A STUDY OF LEARNING EXPERIENCE WITH A DASH-BASED MULTIMEDIA DELIVERY SYSTEM

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Abstract

In order to create an improved learning experience in variable network delivery conditions, multimedia content adjustment is performed when delivered over existing network environments. This paper introduces a study of user learning when multimedia-based study material is distributed at different quality levels in the context of the European Horizon2020 project NEWTON. This paper studies the learning experience with multimedia when employing an MPEG-DASH-based adaptive multimedia delivery in a real life subjective experiment with 88 Data Network students from two Irish and Slovak universities.

Keywords: Multimedia Delivery System, DASH, Learner Experience, QoE.

1 INTRODUCTION

Adaptation techniques have already been used in learning environments, especially for video streaming of e-learning content over the Internet. Moreover, various industry and academic research proposed relevant solutions to address the associated quality problems during video streaming while satisfying different requirements in terms of users' quality of experience given the constraints of the transmission environment.

Basic progressive HTTP downloading/streaming of multimedia is not suitable for mobile environments and radio access networks (RAN) with bandwidth fluctuations. The video stream needs to be adapted in order to deliver best QoE to the user, i.e. video stream without stalls with the best possible quality at the moment. DASH architecture is introduced in ISO/EIC standard. The standard defines MPD format (media presentation description – an xml document), that defines formats announcing resources identifiers (HTTP-URLs) for segments and provides con-text for these resources. Segments identified in the MPD are containing encoded media data and respective metadata [1].

The first international standard on adaptive bit-rate HTTP-based streaming is the Dynamic Adaptive Streaming over HTTP (DASH) referred to as MPEG-DASH [2]. MPEG-DASH supports adaptive bitrate streaming of multimedia content over the Internet. The media content is partitioned into one or more segments and is delivered from conventional web servers to the remote client using HTTP.

This paper presents a research study on learner experience when a new DASH-based Multimedia delivery System (DASHMS) was used to deliver real learning content in a class with the goal of maintaining high user quality of experience by performing content delivery adjustment according to existing delivery network conditions. The study is part of the European Horizon2020 NEWTON project (http://newtonproject.eu).

This research bridges the gap between the development of latest technologies and classic education by providing educators and students with modern tools to enable improved and more attractive teaching and learning. Our research involves delivery of multimedia learning content to students and assesses the benefit of employing the latest technologies in the learning process in terms of learner satisfaction, quality of experience and learning outcome. The use of these technologies in learning shifts the focus from a teacher-centered to a student-centered approach. Pedagogically, these technologies enable a constructive approach towards learning where a student constructs their own learning experience rather than strictly receiving knowledge, as is the case of traditional instruction.

The paper is based on the research activities of the authors within the EU Horizon 2020 NEWTON project [3]. The project is devoted to the design, development and deployment of innovative solutions based on modern forms of on-line education for Technology-Enhanced Learning (TEL) with the orientation to the area of STEM subjects [4], [5], [6], [7]. The NEWTON innovative technologies utilize the principle of "student centric model", problem-based learning and game-based approach [8], [9] and

involve adaptive and personalised multimedia and multiple sensorial media (mulsemedia) delivery, augmented and virtual reality (AR/VR)-enhanced learning, simulation techniques for virtual experiments in educational process (Virtual Labs), fabrication labs (Fab Labs) and gamification [10], [11].

One of the key topics of the NEWTON project is to build a new innovative learning management platform named NEWTELP (http://newtelp.eu) in European space which offer integrated educational environment for learners and teachers. NEWTELP consists of various courses and supports fast dissemination of learning content based on high technology to all involved schools in parallel [12], [13], [14]. Within NEWTON the ultimate goal is to improve the quality of educational process with increasing of learner quality of experience and maintain learning outcome.

The paper is organized as follows. Section 2 introduces the state-of-the-art related works in multimedia communications and describes some research related to the user perceived Quality of Experience (QoE). Section 3 gives an overview of the DASHMS. Section 4 presents research methodology of the case study and its results. Finally, section 5 concludes the paper.

