Bay Networks and First Virtual Corporation Implementing Distance Learning Networks

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Introduction

Distance learning is the application of network technology to education in all areas including K through 12, Higher Education, Continuing Education, Corporate Training, Military and Government Training. Distance learning speeds the process of transferring the knowledge of 'subject matter experts' to others, more efficiently than ever before. Implicit in the term 'distance learning' is the concept of education that can occur without the necessity for the instructor and student being present in the same location at the same time.

What are the potential benefits that flow from implementing a distance learning environment? What equipment is needed to get up and running? What are the staffing and training requirements for the system to be used effectively?

Benefits of Distance Learning

Distance learning has the been shown to produce the following potential benefits (Dennis, 1994; Kearsley, 1990; Wilson, 1991):

1. **Reduced learning time** - typically 30-40% less time is required compared to classroom instruction.
2. **On-demand learning** - instruction is available when and where the learner needs it. No need to wait for or travel to a scheduled class. Increases access to learning for the disabled.
3. **Increased motivation** - students usually report that they find technology-based interactive learning more interesting and enjoyable than classroom lectures.
4. **Increased achievement** - when corrective feedback or a mastery learning strategy is provided, students often show better test results, retention, or job performance from technology-based interactive learning.
5. **Better quality control** - since learning experiences are delivered in the same way each time, they are much more consistent and reliable than classroom instruction.
6. **Increased safety** - learners can learn about and practice dangerous procedures without a safety concern.
7. **Greater flexibility** - fluctuations in the number of learners or their backgrounds can be accommodated more easily than with classroom instruction.
8. **Improved accountability** - automatic collection of data on learner performance can verify learning accomplished and identify learning problems.
9. **Faster revision** - to the extent that the learning experiences are delivered via a networked system, changes and updates to information can be made immediately.
10. **Reduced delivery costs** - once developed, technology-based interactive learning is likely to cost less relative to labor intensive classroom instruction. It can also be used instead of expensive equipment.
11. **Learner controlled** - each learner is able to review topics or to skip beyond the information they already know.

Bay Networks and First Virtual Distance Learning Networks

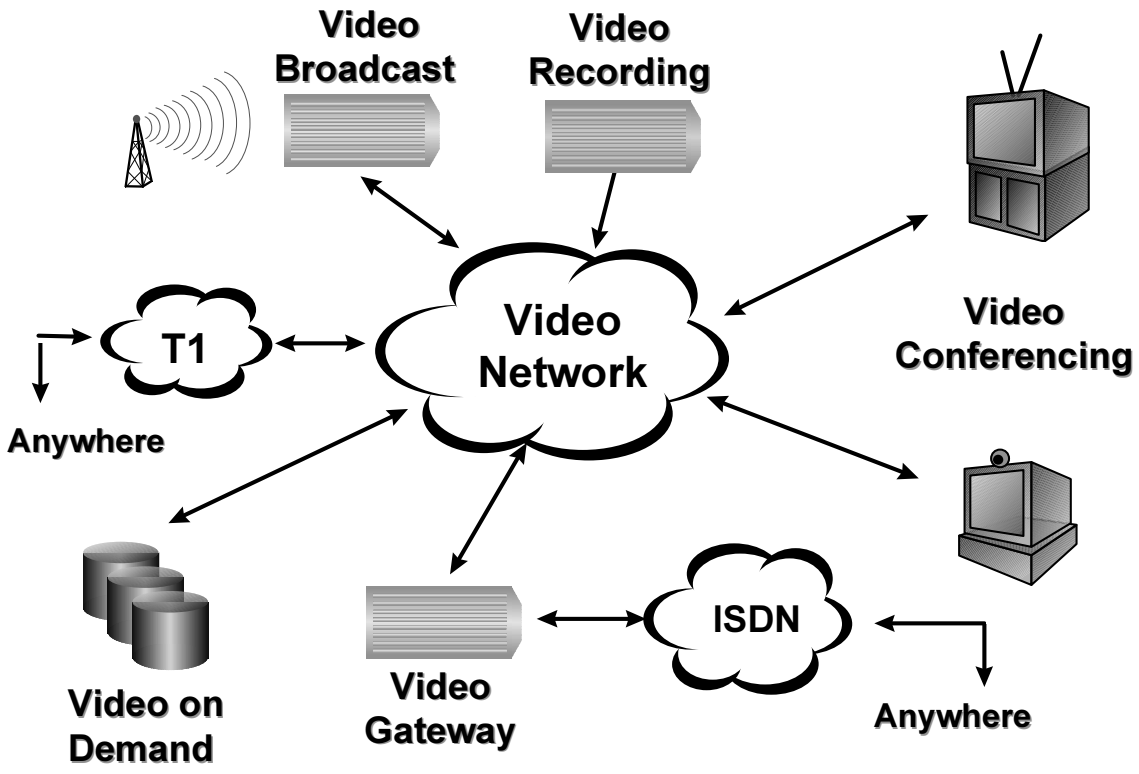
Distance learning has been defined by the United States Distance Learning

