.

4.7 Costs

Several factors affect the cost of a videoconferencing system. The major variable is the system size. Current videoconferencing system prices vary widely from about $2,500 for a bare-bones desktop system to over $50,000 for a top-of-the-line fixed location system. A mid-range mobile system will cost around $15,000 to $25,000. Quantity discounts may be available. Other factors affecting the equipment costs include the warranty and upgrade provisions. Future system prices are expected to follow the general downward trend in consumer electronics.

Installation costs, including room preparation, wiring, special lighting, and furniture procurement, should also be considered. Monthly connection and usage costs will be roughly proportional to the amount of bandwidth reserved and used by the videoconferencing system and the amount of time that the system is used.

The trend toward larger systems being placed into a separate theater meeting room implies higher furniture and room preparation costs. For large systems, these additional costs must not be ignored. The amount of personnel training as well as other costs associated with the use of a system administrator can be non-trivial.

4.8 Supporting Data Transport Service

The choice of communication services to be used among video conferencing peers is not always a function of the options provided by the equipment to be used and the desired quality of the conference. Since all desired videoconferencing options are not always supported by all systems, it is important to remember that the degree of interoperability will normally be determined by the peer whose equipment contains the least number of options. In addition, telecommunication services which are required in order to support a particular option may not be available to all peers participating in the videoconference. This will serve to limit the availability of usable services to all peers.

The use of such services as switched 56 or fractional T1 may be the only options available because these are the most widely supported transmission rates. It is imperative that the local data transport carrier be consulted before deciding on a final equipment configuration. This will help ensure that purchased equipment will be compatible with the services provided by the local communications environment. In addition, features which cannot be used may be eliminated prior to ordering.

4.9 Technological Considerations

In an industry that is rapidly evolving and in which new technologies are appearing almost daily, it is important to ensure that newly purchased systems will not become obsolete within a short period of time. In general, newer standards are expected to evolve with a maximum of backward compatibility. This will help ensure that systems that are purchased today will remain compatible, at least in essential services. With this in mind, all newly purchased systems should be implemented according to the H.320 series of Recommendations.

The videoconferencing market is presently composed of many proprietary systems that will interoperate only in the narrow range of capabilities defined by the standards. Standards appear to be a major factor in the prevention of further division of the market into additional proprietary vendor groups. A few of the current videoconferencing systems utilize software control and are relatively inexpensive and technically easy to upgrade. These software-based systems are much more likely to stay in synchronization with evolving standards and should protect the user's investment better than a strictly hardware-based system would.

5. USAGE CONSIDERATIONS

The way in which a videoconferencing system is to be used can have a major impact on the final configuration. The configuration

of the system can have a major impact on its installation and use. This section presents various items to be considered when planning for the use of a videoconferencing system.

5.1 Installation

Prior to the delivery of a videoconferencing system, all site preparation must have been completed. Because mobile systems may be moved from one location to another, all potential locations must be pre-wired and otherwise prepared to receive and accommodate both the equipment and the potential users. Because larger fixed systems are normally designed to serve a larger audience, they will require the most extensive site preparation. Some systems may even require a "theater-like" environment. Smaller, mobile and desktop systems will require little site preparation other than to provide a means of connection to a communications provider. In all cases, provision must be made for electronic connection to the outside world at the appropriate bandwidth.

In some cases, initial installation will be provided by either the videoconferencing equipment vendor, communications provider, or a separate contractor. Subsequent installations, unless they are unusually complex, will usually be handled by the user. In most cases, a system manager or equipment expert will be required to oversee major installations or to assist in incorporating videoconferencing capabilities onto PC-based workstations.

5.2 Configuration

Because of its size and the viewing area required, a fixed system is normally installed permanently. The room in which it is installed is either multi-purpose or a dedicated area. In either case, the location must be pre-wired to receive the system. The location must also be able to accommodate all auxiliary input and output devices which will be supported by the system.

An intermediate system is designed for use by a smaller group and does not normally require a dedicated room. The ability to store the system when not in use is an important advantage when space is at a premium. These systems are normally mounted on wheeled devices and are capable of being moved anywhere. Their usage requires a proper telecommunications connection. If the site

has an ISDN line, then a BRI connection must be made available in any location that the videoconferencing equipment is to be used.

