Pioneering Video On-demand Projects in K-12 Education

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Abstract

This paper describes two projects of historical significance, because they pioneer the use of real-time video on-demand technologies in K-12 education. The projects are currently in progress at Okazaki City in Aichi Prefecture, Japan, and Lincoln, capital of the State of Nebraska, in the United States. An overview of the projects is provided. Systems configurations and the conceptual approaches are discussed.

Introduction

Digital Libraries and the information highways of the future will enable many new applications and effectively take us further along the path to becoming an information society. Education is perhaps the area of human endeavor that will be affected the most by the information revolution. Access to primary sources of information, and the preservation of information have the potential to change the way in which we teach and learn. New paradigms for learning will be enabled, and new educational models will be developed, over time, to exploit the new ways of learning that technology will offer. Such changes, when deployed in a large scale, have the potential of becoming culture affecting, in the way for instance, in which television affected our culture.

A new paradigm for learning that has never before been a part of our educational environments is video on-demand. In the classroom and at home, educational video could provide a window into the world otherwise limited to students. Video on-demand technology opens that window. In contrast with broadcast television, Internet (store forward), and stand-alone multimedia, video on-demand has the potential to liberate information, and in particular video, from all temporal and spatial constrains. The ability to access information when it would be most meaningful, on-demand, is the most challenging problem of the information age, and it is only recently that our power over information has been extended to include digital video. However harnessing digital video on-demand for educational purposes is a considerable problem that touches upon technical, educational, and social issues. Solving these problems could again trigger the use of video to affect our culture, but in a much different way.

Motivation and Goals

As more emphasis is placed on the use of technology in education, teachers must be supported not only in their efforts to bring technology to students, but to bring knowledge to students by effective use of technology. Video on-demand technologies hold the promise of enriching classrooms and homes with a wealth of information that is compelling, motivational and meaningful. Much educational video is already available and will continue to be produced creating effective, meaningful and vibrant representations of information in every conceivable topic. Many new sources of information will be tapped. Real-life activities will be captured with video for wide dissemination and repeated analysis. But the key to the exploitation of video is the power to use it on-demand.

The challenge is how to exploit these technologies to bring about widespread systemic and sustained educational change. It is not sufficient to bring this technology into the classrooms; it is also necessary to use this technology to bring information into the classrooms in a coherent, well-organized way. A key aspect of organization is the ability to access materials in a timely manner and when they would be most effective. The wealth of information already in video form sought for use in education makes this a significant problem. Many content providers have libraries of videos capable of enhancing many lesson plans. But these are not always available for public viewing when they would be most relevant and desirable.

Other potential sources of educational material such as museums go unexploited, except by students in their immediate vicinity. Greatly enriching experiences are often only shared locally. This is also true of research laboratories and universities. Such resources are more accessible to schools locally, if at all. Thus partnerships among scientists and teachers cannot be easily shared beyond the immediate sites involved in individual projects. Capturing such resources in the form of video would create a legacy of knowledge and information that could be preserved and shared more widely. It is infinitely more practical and realistic to bring a video-captured version of a museum exhibit to a classroom, or an interview with a scientist to a student, than to get a class to the museum, or get time on the scientist's calendar with a student.

But even if existing sources were made available, and potential sources were tapped, the problem would still remain of how to access the information on-demand. The information and communications infrastructures of the future will greatly enhance the ability of teachers and students to access materials, to share knowledge and initiatives, to reach and participate in these, and to relate and compare accomplishments to world-class standards. But the technologies to move information must be coupled with technologies for representing, organizing and distributing the information.

Technical Issues and Other Considerations

The processing power required to manipulate digital video can be achieved in a workstation, but until now has been confined by the limited capacity of local storage. A single hour of compressed digital video requires 700 megabytes, or 1.5 megabits for each second of video. A library of 1,000 hours of digital video would require 700 gigabytes of storage, far beyond the capacity of any workstation. At 1.5 megabits per second, about 10 digital video streams would quickly exhaust the capacity of most existing local area networks (LANs).

