D32.3 Technical Report # 3

on

Transport Methods for 3DTV

Project Number: 511568
Project Acronym: 3DTV
Title: Integrated Three-Dimensional Television – Capture, Transmission and Display

Deliverable Nature: R
Number: D32.3
Contractual Date of Delivery: M45
Actual Date of Delivery: M48
Report Date: 8 August 2008
Task: WP10
Dissemination level: CO
Start Date of Project: 01 September 2004
Duration: 48 months
Organisation name of lead contractor for this deliverable: KU

Name of responsible: A. Murat Tekalp (mtekalp@ku.edu.tr)
Editor: A. Murat Tekalp (mtekalp@ku.edu.tr)

8 August 2008

TC3 WP10 Technical Report 3

EDITOR

A. Murat Tekalp (**KU**)

Contributing Partners to the Technical Report:

Bilkent University (**Bilkent**)
Informatics & Telematics Institute, Centre for Research & Technology Hellas (**ITI-CERTH**)
Koç University (**KU**)
Middle East Technical University (**METU**)
Technical University of Berlin (**TUB**)
Tampere University of Technology (**TUT**)

REVIEWER

Gozde Bozdagi Akar **(METU)**

Project Number: 511568
Project Acronym: 3DTV

Title: Integrated Three-Dimensional Television – Capture, Transmission and Display

TABLE OF CONTENTS

Executive Summary

This report summarizes the joint research performed in EC IST 3DTV Network of Excellence (NoE) under Work Package 10 (WP10), entitled *Transport Methods for 3DTV*, during Year-III of the project. The reported work consists of 14 novel research papers, out of which 7 are achieved as a result of joint research activities between WP10 contributors. In year III, main research efforts have been focused on delivery (streaming) of 3DTV over the Internet Protocol (IP). In addition, preliminary studies on the capabilities of DVB-H to broadcast stereo-video streams have been carried out. This report first provides a brief analysis of the related state-of-the art in Section 1; then, it examines our research activities in Section 2 under the subtopics of streaming with congestion control, robust streaming, selective streaming, peer-to-peer streaming, end-to-end streaming systems, and wireless applications.

Since 3D video/TV delivery over IP requires transporting large volumes of data over the Internet, **congestion control** becomes an important consideration for more efficient and fair streaming. Commonly used current transport protocols are TCP and UDP. TCP features built-in congestion control, but is not very suitable for real-time multimedia streaming. UDP is better suited for real-time multimedia streaming, but does not have congestion control. Most firewalls do not allow UDP traffic, since it is connectionless and can cause flooding. Recently, a new protocol, DCCP, has been introduced which can strike a balance between real-time requirements and congestion control. Among the congestion control options, DCCP features a TCP-friendly rate control (TFRC) mechanism, which the senders should respect. Section 2.1.1 discusses use of DCCP for stereo-video streaming, while Section 2.1.2 discusses modifications needed in the DCCP protocol for efficient use of DCCP over networks with wireless links.

Packet losses are inevitable over the Internet. **Robust streaming** refers to methods that would reduce the effect of lost packets on the received video quality. These methods include packet-level forward-error correction in the application layer and repeat requests within time-limits allowed by the receiver buffer size and maximum tolerable viewing delay. Application layer packet loss protection is a promising option for error-resilient and flexible distribution. Rateless coding is one of recent techniques that is highly suitable for this purpose. In this context, rate-distortion optimized error protection techniques and use of flexible macro block ordering for 3DTV streaming that use rateless codes have been investigated in Section 2.2.

Streaming methods for 3DTV delivery may be optimized according to the requirements of the 3D display at the receiving peer. Head-tracking stereoscopic displays may inform the sending peer which views are needed (out of many at the sender) depending on the detected gaze angle of the viewer. **Selective streaming** refers to such methods, where the receiving peer requests only selected views (which may vary in time) from the sending peer. This approach is investigated in Section 2.3.

When the same video shall be distributed to many receiving peers, collaboration between the peers may significantly enhance the overall network performance. **Peer-to-peer (P2P) streaming** refers to methods where each peer allocates some of its resources to forward received streams to other peers; hence, each receiving peer acts partly as a sending peer. P2P streaming methods for 3DTV delivery have been investigated in Section 2.4.

