YouSlow: A Performance Analysis Tool for Adaptive Bitrate Video Streaming

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ABSTRACT

Adaptive bitrate (ABR) technologies are being widely used in today's popular HTTP-based video streaming such as YouTube and Netflix. Such a rate-switching algorithm embedded in a video player is designed to improve video quality-of-experience (QoE) by selecting an appropriate resolution based on the analysis of network conditions while the video is playing. However, a bad viewing experience is often caused by the video player having difficulty estimating transit or client-side network conditions accurately. In order to analyze the ABR streaming performance, we developed YouSlow, a web browser plug-in that can detect and report live buffer stalling events to our analysis tool. Currently, YouSlow has collected more than 20,000 of YouTube video stalling events over 40 countries.

Categories and Subject Descriptors

D.2.8 [**Software Engineering**]: Metrics—*performance measures*

Keywords

HTTP Video Streaming; Adaptive Bitrate Streaming (ABR); Video Quality of Experience

1. INTRODUCTION AND CHALLENGE

Today's over-the-top (OTT) video streaming services deliver video contents to clients over HTTP. In the early version of HTTP-based video streaming, a progressive download mechanism was used, where the server pushes the content as quickly as possible when a client requests a video. However, the major drawback is that all clients must download videos at the same bitrate [1], regardless of network conditions and performance of their devices. Several ABR technologies such as Apple HTTP Live Streaming (HLS), Microsoft IIS Smooth Streaming, Adobe HTTP Dynamic Streaming and Dynamic Adaptive Streaming over HTTP (DASH) have been introduced to resolve this issue. In ABR streaming, a video delivery node contains a set of segments that encode the same content at multiple bitrates, so a video player can adaptively select the appropriate bitrate based upon network conditions and CPU capacity of the clients' devices.

The self-adjusting mechanism aims to stream a video without interruption in the highest bitrate possible. Currently, video players select the best appropriate bitrates based on playout buffer size and its own bandwidth estimator [1]. The performance of ABR heuristic algorithm is directly related to user-perceived video quality. If the network capacity is overestimated, severe buffer stalling can occur by the video player requesting a higher bitrate than what is actually available. On the other hand, a low quality of video can play if the capacity is underestimated. Therefore, monitoring end-user's video QoE like the above is necessary for the analysis of ABR streaming performance.

Several researchers have been trying to analyze ABR streaming [2, 3]. Also, the performance study can be related to network neutrality issues [4, 5]. Most work has been done measuring video quality-of-service (QoS) metrics such as packet throughput, packet loss, jitter and delay. They collected the data from intermediate nodes (e.g., transit routers) between clients and video delivery nodes. These measurements are generally used to represent the impact on the video quality level from the network operator's point of view. Since they do not directly reflect the end-user's perceived video quality, we cannot simply use these metrics for ABR streaming performance test. In order to address this issue, we introduce YouSlow ("YouTube Too Slow!? - YouSlow"). This web browser plug-in is designed to monitor buffer stalling events while clients watch YouTube videos on Chrome browsers. When a buffer stalling is detected, YouSlow automatically reports the name of the local ISP the client is connected to, the duration, and approximate location of the event to our analysis tool. These collected data are then marked on Google maps (e.g., region, country and state) on our website for calculating statistics.

2. YOUSLOW OVERVIEW

Unlike the prior approaches, YouSlow obtains streaming status directly from a video player embedded in a web browser. Currently, YouSlow has been implemented in YouTube video players and published in the Chrome web store. The plug-in consists of Chrome extension content scripts [6] that allow our JavaScript codes to automatically activate when clients watch videos on YouTube's website. It uses the YouTube ActionScript 3.0 Player API [7] to access the video players

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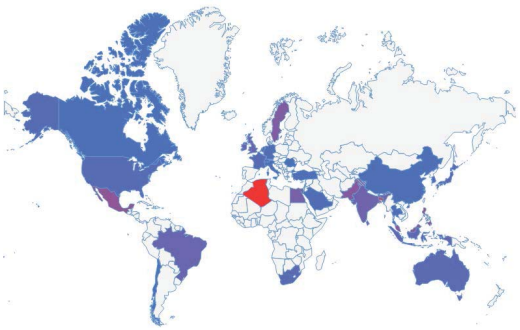

Country and avg. buffer stalling duration (sec)

Country	Avg. duration
Algeria	54
Philippines	25
Bangladesh	20
Sweden	18
Indonesia	12
United Kingdom	11
South Korea	5
United States	4

Table shows partial results

Figure 1: Country maps and YouTube buffer stalling statistics on YouSlow website

embedded in Chrome browsers. Using the player API, YouSlow dynamically monitors player status (e.g., `not started`, `ended`, `playing`, `paused`, `buffering` and `video cued`) and playback quality (e.g., `small`, `medium`, `large`, `hd720`, `hd1080` and `highres`) while a video is playing. We plan to extend our work to other popular video streaming services such as Netflix. YouSlow is designed to report the following objectives to our analysis tool.

- **Initial buffering time**: Measure start-up time from the instant a play button is clicked until it actually starts to play the video.
- **Requested bitrates**: Record bitrates requested from a video player. There are two cases: purposely changed by clients or automatically adjusted by ABR algorithms.
- **Buffer stalling duration**: Measure how long a client experiences buffer stalling during a download.
- **Approximate location of buffer stalling events and local ISP information**: An IP geolocation database[1] is used to pinpoint the approximate location of the event and the name of local ISP.

No other data is collected such as what videos are watched by clients or any account information. Through our website[2], clients can share their buffering experiences and compare local ISPs in their neighborhoods. It is also useful for network operators to analyze performance of their networks by monitoring buffer stalling events in real time. An introduction video can be found on YouTube[3].

3. EVALUATION OF ABR STREAMING

To analyze ABR streaming performance, we calculate 1) how long a buffer stalling event occurs for each bitrate during a download, 2) how long HD bitrates are played during a download, and 3) elapsed time from the instant a buffer stalling event occurs until playback rate changes. This indicates how well a video player adjusts bitrates without viewing interruption. For instance, if a video player changes a bitrate from HD to SD resolution before buffer stalling events occur, this means that the ABR heuristic algorithm is performing an appropriate rate-switching in timely manner.

[1]Maxmind GeoIP database - `http://dev.maxmind.com/`
[2]YouSlow - `http://dyswis.cs.columbia.edu/youslow/`
[3]`https://www.youtube.com/watch?v=9cdOoOkDIi0`

4. PRELIMINARY RESULTS

YouSlow has collected more than 20,000 YouTube buffer stalling events over 40 countries. According to the database, our key observations can be summarized as follows:

- Average watching duration per video session is 7 min 34 sec.
- Average buffer stalling duration as a fraction of the play time per video session is 6.86%. 85.2% of the total events experienced less than 5 sec of buffer stalling.
- Playback rate changes 2.25 times on average per video session. Average buffer stalling duration for each bitrate per video session is 2.59 sec.
- Playback rate statistics are `highres` (greater than 1080p - 0.017%), `hd1080p` (1.93%), `hd720p` (7.81%), `480p` (26.91%), `360p` (43.43%), `240p` (16.17%) and `tiny` (smaller than 240p - 3.72%).
- United States (4.91 sec), South Korea (5.17 sec) and England (11.28 sec) show shorter buffer stalling duration per video session, compared to Sweden (18.65 sec), Malaysia (22.56 sec) and Philippines (25.19 sec).

As more buffer stalling events are accumulated, we expect to conduct a more meaningful empirical investigation of ABR streaming.

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