While CD-ROMs offer an economically viable solution for bringing to education quality multimedia applications that include digital video, the use of such content in a large scale poses serious information management problems. The media in a CD-ROM, for example, cannot be manipulated to target specific curriculum goals. That is, a teacher cannot separate a video clip, image, or document from a CD-ROM for use in a lesson plan or student portfolio, and a student cannot extract CD-ROM media for use in multimedia projects, or research folders. In addition licensing agreements in most cases limit the usability of CD-ROMs to stand-alone environments, making it difficult to share such content. Furthermore, even if a teacher could have all the available CD-ROM titles, and availability is always a problem [1], it would be difficult to integrate such content with curriculum in a systematic, organized manner. Another issue is the quality of CD-ROM video, which does not compare with what students are accustomed to because of television.

Large scale video server technologies are required to store and manage large libraries of information that are digital video intensive; to support simultaneous access by many users; and, to provide the communications support to allow both mass delivery of interactive multimedia with full motion video over local area networks, and wide area network (WAN) access by geographically dispersed users to *superserver* information through networks. These technologies are also required to manage and protect content, and to apply it systematically to a given application area, such as education.

Utilizing its enormous memory, storage and high-bandwidth connectivity a large-scale server could support close to 2,000 simultaneous random access full-motion video streams on a large ES/9000. This corresponds to a community numbering in the tens of thousands with access to a huge library of multimedia content. Because the host disks are so much faster than the workstation disks, in many instances the data from the host is received at the workstation for processing sooner than if it had come from within the workstation itself. The creation of powerful education infrastructure is possible today, with effective use of technology. The two projects described in this report are real examples.

Basic Components of a Video On-demand System

Video on-demand technologies fundamentally allow users to access and play any video clip resident in a digital library at any time. The basic components of a large-scale video on-demand system include:

1. A video server capable of delivering the uninterrupted, smooth flow of video, to many users simultaneously.
2. A network that can support the flow of digital video information.
3. A player that can decompress and play back the digital video.
4. A digital library of content that can include digital video, as well as any other kind of digital media, and the software mechanisms to manager and support its functionality.

The implementation of a video on-demand system for education is a systems design problem that varies with requirements and goals, but contains all of the basic components

The Nebraska Project:

The project in Lincoln, Nebraska started as an extension of a research effort called EduPort [2], to demonstrate the use of video on-demand in education and was first launched at Lincoln High School during National Science and Technology Week in April of 1994. The research project started at the IBM Thomas J. Watson Research Center and was demonstrated in Lincoln as the result of a collaborative among the University of Nebraska, the Lincoln Public Schools, the Lincoln Public School Foundation, Lincoln Telephone, and IBM Research. The technology decisions made in this case, or effectively the systems design was driven partly by use of existing resources. The Lincoln implementation of video on-demand system is illustrated in Figure 1 and described as follows.

MVS Digital Library Server

An MVS digital library server was enabled at the University of Nebraska, using their existing IBM ES/9000. The LAN File Services/Extended Systems Architecture (LFS/ESA) product, which stores LAN formatted files on a MVS system transparently to users on a LAN providing the performance needed to support transparent access from workstation client to large amounts of data in the (video) server. The MVS system at the University of Nebraska is connected via a standard 3900 channel to an OS/2 LAN Server. This OS/2 LAN Server resides on a Token Ring LAN at the University of Nebraska campus and extends to Lincoln High School Campus by means of a Token Ring extender using LAN emulation services provided by Lincoln Telephone.

At the High School campus a Token Ring LAN is connected to a workstation controlled by the teachers, and used via a large screen projection to display the videos to a large group of students. This implementation is unique to the Nebraska project and was selected to give access to the content to large groups of students. With 3000 students and 300 teachers and staff, Lincoln High School is the largest school in the State of Nebraska. Several EduPort classrooms can be easily supported in this manner to give more equitable access to the content. In another setting, PCs might be used to give individual control to students via display stations.

High Speed Network

A high-speed fiber network connects the University of Nebraska to Lincoln High School 12 miles away. The connection starts at the host (video server) as an ESCON channel, which is connected to a parallel channel adapter on a PS/2 Model 95 OS/2 LAN Server via a 9034 ESCON Converter. The OS/2 LAN Server is connected directly to a 16MB Token Ring LAN segment on the University of Nebraska campus. This LAN is extended via a Token Ring LAN extender to LAN segment on the Lincoln High School campus, using a PS/2 as the entrance point. This Token Ring LAN segment contains the control and display stations.