It is desirable that **end-to-end 3D streaming system**s conform to open standards, such as the MPEG and IETF standards. In Section 2.5, we describe an open-standards based end-to-end

3DTV streaming system using server-client architecture, which is developed as a result of collaborative work in WP10; furthermore, we discuss the modifications required to the current SDP and RTP payload format to support various 3D video representations. This end-to-end 3DTV streaming platform has been demonstrated in several high-profile events, such as the IBC Amsterdam in September 2007.

DVB-H has been considered for **wireless broadcast** of media, including the 3DTV, to mobile users. The standard has been a very successful development from the initial idea through comprehensive research and development to commercial services. Its use for broadcasting 3D video is addressed in Section 2.6 both at level of system design and preliminary experiments on optimal error correction rates.

Two comprehensive **survey papers and a book chapter** on transport methods for 3DTV, presenting promising results of research collaboration between contributors of WP10 as well as other related research, are covered in Section 2.7. Several theses works under the scope of WP10 are also listed in Section 2.7. The joint research will continue in the future along the directions presented in Section 3, in order to further develop new and better methods for distribution of 3DTV over the Internet.

1. Introduction and Analysis of the State of the Art

This technical report summarizes continuation of our research efforts towards developing flexible, scalable and robust 3DTV transport technologies. The report starts with an introduction and a brief analysis of the state of the art in this Section. Section 2 presents abstracts of our publications in Year III. Future research directions are discussed in Section 3. Complete manuscripts of the publications presented in Section 2 are given in the Appendix.

The Internet Protocol (IP) architecture is very flexible in accommodating a wide scope of communication applications ranging from voice over IP to video over IP services. Transmission of video over IP is currently an active research and development area where significant results have already been achieved. There are already many video-on-demand and IPTV services offered over the Internet. Also, 2.5G and 3G mobile network operators started to use IP successfully to offer wireless video and IPTV services. The next big step forward is destined to be flexible distribution of a variety of 3D video and 3DTV services over IP networks.

Various 3D displays require different data representations. Even for the same display technology, different data representations may be required depending on whether the video is synthetically generated or how it is acquired. Hence, it is difficult to converge on a universal common 3D data format for all 3DTV applications. The best transport technology or streaming method varies according to video source and display technology used. IP networks provide the best means for flexible transport of 3DTV to allow for multiple 3D data representations and streaming technologies.

Review of the State of the Art

The state of the art in transport of 3DTV signals is reviewed in 2 recent articles by contributors to WP10 (see Section 2.6.1 and 2.6.2). Recent review of state of the art by others can be found in [1]. We know four groups outside the NoE who work on this same problem:

Mitsubishi Electric Research Laboratories (MERL) http://www.merl.com/projects/3dtv/

MERL group is one of the earliest who published an article on end-to-end 3DTV streaming system [2]. However, their streaming system is quite elementary.

Electronics and Telecommunications Research Institute (ETRI) – Korea

ETRI has concentrated on HDTV compatible 3DTV [3] and development of 3D video services over T-DMB [4]. They have a demo, including transmitter, receiver connected to Sony UMPC, equipped with parallax barrier stereoscopic display. Their system employs MVC coding of two-channel (stereoscopic) video, and direct encapsulation within T-DMB with no special error resilience scheme. In addition, their system support 3D data object transmission (using MPEG-4 BIPS) combined with 3D video for advertising applications.

Video Coding and Architectures (VCA) group at the Eindhoven University of Technology:

VCA group has proposed a streaming architecture for 3D-IPTV. They have designed and implemented of a stereoscopic and multiple-perspective video streaming system [5]. This work is also elementary.

Recently, researchers have also started working on P2P streaming for 3DTV transport [6][7]. Standardization of 3DTV specific issues in IETF has been considered in [8].

