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A multiple-source adaptive streaming solution enhancing consumer's perceived quality

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***Abstract*—HTTP Adaptive Streaming (HAS) protocols have become the de-facto solutions to deliver video over the Internet, mainly due to their ability to limit video freezing and thus enhance consumers' Quality of Experience (QoE). Nevertheless, they do not have the possibility to improve the actual delivered video quality, limited by the available throughput between the delivering server and the client. Compared with this single-server approach, multiple-server streaming offers the opportunity to obtain enhanced QoE by benefiting from expanded bandwidth, link diversity and reliability in distributed streaming infrastructures. We present a prototype for a pragmatic evolving HAS-compliant streaming solution, simultaneously using several servers.**

I. Introduction

The demand on network resources is growing every day, driven by the needs of end-users to consume more content with better quality over the Internet. Most of the time, this increase is not followed by the necessary upgrade of core networks capacity, due to the important costs it incurs. A lot of technologies propose alternatives by providing a single intermediate point with high throughput capacity and geographically close to end-users, such as widely deployed Content Delivery Networks (CDNs). CDN solutions rely on a single-server approach using HAS protocols (e.g., MPEG-DASH or HLS), where clients sacrify visual content quality (i.e., related to the requested throughput between client and server) so as to limit video freezing events, hence ameliorating the overall consumers' QoE. Consequently and in order to improve such visual quality, existing CDN/HAS-based solutions scale vertically and horizontally, although at expensive deployment and maintenance costs that eventually make content delivery services prohibitively pricey for Content Providers (CPs). Based on this analysis, we propose to stop confining streaming to the single-server approach and introduce an evolving streaming solution taking advantage of multiple servers simultaneously, including the ones that are not currently used in the content delivery chain (Set-Top boxes, cheap commodity/users' devices, ISPs' and cloud datacenters). Indeed, such system scales horizontally at significantly cheaper costs compared to single-server solutions. Although HAS protocols have been largely integrated into CDN solutions with the single-server approach, they have not been pragmatically enabled for the multiple-server case so that CPs would consider using alternative solutions to CDNs. To that end, we demonstrate Multiple-Source Streaming over HTTP (MS-Stream) [1]. MS-Stream is a pragmatic evolving HAS-compliant streaming solution, simultaneously operating multiple servers towards consumers' QoE enhancement.

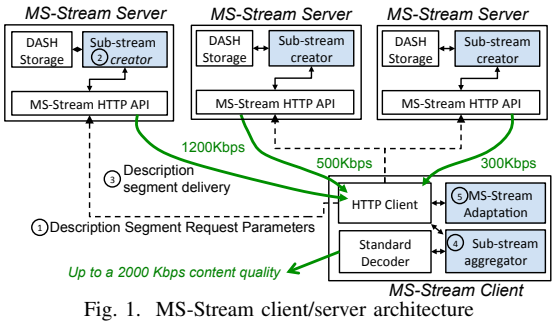

Fig. 1. MS-Stream client/server architecture

II. Multiple-Source Streaming over HTTP

MS-Stream is an evolution of HAS solutions, and more specifically of the DASH standard. Figure 1 depicts the MS-Stream client/server architecture. In addition to the DASH client architecture, MS-Stream incorporates a cost-effective sub-stream aggregation module and an adaptation engine capable of content and server adaptation at client side.

1) MS-Stream's resiliency, flexibility and adaptability to heterogeneous network characteristics: For a given video segment, the MS-Stream client requests servers (e.g., three) to deliver independent codec-compliant playable and aggregatable sub-streams generated from the *DASH storage* and by the *sub-stream creator*. The *DASH storage* contains several bitrate representations of the same content, split in several segments of a few seconds. Sub-streams are generated by interleaving the Group Of Pictures (i.e. sequence of correlated frames -GoPs-) available in two different bitrate representations of the same segment (one low and one high target bitrate). The number of sub-streams for a given segment is an evolving parameter during the streaming session, determined by the client according to the heterogeneous characteristics of the considered paths and servers and to the targeted bitrate. This sub-stream generation scheme has features of interests, easing its adoption by streaming actors: video-codec standard compatibility, tunable redundancy (i.e., the common GoPs in low bitrate copied into all sub-streams), low additional complexity and the possibility to create as many sub-streams as needed.

When retrieved, the requested sub-streams are used to reconstruct the original requested content quality (in the *sub-stream aggregator*). This operation is done by selecting the GoPs of higher size from the set of available sub-streams. In order be resilient to network heterogeneity, we provide a sub-stream synchronization mechanism at client side, so as to ensure uninterrupted video experience. Hence, in the event of sub-stream loss or out-dated delivery, the content is still

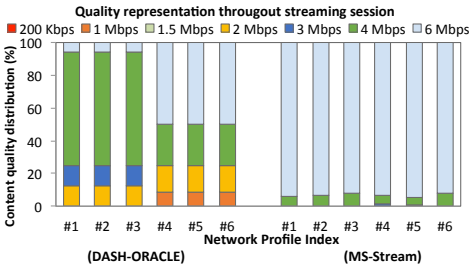

Fig. 2. Quality distribution

playable (content playback continuity is not affected) with sub-optimal visual quality, due to loss of information at the GoP level (inducing lower quality on a GoP-duration basis).