Another configuration for this project being implemented in Omaha, Nebraska, makes use of an existing coaxial cable infrastructure. This configuration was demonstrated with the CableNet'94 fiber/coax network through a 10 Base-T Ethernet connection and a Zenith data-over-cable modem. The cable system and Zenith modem technology is able to support the EduPort interactive multimedia content which is video intensive. The client workstation simply requests that media or a video stream be "played" from the server and into the network. The client has full control over the stream and can pause, stop, start.

Digital Video Library

The content for the EduPort demonstration project in Lincoln Nebraska is almost entirely digital video and all from public domain sources, or homemade video of content of special interest to the students. It was all initially digitized using Intel's digital video interactive (DVI) technology for hardware decompression resulting in 30 frames per second digital video resolution, which is equal to that TV quality. The content was organized within a special methodology developed at IBM Research that utilizes the concept of media blocks composed of media objects. Teachers worked in collaboration with researchers to design a set of media block models [3]. The resulting structure resembles that of an open-ended, changeable and updatable video encyclopedia. That is media objects can be added to the video library or combined in different ways. The following is a brief list of organizations that have contributed content for the project:

- ✓ Exhibits from the Discovery Museum in Bridgeport, Ct.
- ✓ Materials from the Franklin Delano Roosevelt Library in Hyde Park, NY.
- ✓ Images and video materials from NASA
- ✓ Lowell Thomas Archives, Marist College, Poughkeepsie, NY.
- ✓ Mandarin Conversation, Florida State University
- ✓ North Central Regional Educational Laboratory, teacher development videos
- ✓ Mid-Central Regional Educational Laboratory, educational videos
- ✓ Photographs of prairies, Smithsonian Museum of American Art