A desktop system is a personal system and is usually only available with a 128 Kbps or LAN connection. The "window" size picture, in most cases, limits usage to one-on-one communications. An important issue is to decide who gets the use of a desktop system. This is important because the unit cost, while low, could become very high if every user were allowed to have a personal desktop system. The use of a desktop system could be controlled similar to a mobile system whereby, for example, the desktop system could be scheduled on a first-come/first-served basis.

5.3 Scheduling

A videoconference requires that a number of services be available to arrange and control a conference. Proper scheduling will ensure that people, host equipment, rooms, and network equipment are available at the same time, and are capable of communicating. As many of these services as possible should be placed under computer control. If all of the videoconferencing equipment is from a single vendor, then the services will be easier to automate.

For point-to-point conferencing, this is not a difficult problem; however, as the number of people and/or sites increases, scheduling becomes more complex. For example, a room must be both available and large enough to accommodate the number of participants. The network equipment can include multipoint bridges and bandwidth controllers. The difficulty in scheduling the equipment depends on who owns the equipment. The equipment owner could be the local user, the remote user, or the communications provider.

Network interconnections are more difficult to configure when peer sites use different ISDN providers. In the case of different providers, a connection must be scheduled and, if the conference runs over the allocated time, the connection is subject to be broken. This problem is expected to be obviated by the emergence of future implementations of ISDN based on the implementation agreements, application profiles, and conformance tests of the North American ISDN Users Forum (NIUF) [20]. The NIUF agreements, while non-binding, are expected to be implemented by the vendors.

Network equipment is usually capable of being locally or remotely configured and controlled by computer. Network control can include multipoint call setup, use of remote diagnostics, and local parameter control. Local parameter control is necessary to compensate for line variations or different parameter settings at the remote site. One such parameter is the audio-video timing which controls lip synchronization. If this parameter is not set properly, there will be distracting delays between the sound portion of the conference and the expected motion or reaction.

5.4 Training

The successful and efficient use of most videoconferencing equipment will normally require a certain amount of training and administration. The amount of training required can vary greatly depending on the complexity of the equipment and the responsibility of the person receiving the instruction. The following sections present guidance on the various training requirements associated with a videoconferencing facility.

5.4.1 System Administrator

Most complex equipment, such as that used in videoconferencing, requires an on-site expert from time-to-time. This person should be proficient in the equipment operation through training and experience. If the equipment is very complex, many hours of concentrated and specific training may be necessary; however, for simple systems, a brief review of an installation manual may be sufficient.

Prior to the establishment of a connection with a videoconferencing peer, it may be necessary to run system diagnostics and to coordinate with the communications switching center in order to establish and verify the proper bandwidth and bridging parameters. It may also be useful to make a trial connection for the purpose of adjusting various common system parameters. In some cases, these tasks may be handled by an informed user; but, in most cases, an on-site expert will be required.

5.4.2 Users

Before participating in a videoconference for the first time, most users will probably need a short period of familiarization and training. For very simple setups, such as desk top or PC-based systems, self-taught, hands-on training may be sufficient. In other cases, a more comprehensive training session, which includes instructions on how to operate the various system controls, may be required. Desktop systems with advanced features, such as application or computer sharing and whiteboard operations, may require the most training. The technical sophistication of the users will affect the amount of training necessary. Although the control panels on currently available videoconferencing equipment differ, none appear to be overly complex. Most users will become proficient in the use of the equipment after only a few sessions.

5.5 Accounting

Accounting is a necessary administrative tool that is useful for billing purposes and for tracking usage by user and site. Large organizations must develop their own procedures for assigning cost. The reports generated by accounting information can be used to assist in future scheduling or purchases.

6. RECOMMENDED INTEGRATION STRATEGY

This section describes a suggested multi-phased implementation program plan. In addition, criteria for the evaluation of the effectiveness of the videoconferencing program are presented.

6.1 Implementation Plan

An organization should implement videoconferencing in a phased approach to gain the maximum benefit while minimally disrupting the organization. A seven step implementation plan is outlined here to assist an organization in a smooth transition to the use of videoconferencing. These steps are given below.

1. Evaluate the organization's requirement for videoconferencing.
2. Partition the organization to facilitate staggered Implementation.
3. Specify an implementation schedule.
4. Implement the first stage of the schedule.