2 RELATED WORKS

Multimedia adaptation refers to changing some parameters of a media component such as bit rate or resolution in case of video during the streaming process. Most of the adaptive methods can be divided into two categories depending on their primary objective. First some schemes allow media content delivery addressing the degradation of network condition without impacting too much user QoE. The second category targets energy-saving and/or cost-saving methods. In the first category, the reduction of bit rate and bandwidth is imposed by the degradation of network conditions whereas in the second category some parameters are reduced in a controlled manner, and thus reducing the video/audio quality in order to save energy or money.

Muntean et al. [15] presented a high-level adaptive multimedia delivery system for all-IP networks, namely Quality-oriented Adaptive Scheme (QOAS), which aimed to provide a good perceptual quality of the multimedia stream to end-users. This proposed solution consists of a server side and a client side. The quality-oriented grading functionality of the server conducts and delivers the adaptation of different quality levels of multimedia streams depending on the feedback on the perceived quality assessment scheme located at the clients. The quality assessment scheme takes into consideration packet loss ratio, delay and jitter of the current multimedia transmission. The grading scheme combines these parameters and generates a score for the final delivery, based on which the adaptation is performed. A prioritised version of QOAS has been proposed in [16] in which different adaptive algorithms are applied according to the client relative importance and therefore adaptation will imply higher or lower quality levels, respectively.

De Vleeschauwer et al. [17] proposed a HTTP-based Adaptive Streaming (HAS) scheme built on top of the Proportional Fair (PF) scheduler at the base station of the cellular networks, referred as Adaptive Guaranteed Bitrate Scheduler (AGBR). AGBR makes use of the utilities of different traffic types (i.e. video traffic and data traffic) to prioritize the served traffic. A utility maximization problem is considered and the highest utility for video traffic is aimed at being achieved. The performance evaluation shows that the proposed scheme guarantees the utility maximization for the video traffic and the target bitrate for the data traffic.

Recently, the authors of [18] described an HTTP-based adaptive streaming scheme considering the quality-fairness problems, referred to as Quality-Fair Adaptive Scheme (QFAS). The framework of QFAS consists of an HTTP Adaptive Scheme (HAS) Server, Media-Aware Network Elements (MANE), eNodeB (eNB) and HAS clients. HAS server stores video sequences, and generates Media Presentation Descriptors (MDP) which contain video segmentations and manifest files requested by HAS clients. The MANE located close to eNB, is in charge of intercepting and processing the MDP requests in order to collect Channel State Information (CSI) from eNB and update the adaptive bitrate of video segmentations (i.e. called Chunks). The fairness of video quality among multiple HAS clients is considered by controlling the rate on MANE. The proposed scheme was evaluated using simulations and compared to the Best-effort scheme and AGBR scheme in [17].

Essaili et al. [19] proposed a QoE-driven algorithm for multi-user over Dynamic Adaptive Streaming over HTTP (DASH) in LTE networks. In order to enhance QoE awareness to the end-user, the proposed scheme makes user of a QoE estimation model which calculate the Mean Opinion Score (MOS) based on the video stream data rate variation. Jointly considering the estimated MOS of each video and channel conditions and for each end-user the optimal streaming rate is adjusted. This QoE driven

scheme also implements a QoE-based proxy server which is redirecting the video requests from the end-users and proactively adapts the streaming rate while the channel condition is bad. The proposed solution was evaluated and was implemented for two standard adaptive HTTP clients: Microsoft Smooth Streaming and DASH-enable VLC.

However, very few studies have investigated the user perceived QoE associated with the effect of multimedia adaptation during learning. This study will investigate the learning outcome with variation of multimedia quality when employing DASHMS.

3 SYSTEM ARCHITECTURE

MPEG-DASH has two main components: Media Presentation and Media Presentation Description (MPD) [1]. Media Presentation is a sequence of one or more segments that incorporate periods, adaptation sets, and representations, which break up the media from start to finish. MPD is like a manifest file and is an eXtensible Markup Language (XML) document that identifies the various content components and the location of all alternative segments, providing the relationship between them.

