AdViSE: Adaptive Video Streaming Evaluation Framework for the Automated Testing of Media Players

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ABSTRACT

Today we can observe a plethora of adaptive video streaming services and media players which support interoperable formats like DASH and HLS. Most of the players and their rate adaptation algorithms work as a black box. We have developed a system for easy and rapid testing of media players under various network scenarios. In this paper, we introduce **AdViSE**, the **Ad**aptive **Vi**deo **S**treaming **E**valuation framework for the automated testing of adaptive media players. The presented framework is used for the comparison and testing of media players in the context of adaptive video streaming over HTTP in web/HTML5 environments.

The demonstration showcases a series of experiments with different media players under given context conditions (e.g., network shaping, delivery format). We will also demonstrate the real-time capabilities of the framework and offline analysis including several QoE metrics with respect to a newly introduced bandwidth index.

CCS CONCEPTS

•**Networks** →**Network performance modeling**; **Network experimentation**; Network reliability; •**Information systems** →**Multimedia streaming**;

KEYWORDS

Evaluation framework; AdViSE; Adaptive streaming; Media players; MPEG-DASH; Network emulation; Automated Testing; Mininet; Selenium; Quality of Experience; Metrics

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1 INTRODUCTION

Adaptive video streaming over HTTP is becoming more and more the primary technology for video delivery in the open internet. For example, Netflix and YouTube alone account for more than 50% of the traffic [12] thanks to open, interoperable formats such as MPEG-DASH [14] or HLS [11]. In the past, we have witnessed many deployments in web environments implemented using Javascript by utilizing HTML5 and media source extensions (MSE) enabling a plugin free video streaming.

The technology behind adaptive video streaming over HTTP implies media representation switching (e.g., bitrate/resolution) depending on context conditions such as network characteristics and client device properties. An integral part of each player implementation is the usage of an appropriate rate adaptation algorithm which aims to follow dynamically changing context conditions. Thus, we are in a situation with many unknowns variables and the problem of choosing the appropriate media player for video streaming and playback arises.

In this demo paper, we introduce ***AdViSE***, an **Ad**aptive **Vi**deo **S**treaming **E**valuation framework which enables the automated testing of media players — and, thus, rate adaptation algorithms — under various context conditions (e.g., client devices/platforms, network characteristics/conditions). The main focus of AdViSE is the provisioning of tools for easy and rapid experimentation with media players and algorithms as they appear on the market including updates thereof which become available in relatively short periods.

The rest of this paper is organized as follows. Section 2 describes the underlying scientific problems leading to the development of AdViSE. In Section 3, we present the architecture of the designed system and its components. Section 4 provides a brief description about the demo itself and Section 5 concludes the paper.

2 UNDERLYING SCIENTIFIC PROBLEM

Nowadays, there exists a large number of different players/algorithms (including commercially available ones) and most of them have been implemented in JavaScript. However, no common performance evaluation framework/system