5. Evaluate the implementation.
6. Implement and evaluate subsequent stages of the schedule.
7. Monitor use.

The first step is to evaluate the organization's requirement for videoconferencing. It must be determined whether or not videoconferencing can be beneficial to the organization. Each site must specify how many people from that site could benefit from videoconferencing and what type(s) of videoconferencing could be used at that site -- large systems, mobile systems, or desktop systems. The sites to use videoconferencing should then be selected and the telephony carriers serving those sites should be determined. A minimum number of carriers is desired so that scheduling problems can be minimized. The topology of the organization must be examined to determine how many multipoint bridges are required and where each should be placed. Basic videoconferencing services are defined by the H.320 series of Recommendations and should be required. Any additional required functionality that the vendor(s) must provide should be specified at this time. The transmission rate, which will determine the resolution and motion handling capabilities, must be specified; the transmission rate will determine the type of connectivity that the carrier(s) must provide. If low speed transmission is sufficient (112/128 Kbps), then, depending on availability, either switched 56 or ISDN must be used. If high speed transmission is required, then fractional T1 should be used. The organization must determine how much of the installation, maintenance, and daily operation will be done in-house and how much will be contracted out. There are service providers that will do everything, including equipment purchase and room preparation. The organization should know at this time how many carriers are necessary, how many vendors can supply the required functionality, and, if necessary, who will be running the videoconferencing network.

The second step is to prioritize the sites by partitioning the sites into a set to be implemented first, second, and so on for as many sites as are to be conferenced. Each set should contain a sufficient number of each type of videoconferencing system so that all of the capabilities of videoconferencing can be exercised as the set is implemented.

The third step is to specify an implementation schedule. To do this, each site must have a site preparation plan that includes where the system is to be installed, who is in charge of the installation, and who is the administrator of the system. The person in charge of the installation must schedule the room preparation, telephony hookup, equipment installation, and acceptance test. The administrator must schedule training, videoconferences, and maintenance. The first few sites implemented will require more time to implement than succeeding sites. The person in charge of installation and the administrator should be trained.

The fourth step is to install, test, and operate videoconferencing equipment at the selected sites. When the equipment is installed at a site, tests are required to be certain that the equipment is operationally functional. Then tests for interoperability with all sites with which the newly installed site expects to videoconference must be conducted. Training may be provided to users to ensure that they can begin using the equipment as soon as a sufficient number of sites are on-line. There may be problems with early installations that should be addressed immediately so that users do not become discouraged at the selected sites. The person in charge of the installation must schedule the room preparation, telephony hookup, equipment installation, and acceptance tests. The administrator must schedule training, videoconferences, and maintenance. The first few installed sites will require more time to install than succeeding sites. The person in charge of installation and the administrator should be trained.

The fifth step is to evaluate the implementation, usage, and benefits of the installed equipment. The implementation will be the easiest to evaluate and the lessons learned from the first set of implementations can be used to procure, to use, and to implement future systems. In addition to adjustments in the implementation schedule, the organization may decide to change its use of a service provider or to vary the amount of training given to system administrators and installation personnel. Evaluation of the usage and the benefits will take several months. Usage will go up with familiarity with the equipment and availability of sites. While the benefits of increased productivity are difficult to measure, increased usage should indicate increased productivity.

The sixth step is to install and evaluate the videoconferencing equipment at the next set of sites. This is an iterative procedure that consists of performing steps three, four, and five until all sites are operational.

The last step is to monitor the ongoing use and benefits of the videoconferencing equipment. This will permit more efficient use of the equipment and will indicate where additional equipment may be needed.

6.2 Evaluation Criteria

The effectiveness of videoconferencing will be evaluated at the end of each implementation set and on an ongoing basis. This evaluation must consider cost, productivity, and satisfaction. There should be a net savings after the increased telecommunications costs are subtracted from the total travel costs. This net savings is the one easily measured and evaluated criterion; i.e., the greater the savings, the greater the benefit.

Productivity gain consists of the quantity, quality, and timeliness of the work. Productivity gain is not easy to measure and will require a significant management effort to gather and examine the pertinent data.

Satisfaction can be measured both by questionnaires and by monitoring the usage of the videoconferencing equipment. Weekly statistics should be kept on the number of conferences, the average length of conferences, the number of scheduled conferences cancelled, the number of people using the equipment, the number of different people using the equipment, and the number of problems reported. As the users become familiar with the equipment and understand the power of videoconferencing, the number of conferences, the length of the conference, hours of use, the number of users, and the number of different users should increase. The percentage of cancellations and the number of problems should decrease. Upward trends in usage will show both user acceptance and satisfaction. As users become familiar with the capabilities of videoconferencing, there will be an increase in the use of the advanced features provided by vendors, such as whiteboarding and application sharing. These features, which can only be used if both parties are using a single vendor's equipment, will also increase productivity. Public acceptance of the use of

videoconferencing, through the use of a help desk, can be measured by a questionnaire and by monitoring the usage of the equipment.

