Designing a High Definition Television Laboratory for Technology Students

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Abstract

Over the course of the last year we have developed a course on High Definition Television (HDTV) for technology students[1]. One of the major steps in providing practical experience for students is the implementation of a cost-effective HDTV laboratory. As it can be expected, the equipment needed to implement a full-fledged, real-time, broadcast HDTV lab is cost prohibitive and technically problematic. However, a meaningful laboratory environment can be designed around a somewhat limited budget. Our proposal is as follows: a meaningful lab environment must give practical experience with a full range of HDTV related issues. The most major concerns for laboratory equipment are video acquisition, MPEG encoding, broadcast capabilities, reception and decoding. Signal broadcast, reception and decoding are the easiest issues to resolve if we think creatively. We propose to enhance our existing local area network (LAN) laboratory such that it will serve as our broadcast and reception hardware. HDTV is, after all, digital. An upgrade of a few Hubs and Ethernet switches to 100 Mbps equipment along with network performance monitoring software will allow a double check of actual bandwidth used. The addition of MPEG decoders to existing computers is relatively inexpensive and sound capabilities are built into most machines already in place. This leaves image acquisition and MPEG encoding as the only obstacles to overcome. These, however, are not minor obstacles. MPEG hardware-encoders range in price from a low of four thousand dollars to a high of well above $50,000.00. MPEG software-encoders cost considerably less. Funding sources for the low range or software MPEG-encoders can be found. The unfortunate problem of the lack of AC-3 audio encoding in the lower price range can be turned into an educational positive. Audio can be captured and resampled later. This process will preclude the possibility of live broadcasting. It is estimated that the cost of the upgrades to the LAN lab for cost-effective HDTV lab is about $5,000.

I. Introduction

An HDTV for Technology students was developed last year[1]. The one credit course was developed with the purpose of introducing technology students to the practical aspects of HDTV technology. The major topics proposed were HDTV overview, digital imaging, file compression, MPEG encoding, sound handling, broadcast and reception. Major

obstacles that were identified are: lack of appropriate textbooks, lack of experiments, and lack of guidelines to implement a cost-effective laboratory. Although, this latter issue was discussed somewhat in our previous paper, we were not specific in the type of hardware and software necessary for this course. In this paper we report some of our findings for the implementation of a cost –effective HDTV lab. The goal of this lab is to provide good imaging experience, broadcast and reception of digital video. The beneficiaries of this lab will be Electrical Engineering Technology and Information Sciences Technology students at Penn State DuBois.

We will design an HDTV lab around existing LAN lab with minimal equipment and software up-grades. Among the major components to include are: a video server, image capture and editing, network switches, MPEG encoders, HDTV cameras, network analyzers (for traffic analysis) and software for image coding and decoding. The majority of these items should already exist in a well-implemented LAN lab. For instance, a high-end workstation can be devoted to video server. Adobe Photoshop (along with Adobe Premier, which can been downloaded) for video editing is more or less standard software in most computer labs. Matlab, with the image processing toolbox, can be used for low-level demonstrations of image coding and decoding. Matlab is also a standard software package in most computer labs. This will leave us with MPEG encoder, image capture, and HDTV cameras as the major items to acquire to implement a basic HDTV lab. If we constraint ourselves to software MPEG –encoders, the cost of the few upgrades is around $5,000. In the next section, we will detail our proposal.

II. Lab Development and Cost

The equipment needed to implement a full-fledged, real-time, broadcasting HDTV lab is cost prohibitive. To design such a lab that provides a meaningful practical experience to our students we use our newly funded LANs lab. This lab has been recently upgraded and the upgrade was tailored to incorporate new technologies (such as HTDV).

The lab should be designed considering the major areas of practical HDTV experiences that students should have. We believe that these areas are: Digital imaging, File compression and MPEG encoding, implementation of a Video Server, Network traffic and analysis**.**

One high-end machine should be devoted exclusively as Video Server Station. The machine that we propose is IBM netfinity 7100 dual processor (with capability for 4 processors), 512 MB of RAM, RAID 5 system and a Fast Ethernet Fiber Network Interface Card for increased bandwidth. This machine should be able to digitize full screen video, produce AVI, QuickTime and MPEG movies. In order for this machine to be fully functional a video capture card such as Pinnacle DV 500 should be utilized. The Pinnacle[2] DV 500 uses a fully-featured dual-stream, real time editing system that uses a high quality DV CODEC (digital video coder-decoder). Although this card is more expensive than others with similar capabilities, it offers input for both analog and digital video. This card package includes standard Adobe Premier 5.1 RT for editing, Minerva

Impression for CD-R & DVD authoring, Pinnacle System's FreeFX and Hollywood FX Cooper.