There are three related FP7 projects that are known to us. Research towards delivery of 3DTV over DVB-H system is addressed in the FP7 MOBILE3DTV project [9]. The project aims at developing the optimal representation and coding formats for stereo video and its robust transmission over DVB-H utilizing novel, stereo-video dedicated, UEP schemes. 3DTV broadcast solutions are studies in the 3D4YOU project [10]. It favors the "video+depth" representation format as the most broadcast-friendly one and aims at developing format conversion tools and carrying out broadcast demonstrations. P2P-Next [11] project addresses standard (2D) IPTV over P2P networks.

Finally, first commercial 3DTV broadcast over cable has been very recently reported in http://www.cnn.com/2008/TECH/biztech/06/19/hyundaitv.ap/index.html

Organization and Analysis of Joint Research in WP10

We organize the joint research activities in 3DTV over IP under the subtopics of streaming with congestion control, robust streaming, selective streaming, peer-to-peer streaming, end-to-end streaming systems, and wireless applications. The research conducted in WP10 on streaming with congestion control, selective streaming and adaptation to DVB-H is groundbreaking with no previous literature available, whereas research in robust streaming and P2P streaming is incremental over the existing state of the art.

Since 3D video/TV delivery over IP requires transporting large volumes of data over the Internet, **congestion control** becomes an important consideration for reliable and fair streaming. Commonly used current transport protocols are TCP and UDP. TCP features built-in congestion control, but is not very suitable for real-time multimedia streaming. UDP is better suited for real-time multimedia streaming, but does not have congestion control. As a result, most firewalls do not allow UDP traffic, since it can cause flooding. Recently, a new protocol, DCCP, has been introduced which can strike a balance between real-time requirements and congestion control. Specifically, DCCP features a TCP-friendly rate control (TFRC) mechanism, which the senders should respect. Section 2.1.1 discusses use of DCCP for stereo-video streaming, while Section 2.1.2 discusses modifications needed in the DCCP protocol for efficient use of DCCP over networks with wireless links.

Packet losses are inevitable over the Internet. **Robust streaming** refers to methods that would reduce the effect of lost packets on the received video quality. These methods include packet-level forward-error correction in the application layer and repeat requests within time-limits allowed by the receiver buffer size and maximum tolerable viewing delay. Application layer packet loss protection is a promising option for error-resilient and flexible distribution. Rateless coding is one of recent techniques that is highly suitable for this purpose. In this context, rate-distortion optimized error protection techniques and use of flexible macro block ordering for 3DTV streaming that use rateless codes have been investigated in Section 2.2.

Streaming methods for 3DTV delivery may be optimized according to the requirements of the 3D display at the receiving peer. Head-tracking stereoscopic displays may inform the sending peer which views are needed (out of many at the sender) depending on the detected gaze angle of the viewer. **Selective streaming** refers to such methods, where the receiving peer requests only selected views (which may vary in time) from the sending peer. This approach is investigated in Section 2.3.

When the same video shall be distributed to many receiving peers, collaboration between the peers may significantly enhance the overall network performance. **Peer-to-peer (P2P) streaming** refers to methods where each peer allocates some of its resources to forward received streams to other peers; hence, each receiving peer acts partly as a sending peer. P2P streaming methods for 3DTV delivery have been investigated in Section 2.4.

It is desirable that **end-to-end 3D streaming system**s conform to open standards, such as the MPEG and IETF standards. In Section 2.5, we describe an open-standards based end-to-end 3DTV streaming system using server-client architecture, which is developed as a result of collaborative work in WP10; furthermore, we discuss the modifications required to the current SDP and RTP payload format to support various 3D video representations. This end-to-end 3DTV streaming platform has been demonstrated in several high-profile events, such as the IBC Amsterdam in September 2007.

A key feature of DVB-H as a **wireless broadcast** standard is its flexibility. It is not just a tiny TV channel but rather general and powerful data broadcast technology, ensuring also robust transmission through its multi-protocol encapsulation and forward error correction (MPE-FEC) scheme. So far, DVB-H has been extensively studied for its capability to provide error protection proportional to the importance of the content to be transmitted (i.e., unequal error protection - UEP). Software packages simulating the link and physical layers have been developed in parallel to the existing fully-functional channel test-bed. First studies on the optimal error correction rates have been carried out. These are described in Section 2.6.

