A DASH-aware Performance Oriented Adaptation Agent

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***Abstract*. The proliferation of low-cost multimedia-enabled mobile devices and free educational video content is adding strain to existing limited bandwidth resource delivery networks. The newly introduced Dynamic Adaptive Streaming over HTTP (DASH) standard is a cross-platform, efficient and cost-effective solution for media streaming to a variety of IP/multimedia enabled devices. This standard supports access to content stored at multiple hosts, but does not suggest any selection mechanism. This paper describes and evaluates a DASH-aware Performance Oriented Adaptation Agent (dPOAA) which dynamically selects best performing hosts for video delivery. Preliminary evaluation shows that this solution improves the quality of delivered video in terms of maintained estimated MOS and reduced buffering and initial delay on the client side.**

***Index Terms*—Video distribution, Performance evaluation, Networking and QoS, Quality of Experience.**

I. Introduction

THE cost of multimedia-enabled mobile devices continues to decrease, which together with the proliferation of free educational video content offerings such as Coursera's (www.coursera.org) has led to the expansion of the global community of e-learners. Today's learners are using increasing amounts of media-rich content which adding strain to existing delivery network resources. Adaptive video delivery mechanisms which adjust the content to match available network bandwidth and by eventually reducing the loss rate increase user Quality of Experience (QoE) levels are needed [1]–[4]. Dynamic Adaptive Streaming over HTTP (DASH) [5] is a scalable client-based solution offering support for adaptive video streaming by enabling consecutive downloads of short video segments to match the viewer's current delivery conditions (e.g. viewer preferences, viewing device capabilities and/or current network connectivity characteristics). The popularity of MPEG-DASH is growing, as it is seen as a cost-effective solution for heterogeneous video delivery environments.

This paper describes and evaluates a **DASH-aware Performance Oriented Adaptation Agent (dPOAA)** [6] that supports dynamic selection of remote servers storing identical MPEG-DASH content, based on the server's historic delivery performance and its effect on user QoE. We suggest, dPOAA can be deployed as a plugin for DASH players or as a server rating solution for the DASH-based performance oriented Adaptive Video distribution solution (DAV) [7], the latter being illustrated in Fig. 1.

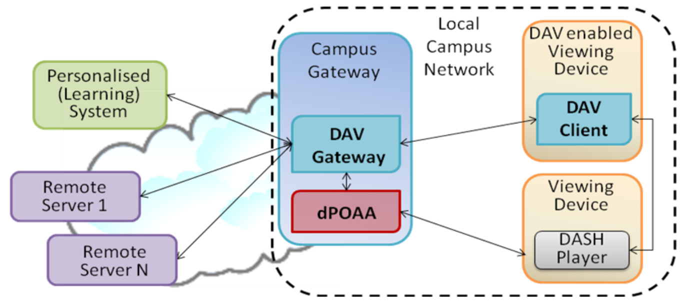

Fig. 1. dPOAA Deployed with DAV

II. Related Work

Dynamic Adaptive Streaming over HTTP (DASH) [5], [8] is gaining popularity, as it improves resource utilization while maintaining high QoE levels. DASH video is delivered using consecutive downloads of short video segments (e.g. 6 seconds) leveraging existing HTTP-based infrastructure. Web servers host multiple presentations (versions) of video content differing in temporal and spatial quality, which can be delivered to remote clients at request. DASH-based solutions scale well, as video streaming is controlled by the client, which requests content quality that matches delivery conditions (e.g. available bandwidth, remaining battery life) without the need to negotiate with the streaming server. As the client controls its streaming buffer (including buffer fill level and size), it requests the quality of the next segment to avoid buffer starvation and playback stalls due to rebuffering. An XML-formatted Media Presentation Description (MPD) file is a DASH manifest file containing sufficient information for a DASH client to request content from the server and support streaming services. It contains location information (i.e. URL) for all video segments.

Personalised Learning Systems (PLSs) (e.g. WHURLE 2.0 [9]) adjust the learning content to the needs of learners. PLS solutions focus on learner characteristics, but seldom consider the technical aspects of the learning context – the viewing device and delivery network characteristics. Exceptions include the QoE-aware AHA system (QoEAHA) [10], [11] and the Mobile Mathematics Tutoring (MoMT) System [12]. QoEAHA generates recommendations about the learning content quality and media type based on the learner's perception of the network delivery performance to enhance viewing experience. MoMT performs contextual content adaptation using transcoding based on the learner and viewing device characteristics. However, neither of these solutions considers transmission of video content.

