AC 2009-1829: THE DEVELOPMENT OF A MULTIMEDIA NETWORKING COURSE FOR AN ELECTRICAL AND COMPUTER ENGINEERING TECHNOLOGY PROGRAM

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Development of a Multimedia Networking Course for Electrical and Computer Engineering Technology Program

1. Introduction

There is an explosive growth of multimedia data transmitted over the Internet recently. Multimedia data includes image, audio and video. Video-on-demand (VoD), videoconferencing, voice-over-IP (VoIP), Internet television (IPTV), video surveillance systems are some of the popular multimedia networking applications. For example, Netflix's [5] Watch Instantly is a video-on-demand service now available for its subscribers. People can watch the movies online instantly at home over the high-speed Internet connections using this service. YouTube [6] is a video sharing web site, where people can upload, browse and share the videos. Millions of people are now using Skype [4] to make phones calls and have video conferencing over the Internet. People can watch TV programs broadcasted over the Internet using a computer, for example, PPLive [8] is one of the successful deployments of IPTV over the Internet. Besides the traditional client/server architecture, peer-to-peer networking architecture becomes very popular in the Internet because of its scalability and efficient utilization of network bandwidth. BitTorrent [1], Skype and PPLive are popular applications built over peer-to-peer networking technology. With the fast advances of wireless network and mobile devices, people can use the cellular phone, PDA to access Internet, check email, and even watch video clips using 3G cellular networks or Wi-Fi.

Multimedia networking application is different from the traditional FTP file downloading. In a multimedia networking application, which is also called streaming media, the media is being played while being downloaded. On the contrary, in traditional FTP applications, the media starts playback after it is downloaded to the local computer. Multimedia networking application has its own Quality of Service (QoS) requirements, such as bandwidth, packet loss rate, delay and jitter. The transmission of the audio and video has a minimum requirement on the network bandwidth in order to provide a continuous playback. Streaming media is highly sensitive to end-to-end delay and delay jitter, but can tolerate a certain degree of packet loss. Most of the nonreal-time Internet applications, such as Web browsing, FTP, and email, prefer a high throughput and can not tolerate packet loss. The current Internet is known as a best effort network. IP protocol at the network layer delivers the packet as fast as it can, but can not guarantee the quality of service needed for the multimedia applications. The lack of QoS support and the heterogeneity of Internet make the transport of multimedia over the Internet a challenging task. How to provide QoS for multimedia transmission in current best-effort Internet has been an active research area in both academic and industry.

Consider the popularity and challenges of multimedia networking applications, it is of great importance to introduce multimedia networking course to enhance the curriculum. The Computer Engineering Technology program in our university has a strong curriculum in networking. A variety of courses on networking are offered in the department, which includes Data Communication and Networking, Local Area Network and Management, Wide Area Network Design, Wireless Networking, Mobile Computing, Sensor Network, and Network Security. However, multimedia networking has not been covered in the courses. In addition, a Master of

Science in Technology program was recently developed in our department. The advanced computing application is one of the tracks offered in this program. So development of a graduate course on multimedia networking is imperative to the curriculum of the Master program.

This course was first offered in Fall 2008 as a 3 credit hour course. It is offered as a senior required course for the undergraduate program and a graduate elective course for the Master of Science program. The topics selected in this course should help the students understand both the fundamentals of multimedia networking technologies and the current multimedia Internet applications. It should also prepare the student for the emerging new technologies and applications in the future.

The rest of the paper is organized as follows. The course development is presented in Section 2, including the course objectives, course contents and laboratory assignments. The student feedback and further improvement are discussed in Section 3. Section 4 concludes the paper.

2. Course Development

2.1 Course Objectives

This multimedia networking course is introduced at the graduate and senior undergraduate level, designed for the Master program in Engineering Technology.

The main objectives of this new course are:

- Understand the underlying principles of providing QoS for multimedia networking applications
- Know the fundamental lossless compression and lossy compression techniques
- Know the current image compression and video compression standards
- Know the basic technologies in designing adaptive multimedia applications
- Know the different protocols for multimedia transmission
- Write a simple Internet networking application using socket programming
- Know the current peer-to-peer multimedia networking applications
- Gain hands-on experiences on multimedia transmission technologies

To accomplish these objectives, the course is composed of lectures, homework, laboratory assignments, literature readings and course project. Hands-on laboratories are mainly designed to help students get familiar with the multimedia compression and transmission technologies.

Although there are many books about multimedia systems or computer networks, there is not a suitable book that satisfies the requirements of this course. Some books focus on the video processing and compression, or processing and retrieval of multimedia data. Some books focus on the networking technologies with only one chapter covering the multimedia transmission. Since the available books are not designed for our course which is provided for a Master program in Engineering Technology, there is no required textbook for this course. The materials covered in this course are selected from some reference books and recently published research papers in journals and conferences. The instructor designed the problem sets and lab assignments based on the research experiences in the multimedia networking.