2. Abstracts of Publications for Year-III

2.1. Streaming with Congestion Control

2.1.1. Adaptive Streaming of Scalable Stereo Video over DCCP

Authors: N. Ozbek, B. Gorkemli, A. M. Tekalp and E. T. Tunali

Institutions: Koc University and Ege University

Publication: Proc ICIP 2007, IEEE International Conference on Image Processing, San Antonio, TX, USA, September 2007.

We propose a new adaptive streaming model that utilizes DCCP in order to efficiently stream stereoscopic video over the Internet for 3DTV transport. The model allocates the available channel bandwidth, which is calculated by the DCCP, among the views according to the suppression theory of human vision. The video rate is adapted to the DCCP rate for each group of pictures (GoP) by adaptive extraction of layers from a scalable multi-view bitstream. The objective of the streaming model is to maximize perceived quality of the received 3D video while minimizing the number of possible display interrupts. Experimental results successfully demonstrate stereo video streaming over DCCP on wide area network.

2.1.2. Video Streaming over Wireless DCCP

Authors: B. Gorkemli, M. O. Sunay, and A. M. Tekalp

Institutions: Koç University

Publication: Proc ICIP 2008, IEEE International Conference on Image Processing, San Diego, CA, USA, September 2008.

It is envisioned that access networks will be mostly wireless in the future. Hence, it is of interest to consider extensions of the Datagram Congestion Control Protocol (DCCP) for wireless networks. This paper focuses on the problems of video streaming over DCCP in the wireless domain and proposes a cross-layer solution in which the wireless packet loss information available in the Medium Access (MAC) layer is utilized by DCCP to distinguish congestion losses from wireless losses and behave accordingly. Tests performed with our modified DCCP confirm that using cross-layer loss information prevents unnecessary rate decreases and results in better video streaming experiences.

2.2. Robust Streaming

2.2.1. Rate-Distortion Optimization for Stereoscopic Video Streaming with Unequal Error Protection

Authors: A. Serdar Tan, A. Aksay, G. Akar, E. Arikan

Institutions: Bilkent University, Middle East Technical University

Publication: to appear EURASIP Journal on Advances in Signal Processing Special Issue 3DTV: Capture, Transmission and Display of 3D Video.

We consider an error resilient stereoscopic streaming system that uses a H.264-based multi-view video codec and a rateless Raptor code for recovery from packet losses. One aim of the present work is to suggest a heuristic methodology for modeling the end-to-end rate-distortion (RD) characteristic of such a system. Another aim is to show how to make use of such a model to optimally select the parameters of the video codec and the Raptor code to minimize the overall distortion. Specifically, the proposed system models the RD curve of video encoder and performance of channel codec to jointly derive the optimal encoder bit rates and unequal error protection (UEP) rates specific to the layered stereoscopic video streaming. We define analytical RD curve modeling for each layer that includes the inter-dependency of these layers. A heuristic analytical model of the performance of Raptor codes is also defined. Furthermore, the distortion on the stereoscopic video quality caused by packet losses is estimated. Finally, analytical models and estimated single packet loss distortions are used to minimize the end-to-end distortion and obtain optimal encoder bit rates and UEP rates. The simulation results clearly demonstrate the significant quality gain against the non-optimized schemes.

2.2.2. Rate-Distortion Optimized Layered Stereoscopic Video Streaming with Raptor Codes

Authors: A. Serdar Tan, A. Aksay, C. Bilen, G. Akar, E. Arikan

Institutions: Bilkent University, Middle East Technical University

Publication: PV'07, Lausanne, Switzerland, Nov. 2007

A near optimal streaming system for stereoscopic video is proposed. Initially, the stereoscopic video is separated into three layers and the approximate analytical model of the Rate-Distortion (RD) curve of each layer is calculated from sufficient number of rate and distortion samples. The analytical modeling includes the interdependency of the defined layers. Then, the analytical models are used to derive the optimal source encoding rates for a given channel bandwidth. The distortion in the quality of the stereoscopic video that is caused by losing a NAL unit from the defined layers is estimated to minimize the average distortion of a single NAL unit loss. The minimization is performed over protection rates allocated to each layer. Raptor codes are utilized as the error protection scheme due to their novelty and suitability in video transmission. The layers are protected unequally using Raptor codes according to the parity ratios allocated to the layers. Comparison of the defined scheme with two other protection allocation schemes is provided via simulations to observe the quality of stereoscopic video.