III. dPOAA Solution

The proposed DASH-aware Performance Oriented Adaptation Agent (dPOAA) [6] aids informed selection of remote servers storing identical versions of the required MPEG-DASH content, and can be used to enhance the performance of Personalised Learning Systems (PLS) utilizing such content.

A PLS provides learner specific information and selects relevant and suitable learning content to match every learner's request. Typically, the PLS identifies the video content that matches the current learning objective taking into consideration learner attributes and learning context. Once the matching content is identified, the PLS builds a presentation suitable for the learner and, as a final step, delivers this presentation to the learner's device. These presentations contain MPD location information for the containing video. The requested content will be played out using a DASH player. Once the DASH player receives the MPD file, it parses it and requests media segments from the server as specified by the server's BaseURL [5]. Multiple server URLs are listed in the MPD file when the chosen video resides on multiple hosting servers.

When alternative base URLs are provided within an MPD file, identical video Segments are available at multiple locations (hosting servers). The MPEG-DASH standard advises that the client "may implement any suitable algorithm to determine which URLs it uses for requests" [5]. In this context, we propose the use of dPOAA for selection of the best performing hosting server when the requested content is available from multiple servers.

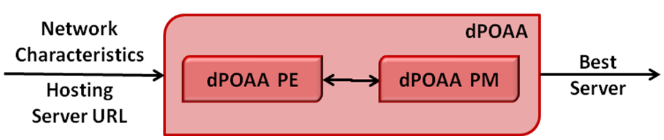

Fig. 2. dPOAA Architecture

In terms of deployment, dPOAA could be used with DAV or as a plug-in for DASH players to aid informed selection of servers storing requested video content. In the first case, the dPOAA server rating is used by the DAV Gateway in the process of MPD creation and the rating is based on the information about video requests obtained from associated DAV clients. In the second case, the rating is calculated based on the player's requests. An evaluation of the first case of dPOAA deployment is presented in this paper.

IV. dPOAA Architecture

Fig.2. illustrates dPOAA block level architecture consisting of two components. *dPOAA Performance Model (dPOAA PM)* stores host performance information in a sliding-window structure containing readings calculated from the most recent requests from a given server. *dPOAA Performance Engine (dPOAA PE)* calculates performance ratings for all remote servers hosting the requested video. A performance rating is calculated per video request by the learner. This historic performance information is gathered over a number (X) of recent sessions with the servers that store the requested video content. The server rating - R_n, is estimated server throughput and it is calculated as given in equation (1).

$$R_n = (1-w)\cdot Tp_{nX} + w\cdot Tp_{nL} \qquad 0 < w < 1 \tag{1}$$

Tp_{nL} denotes the throughput for the last (most recently) downloaded segment for server *n*, whilst Tp_{nX} denotes the average throughput over the X previous requests. The factor *w* is calculated using the formulae given in equation (2).

$$\Delta = \frac{Tp_{nL} - Tp_{nX}}{Tp_{nX}} \qquad w = \frac{1}{1+e^{\Delta}} \tag{2}$$

An exponential function is used to ensure the server rating is quickly adjusted to decreasing throughput, where *Δ* is a normalized throughput difference. Drops in measured throughput will make *w* larger than 0.5, which favors the most recent throughput measurements.

An outline of dPOAA PE selection algorithm is provided in Table I.

TABLE I
dPOAA PE Selection Algorithm Outline

Input: list of hosting servers (from the original MPD) and collated host server data
Output: Best performing server
For each hosting server
Calculate the hosting server rating based on equations (1) and (2).
Find and return the most efficient server URL.

V. Simulation-based dPOAA Evaluation

The proposed dPOAA is evaluated using modeling and simulations in the Network Simulator version 3.14 NS-3 [13].