Association (USDLA) as:

> "Distance Education refers to teaching and learning situations in which the instructor and the learner are geographically separated, and therefore, rely on electronic devices and print materials for instructional delivery. Distance Education includes distance teaching—the instructor's role in the process, and distance learning—the student's role in the process."

The fundamental methodology of uniting the 'distance teacher' with the 'distance learner' is the 'network' - technology that bridges the gap between the teacher and the learner. Networks suitable for distance learning come in many shapes and sizes, everything from satellite transmission systems to long-haul, statewide fiber networks.

Perhaps the most important issue to be addressed when selecting a network for any significant distance learning environment is the ability for the network to operate in a very heterogeneous environment. This requirement stems from the fact most practical distance learning environments span very significant geographical distances, and typically present the network implementers with a mixture of delivery systems with widely varied capabilities. In practice a large distance learning deployment may span territories that present the challenge of uniting technologies as disparate as ISDN, T1, ATM, Frame Relay and Ethernet into a single unified content delivery system. Because the underlying characteristics of the network transmission technologies all have different capabilities, it is important to match the format of the content to the delivery system.



Fundamental Video Types

Video is the cornerstone technology of distance learning environments, and is the key data type that must be successfully transmitted if instruction is to be successful. Video type can be categorized in many ways, but there really are three key types of video content.

Video On Demand - The ability of a distance learner to access educational content that is stored on the network on a video server. The content may be video of a 'normal' lecture that a student could not physically attend because of a scheduling conflict, or a session that was recorded in a studio for the express purpose later transmission on the network as part of standard course-work.

Live Broadcast Video - The ability of a distance teacher to deliver a lecture or other educational session directly into a video camera and to broadcast this material in real-time to distance learners out across the network. Simultaneously, this video could also be copied to a video server, to facilitate the needs of students unavailable at the actual lecture time. These students could then access the material as a 'Video On Demand' session as described above.

Videoconferencing - The ability of distance learners and distance teachers to participate in a two-way interactive educational environment. Video cameras must be employed at all points of the videoconference to allow this two-way interactivity to occur, and the network must be able to support this real-time data transfer in both directions. Videoconferencing re-creates the typical classroom environment, even though participants may be miles or countries apart.

The Importance of Quality

Quality of transmission of educational video is a critical success factor in establishing a distance learning environment. Regardless of the type of video that is being transmitted — Live Broadcast, Video on Demand or Videoconferencing — the quality of the video is a key determinant in passing on the knowledge of the video teacher to the video learner. Students quickly become disinterested or frustrated if the quality of the audio or video is substandard.

A core challenge then is how to provide the required video quality over a network with a wide range of transmission characteristics and capabilities.

Video Technologies

The three fundamental types of video teaching tools, Video on Demand, Broadcast Video and Videoconferencing can be further broken down into two simple classes of video: one way non-interactive video and two way interactive video.