Both the topics and the sequence to present the topics are important to the development of this new course. The materials should be self-contained, so graduate students from various backgrounds can easily follow the contents. Engineering technology program focuses on the application of knowledge, so the principles and theories should be presented under the context of a real application. Laboratory assignments are necessary to help the students understand the principles and concepts covered in the lectures.

The course starts with a review of the network technology and digital image representation, which prepares the necessary background knowledge for the students. Since multimedia data transmitted over the Internet are mostly in compressed formats, a number of data compression algorithms are presented, which are categorized into lossless compression and lossy compression. Based on these, the current standards for image and video compressions in industry are introduced, e.g., JPEG, MPEG and H.264. The provision of QoS is addressed first from the perspective of end-to-end applications. Various adaptation techniques at the sender and receiver of an end-to-end application are presented. Protocols used at the transport layer and application layer are introduced, so the students learn how to build a real end-to-end multimedia streaming application using those protocols. Since the end-to-end approaches alone can not guarantee the QoS, DiffServ and IntServ architectures were proposed, which treat the traffic differently and provide differentiated services at the Internet routers. Other existing technologies for multimedia delivery are presented, such as IP multicast, overlay networks, Content Delivery Network (CDN), peer-to-peer networks. Real applications of file, voice, and video transmission over peer-to-peer networks are introduced as case study. The last topic in this course addresses the multimedia transmission over wireless and mobile networks.

With a broad range of topics in multimedia networking covered in this course, a good organization and categorization of the techniques can facilitate the understanding. The provision of QoS for multimedia applications is addressed from several different perspectives, which presents a big picture of the current technologies to the students. In summary, the techniques to provide QoS are addressed from the following aspects,

- at different layers of the network model, including application layer, transport layer and network layer
- with different network architectures, including client-server and peer-to-peer
- at different locations of the network, including end host, proxy server and network router
- at different sides of an end-to-end application, including the client side and the server side
- at different communication networks, including wired network, and wireless and mobile network
- with different transmission schemes, including unicast, multicast and broadcast

2.2 Course Contents

The course consists of seven modules that cover the basic elements of networking and multimedia, compression of image and videos, adaptive transmission technologies, and current applications. The seven modules and lecture topics are listed below.

The first module is fundamentals of networking and multimedia. It consists of two parts, and provides the basic knowledge for networking and multimedia. The first part gives an introductory review of the Internet architecture. It discussed the layered network design and protocols at each layer, which leads to the fundamental problem for multimedia transmission. How can we provide QoS for multimedia transmission under the current best-effort Internet infrastructure? The advantages and disadvantages of two available transport layer protocols, TCP and UDP, are then investigated. The second part covers the representation of image in the computer and different color spaces.

The second module discusses the lossless compression and lossy compression algorithms. First, basic concepts of information theory are introduced to enhance the understanding of compression ratios. For the lossless compression, several entropy coding methods are covered, including run-length encoding, Shannon algorithm, Huffman coding, dictionary-based coding (LZW), and arithmetic coding. Lossy compression covers topics such as rate-distortion theory, quantization and transform coding. Discrete Cosine Transform (DCT) is illustrated as an example of transform coding method since it is widely used in image compression.

The third module presents the current image and video compression standards. The steps in JPEG image compression are illustrated in details since JPEG is a widely used image format in the current Internet. Common techniques used in video compression are discussed, including intra-frame coding, inter-frame coding, motion estimation and motion compensation. Then the current video compression standards in industry and their applications are discussed, e.g., MPEG2, MPEG4 and H.264.

The fourth module addresses the adaptation transmission technologies from the end-to-end perspective. That is, how a server/client multimedia application running on an end system can adapt the transmission to the network situation. A variety of adaptation techniques implemented at end systems are discussed, such as congestion control, rate control, adaptive encoding, Forward Error Correction (FEC), automatic repeat request (ARQ), and adaptive playback. After the discussion of the techniques at the application layer, the topics move to the protocols at the transport layer. Protocols suitable for multimedia transmission are examined, including Real-time Protocol (RTP), RTP Control Protocol (RTCP), Real-time Streaming Protocol (RTSP), and Session Initiation Protocol (SIP). Socket programming is the basis to build a client/server networking application, so it is included to teach the students how to write a real video streaming application. After the completion of this module, the students have an in depth understanding about how to build an end-to-end streaming application that is adaptive to the network conditions to provide QoS.

The fifth module presents researches on QoS provision with the network support. Traffic from different applications, such as data, voice and video, can be treated with different priorities at the

router, so differentiated service can be provided for the applications. To regulate the incoming and outgoing traffic of the Internet, traffic packet scheduling and traffic policing techniques are adopted at the edge routers. In this module, the DiffServ and IntServ architectures are discussed as the possible solutions to provide differentiated services.

