CS 410/510

Introduction to Multimedia Computing and Networking
Course Notes

Chapter 1 - Introduction

"Multimedia is Dead" declared the heading of an editorial by Sorel Reisman in the January 1998 issue of the *IEEE Multimedia* magazine. How could this be possible? Multimedia computing, digital imaging, and digital audio and video were just becoming possible for the general population. Clearly, the incredible success of digital cameras, DV cameras, and DVDs in the early 2000's seemed to indicate the complete permeation of multimedia into the general population. The article continues to describe how multimedia had become a noun; for example, the magazine was titled *IEEE Multimedia.* Without a noun for which it describes, multimedia really does not exist. This book focuses on *multimedia computing and networking*. Before defining multimedia computing and networking, we first describe what we mean by multimedia is.

1.1 What is Multimedia?

Multimedia implies the use of multiple media. Of course, this can take on any number of meanings. For example, one could argue the following are *multimedia*:

- A newspaper that incorporates images and text together
- Television that incorporates audio and video together
- Comics that incorporate text into pictures
- Web pages that include text, images, and links to other media

A visit to dictionary.com does not help clarify the situation:

- "The combined use of media, such as movies, music, lighting, CD-ROMs, and the Internet, as for education or entertainment." – American Heritage Dictionary
- "Transmission that combine media of communication (text and graphics and sound etc.)" – WordNet 2.0, Princeton University
- "Human-computer interaction involving text, graphics, voice and video. Often also includes concepts from hypertext." – The Free On-line Dictionary of Computing

Clearly, the definitions of multimedia are quite diversified including interaction, transmission, storage, hypertext, music, lighting, etc. Most definitions of multimedia generally have a common theme of images, text, audio, and video.

1.2 What is Multimedia Computing and Networking

Multimedia computing and networking is the field of computer science concerned with designing computing systems and networking systems to efficiently support multimedia applications. Alternatively, the term *multimedia systems* can also be used.

There are several reasons why multimedia is different than their plain-text counterparts such as e-mail. First, with multimedia data such as audio, images, and video, the amount of data generated by such applications compared to their textual counterparts is tremendous. Uncompressed video signals can easily saturate the computing and networking systems that handle the data. Second, multimedia data such as audio or video have a continuity requirement over time. Displaying multimedia with one to two second breaks intermittently spaced in the presentation of such data to the user can be extremely annoying and potentially

break the applications. Thus, careful attention needs to be paid in designing the systems such that the continuity of data presentation is preserved. Third, integrating multiple media such as audio and video, or multiple video streams, requires the system to support the synchronization of the various streams. If the video stream is displayed without the audio, or having the audio delayed several seconds, can lead to extremely poor user experience. Fourth, because multimedia data typically requires compression for scalability and resource reasons, the requirements for multimedia data tend to fluctuate over time. This can cause problems for systems that are attempting to adapt the resources for the multimedia application. Finally, for some multimedia applications such as video conferencing, very low latencies from capture, compression, transmission, decompression, and display are required. This means that all parts of the system need to be optimized and work together for the best user experience. For the purposes of this book, we will be focusing on the efficient handling of images, audio, and video because they have the largest resource demands when deployed.

1.2.1 Multimedia Computing

Multimedia computing focuses on the handling of multimedia within a single host computer. This encompasses a number of diverse topics including operating systems scheduling, file systems, display devices, and processing architectures. Several topics in these areas that we will focus on include:

- Operating systems scheduling mechanisms in order to ensure timely and continuous scheduling of multimedia data.
- File system mechanisms that support the timely and continuous retrieval of data from storage mechanisms
- Display device mechanisms and managing the multimedia to display interface efficiently
- Architectural considerations including instruction-level hardware support for multimedia

Operating systems have traditionally provided best-effort service, in that there are no guarantees to the application that any application will get the CPU at any given time or for any given amount. Traditional operating systems like UNIX use feedback based schedulers that bias towards interactive systems. Heavy computing tasks that remain in the system ultimately end up at the lowest priority. In order to ensure progress, however, these tasks are given the CPU for a longer period of time every now and then because they are compute bound. This can cause unintended effects for multimedia applications such as a DVD player.

File systems provide the store of information for computing systems. Retrieving data off of a disk surface typically takes tens of milliseconds. An application needing data by a certain deadline may have its data delayed by the retrieval of data for other applications. Thus, either an interruption in the display of the multimedia may follow or the data presented to the application late may be useless. Of course, this is not the only problem. For applications such as a video player, the data needs to be retrieved from the disk, decompressed into the displayable frame, and then displayed. This potentially requires the coordination of several entities.

As we will see in the later chapters, most modern computing hardware is focusing on providing 64-bit addresses and operands. Unfortunately, most multimedia applications work

with 8 or 16-bit values. Thus, the computation on multimedia data typically requires many computations with smaller numbers of bits. Clearly, computer architecture companies understand the trend of multimedia and have begun incorporating "multimedia" operations within their architectures. Intel's MMX technology is an example of one. MMX technology allows a number of 8-bit operations to be accomplished in parallel. Thus, four 8-bit values can be loaded into a single 32-bit register and can have four parallel operations occur at the same time.

1.2.2 Multimedia Networking

Multimedia networking focuses on the efficient transmission, recovery, and adaptation of streaming multimedia data. Several of the topic areas of focus will include:

- Reservation-based networking technologies
- Adaptive video-streaming techniques over best-effort networks
- The impact of network packet loss on video transmission
- Adaptive delivery techniques for audio and video for interactive video conferencing applications
- Adaptive buffering and transmission techniques for the delivery of stored video over networks
- Scalable video conferencing systems networking and hardware issues

For networks that support reservation-based bandwidth requirements, the streaming of multimedia data can be made easier. An example of a reservation-based network is the telephony network that allocates bandwidth in multiples of 64 kbps. Multimedia networking over reservation-based networks, while easier, still needs the streaming system to understand the reservation.