2.2.3. Robust Transmission of Multi-view Video Streams using Flexible Macroblock Ordering

Authors: S. Argyropoulos, A. S. Tan, N. Thomos, E. Arikan, and M. G. Strintzis

Institutions: CERTH/ITI and *Bilkent University*

Publication: Proc. 3DTV International Conference: True-Vision, Capture, Transmission, and Display of 3D Video (3DTV-CON), 2007.

The transmission of fully compatible H.264/AVC multi-view video coded streams over packet erasure networks is examined. Macroblock classification into unequally important slice groups is considered using the Flexible Macroblock Ordering (FMO) tool of H.264/AVC. Systematic LT codes are used for error protection due to their low complexity and advanced performance. The optimal slice grouping and channel rate allocation are jointly determined by an iterative optimization algorithm based on dynamic programming. The experimental evaluation clearly demonstrates the validity of the proposed method.

2.3. Client-Driven Selective Streaming of Multi-View Video for Interactive 3DTV

Authors: E. Kurutepe, M. R. Civanlar, and A. M. Tekalp

Institutions: Koç University, Technical University of Berlin

Publication: IEEE Trans. on Circuits and Systems for Video Technology, vol. 17, no 11, Nov. 2007, pp. 1558-1565

We present a novel client-driven multi-view video streaming system that allows a user watch 3-D video interactively with significantly reduced bandwidth requirements by transmitting a small number of views selected according to his/her head position. The user's head position is tracked and predicted into the future to select the views that best match the user's current viewing angle dynamically. Prediction of future head positions is needed so that views matching the predicted head positions can be prefetched in order to account for delays due to network transport and stream switching. The system allocates more bandwidth to the selected views in order to render the current viewing angle. Highly compressed, lower quality versions of some other views are also prefetched for concealment if the current user viewpoint differs from the predicted viewpoint. An objective measure based on the abruptness of the head movements and delays in the system is introduced to determine the number of additional lower quality views to be prefetched. The proposed system makes use of multi-view coding (MVC) and scalable video coding (SVC) concepts together to obtain improved compression efficiency while providing flexibility in bandwidth allocation to the selected views. Rate-distortion performance of the proposed system is demonstrated under different experimental conditions.

2.4. Peer-to-Peer Streaming

2.4.1. Feasibility of Multi-View Video Streaming over P2P Networks

Authors: E. Kurutepe and T. Sikora

Institution: Technical University of Berlin

Publication: Proceedings of the IEEE 3DTV-CONFERENCE: Capture, Transmission and Display of 3D Video, Istanbul, Turkey, May 2008.

We propose to stream multi-view video over a multi-tree peer-to-peer (P2P) network using the NUEPMuT protocol. Each view of the multi-view video is streamed over an independent P2P streaming tree and each peer only contributes upload capacity in a single tree, in order to limit the adverse effects of ungraceful peer departures. Additionally, we investigate the feasibility of using the proposed P2P networking architecture, NUEPMuT, for the streaming of multi-view video content with the currently available Internet connection bandwidths.

2.4.2. Multi-view Video Streaming over P2P Networks with Low Start-up Delay

Authors: E. Kurutepe and T. Sikora

Institutions: Technical University of Berlin

Publication: submitted to IEEE Int. Conf. on Image Processing, 2008

We propose to stream multi-view video over a multi-tree peer-to-peer (P2P) network using the NUEPMuT protocol. Each view of the multi-view video is streamed over an independent P2P streaming tree and each peer only contributes upload capacity in a single tree, in order to limit the adverse effects of ungraceful peer departures. Additionally, we introduce a quick join procedure to reduce the start-up delay for the first data packet after a join request. Continuity index and decoded video quality performance in a large topology under different settings are reported, in addition to the improvements achieved by quick join.