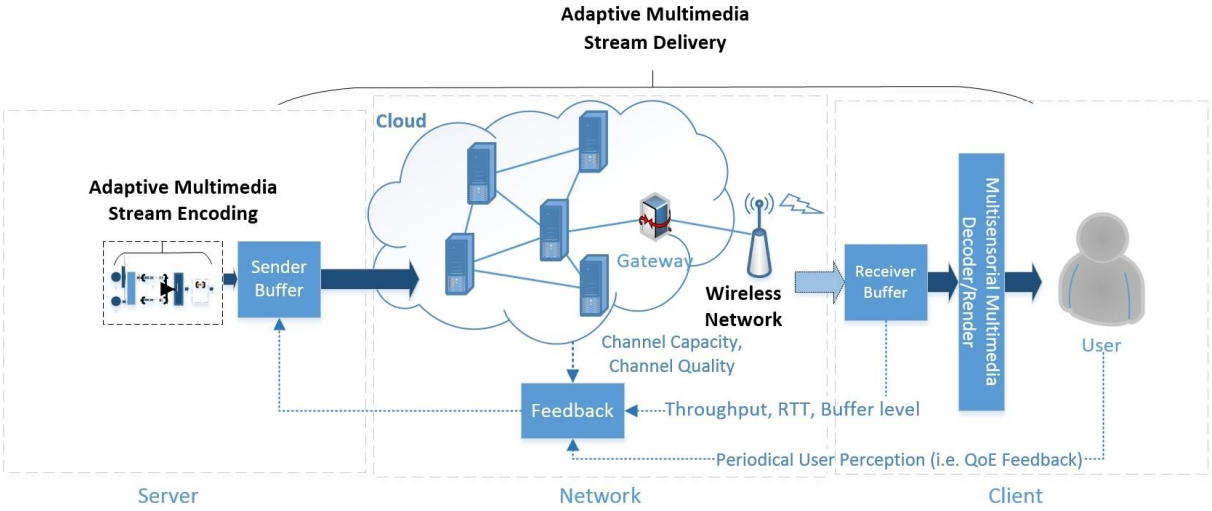

Figure 1 DASHMS Adaptive multimedia delivery system

DASHMS employs MPEG-DASH in order to perform its multimedia adaptation. The architecture of the DASHMS is described in Fig.1. The system consists of two sides: Client and Server. On the Client side, the adaptive multimedia player renders various multimedia segments into video/audio streaming. On the Server side, the NEWTON platform annotates different multimedia information and encodes all information into an adaptive multimedia stream, which includes the video clip and its associated adaptive multimedia MPD files. In this system, following the DASH framework, the receiver buffer will receive the "Adaptive Multimedia Stream" from the cloud network based on the network condition and user preference, and it will send to the MPEG-DASH decoder to decode the video/audio content from the MPD format files. Then, adaptive multimedia player on client sides will show the video/audio stream.

4 CASE STUDY

The goal of the research study was to investigate learner experience when the education material involving adaptive multimedia was used in the class to teach scientific knowledge on "Networking Performance" part of the *Data Networks* course to undergraduate students.

This section presents the evaluation methodology applied, case study set-up and results analysis for of the collected data.

4.1 Research Methodology

The evaluation included a group of undergraduate students who were taught using DASHMS. The learning activity took place in class, during the normal hours of study. A total of 88 students of age 19-

25 years from Dublin City University (DCU) located in Dublin, Ireland and Slovak University of Technology in Bratislava (STUBA) located in Bratislava, Slovakia took part in this case study. NEWTON project team members from DCU and STUBA have prepared and helped perform the tests.

The evaluation meets all Ethics requirements. Prior to running the case study, the Ethics approval was obtained from both DCU and STUBA Ethics committees. All Ethics associated forms were provided to the students, including plain language statement, informed consent form, and data management plan. These documents include a detailed description of the testing scenario, as well as information on study purpose, data processing and analysis, participant identity protection, etc. Students took part on the experiment after free decision, with high interest on the topic.

The flow of the evaluation has 6 steps followed by the researchers. Prior to the beginning of the learning and testing, the students were introduced to the research case study, the plain language document was circulated and the consent forms were signed by the participants. The students had roughly 45 minutes to watch 8 multimedia clips using DASHMS. Each clip involved with 3-question pre-test and 6-question post-test.