For best-effort networks, streaming of multimedia data for applications such as video playback or video conferencing applications require the application to adapt to the underlying network resources. Transport layer algorithms such as TCP ensure that the application is getting its fair share of network bandwidth. It does not, however, ensure the continuity of bandwidth nor guarantee any packet will arrive at the destination within a specified time. As a result, the multimedia networking application will have to be built so that it can *modify the video* to fit within the changing network resources.

1.3 Notable Events in Multimedia Computing and Networking

There are a number of major events that have shaped multimedia computing and networking as we know it today. We will primarily focus on the events that have directly affected digital multimedia. A brief timeline is shown below:

- 1940 – First color television broadcast. The ability to distribute audio and video becomes possible.
- 1963 – First home video tape recording. The ability to record television becomes possible.
- 1969 – Ted Nelson proposes "Hypertext". The notion of hyper text that links multiple types of data through links was proposed using a CRT with two documents and tape to "link" the documents together.

- 1974 – Kahn and Cerf propose TCP as a protocol to transfer information between heterogeneous clients. This ends up forming the basis of the Internet we have today.
- 1980 – Sony introduces consumer camcorder. The ability of common consumers to record and playback audio and video becomes possible.
- 1982 – CD-audio is introduced. Allows users to store digital audio and music onto a CD.
- 1983 – TCP/IP is the transport mechanism of the new "Internet"
- 1985 – CD-ROMs are introduced that hold digital information on a CD audio format.
- 1987 – Apple introduces Hypercard. The first authoring mechanism that allows users to link documents and build interlinking systems.
- 1987 – Compuserve introduces the graphics interchange format (GIF) for the storage and transmission of digital imaging data.
- 1989 – Tim Berners-Lee proposes World Wide Web based upon the HyperText Markup Language (HTML). The system uses the hypertext transfer protocol (HTTP).
- 1989 – MPEG (Motion Pictures Experts Group) standards group formed to develop a standard for the compression of VHS quality audio and video into a 1.5 Mbps stream.
- 1990 – The Joint Photographics Experts Group standardizes the JPEG image compression format
- 1990 – ITU standardizes the H.261 video telephony standard for the compression of video and audio for transmission across telephony networks.
- 1991 – MPEG-1 draft approved. Standardized a year later.
- 1993 – Mosaic web browser released by NCSA. Mosaic allows users to browse the information being distributed via the HTTP protocol in graphical format.
- 1994 – MPEG-2 standardized by the ISO for the compression of digital video and audio up to 20 Mbps. Forms the basis of DVD video format.
- 1995 - H.263 developed for video conferencing and mobile systems.
- 1995 – Real Networks distributes a "streaming" media player for the Internet.
- 1995 – NSFnet decommissioned, commercialization of the Internet begins
- 1995 – DVD video format unifies the optical storage standards under development. This avoids a repeat of the betamax and VHS video cassette problem a decade earlier.
- 1996 – RFC 1945 describes HTTP/1.0, the protocol that has been in use on the Internet for the previous 6 years.
- 1999 – Shawn Fanning develops original Napster application for sharing MP3 audio files. Start audio sharing / pirating phenomena
- 2001 – Apple introduces the iPod MP3 player, the first small-form digital audio player.
- 2003 – Wikipedia started
- 2003 - Skype started
- 2003 – Social networking becomes popular starting with MySpace
- 2004 – Multimedia enabled phones begin to be released.
- 2005 – Facebook is launched by several undergraduates from Harvard as a "local" social networking mechanism with controls
- 2006 – YouTube is started.
- 2007 - Netflix begins Internet streaming service - a primitive form at least

- 2007 – eBook readers start to come onto the market touting ability to read at very low-power. Many based upon e-Ink technologies.
- 2010 – Apple introduces the iPad portable device primarily for consuming multimedia information
- 2010 – Apple introduced FaceTime, Apple's entry into video communications
- 2011 – Skype acquired by Microsoft
- 2011 – Work at the World Wide Web Consortium (W3C) begins work on browser-based multimedia communications
- 2011 – Google starts beta testing Google Hangout, Google's entry into video communications

There are several observations one can make from this list of noteworthy events in multimedia computing and networking. First, digital multimedia has become more and more integrating into our daily lives. Smartphone are integrated with video capture and playback capabilities, allowing users to share over social networks such as Facebook. Devices for multimedia data are becoming much smaller allowing, for example, video sensor networks to be deployed over large regions. Second, with advances in networking technology, the ability to bring multimedia data to virtually anywhere will only aid in its ubiquity.

1.4 Summary

Multimedia computing and networking is an emerging area of computer science focused on the efficient systems and networking support for multimedia data, including audio, video, and 3D graphics. The main difference between multimedia systems processing and traditional systems include (i) the amount of data for multimedia tends to be much larger than traditional systems, (ii) multimedia processing requires continuity in presentation over time, meaning the systems that support them need to provide continued service to the application, (iii) the synchronization of multiple data elements is typically required (e.g. audio and video), and (iv) due the compression techniques typically employed for multimedia systems, the requirements for handling multimedia data tend to fluctuate over time, making it difficult to assign resources for. In the remainder of this book, we will explore the impact of multimedia on traditional operating systems and networking infrastructures.