2.5 A Standards-Based, Flexible, End-to-End Multi-View Video Streaming Architecture

Authors: E. Kurutepe, A. Aksay, C. Bilen, C. G. Gurler, T. Sikora, G. Bozdagi Akar, and A. M. Tekalp

Institution: Technical University of Berlin, Middle East Technical University, Koç University

Publication: Packet Video Workshop 2007, Lausanne, Switzerland

In this paper we propose a novel framework for the streaming of 3-D representations in the form of Multi-View Videos (MVV). The proposed streaming system is completely standards based, flexible and backwards compatible in order to support monoscopic streaming to legacy clients. We demonstrate compatibility of the proposed system with various possible encoding schemes and operating scenarios. In the current implementation, the MVV's in the server are compressed using a simplified form of MVC with negligible loss of compression efficiency and streamed using Real Time Streaming Protocol (RTSP), Session Description Protocol (SDP) and Real Time Protocol (RTP) to the clients. We describe our extensions to SDP and discuss a preliminary RTP payload format for MVC. The clients in this implementation perform basic error concealment to reduce the effects of packet losses and decode MVC in near-real-time. The modular clients can display decoded 3-D content on a multitude of 3-D display systems.

2.6. 3DTV over DVB-H

2.6.1. Delivery of 3D Video over DVB-H: Building the Channel

Authors: M. Oksanen, A. Tikanmäki, A. Gotchev, I. Defee

Institution: Tampere University of Technology

Publication: Submitted to NEM Summit, Saint Malo, Frances, October 2008.

In this contribution, the channel issues of 3D video delivery over DVB-H channel are addressed. The full-scale DVB-H broadcast channel set in Tampere University of Technology is described. In addition, an experimental DVB-H software environment has been built to run extensive channel simulations using 3D video content. Simulation results are compared with experiments in the real broadcast environment. The paper summarizes the plan and goals for the simulations and real life experiments. Especially, 3D specific issues related to DVB-H delivery are evaluated.

2.6.2. Source/Channel Rate Allocation in DVB-H Transmissions

Authors: A. Tikanmäki and A. Gotchev

Institutions: Tampere University of Technology

Publication: Internal report, submitted to the Workshop on Information Theoretic Methods in Science and Engineering (WITMSE), Tampere, Finland, August 2008.

This report summarizes our experimental studies on how the visual quality of H.264 coded video depends on the link-layer MPE-FEC encapsulation mechanism of DVB-H. We aimed at finding an optimal ration between the bit rates allocated for the video stream and the MPE-FEC forward error correction data. In the experiments, we fixed the total bit rate for source and channel coding data, simulated the encoding and transmission process of the video with different combinations of FEC code rate and video bit rate, and then measured the quality of received video. The erroneous transmission channel was simulated on IP packet level by using pre-computed error traces that were generated by simulating the physical channel with the 6-tap Typical Urban channel model. Video quality was estimated using PSNR and a perceptually more accurate metric, VSSIM. The simulation results show that depending on complexity of the test sequence and channel SNR, the best quality of delivered video is achieved using MPE-FEC code rates between 1/2 and 3/4.

2.7. Overview Papers and Other Research Outputs

2.7.1. Transport Methods for 3DTV – A Survey

Authors: G. Bozdagi-Akar, A. M. Tekalp, C. Fehn, and R. Civanlar

Institutions: Middle East Technical University, Koç University, Bilkent University, Fraunhofer Institute for Telecommunications-Heinrich-Hertz-Institute

Publication: IEEE Trans. on Circuits and Systems for Video Technology, Special Issue on Multi-view Video Coding and 3DTV, vol. 17, no. 11, pp. 1622-1630, November 2007.

Three dimensional (3D) movies have quite a long history. However, technologies needed for successful deployment of 3D television (3DTV) systems are becoming available only recently. This survey outlines previous attempts to transport 3D video signals, and technologies that may be useful in designing 3DTV systems of tomorrow. Current approaches for digital broadcast and streaming over the Internet are discussed in more detail, including the 3D video representations and encoding methods; rate adaptation/error correction methods and transport protocols. Streaming over the Internet provides a flexible architecture to support different display technologies, visual data representations, and encoding options, as well as different transport protocols for unicast and multicast 3DTV distribution. Some exemplary digital 3DTV broadcast and streaming system demonstrations are also reviewed. This survey is intended as a starting reference for 3DTV transport researchers.