One way, non-interactive video - Both Video on Demand and Live Broadcast Video are forms of this video type. Video is streamed from either a 'broadcast-server' or a 'video-disk server' in one direction only from the server to the distance learners. The nature of one way, non-interactive video allows for some buffering of video at the 'edge' of the network. This permits the smoothing out of underlying latency and inconsistency of the transmitting network.

Two way, interactive video (Videoconferencing) - Video is transmitted in both directions simultaneously between the student and the teacher. The real-time two way interactive nature of this style of video traffic permits almost no 'delay inducing' buffering of video within the network itself. This implies transport by a network with very low underlying latency and inconsistency.

Video Compression

The science of transmitting video across networks is essentially the science of compression. The need for compression is easily illustrated by the following example. The typical analogue NTSC video that we see on our television screens at night if turned into digital format and maintained at a resolution of 640x480, with a color depth of 24 bits, at 30 frames per second would consume approximately 240Mb/s of network bandwidth. This amount of network bandwidth is impossible to service on today's typical LAN networks that provide from 10 - 155Mb/s of bandwidth, and is orders of magnitude more that the typical 1.4 Mb/s found on wide area links (WAN's). The compression is therefore needed to permit video traffic to be transported effectively over networks.

It is essential to employ compression and transmission standards that allow video of very high quality to be

transmitted over the extremely heterogeneous network environment typically found in distance education environments. The 'distance' nature of distance education implies that learning will take place over a wide geography, thus spanning both LAN and WAN network technologies. Compression and transmission schemes employed must then be able to be delivered over the widest range of network technologies.

The video networking standards of choice are simple to arrive at under these constraints - H.320 for two way interactive video and MPEG-1 for one way non-interactive video.

The H.320 System for Videoconferencing

The H.320 standard for video conferencing has been in existence for some years now and fully 95% of all videoconferencing systems implemented in the world today use this standard. Video CODEC manufacturers such as PictureTel, VTEL and Zydacron use this standard exclusively. H.320 videoconferencing can be implemented over a very wide range of networking technologies such as ISDN, ATM, T1 and E3. This permits deployment in distance learning applications that span the globe. The H.320 standard also provides scaleable bandwidth utilization delivering very high quality two way interactive video transmission at speeds that include 128Kb/s, 384Kb/s, 768Kb/s and 1.5Mb/s. A key advantage of H.320 is that it supports dial up connectivity to virtually every other installed videoconferencing systems in the world. In a distance learning environment this is essential as it facilitates the use of experts from universities and learning establishments all over the world with a dial-up procedure as simple as the telephone.

H.320 provides outstanding quality images at any speed from 384Kb/s and up - its unique ability to support a range of speeds lends itself well to the disparate nature of the distance learning environment. A lecturer could be presenting a real-time lecture to hundreds of students in dozens of locations across an ISDN based WAN at 384Kb/s, and moments later could conduct a conference with a student on his campus across their ATM LAN at 25Mb/s.

The H.320 system of videoconferencing has developed sophisticated and effective methods of enabling multipoint video calls - allowing any number of discrete locations to participate in the same interactive videoconference. This is an essential enabling element of distance education. H.320 multipoint calling is indeed so popular that many service providers now offer this as a standard service, rending multipoint videoconference as simple as a phone call.