A. Evaluation criteria

Data transmission performance during the simulations is measured in terms of: *Join time* (initial buffering time - the time that elapses from the initiation of the connection until the client buffer reaches playout level - the segment length of data); *Buffering ratio* (the relative time spent in re-buffering, calculated as the total time of buffer starvation over the total length of playout including pauses for re-buffering); *Rate of buffering events* (relative frequency of induced interruptions calculated as the number of buffering events over the playout time); and *Average bitrate* (the average of bitrates played), as proposed in [14]. Furthermore, estimated Mean Opinion Scores (MOS) were calculated and compared. The MOS is determined based on an equation that considers respective levels of Initial Buffering Time (Join time), Rebuffering frequency (how frequent the rebuffering events are), and Mean Rebuffering duration (the average duration of a rebuffering event) as proposed in [15].

B. Testbed

The simulations model a university campus setting, where dPOAA resides on the university gateway and learners are using personal computers within the campus local area network. The test setup is presented in Fig. 3. There are M clients and N remote servers which are connected to the DAV Gateway on which dPOAA is deployed. The network connections from the campus gateway to the remote servers differ in terms of bandwidth and propagation delay. The links between the gateway and clients are over provisioned (bandwidth: 100Mbps and delay: 0.5ms), assuming on-campus use and ensuring that no performance bottleneck exists. Three remote servers (N = 3) are used, where the ServerX-dPOAA link characteristics range from 5Mbps/15ms to 1Mbps/85ms and represent available throughput for video streaming.

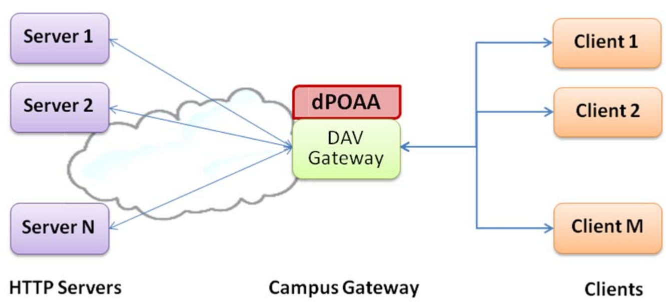

Fig. 3. dPOAA Simulation Topology

C. Characteristics of Users and User Devices

Simulated tests involve a varying number of clients starting from five and gradually increasing the number in steps of five. Users are students in a simulated classroom setting, each being asked to watch the same video content. All students are within the local network using devices with either wired or excellent wireless connection. The network link between the gateway and the students is hence over-provisioned such that no loss or significant delays are observed, and therefore no major impact on the delivery performance is expected. The clients use the bandwidth estimation formula proposed by [16] where weight factors w_1 and w_2 are used for adjusting the influence of the recently measured segment throughput (w_2= 1.3) on the previous estimated throughput (w_1 = 0.7).

The learners could use any of three types of devices, with different display characteristics and hence different bitrate requirements. The device category and the corresponding display resolutions and bitrates are given in Table II. These tests are performed with learners using *Portable* devices.

D. Characteristics of Requests

Performance metrics are collected in a number of scenarios, where all clients are requesting all video segments from the remote servers. The clients are sending their initial request for video content at uniformly distributed times ranging from 1 to 90 seconds. Each simulation run uses a different uniform distribution of times. Data is collected for ten runs. The simulations are performed with the same one minute video clip for all users. It is assumed that copies of the requested video reside on all remote servers. The requested content is delivered in chunks – segments of predefined duration. Segments of 6 seconds are used in this evaluation. Whilst this is a simulated environment, to maintain realism, the segment file sizes are obtained from the first freely available DASH dataset [17]. The Big Buck Bunny animation video segment sizes are used, where the original files are in AVC codec, created from the source quality of 1080pYUV.

TABLE II
DEVICE TYPE, DISPLAY RESOLUTION AND REQUIRED BITRATES

Device Category	Display Resolution	Bitrates (Kbit)
Handheld	320×240, 480x360,	**50**, 100, 200, 300, 400, **500**
Portable	853X480 1280x720	**600,** 700, 900, 1200, 1500, **2000**
Large-Screen	1920x1080	**2500**, 3000, 4000, 5000, 6000, **8000**

E. Test Scenario

The testing sequence involves a learner requesting some learning content, and DAV intercepting the request sent to the PLS. The PLS identifies the video relevant for the learner's objective and sends the MPD URL to DAV. dPOAA then calculates the rating for each remote host storing the requested video based on the BaseURL element provided in the MPD file. DAV modifies the MPD file so that the URL of the best rated server is set as the only MPD BaseURL, which forces the client to request the segments from the remote server selected by dPOAA.