2.7.2. 3DTV over IP

Authors: A. M. Tekalp, E. Kurutepe and R. Civanlar

Institutions: Koç University, Technical University of Berlin, DoCoMo Labs USA

Publication: IEEE Signal Processing Magazine, vol. 24, no 6, Nov. 2007, pp. 77-87

We provide a tutorial overview of end-to-end streaming of multi-view video over the Internet Protocol (IP) for various 3D display clients. We start with a brief overview of different 3D video representations and their associated compression methods, followed by a discussion of generic streaming architectures and protocols for on-demand server- client and broadcast/multicast 3D video/TV applications. We then present three specific multi-view video streaming system architectures: first, a classic end-to-end server-client unicast system for stereo or multi-view display clients; second, an interactive view-selective unicast server for a single-user head- tracking display client; and third, generic cooperative streaming architectures for multi-view video distribution. Finally, packet-loss resilient multi-view video streaming and error concealment at the clients are introduced.

2.7.3. Efficient Transport of 3DTV

Author: A. M. Tekalp and R. Civanlar

Institution: Koç University

Publication: In Three-Dimensional Television – Capture, Transmission, Display, (Chapter 6), Edited by H. M. Özaktaş and L. Onural, Springer, 2007.

The Internet Protocol (IP) architecture is very flexible in accommodating a wide range of communication applications ranging from the ongoing replacement of classical telephone services by voice over IP applications to new video over IP services. There are already video-on-demand services, both for news and entertainment applications, offered over the Internet. Also, 2.5G and 3G mobile network operators started to use IP successfully to offer wireless video services. Flexible transport of a variety of 3DTV representations over IP networks seems to be a natural extension of monoscopic video over IP applications. This chapter starts with a brief overview of 3D/multi-view video representations and encoding in Section 2. Section 3 discusses transmission of encoded “video-plus-depth” data over the MPEG-2 transport stream for broadcast applications. Unicast and multicast streaming of multi-view encoded representations over IP are discussed in Section 4. A block-diagram of a complete framework for end-to-end unicast transport over IP is shown in Figure 2. This framework includes several options for video representation, encoder/decoder, streaming protocols, rate scaling and allocation strategies, error control and concealment schemes, and client support for various 3D displays. We present a stereo video unicast test-bed, including a server and multiple clients, for demonstration of the concept in Section 5. Conclusions and future research directions are discussed in Section 6.

2.7.4. Theses

The following theses are completed or expected to be completed before 1 September 2007:

1) Burak Gorkemli, Adaptive Video Streaming over DCCP, Ph.D. Thesis, Koç University, December 2008.

2) Göktuğ Gürler, An open-standards based server-client model for robust streaming of 3DTV over the Internet, M.S. Thesis, Koç University, July 2008.

3) Berkin Abanoz, Optimization of Scalable Multiple Description Coding for Monocular and Multi-View Video over IP, MS Thesis, Koç University, July 2008.

4) Antti Tikanmäki, Video Quality Evaluation for Mobile and Three Dimensional Television, M.S. Thesis, Tampere University of Technology, September 2008.

2.7.5. Demonstrations

Extensive demonstrations of our end-to-end streaming platform with several 3D display clients have been conducted in the following events:

1) IBC Amsterdam (September 2007)

2) EC-ICT E2 Day Luxembourg (12-13 Dec 2007)

3. Conclusions and Roadmap

In Year-III, WP10 activities have been focusing on new research on robust transport of 3DTV over IP with congestion control and over DVB-H, as well as further development of our streaming demo platform based on open IETF and MPEG standards. As these are currently hot topics for research, we will continue to focus on these same directions in the near future.

New research will focus on i) improving packet loss control and error concealment in streaming 3DTV, ii) streaming with congestion control using TFRC, iii) multiple QoS support in 3DTV streaming using TFRC, iv) cross-layer optimization of transport protocols for 3DTV over wireless links for better end-to-end quality, v) cooperative streaming protocols, such as P2P streaming, for 3DTV transport, vi) optimization of streaming for other 3D video representations and 3D displays, vii) evaluation of end-user quality of experience for 3DTV services. Research towards delivery of 3DTV over DVB-H system will continue under the FP7 MOBILE3DTV project [9]. Specifically, new UEP scheme, especially designed or stereo video is targeted. Other related projects are 3D4YOU [10] and P2P-Next [11].