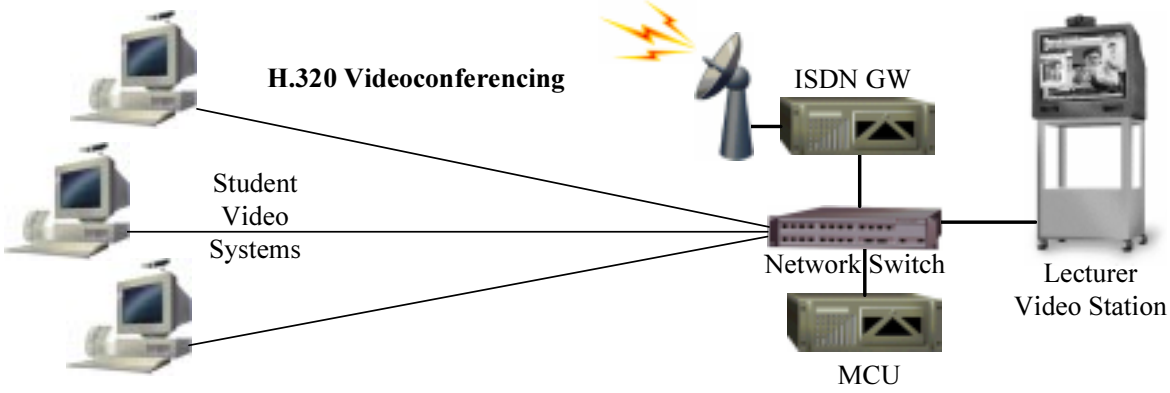


Figure 2. H.320 Videoconferencing Systems

Alternatives to H.320 Videoconferencing

There are alternatives to H.320 videoconferencing, however they all fail to pass the essential test of operation in a practical distance learning environment that naturally embodies a great range of network types.

MPEG-2. Also referred to as H.310 when implemented over ATM, MPEG-2 provides very high quality

videoconferencing. It however has three key shortcomings - (i). MPEG-2 is a compression system that assumes an underlying network of very prodigious capability - requiring 6 - 8 Mb/s of transmission bandwidth. This limits these systems to implementation over the very restricted geographies that can support this data transport rate. Realistically MPEG-2 can only be implemented over 100Mb/s Ethernet or ATM in the local area and is dependent on the availability of extensive long haul fiber of any WAN deployment. (ii). MPEG-2 is used in less that 5% of videoconferencing applications - there is no implementable way of connecting to external experts through simple dial-up technology as H.320 provides over ISDN. (iii). MPEG-2 is very expensive to implement, typically requiring specialized 'black-box' like hardware with little useful connection to the universal world of PC technology.

Motion JPEG. Another compression technique capable of providing very high quality videoconferencing, suffers from essentially the same weaknesses as MPEG-2. It also requires very high bandwidth - 8 - 12Mb/s, making it unsuitable to the distributed nature of distance learning. M-JPEG (as it is often refered to) has found very little acceptance in the marketplace as a videoconferencing technology. It also has no real way of communicating with the vast installed base of H.320 videoconferencing systems, and no dial-up capability.

H.323. The 'new kid on the block' for videoconferencing is designed to implement videoconferencing over TCP/IP networks. This style of videoconferencing shows promise in terms of its ability to deliver video over a wide range of network types and architectures. It is severely challenged, however, in its ability to deliver video of the required quality - a critical success factor in distance duration. The 'best effort' nature of router based long-haul TCP/IP networks simply does not deliver video the consistency or quality required for successful distance training.

There are presently no effective alternative methods for multipoint videoconferencing that effectively allows outside participants to dial into a video call from anywhere in the world. Only H.320 has this capability.

The MPEG-1 System for video

MPEG-1 is the video compression standard of choice for implementing one way non-interactive types of video in distance learning environments. MPEG is an acronym for the Motion Picture Experts Group and uses a style of compression that relates the video information on a given frame to the frames that surround it. Computations are made to determine what video has changed from one frame to the next - and only the changed video is sent across the network. This compression style yields very high levels of compression with very high quality. The transmission rate of MPEG-1 is approximately 1.2 Mb/s rendering it suitable to transport on all LAN types and to a wide range of WAN's as well. MPEG-1 has been very widely implemented as a compression technology and is the default format for commercially available educational video content. MPEG-1 is well suited to delivering content in both Video on Demand applications and Live Broadcast Video applications.