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Peer-to-Peer Video Streaming Eric Setton,Bernd Girod,2007-09-30 Peer to Peer Video Streaming describes novel solutions to enhance video quality increase robustness to errors and reduce end to end latency in video streaming systems This book will be of use to both academics and professionals as it presents thorough coverage and solutions for current issues with Video Streaming and Peer to Peer architectures Key Features Provides overview of today s state of the art video streaming technology Presents adaptive video coding and streaming techniques for performance enhancement of conventional client server systems and P2P multicast Focus on throughput limited environments where congestion often hampers interactivity and fast response times Results derived from experiments carried out over large scale simulated peer networks Detailed appendix incorporates various additional experiments **Subjective and Objective Quality-of-experience of Adaptive Video Streaming** Zhengfang Duanmu,2017 With the rapid growth of streaming media applications there has been a strong demand of Quality of Experience QoE measurement and QoE driven video delivery technologies While the new worldwide standard dynamic adaptive streaming over hypertext transfer protocol DASH provides an inter operable solution to overcome the volatile network conditions its complex characteristic brings new challenges to the objective video QoE measurement models How streaming activities such as stalling and bitrate switching events affect QoE is still an open question and is hardly taken into consideration in the traditionally QoE models More importantly with an increasing number of objective QoE models proposed it is important to evaluate the performance of these algorithms in a comparative setting and analyze the strengths and weaknesses of these methods In this study we build two subject rated streaming video databases The progressive streaming video database is dedicated to investigate the human responses to the combined effect of video compression initial buffering and stalling The adaptive streaming video database is designed to evaluate the performance of adaptive bitrate streaming algorithms and objective QoE models We also provide useful insights on the improvement of adaptive bitrate streaming algorithms Furthermore we propose a novel QoE prediction approach to account for the instantaneous quality degradation due to perceptual video presentation impairment the playback stalling events and the instantaneous interactions between them Twelve QoE algorithms from four categories including signal fidelity based network QoS based application QoS based and hybrid QoE models are assessed in terms of correlation with human perception on the two streaming video databases Experimental results show that the proposed model is in close agreement with subjective opinions and significantly outperforms traditional QoE models *Content-aware and Context-aware Adaptive Video Streaming Over HTTP.* Ognen Ognenoski,2016 **Towards a Small Buffering Delay in Adaptive Video Streaming** Yongtao Shuai,Thorsten Herfet,Tobias Lange,2015 **Network and End-host Support for HTTP Adaptive Video Streaming** Ahmed Mansy,2014 Video streaming is widely recognized as the next Internet killer application It was not one of the Internet s original target applications and its protocols TCP in particular were tuned mainly for e efficient bulk file

transfer As a result a significant effort has focused on the development of UDP based special protocols for streaming multimedia on the Internet Recently there has been a shift in video streaming from UDP to TCP and specifically to HTTP HTTP streaming provides a very attractive platform for video distribution on the Internet mainly because it can utilize all the current Internet infrastructure In this thesis we make the argument that the marriage between HTTP streaming and the current Internet infrastructure can create many problems and inefficiencies In order to solve these issues we provide a set of techniques and protocols that can help both the network and end hosts to make better decisions to improve video streaming quality The thesis makes the following contributions We conduct a characterization study of popular commercial streaming services on mobile platforms Our study shows that streaming services make different design decisions when implementing video players on different mobile platforms We show that this can lead to several inefficiencies and undesirable behaviors specially when several clients compete for bandwidth in a shared bottleneck link Fairness between traffic flows has been preserved on the Internet through the use of TCP However due to the dynamics of adaptive video players and the lack of standard client adaptation techniques fairness between multiple competing video flows is still an open issue of research Our work extends the definition of standard bitrate fairness to utility fairness where utility is the Quality of Experience QoE of a video stream We define QoE max min fairness for a set of adaptive video flows competing for bandwidth in a network and we develop an algorithm that computes the set of bitrates that should be assigned to each stream to achieve fairness We design and implement a system that can apply QoE fairness in home networks and evaluate the system on a real home router A well known problem that has been associated with TCP traffic is the buffer bloat problem We use an experimental setup to show that adaptive video flows can cause buffer bloat which can significantly harm time sensitive applications sharing the same bottleneck link with video traffic In addition we develop a technique that can be used by video players to mitigate this problem We implement our technique in a real video player and evaluate it on our testbed With the increasing popularity of video streaming on the Internet the amounts of traffic on the peering links between video streaming providers and Internet Service Providers ISPs have become the source of many disputes Hybrid CDN P2P streaming systems can be used to reduce the amounts of traffic on the peering links by leveraging users upload bandwidth to redistribute some of the load to other peers We develop an analysis for hybrid CDN P2P systems that broadcast live adaptive video streams The analysis helps the CDN to make better decisions to optimize video quality for its users *Intelligent Dynamic Adaptive Video Streaming Over HTTP Using Smart Adaptation and Machine Learning Solutions* Ibrahim Rizqallah Alzahrani,2019 **Efficient Quality of Experience Informed Schemes for Dynamic Adaptive Video Streaming** Iheanyi Caleb Irondi,2017 **Adaptive Bitrate Streaming Over Cellular Networks** Yanyuan Qin,2020 Adaptive bitrate streaming ABR has become the de facto technique for video streaming over the Internet Despite a flurry of techniques achieving high quality ABR streaming over cellular networks remains a tremendous challenge First the design of an ABR scheme needs to balance conflicting Quality of