The simulation involves four cases using scenarios with different remote host selection approaches. A simple algorithm name is provided in brackets, and it is used for test result identification in the graphs provided.

Case 1: Informed hosting server selection - dPOAA selects the hosting servers according to equations (1) and (2) with X = 5 (dPOAA).

Case 2: Informed hosting server selection - oPOAA selects the hosting servers based on the past server throughput and round trip times [18] (oPOAA).

Case 3: A random hosting server selection approach where the hosting server selection is uniformly distributed (RandS).

Case 4: No selection algorithm is deployed and all segments are requested from the same server – the best connected server (BestS).

VI. TEST RESULTS AND ANALYSIS

There is a tradeoff between some evaluation criteria. For example, a longer join time (initial buffering) typically results in fewer interruptions of playback due to rebuffering at later stages, to which viewers are particularly sensitive [19].

The preliminary results of the dPOAA evaluation show reductions in both the rebuffering rate and join time with improvements particularly evident when video content is streamed to a larger number of clients.

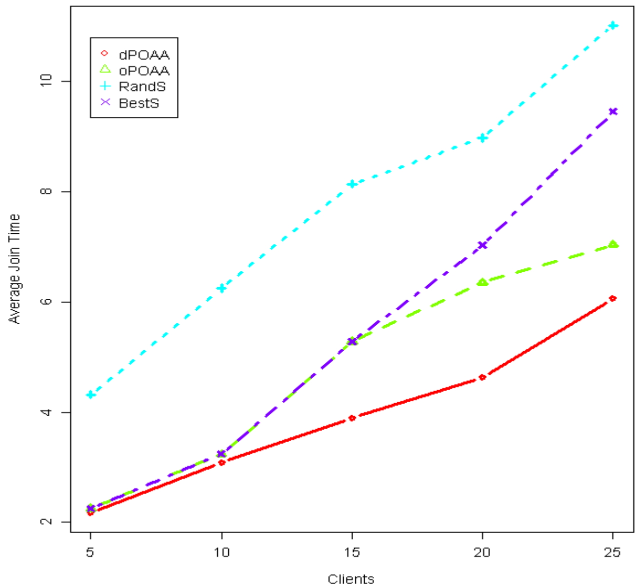

Fig. 4. Average Join Time in seconds

Obtaining all segments from the same server, albeit the best provisioned one, results in a prolonged initial delay proportional to the increasing number of client requests as indicated in Fig. 4.

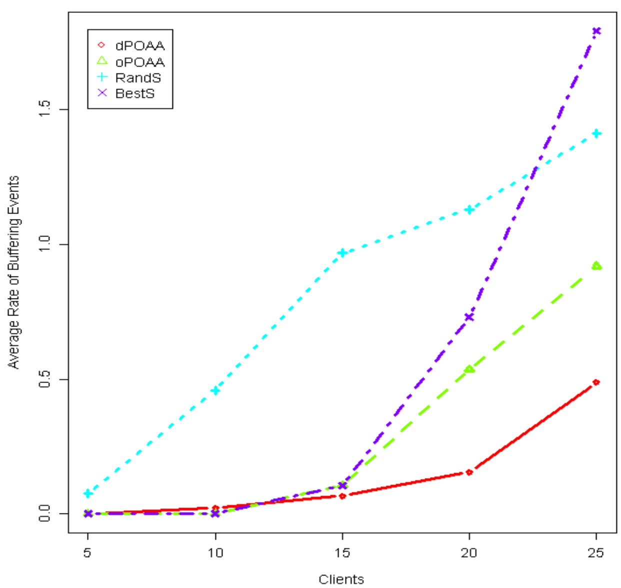

Fig. 5. Rate of Buffering Events

However, learners are more concerned with the higher frequency of playback interruptions (Fig. 5) which is also reflected in the high rebuffering ratio where almost half of the total playout time is made up of stalls required to replenish the buffer for all clients requesting from a single server as indicated in Fig. 6.