To produce MPEG movies, due to cost constraints, we have chosen a software solution based on Digigami's MegaPeg Batch encoder[3]. The hardware-based solutions are expensive at the moment[4], with a price in the range of four thousand to well above $50,000. We expect that the prices will come down in the near future. MegapPeg is a fully featured, software-based MPEG encoder for transforming existing QuickTime and Video for Windows (AVI) movies to the standard MPEG-1 and MPEG-2 formats. Converting movies into the MPEG format is one the key aims of the lab, as it will demonstrate the students the basics of HDTV. Most computer platforms support this standard. While MPEG-2 format is excellent for broadcasting is not very apparent for movie editing. Thus digital video will still be produced by typical capture and editing solutions such as Pinnacle's DV 500 and Adobe's premiere, and only create MPEG as the final product. Digigami's MegaPeg supports Layer II MPEG audio, it will support AC-3 format very soon.

We will also need an Ethernet Switch, 22 port, 10/100 mbps auto sensing with 100base-FX mbps fiber optic uplink port and stackable fast Ethernet Hub, 12 port 100Base-TX with one 100Base-FX port[5,6]. The last piece of equipment will be used to segment the networks so students using lower traffic applications will be not be affected by the testing of video applications. To monitor traffic the NetRanger TS850A will be utilized. This device is a versatile instrument that can monitor traffic as well as troubleshoot networks.

Matlab[7], and its image processing toolbox, will be used to introduce the concepts of digital video. The use of Matlab is warranted because it will introduce nicely the concepts of picture elements in a matrix form, which an image is after all. Basic image manipulations color maps, and actual compression algorithms based on the Discrete Cosine Transform will be explored. While we are aware that the mathematical background for technology students probably preclude a thoroughly detailed-understanding of the coding-decoding processes, we think that can provide a simple routines that they can easily understand. In addition, Matlab is standard software used on campus.

For the Video Server station we envisioned the use of an HDTV video camera compatible with the image capture card. HDTV cameras are expensive, so for the time being, we propose the use of an analog camera, as we experiment with other major components of this technology. This should not be a major problem as the desired capture card can accept both analog and digital video signals. To make sure that we are compatible with the existing LAN lab, all the software and hardware should be Windows-based, including the network operating system. For initial testing, we will segment some users workstations connecting them via the Ethernet switch and fiber optic. We estimate that the cost of few upgrades is about $5,000.

III. Lab Layout

We believe that the LAN lab should be segmented into two sections, one segment with the video servers and powers users and the other with their own server (s) and typical users. The switch will connect to the video users; in this scenario each power user has it own unshared collisionless connection to the switch. This approach allows configuring each port for duplex-operation, thereby doubling the available bandwidth to each user[5,6]. The segment with typical users will be connected though a 100 Base TX hub, thus these users will not be affected by the video experiments.

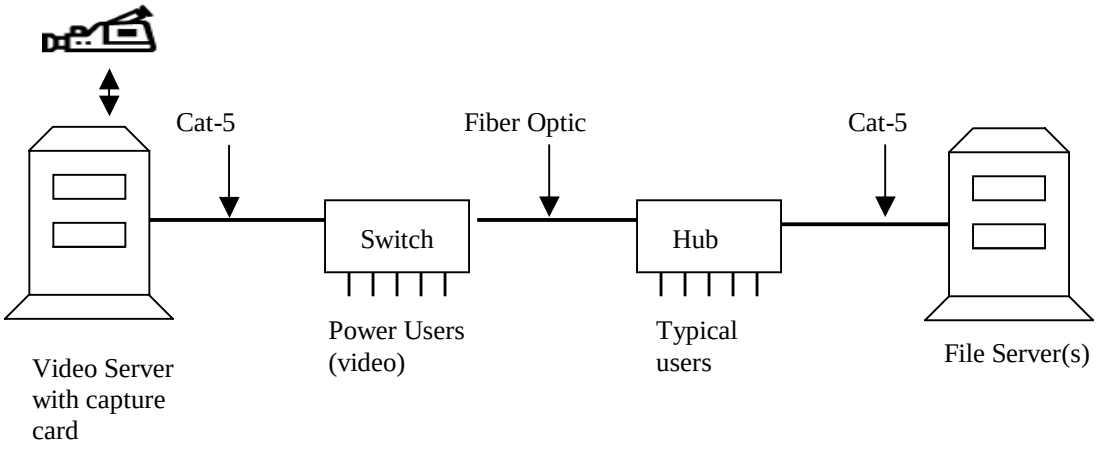

Figure 1 Basic HDTV lab embedded in a LAN lab

IV. Laboratory Instruction

As outlined in our previous paper[1], the lab should be concentrated around:

A) Image formats and colors: Students will have a brief review of matrices, image file formats, color in images, and color maps. Matlab and its image processing toolbox are ideal for this part.