Experience QoE metrics such as video quality quality changes stalls and startup performance which is even harder under highly dynamic bandwidth in cellular network Second streaming providers have been moving towards using Variable Bitrate VBR encodings for the video content which introduces new challenges for ABR streaming whose nature and implications are little understood Third mobile video streaming consumes a lot of data Although many video and network providers currently offer data saving options the existing practices are suboptimal in QoE and resource usage Last when the audio and video tracks are stored separately video and audio rate adaptation needs to be dynamically coordinated to achieve good overall streaming experience which presents interesting challenges while somewhat surprisingly has received little attention by the research community In this dissertation we tackle each of the above four challenges Firstly we design a framework called PIA PID control based ABR streaming that strategically leverages PID control concepts and novel approaches to account for the various requirements of ABR streaming The evaluation results demonstrate that PIA outperforms state of the art schemes in providing high average bitrate with significantly lower bitrate changes and stalls while incurring very small runtime overhead We further design PIA E PIA Enhanced which improves the performance of PIA in the important initial playback phase Secondly we identify distinguishing characteristics of VBR encodings that impact user QoE and should be factored in any ABR adaptation decision and find that traditional ABR adaptation strategies designed for the Constatn Bitrate CBR encodings are not adequate for VBR We develop novel best practice design principles to guide ABR rate adaptation for VBR encodings As a proof of concept we design a novel and practical control theoretic rate adaptation scheme CAVA Control theoretic Adaption for VBR based ABR streaming incorporating these concepts Extensive evaluations show that CAVA substantially outperforms existing state of the art adaptation techniques Thirdly we analyze the underlying causes for suboptimal existing data saving practices and propose novel approaches to achieve better tradeoffs between video quality and data usage The first approach is Chunk Based Filtering CBF which can be retrofitted to any existing ABR scheme The second approach is QUality Aware Data efficient streaming QUAD a holistic rate adaptation algorithm that is designed ground up Our evaluations demonstrate that compared to the state of the art the two proposed schemes achieve consistent video quality that is much closer to the user specified target lead to far more efficient data usage and incur lower stalls For the fourth challenge we shed light on a number of limitations in existing practices both in the protocols and the player implementations which can cause undesirable behaviors such as stalls selection of potentially undesirable combinations such as very low quality video with very high quality audio etc Based on our gained insights we identify the underlying root causes of these issues and propose a number of practical design best practices and principles whose collective adoption will help avoid these issues and lead to better QoE Adaptive Video Streaming Over Peer-to-peer Networks Kadir Tolga Bağcı,2012

Evaluation of Adaptive Video Optimization for Stall Minimization in Wireless Networks Karishma Katara,2015 Mobile devices such as smart phones and tablets have become an integral part of peoples daily lives Users are consuming