The sixth module covers the current peer-to-peer multimedia applications. The first part discusses available networking architectures for multimedia transmission, including traditional client/server architecture, multicast, Content Delivery Network, and peer-to-peer networking. The characteristics and performance of peer-to-peer networks are examined. The second part introduces several popular applications based on peer-to-peer networks, including file distribution, voice and video transmission. It starts with the file-sharing application using BitTorrent as an example. Skype is discussed as an example of peer-to-peer VoIP application, and PPlive is introduced as an example of Internet video broadcasting application. With the focuses on the design, operation, and performances of these applications, the students can understand the design issues of a peer-to-peer multimedia application.

The seventh module discusses the multimedia transmission over wireless and mobile networks. Multimedia transmission over two wireless networks with different coverage areas is presented. The IEEE 802.16 WiMax is the new standard for broadband Metropolitan Area Network wireless networking access. The characteristics of WiMax and the QoS support in WiMax are discussed. Research issues, existing solutions, and current technologies of wireless multimedia sensor networks are also addressed in this module.

2.3 Lab Assignments

Hands-on laboratory assignments are provided to enhance the understanding of the concepts and theories covered in the lectures. Labs are designed to provide the students with hands-on experiences on image and video compression and transmission. A variety of software is required for the assignment, e.g., MATLAB, H.264, Wireshark [3]. A brief introduction of the laboratory assignments is given below.

- Laboratory 1. MATLAB preparation. The lab is designed to help the students get familiar with MATLAB environment and write programs using MATLAB.

- Laboratory 2. Basic image representation. Students use MATLAB to study the characteristics of digital images. Different image representations and color space are covered, which help the students to understand the basics of image operations.

- Laboratory 3. Entropy encoding methods. MATLAB implementations of several lossless encoding algorithms are studied. The students test on the efficiency of run-length encoding, Huffman coding, arithmetic coding, and dictionary-based coding. This lab enhances the understanding of different coding algorithms and the compression ratios they can achieve.

- Laboratory 4. JPEG compression. The students are required to work on the MATLAB implementations of JPEG algorithms and test the quality of the JPEG image under different

compression ratios and other parameters. The lab is designed to help the students understand the components of JPEG algorithm including lossless compression and DCT transformation.

- Laboratory 5. H.264 video compression codec. Open source H.264/AVC JM reference software [2] is used as the video codec. The students compile the video codec under Visual C++ environment and test different compression schemes. Students are required to use raw video sequences to generate compressed video streams of different bit rates suitable for different network environments. The lab is designed to help the students understand the importance of different frames in a group of picture. It explains how the loss of packets in each frame affects the quality of decoded video frames.

- Laboratory 6: Use free software Wireshark to study the protocols used in the real Internet video streaming websites. Students are required to use Wireshark to capture and analyze the traffic generated by the streaming application in the Internet. It helps them understand the design of web servers and streaming servers and the protocols used in the applications.

- Laboratory 7. Build a multimedia transmission application using Java programming language. The lab focuses on writing a real end-to-end video streaming application over the Internet using socket programming. The students learn about how to generate the data packet, control information, header of a packet, and payload of a packet. They can test different adaptive streaming technologies based on the feedback information collected at the client. It enhances the understanding of the protocol design of RTP, RTSP and RTCP. Using this program as a prototype, the students should be able to build a working video streaming system with more advanced functionalities after the completion of this lab.

3. Student Feedback

The effectiveness of the new course is assessed in various ways, including tests, homework, lab work, and course project. The feedback from the students is summarized as below.

- They are interested in the video compression codec introduced in the class.
- They are interested in the real applications such as Skype, BitTorrent.
- They are interested in the current technology used in the Internet to deliver multimedia data, such as peer-to-peer network, Content Delivery Networks, and so on.
- They like the sequence of the topics introduced in this course.
- Hands-on lab assignments are very helpful.

The overall feedback indicates the satisfaction to this course. In general, the students are interested in the topics covered, especially new technology and real Internet applications. Based on the feedback from the students, some modifications of the course materials will be made in the future. Coverage of lossless compression can be reduced since they are too theoretic, so only compression methods used directly in image or video compression need to be covered. New lab assignments need to be designed to provide more hands-on practice. For example, the students should be able to work on a multimedia networking system in real Internet. In addition, case study about the multimedia applications in different areas can be introduced, such as video

surveillance system, video conferencing. The students can learn more about the design issues and performance requirements of a streaming system.

4. Conclusion

With the increasing multimedia data transmitted over the Internet, it is important to introduce the multimedia networking technologies into the Electrical and Computer Engineering Technology curriculum. The paper gives a description of a newly developed graduate course on multimedia networking and applications designed for Master of Science program in Engineering Technology. The course covers a broad range of techniques to provide QoS for multimedia networking applications under the best-effort Internet. Feedback from the students shows that this is an interesting course. The students learn about the update-to-date developments, technologies and applications in multimedia networking.

References

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