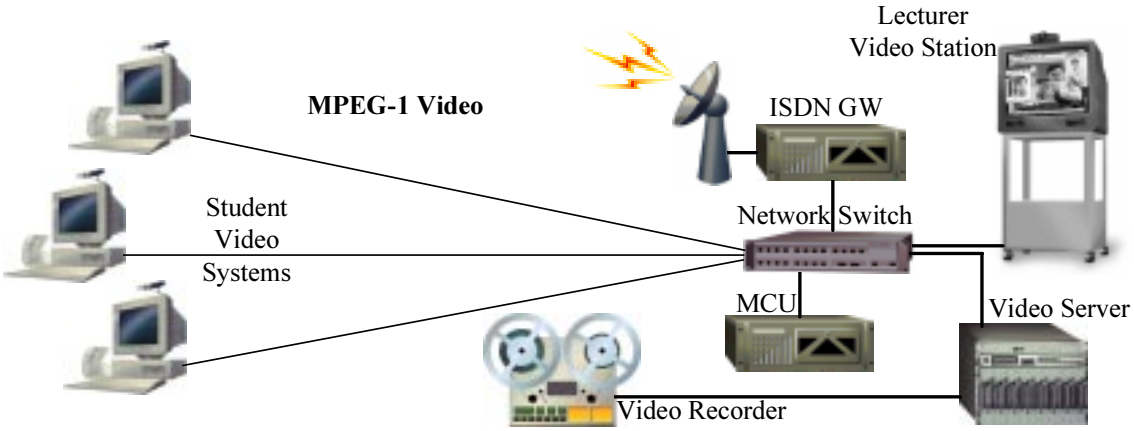


Figure 3. MPEG-1 Video

Alternatives to MPEG-1

The key alternatives to MPEG-1 can be broken down into two broad areas - high bandwidth and low bandwidth.

High Bandwidth. Motion-JPEG and MPEG-2 can also be utilized with video systems for implementing one way non interactive video, however they suffer from a number of fundamental shortcomings in this role. Firstly they consume too much network bandwidth to be practically implemented in wide area or even Ethernet environments; second, their large size/frame ratio prevents video servers from providing a high number of concurrent video streams to students in the distance learning environment; and lastly they are too expensive, consuming too high a portion of the total budget allocated to distance training with only negligible gains in video quality as compared to MPEG-1.

Low Bandwidth. The success of the Internet has spawned a raft of compression systems that are suited to implementation over the low bit-rate connections afforded by dial up access to the Internet. These compression schemes such as Vivo and RealVideo provide video at low frame rates and very small image size to permit their operation over constrained bandwidth. These low bit-rate can hence be implemented over a wide range of networking technologies, but they cannot provide the video quality required for successful educational outcomes in distance instruction environments.

Combining MPEG-1 and H.320

MPEG-1 and H.320 are the preferred systems for delivering video into educational environments. They provide the required level of high quality video, whilst being implementable on a wide range of networking technologies, both in the LAN and the WAN. MPEG-1 and H.320 are also *the* standards in their respective arenas, providing access to a wealth of commercial instructional content for video servers, and to simple dial-up communications for videoconferencing.

First Virtual Corporation, the leading provider of video networking products, headquartered in Santa Clara, California, has developed methods of allowing the practical combination of both of these two types of preferred video in a way that is very useful for video instruction. For example, by using the First Virtual equipment an instructor could give a lecture using standard H.320 videoconferencing products and then show the students an MPEG-1 based instructional video as part of the lecture, all 'inside' the actual videoconference. In the same way the teacher could introduce 'live broadcast feeds' into the videoconference as required, to enhance the educational experience.

First Virtual's product set allows the simple and effective blending of H.320 and MPEG-1 video over a very wide range of networking technologies including ATM, T1 and ISDN networks.

Summary

Distance education can both improve the quality of instruction as well as lower the cost of education delivery. Distance education networks typically employ a wide range of networking technologies with a corresponding range of capabilities to deliver instruction via video. Video implementations must take into account the requirement for high video quality as well as the requirement for transmitting the video over a mixture of high speed LAN and low speed WAN network topologies. The accepted industry wide standards of MPEG-1 and H.320 are hence the preferred means of implementing video.

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