more content over wireless networks than ever before and the largest portion of that traffic by volume is delivered as video Even with the rollout of high speed LTE networks subscriber demand for content is growing at an overall faster rate than network capacity is being added in many urban areas This presents a challenge to the network operators since users expect a stall free playback experience on devices that support high resolution and high quality content To help maintain the subscriber experience operators may deploy a solution to adjust the video transmission rate requirements depending on varying network capacity Mobile users would otherwise experience sudden stalls during the video playback in a congested network The main objective of this thesis is to analyze a system or solution to optimize video content such that finite network resources are more fairly shared and the subscriber experience is protected during times of network congestion by reducing the number of stalls The goal is provide smooth video playback on the mobile device with the best video quality possible by applying adaptive video optimization Adaptive optimization allows a change in resolution bit rate or quantization of the video in accordance with the available bandwidth The user s experience for the video played on these device depends mainly on the stalls and the perception of quality Compared to the conventional compression schemes where optimization is applied universally regardless of network congestion the adaptive optimization algorithm described in this paper adjusts the compression level applied based on the fluctuating channel throughput In this paper real world data collected from a live network is studied and analyzed how the number of stalls vary for dynamic compression By simulating this scenario I can say that the highest overall playback quality possible is achieved by selecting the best video bit rate depending on the channel condition and the amount of video stream buffered in the client **Perceptual Quality Driven Video Evaluation and Processing** Jingteng Xue,2014 Video is becoming more and more important in our daily life while the Internet video traffic experiences rapid growth in the recent years It is predicted that in 2016 there will be 1 2 million minutes of video content cross the network every second In the meantime the way people consume video is becoming greatly diversified Such diversity can be found in various display terminals including smartphone tablets and stereoscopic screens as well as in the new delivery means such as popular adaptive HTTP Internet streaming In order to regulate and maintain the quality of these video services it is important for the video delivery system to automatically evaluate picture fidelity Such quality monitoring helps adjusting the resource allocation among the clients that share a communication channel Conventional signal quality estimator such as the mean square error metric has been universally employed to evaluate video However it has been proved to correlate poorly with human perception Recently developed new video quality assessment tools include the structural difference based approaches SSIM the visual information fidelity based approaches VIF the entropic difference based approaches RED and the perceivable distortion estimation based approaches JND etc While these methods correlate better with subjective evaluation the expensive cost prevent them from being widely adopted in commercial systems which generally demands low complexity In this research we aim at developing light weight quality estimation and enhancement

approaches for several new application scenarios The problem of video perception evaluation is tackled by the study of the specific source of distortion for each application This thesis addresses quality issues in four important and new video services These are mobile video viewing HTTP adaptive video streaming video watermarking and depth information based DIBR multiview video In the first topic the influence of physical environment factors on mobile video viewing is studied The factors include the display size the ambient luminance and the motion of viewer Their influence on video viewing is quantified and modeled by subjective tests Based on the result an environment sensitive quality metric can be derived to estimate the mobile video perception in a specific context In the second topic a parametric model that evaluates both the picture fidelity and the temporal playback continuity is proposed The two major quality factors of adaptive HTTP streaming are synthesized to provide a unified quality indicator It can improve streaming experience by optimizing the selection of the bitstream segments In the third topic it is proposed to generate a coding dependency graph to guide the watermark embedding in a compressed bitstream A topological sort of the dependency graph reveals the minimal distortion path without the need of error drift compensation Hence a fast yet visually optimized embedder can be implemented In the last topic a blind depth quality evaluation and error detection method for DIBR system is proposed The depth acquisition estimation and coding process is assumed to be error prone The displacement distortion of depth especially the misalignment around the object edges may cause ghosting and flickering artifacts during 3D playback The proposed method is expected to estimate the depth map quality and detect the potential problematic depth information for error correction and further processing

Perceptual Video Quality and Quality of Experience for Adaptive Video Streaming Christos George Bampis,2018 We live in a world where images and videos dominate our everyday lives Every day an enormous amount of video data is being shared in social media and consumer applications while video streaming is becoming a new form of digital entertainment Large scale video streaming on demand has become possible thanks to numerous engineering achievements in fields such as video compression high speed computation and display technologies Nevertheless the skyrocketing needs for bandwidth and network resources consumed by video applications challenges modern video content delivery Since the available bandwidth resources are limited streaming service providers have to mediate between operation costs bandwidth efficiency and maximizing user quality of experience However these goals are inherently conflicting and require knowledge of how user quality of experience is affected by the network induced changes in video quality Being able to understand and predict user quality of experience and perceptually optimize rate allocation can have significant effects in better network utilization reduced costs for service providers and improved user satisfaction The goal of this dissertation is to study and predict user quality of experience in video streaming applications by exploiting perceptual video quality and human behavioral responses to streaming related video impairments To this end I present the details of three large scale video subjective studies which target video streaming under multiple viewing conditions such as display device session duration content characteristics and

network buffer conditions By analyzing how humans react to changes in visual quality and streaming video impairments I also design numerous video quality and quality of experience prediction models that can be used to evaluate the overall and the continuous time perceived video quality Throughout this dissertation my goal is to perceptually optimize various stages of the video streaming pipeline such as video encoding and video quality control as well as client based rate adaptation Ultimately I envision that the outcome of this dissertation can be useful for video streaming applications at global scale