As content is being delivered over N paths (N sources), a first adaptation process is required to evaluate and provide flexibility in the amount of network resources requested on each path. Thus, we incorporate a scheduler modifying the number of GoPs in a target B bitrate requested to a server according to the observed throughput on the associated path. The target video bitrate B is also adapted according to the global throughput estimation at client side. Finally, as sub-streams are independent, switching, adding or removing servers to the streaming session is seamlessly achieved by the client.

2) QoE gains in using MS-Stream over DASH: The MS-Stream protocol has been evaluated over six Network Profiles (NPs) provided by the DASH-Industry Forum[2], featuring different bandwidths, delays, packet loss. We implemented MS-Stream (simultaneously using 3 servers in a pool of 9 available servers) with bitrate and server adaptation against the optimal DASH solution (using a single server from a set of 3 available servers and having prior knowledge of throughput fluctuations). For each experiment, we used a 10-minute segmented video (12 GoPs/segment). We repeated the video 45 times per NPs and per protocol, a total of 15 hours of playback. We evaluated the quality distribution throughout the streaming sessions. According to Fig.2, MS-Stream took benefit of link diversity and provided the 6Mbps quality for 94% of the time in average, on all NPs with very few quality changes (less than 3 per NPs). The DASH-ORACLE client could not obtain similar distribution while using one server.

III. Showcase Description

The MS-Stream protocol has been implemented in a pragmatic vision conforming to the H.264 and DASH standards. A demonstration is available online at [3]. For the CCNC2017 demonstration track, we provide a virtualized distributed Video-on-Demand platform hosted into a physical server (Fig.3). This platform implements individual, personalizable and interactive demonstrations of the MS-Stream protocol for multiple users at the same time, in heterogeneous network environments. In this implemented virtualized streaming platform, end-users are given the possibility to add/discard servers contributing to their streaming session and can also tune MS-Stream servers' upload throughput capacity as shown in Fig.4. Additionally, live QoE feeds (content bitrate, available buffered content) are provided to end-users to let them know the QoE impact of adding/discarding servers and of modifying

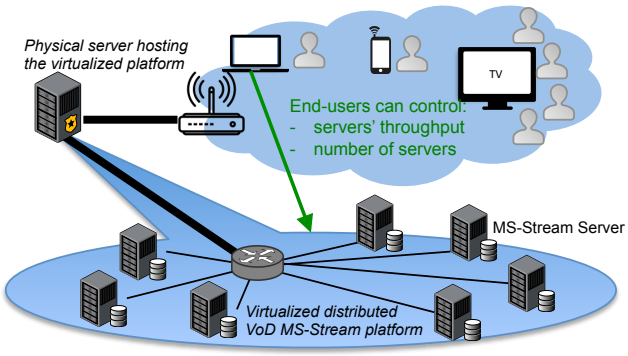

Fig. 3. Demonstration platform

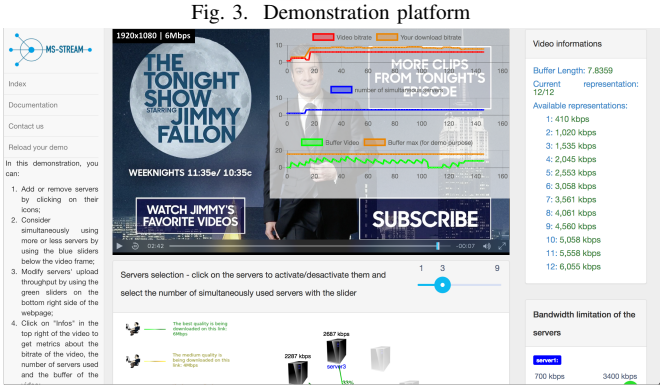

Fig. 4. Demonstration website

servers' throughput. Finally, end-users can also switch back to a regular single-server DASH use-case.

IV. Impacts & Potential Commercial Applications

The advent of an evolving streaming solution that takes advantage of multiple types of content sources simultaneously could change the existing content delivery value chain. Indeed, existing infrastructures and devices that are not currently involved in the content delivery chain could be used to achieve better streaming QoE at cheaper deployement and maintenance costs. Therefore, several potential business models rise, in which content delivery services are sold to CPs by: (i) STB providers relying on STB overlays and cloud servers to easily and in-live adjust the scalability of their services; (ii) ISPs willing to fight the OTT delivery trend by being part of the content delivery value chain through the use of their datacenters as well as their deployed home-gateways. Additionally, this streaming evolution permits new types of applications, e.g.: distributed social networks hosted on STBs or home-gateways located at consumers' premises and where sharing User-Generated-Content can be achieved with VoD or live use-cases (such as broadcasting a local poker tournament or a theater play); tracker-based P2P streaming applications where consumers can create their own content-sharing platform.

References

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