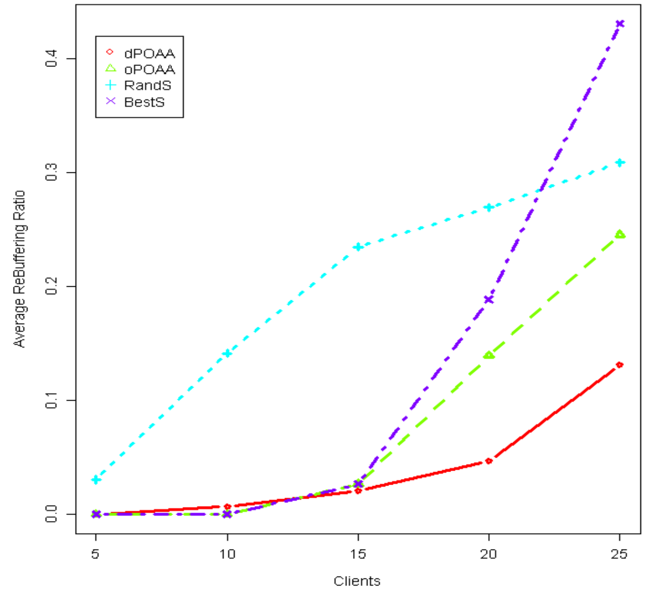

Fig. 6. Average Buffering Ratio

The introduction of a server selection algorithm reduces interruptions while maintaining acceptable join times. However, random selection results in unpredictable video quality, as indicated in Figs. 5 and 6, and therefore a better informed selection algorithm is required. Both oPOAA and dPOAA base their decisions on historic server performance and consistently outperform other approaches, where dPOAA outperforms oPOAA.

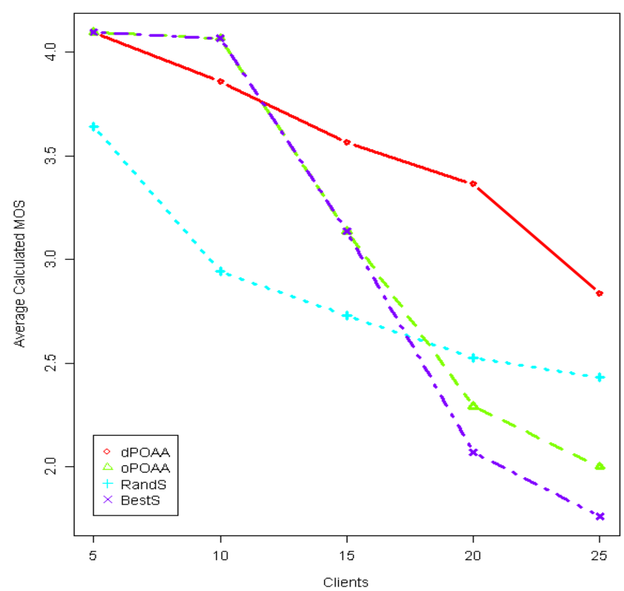

Fig. 7. Average Calculated MOS

It can be seen from the graph in Fig. 7 that the calculated MOS for both the best server and oPOAA selected server falls to a low level, while the deployment of the newly proposed dPOAA maintains adequate levels of MOS.

Overall, these preliminary results indicate that even a simple, informed remote server selection algorithm improves overall viewing experience.

VII. Future Work and Conclusions

The idea behind Adaptive HTTP-based streaming technologies is to use available, low cost HTTP servers that host multiple versions of a video in terms of bitrate, resolution, colour depth, level of detail, ranging from lower quality renditions for 3G connections, up to high definition quality for video streaming. These technologies, including MPEG-DASH [5], introduce client controlled delivery of video segments which provides a practical solution in the face of the ubiquitous utilization of smart phones in future (e.g. a 14-fold increase in mobile video between 2013 and 2018 is predicted [20]).

In this context, we describe and evaluate the DASH-aware Performance Oriented Adaptation Agent (dPOAA) for MPEG-DASH enabled Personalised Learning Systems which enhances remote host selection for video delivery when the video content resides on multiple remote servers. To our knowledge, there is no other similar solution. dPOAA selects the best performing host, based on the hosts' past delivery performance and the category of the requesting user device. The proposed solution requires no modification of the HTTP servers hosting video content and could be easily applied as a plug-in for MPEG-DASH players or as a server rating solution for DAV [7]. The preliminary evaluation results presented here indicate that deployment of dPOAA enhances user experience as it significantly reduces both rebuffering rate and ratio as well as join times, while maintaining calculated MOS levels.

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