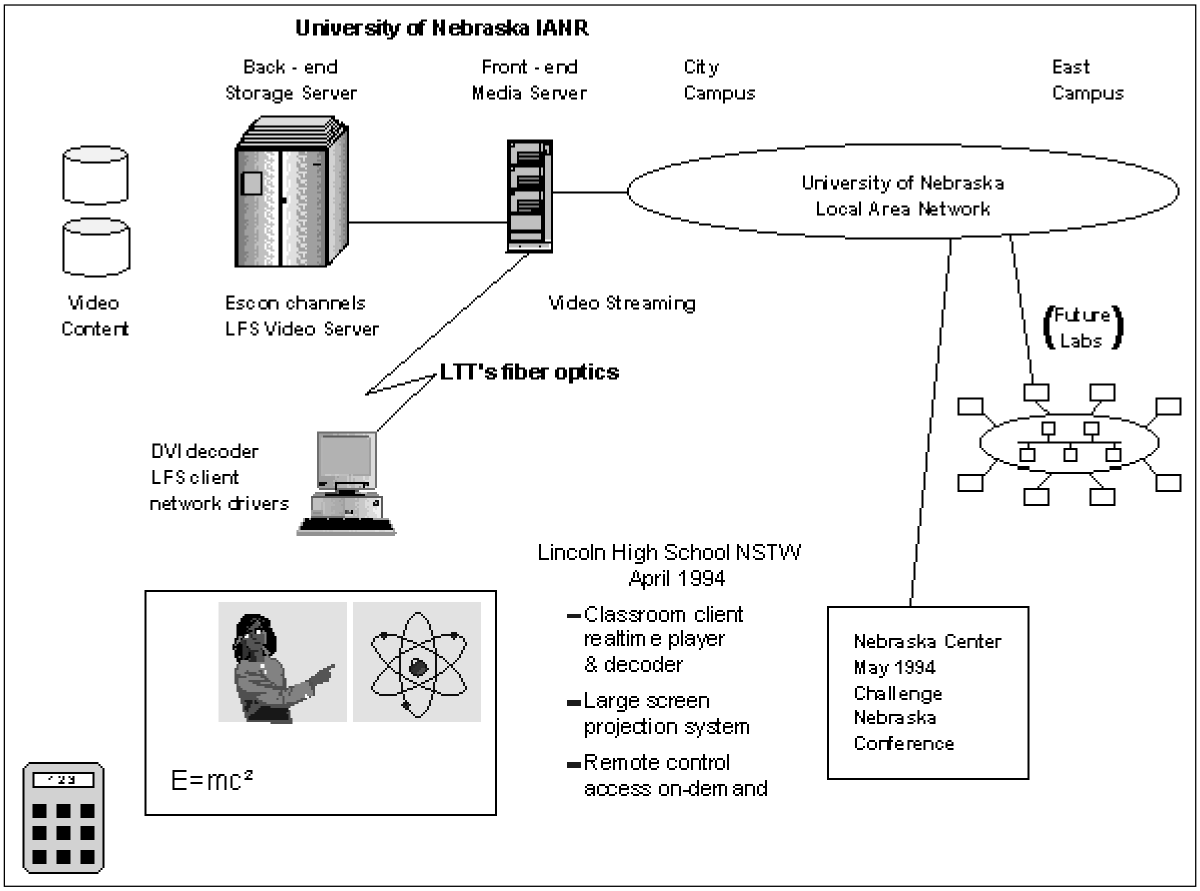

Figure 1. Diagram of the Nebraska Project.

End User Scenarios

The player or control and display equipment at the Lincoln High School consists of PC client workstation running OS/2 LAN server. The EduPort application as well as the digital video content reside on the remote server and are accessed in real-time on-demand over the network. The teacher selects an item for display from what appears to be storage on the OS/2 LAN Server; in reality, the storage on the OS/2 LAN server is mapped to much larger storage on the MVS/ESA system, using LFS/ESA. The request triggers the display of the item requested on the student displays. This request is satisfied from the MVS/ESA system. The user of the video on-demand application, in this case the teacher has complete control over the video content. The environment allows the user to select any video from the library, be able to combine it with any other video or media, and access it on-demand having control over the flow of information. This power over information will be specially beneficial to students giving them the ability to move through information at their own pace (to preview or review content used in school), and to do research, exploring media at will.

The Okazaki City Project: Probably the most advanced educational video on-demand system in the world is currently in use at Okazaki City Public Schools in Aichi Prefecture, Japan. With support from IBM's System/390 Division and IBM Research, IBM Japan is the systems integrator for a major project that provides a video on-demand system to 30 Elementary and Junior High Schools, each linked to the video server via optical fiber network. From multimedia workstations at each school, teachers and students have access to a full range of interactive educational video and course materials.

Announced in September 1994, the project is supported by the Japanese Ministry of Posts and Telecommunications, and involves the Telecommunications Satellite Corporation of Japan, Sony Corporation, Sumitomo Electric Industries, as well as IBM. Okazaki City is located near the city of Nagoya, about 150 miles southwest of Tokyo. The video on-demand system implemented at Okazaki, illustrated in Figure 2, was commissioned with the following goals:

✓ To fully digitize video data created and owned by Okazaki City. After being compressed in special multimedia format (MPEG1), the videos are stored at the central digital library.
✓ To construct a video-on-demand system that will enable users at local Elementary and Junior High Schools to interactively exchange data stored at the central system, by building an optical fiber multimedia network based on an existing cable television network.
✓ To fully support performance levels allowing 80 concurrent video streams of 400 Kbytes/sec (3.2 Mbits/sec) from a single copy of a video asset.

The Okazaki video on-demand system held its inaugural demonstration to press and public officials in November 1994. During early 1995, system capacity and scope was extended until it included multiple workstations at all schools at full rated bandwidth. Based upon core technologies similar to the Nebraska project, the Okazaki City system contains the following elements.

MVS Digital Library Server

The digital library server is an IBM 9672 Parallel Transaction Server with 3 processors and 256 Mbytes of memory, running the latest version of the MVS Operating System. Like the Nebraska project, high-performance video file serving at Okazaki is performed by IBM's LAN File Services software product, with special extensions provided for disk striping, guaranteed "Quality of Service" delivery, and easy management of a large digital video library. The digital library content is also housed at the central site and occupies 144 Gbytes of 9345 DASD (Direct Access Storage Device). This storage is accessed over fiber channels through four 9343 Control Units. Multimedia and video assets exist as longer 30 minutes segments that are divided into shorter video clips that the students can readily access.