7. SUMMARY

Videoconferencing provides an interactive audio and video means of conducting a meeting. Videoconferencing has grown from a very specialized niche market into a widely recognized business tool. Vendors provide three types of systems: large classroom systems, smaller mobile systems, and desktop systems. These systems require as little as 112 Kbps transmission rate to provide a very acceptable videoconferencing capability. Increasing the transmission rate will allow better motion handling and permit a constant frame rate. A transmission rate of 384 Kbps permits a high quality conference at a low transmission cost. The highest transmission rate that is supported by most vendors is a T1 rate of 1.544 mbps. This rate is only necessary for the most demanding video applications. The ITU px64 standard, supported by most vendors, allows videoconferencing among all vendors that support the standard. The use of compression techniques, reduced cost (both system and transmission), and increased functionality have placed videoconferencing in a very enviable position.

Videoconferencing is now a viable and cost effective method of conducting meetings. The advanced features that are just now becoming available will make videoconferencing a continually more beneficial product. It is clear that videoconferencing has not finished evolving. Vendors will continue to introduce capabilities that will make videoconferencing a progressively more powerful and effective business tool. The standards bodies will continue to enhance the px64 standard with these additional capabilities. As standards progress, advanced feature availability and use will increase due to interoperability.

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GLOSSARY OF ACRONYMS AND DEFINITIONS

ATM: Synchronous Transfer Mode, a 53-byte cell used to efficiently transmit voice, video, and data.

bandwidth: A measure of the frequency spectrum that a system is able to process or transmit.

B-ISDN: Broadband ISDN, a high speed network technology using ISDN channels which support rates above the ISDN primary rate (1.544 or 2.048 Mbps).

BRI: Basic Rate Interface, the lowest class of service provided by ISDN. Two 64 Kbps B-channels and one 16 Kbps D-channel, providing 128 Kbps of user data and 16 Kbps of control data.

bridge: A device which is used to interconnect two or more networks at the data link layer. This is useful when the networks have different data link layers but share the same network layer.

broadband: A transmission technology where a data signal is modulated to a separate higher frequency enabling multiple data signals to be carried on the same transmission medium.

CATV: Cable television.

CCITT: International Telephone and Telegraph Consultative Committee, an international standards setting body.

codec: An abbreviation for coder/decoder. A device that converts an analog signal to a binary coded digital signal and vice versa.

FCIF: Full Common Intermediate Format.

FIPS:	Federal Information Processing Standard.
fractional T1:	A portion of a T1 line that is a multiple of 64 Kbps.
frame:	The structure of the repetitive bit grouping that constitutes the control and data fields.
ISDN:	Integrated Services Digital Network.
ITU:	International Telecommunication Union, the successor to the CCITT.
LAN:	Local Area Network.
lip sync:	The synchronization between the motion of the lips and mouth and the spoken sounds which are being produced.
modem:	Abbreviation for modulator/demodulator. A device that converts digital data into a voice frequency analog signal, and vice versa, for transmission over standard telephone lines.
NIUF:	North American ISDN Users' Forum.
PIP:	Picture in picture, a means of showing two or more independent pictures on the same screen by displaying one in part of another.
pixel:	The smallest portion of a screen that can be illuminated, the set of all pixels is the screen.
point-to-point:	The sending and receiving of data from/to a pair of connected sites.
POTS:	Plain Old Telephone Service.

PRI: Primary Rate Interface, the class of service that offers twenty-three 64 Kbps B-channels and one 16 Kbps D-channel. A user may be assigned all or some of the B-Channels providing bandwidth in multiples of 64 Kbps up to 1.472 megabits per second. The D-Channel is used for control data.

QCIF: Quarter Common Intermediate Format.

switched 56: A commercially offered service whereby bandwidth is provided in increments of 56 kbps depending on the user requirements. Each multiple of 56 kbps is normally equated to a single twisted wire pair.

T1: A digital transmission system operating at a nominal rate of 1.544 Mbps.

tile: A rectangular area of a frame which is composed of only a small number of pixels and lines. This small area is often analyzed for the purpose of attempting to predict what is happening in adjoining tiles.

VHS: Video Home System is a commercial format which is used for the recording and playback of television signals for home use.

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