4.2 Case Study Set-up

Three different scenarios are considered employing 8 multimedia sequences. The multimedia sequences focused on data networks knowledge. They had the same encoding settings within the same scenario, but different in the different scenarios. The clips were each 180 seconds long and had a frame rate of 30 fps. In scenario 1, low quality video (480p video, resolution of 854x480 pixels) is played to participants; in scenario 2, medium quality video (720p video, resolution of 1280x720 pixels) is presented and in scenario 3, high quality video (1080p video, resolution of 1920x1080 pixels) is displayed.

The 8 multimedia clips are labelled based on their content and are briefly described as follows:

- ***Adaptive Multimedia***: The video covers four upper application layer adaptive multimedia delivery solutions: Layered Quality Adaptation, Quality-Oriented Adaptive Scheme, Region of Interest Adaptive Streaming and Prioritised Adaptive Multimedia Streaming.

- ***Mobility Solutions***: The video describes briefly the IP routing concept and presents the basic principles of Mobile Internet Protocol (IP), Mobile Stream Control Transport Protocol (SCTP), Mobile Datagram Congestion Control Protocol (DCCP) and Mobile Session Initiation Protocol (SIP).

- ***MPEG-DASH and adaptive MPEG-DASH***: The video covers the main components of MPEG-DASH such as MPD and segments, and presents how adaptation of multimedia content happens when employing this standard.

- ***Mobility Management and Handover***: The video presents cellular technologies focusing on types of handover, how these handovers are initiated and how networks manage them.

- ***Software Defined Networking (SDN)***: The video introduces the concept of SDN, its basic framework and the benefits of SDN adoption.

- ***Network Functions Virtualisation (NFV)***: The video presents NFV high-level framework and introduces the implementation of Network Functions (NF) as software-only entities running over the NFV infrastructure.

- ***5G focused on SDN+NFV***: The video introduces 5G and how Software Defined Networks and Network functions virtualisation presented in the previous videos are being used in the design of 5G networks.

- ***IoT***: The video introduces the Internet of Things (IoT) and discusses the main technologies behind it. There is also a focus on how 5G enables advances in IoT.

4.3 Results Analysis

Table 1 Learning outcome in the 3 different video quality levels

% correct answers	High Quality		Medium Quality		Low Quality	
	Pre	Post	Pre	Post	Pre	Post
SDN	26%	67%	28%	62%	23%	76%
NFV	30%	62%	24%	67%	33%	64%
5G NFV + SDN	39%	72%	42%	69%	45%	65%
IoT	38%	67%	39%	66%	27%	62%
Adaptive Multimedia	56%	52%	52%	57%	55%	63%
MPEG DASH	30%	60%	35%	54%	36%	55%
Mobility	67%	60%	64%	54%	62%	53%
Handover	53%	59%	45%	57%	63%	63%
Average:	42%	62%	41%	61%	43%	62%
Improvement:		20%		20%		19%

For all scenarios, the participants have answered 3 questions in a pre-test before viewing each mulsemedia clip and 6 questions in a post-test after each clip. Each of the correct answers is associated with 1 point, and the maximum score is 3 points for pre-test and 6 points for the post-test.

Table 1 presents the correct answer ratios of pre- and post-tests for the 8 different multimedia clips in 3 different scenarios. The average post-test questionnaire correct response ratio is on average with 20% higher than the one for the pre-test questionnaire. The study shows that when using the three different quality level videos, the video quality degradation, if performed under controlled conditions does not have a significant effect on the learning outcome. However, it can be noted that for 3 videos (marked in Table 1), there is a positive correlation between the video quality and learning outcome. This means an adaptive multimedia delivery solution based on network conditions could be deployed while maintaining high level of learning outcome.

5 CONCLUSIONS

This paper introduces, describes and tests a DASH-based adaptive multimedia delivery system (DASHMS). This study delivers multimedia content and assesses the benefit of employing the DASHMS in the learning process in terms of learning outcome and video quality. An analysis of the results collected in a case study conducted on a group of 88 students was presented in the paper. The study shows that when using three different quality level videos, the controlled video quality degradation does not have a significant effect on the learning outcome.

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