At the central site the MVS system delivers streams of data over multiple fiber-optic channels to 3172 Interconnect Controllers running OS/2 and OS/2 LAN Server. These Front End Processors connect to an FDDI optical fiber backbone connecting all of the schools. At an individual school, the fiber backbone is connected to a 16 Mbit/sec Token Ring LAN via an FDDI-TRN Bridge. Workstations on the LAN receive the digital video stream where it is de-compressed using an MPEG decoder card and displayed on the screen. Alternately, an NTSC output stream can be delivered to a TV or in-school cable network for broadcast throughout the school.

High Speed Network

Development of the optical fiber multimedia network was accomplished through a partnership with Sumitomo Electric Industries. The network consists of five 100 Mbit/sec FDDI (Fiber Distributed Data Interface) rings of up to 200 km. in length. Several schools are connected via a single ring, and full video delivery has been demonstrated at schools 30 km. from the server. The connection starts at the central video server as an ESCON channel, which is connected to a parallel channel adapter on a 3172 OS/2 LAN Server. The 3172 Interconnect Controller houses an FDDI adapter that connects the OS/2 LAN Server to the FDDI network. Five separate FDDI optical fiber rings are used to provide overall bandwidth of 1 Gbit/sec to the Okazaki City school community. Each individual FDDI ring links an average of six schools, with a 16 Mb/s Token Ring LAN segment at each school. This Token Ring LAN segment supports multiple display stations, each with the capability to select and play independent high-quality video streams. The client workstation simply requests that media or a video stream be "played" from the server and into the network. The client has full control over the stream and can start, stop, pause, rewind, or jump to locations within the video.