Further development and optimization of the 3DTV streaming demo platform will include: i) full compliance with the MPEG MVC standard, while real-time decoding using slice-mode and packet-based rateless FEC in the application layer, ii) incorporation of congestion control into the demo platform using TFRC, iii) incorporation of other 3D video representations, iv) support for other 3D displays at the receiving peers, iv) testing over the real Internet using the PlanetLab (Koc University is now a member of the PlanetLab Consortium), v) developing MPE-FEC encapsulation and decapsulation and signaling tools, including ESG for 3D video content within the DVB-H specifications.

4. References

[1] A. Kubota, A. Smolic, M. Magnor, M. Tanimoto, T. Chen, and C. Zhang, “Multiview Imaging and 3DTV,” Special issue of IEEE Signal Processing Magazine., vol. 24, no. 6, pp. 10-21, Nov. 2007.

[2] W. Matusik and H. Pfister, “3D TV: A scalable system for real-time acquisition, transmission, and autostereoscopic display of dynamic scenes,” SIGGPRAPH 2004; ACM Trans. on Graphics (TOG) , vol. 23, no. 3, pp. 814-824, August 2004.

[3] N. Hur, G. Lee, W. You, J. Lee, and C. Ahn,.”An HDTV-compatible 3DTV broadcasting system,” ETRI Journal, vol.. 26, no..2, pp..71-82, Apr. 2004.

[4] S. Cho, N. Hur, J. Kim, K. Yun, and S.-I. Lee, “Carriage of 3D audio-visual services by T-DMB,” Proc. IEEE Int. Conf. Multimedia and Expo (ICME), pp. 1881-1884, Toronto, Canada, July 2006.

[5] G. Petrovic and P. H. N. de With, “Near-future streaming framework for 3D TV applications,” Proc. IEEE Int. Conf. Multimedia and Expo (ICME), pp. 1881-1884, Toronto, Canada, July 2006.

[6] S.-Y. Hu, “A case for 3D streaming on peer-to-peer networks,” Proc. ACM Web3D, pp. 57-64, Columbia, Maryland, USA, April 2006.

[7] W.-L. Sung, S.-Y. Hu, J.-R. Jiang, “Selection strategies for peer-to-peer 3D streaming,” Proc. ACM NOSSDAV, pp. 15-20, Braunschweig, Germany, 2008.

[8] Y.-K. Wang and T. Schierl, RTP Payload Format for MVC Video, Feb. 2008 http://www.ietf.org/internet-drafts/draft-wang-avt-rtp-mvc-01.txt

[9] Mobile3DTV Project, http://sp.cs.tut.fi/mobile3dtv

[10] 3D4YOU Project, http://www.3d4you.eu/index.php

[11] P2P-NEXT Project, http://www.p2p-next.org/

5. Annex

5.1. Adaptive Streaming of Scalable Stereo Video over DCCP

5.2. Video Streaming over Wireless DCCP

5.3. Rate-Distortion Optimization for Stereoscopic Video Streaming with Unequal Error Protection

5.4. Rate-Distortion Optimized Layered Stereoscopic Video Streaming with Raptor Codes

5.5. Robust Transmission of Multi-view Video Streams using Flexible Macroblock Ordering

5.6. Client-Driven Selective Streaming of Multi-View Video for Interactive 3DTV

5.7. Feasibility of Multi-View Video Streaming over P2P Networks

5.8. Multi-view Video Streaming over P2P Networks with Low Start-up Delay

5.9. A Standards-Based, Flexible, End-to-End Multi-View Video Streaming Architecture

5.10 Delivery of 3D Video over DVB-H: Building the Channel

5.11 Source/Channel Rate Allocation in DVB-H Transmissions

5.12. Transport Methods for 3DTV – A Survey

5.13. 3DTV over IP

5.14. Efficient Transport of 3DTV