B) File compression: Low level coding and decoding. Although the mathematical background of technology students is not very sophisticated, we believe that a good handle of these issues can be accomplished by the use of pre-packaged Discrete Cosine Transform routines. These routines are easily available in Matlab and its image processing toolbox.

C) Setting up a video server, the video server should include the imaging capture card, video camera and the MPEG encoder. Students will need a review of MPEG technology[8]. The students should understand the bandwidth requirements, as well as the hardware necessary to implement such as server. The machine of choice was outlined in section II. Windows NT will be the

operating system of choice since the rest of the LANs lab is also based on Windows. If possible students should have a review (or reinforcement) in the basic aspects of NT administration.

D) Broadcasting and Network traffic analysis: Students will broadcast video into their LAN segment. They will learn to use a network analyzer such as the Black Box's Netranger[4]. The lab(s) will be centered on broadcasting and traffic analysis.

E) Digital Imaging: Students will learn to use a capture card, edit videos and compose videos with Adobe's premier editing software.

While the scope of the labs seems ambitious for a 1-credit course, we believe that we need to test these ideas, evaluate the objectives and modify them accordingly.

V. Conclusions

A cost-effective HDTV lab has been proposed, based on an existing LAN lab. The appropriate hardware and software for the HDTV can be acquired with low cost. Due to cost constraints, and test this initiative, a software MPEG-encoder has been proposed. The goal is to purchase a high-end hardware encoder later. Capture cards that can input both analog and digital has been proposed with the analog camera as initial input, with the expectation of purchasing an HDTV camera. High speed Ethernet hubs and a switch will be available for segmenting and connecting the workstations and servers. Standard software packages such as Matlab and Adobe's Photoshop are already on place, minimal investing will be necessary to include Matlab's image processing toolbox. The network analyzer is also part of LAN lab, and will be utilized for traffic analysis. The advantages of having an existing LAN have been fully exploited, and only around $5,000 of investment is necessary to have a basic HDTV lab. To have a fully real-time broadcasting HDTV station seems to be beyond the budget of our campus. In addition, the set of lab experiments proposed we believe are ambitious enough to cover a wide variety of current topics.

VI. Bibliography

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Patrick Kalgren is currently an engineering student at The Pennsylvania State University majoring in Computer Engineering. Mr. Kalgren will graduate in May 2002 with a B.S. degree. He is a Schreyer Scholar at Penn State. He is currently a student employee at Penn State's Applied Research Lab in the Autonomous Controls and Intelligent Systems department. His honors thesis is progressing toward feature extraction and automated object classification on varied data sets.

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Dr. Morales received his electronic engineering degree with distinction from the University of Tarapaca, Arica, Chile (formerly North University) and M.S. and Ph.D. degrees in electrical and computer engineering from the State University of New York at Buffalo in 1978, 1986, and 1990, respectively. Since September 1990, he has been working as an assistant professor of engineering at the Penn State DuBois. He is now Associate Professor of Engineering. His research interests are in mathematical morphology, digital image processing, computer vision, and neural networks. Dr. Morales has been involved in teaching microprocessors applications, computer languages, software application and local area networks for many years. Dr. Morales was recently honored by the Institute of Electrical and Electronic Engineers (IEEE) with the Best Paper Award at the International Asia Pacific Conference on Circuits and Systems for the paper " Basis Matrix Representation of Morphological Filters with N-Dimensional Structuring Elements."

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Glossary of Terms

AC-3 – Audio encoding technology used for HDTV

CD-R - Compact Disk – Recordable, storage capacity 620MB

Duplex – Describes communication between entities in a system, i.e. full duplex – entity can receive and transmit simultaneously, half duplex – entity is able to receive and transmit, but not simultaneously.

DVD - Digital Versatile Disk, storage capacity 2.6GB

Ethernet – Local area network technology widely used as specified by IEEE standard 802.3, most commonly provides for transmission rates of 10mbps. Fast Ethernet provides for transmission rates of up to 100mbps

HDTV – High Definition Television

MBPS – Megabits per second, transfer rate of data

MPEG – Moving Picture Experts Group, an industry standards organization responsible for developing standards for video and audio compression.

MPEG–1 – Designed for CD and CD-i media. Provides coded progressive video at a transmission rate of 1.5mbps

MPEG–2 – Provides for compressed video transmission rates of 4mbps. A proposed MPEG-3 standard was merged with MPEG-2 when it was realized that MPEG-2 would meet the needs of HDTV.

MPEG-4 – A much more ambitious standard, still in development, that also addresses speech and video synthesis and an artificial intelligence approach to image reconstruction.

QuickTime - Multimedia format from Apple that combines audio and video into one file for playback, one of the earliest digital video standards.

RAID 5 – Redundant Array of Independent Disks

RAM - Random Access Memory