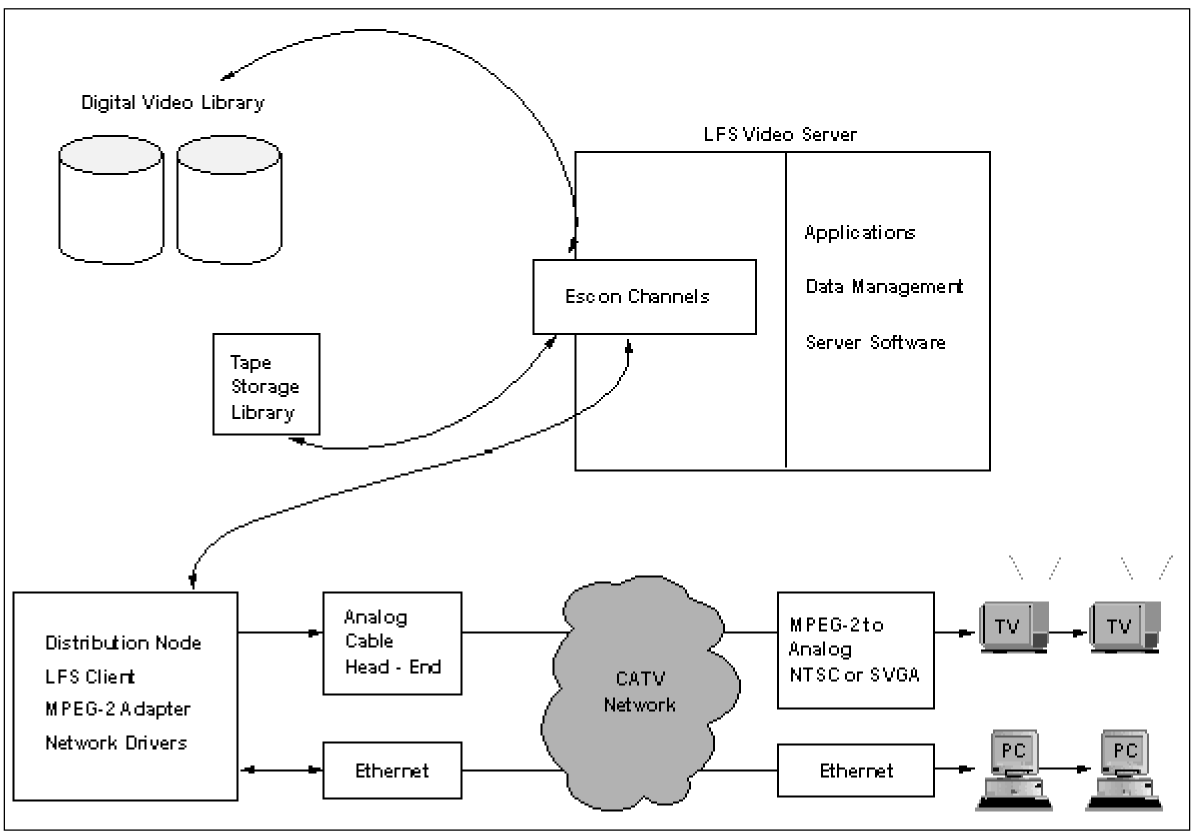

Figure 2. Diagram of the Okasaki City Project.

Digital Video Library

The initial set of digital videos at Okazaki City was created from video materials owned by the city involving local history or local educational resources. Teachers within the public school system created additional video clips. IBM Japan, working in partnership with Sony Corporation provides the imaging equipment and studio support required to create the video content. Advanced development tools include the IBM Power Visualization System (PVS).

End User Scenarios

Finally, from any of the special VOD workstations students or teachers are guided through a set of menus to choose course material or video selections. The use of computer animation and an on-screen "talking robot" provide an entertaining guide for novice users. As simply as selecting a CD-ROM game, students can call up video data from the remote server and it is accessible immediately over the network. The immediate benefits and future potential for this networked multimedia approach are substantial. Teachers and students gain equal access to a wealth of educational resources, which can be centrally managed, updated, and controlled. The material is available just-in-time to students when they want it, and the pace, repetition, and depth of inquiry is fully controlled by the requestor.

Experiences and Feedback from the Users

In Nebraska students excitingly think of the video on-demand system as television with control of the programming at the receiving end. But, the options range from an exploration of the NASA Space Program, to an in-depth look at fractals, to a peak at West African dance from the Kennedy Center. An art teacher is using fractal images from EduPort in her Jewelry Making course. Another teacher is using NASA footage of Space Station Freedom in her Science Fiction class. The response to the video on-demand system at the Okazaki City schools has been overwhelmingly positive. Students find the interactive nature of the system and the on-demand video as compelling as video games. Yet the focus of their interest includes lessons in classical music, language study, or a virtual field trip to a space station or underwater laboratory. Perhaps the most rewarding experience so far has been the comments from teachers and students. On teacher in Lincoln had this to say: "This is the first time in my career that I was given the most advanced technology available to anyone, and the best quality and most current source of content" [4].

Conclusion

Video on-demand is a technical reality. While its introduction in the marketplace may be slow and difficult its usefulness beyond entertainment has been proven by these two projects. The creation of a powerful media infrastructure is possible, but its impact needs to be assessed. To get there however it will be necessary to first target specific goals that include the use of video on-demand in education. Information Infrastructure plans globally do include the goal of connecting schools to sources of information, but that is not enough in this case. In order to bring the benefits of instantaneous access to high quality media in any form, including video, it will be necessary to connect schools via broadband networks to specially designed digital libraries of educational resources. Only then will we begin to understand its potential impact. Two isolated projects are not enough to assess results.

Based on observation however, the initial results are encouraging. Specific findings from these projects need to be documented and examined, and that will require more time in practice. The results should then be used to determine if current infrastructures plans for our schools are adequate and do indeed target the needs of 21st Century students. Future plans include recording and examination of the experiences. Adding more content to the digital libraries is always on the agenda. Therefore contributions of educational video content for this project are welcome. Research focus for the near future will be on how to better organize content for these emerging information environments. Our work so far has revealed that organization of content across technical platforms is a nontrivial problem. [5]. Because much of the work both in the educational and the technical areas is of pioneering nature it is very difficult to base any design decisions on past experiences. Much of the work has been done based on the sense of the teachers involved, and the goals of the communities.

Based on the amount of interest and inquiry generated by these projects it is certain that more EduPort sites will be made operational the near future. And, based on the many questions that have been generated it is also certain that new kinds of research need to be carried out as the EduPort user population increases. The clear, tangible outcome so far, is the satisfaction and excitement in facilitating the sharing of knowledge and information with teachers and students.

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