Improving Quality of Experience for HTTP Adaptive Video Streaming Afshin Taghavi Nasrabadi,2019 Adaptive Video Streaming Over the Internet Ling Shun Lam,2004 Neural Adaptive Video Streaming with Pensieve Hongzi Mao,2017 Client side video players employ bitrate adaptation algorithms to cater to the ever growing QoE requirements of users These ABR algorithms must balance multiple QoE factors such as maximizing video bitrate and minimizing rebuffering times Despite the abundance of recently proposed ABR algorithms state of the art schemes suffer from two practical challenges 1 throughput prediction is difficult and inaccurate predictions can lead to degraded performance 2 existing algorithms use fixed heuristics which have been fine tuned according to strict assumptions about deployment environments such tuning precludes generalization across network conditions and QoE objectives To overcome these challenges we develop Pensieve a system that generates ABR algorithms entirely using Reinforcement Learning RL Pensieve uses RL to train a neural network model that selects bitrates for future video chunks based on observations collected by client video players Unlike existing approaches Pensieve does not rely upon pre programmed models or assumptions about the environment Instead it learns to make ABR decisions solely through observations of the resulting performance of past decisions As a result Pensieve can automatically learn ABR algorithms that adapt to a wide range of environmental conditions and QoE metrics We compare Pensieve to state of the art ABR algorithms using trace driven and real world experiments spanning a wide variety of network conditions QoE metrics and video properties In all considered scenarios Pensieve outperforms the best stateof the art scheme with improvements in average QoE of 13 1% 25 0% Pensieve s policies generalize well outperforming existing schemes even on networks on which it was not trained Efficient HTTP-based Adaptive Streaming of Linear and Interactive Videos Vengatanathan Krishnamoorthi,2018 Online video streaming has gained tremendous popularity over recent years and currently constitutes the majority of Internet traffic As large scale on demand streaming continues to gain popularity several important questions and challenges remain unanswered This thesis addresses open questions in the areas of efficient content delivery for HTTP based Adaptive Streaming HAS from different perspectives client network and content provider and in the design implementation and evaluation of interactive streaming applications over HAS As streaming usage scales and new streaming services emerge continuous improvements are required to both the infrastructure and the techniques used to deliver high quality streams In the context of Content Delivery Network CDN nodes or proxies this thesis investigates the interaction between HAS clients and proxy caches In particular we propose and evaluate classes of content aware and

collaborative policies that take advantage of information that is already available or share information among elements in the delivery chain where all involved parties can benefit Asides from the users playback experience it is also important for content providers to min imize users startup times We have designed and evaluated different classes of client side policies that can prefetch data from the videos that the users are most likely to watch next without negatively affecting the currently watched video To help network providers to monitor and ensure that their customers enjoy good playback experiences we have proposed and evaluated techniques that can be used to estimate clients current buffer conditions Since several services today stream over HTTPS our solution is adapted to predict client buffer conditions by only observing encrypted network level traffic Our solution allows the operator to identify clients with low buffer conditions and implement policies that help avoid playback stalls The emergence of HAS as the de facto standard for delivering streaming content also opens the door to use it to deliver the next generation of streaming services such as various forms of interactive services This class of services is gaining popularity and is expected to be the next big thing in entertainment For the area of interactive streaming this thesis proposes models designs and evaluates novel streaming applications such as interactive branched videos and multi video stream bundles For these applications we design and evaluate careful prefetching policies that provides seamless playback without stalls or switching delay even when interactive branched video viewers defer their choices to the last possible moment and when users switches between alternative streams within multi video stream bundles Using optimization frameworks we design and implement effective buffer management techniques for seamless playback experiences and evaluate several tradeoffs using our policies *Adaptive Video Streaming Over Openflow Networks with Quality of Service* Hilmi Enes Eğilmez,2012 **QoE-Centric Stepwise Adaptive Video Streaming Using the Temporal-Geo Bandwidth Estimation Method in the Wireless Mobile Network** □□□,2017

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