An Experimental Evaluation of Rate Adaptation Algorithms in Adaptive Streaming over HTTP

Saamer Akhshabi, Constantine Dovrolis
Georgia Institute of Technology

Ali C. Begen
Cisco Systems

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Objectives

• Examine the performance of adaptive streaming over HTTP
• Three important operating conditions
  • How adaptive players react to available bandwidth variations
    • Persistent variations
    • Short-term variations (spikes)
  • How adaptive players compete for available bandwidth
  • How adaptive streaming performs with live content
    • What are the differences with on-demand content?
Outline

• Overview of adaptive streaming over HTTP
• Experimental methodology
• Rate adaptation under available bandwidth variations
  – Microsoft Smooth Streaming player
  – Netflix player
  – Adobe OSMF player
• Competition between two players
• Live streaming
• Conclusions
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Adaptive Streaming over HTTP

From IIS Smooth Streaming Website
Adaptive Streaming over HTTP: Manifest File and Fragments

<SmoothStreamingMedia MajorVersion="1" Duration="150483666" …>

<StreamIndex Type="video" Chunks="52"
Url="QualityLevels({bitrate})/Fragments(video={start time})" …>

<QualityLevel Bitrate="3450000" Width="1280" Height="720" …/>
<QualityLevel Bitrate="1950000" Width="848" Height="480" …/>
<QualityLevel Bitrate="1250000" Width="640" Height="360" …/>

……..

<c n="0" d="9342667" />
<c n="1" d="5338666" />
<c n="2" d="11678334" />

……..
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Experimental Methodology
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Smooth Streaming Player
Smooth Streaming Player

• Sample HTTP Request:
  - GET
    /mediadl/iisnet/smoothmedia/Experience/BigBuckBunny720p.ism/QualityLevels(2040000)/Fragments(video=400000000) HTTP/1.1
Smooth Streaming Player Buffering and Steady State

• One fragment per HTTP request

• No HTTP pipelining

• Two states:
  1. Buffering state
     • Request fragments as fast as possible
  2. Steady-state
     • Request new fragment every $T$ seconds
Smooth Streaming Player
Behavior under Unrestricted Available Bandwidth

- Average throughput: running average of *two-second* TCP throughput measurements.
- Fragment throughput: per-fragment throughput measurement
Smooth Streaming Player
Behavior under Unrestricted Available Bandwidth

- Two successive, say video, requests sent at times $t_1$ and $t_2$ ($t_1 < t_2$) with timestamps $t'_1$ and $t'_2$ ($t'_1 < t'_2$) respectively.
- The playback buffer size (in seconds) for video at time $t_2$ is estimated as:

$$B(t_2) = B(t_1) - (t_2 - t_1) + (t'_2 - t'_1)$$
Smooth Streaming Player Behavior Under Persistent Changes in Available Bandwidth

- Rate adaptation occurs after long delays
- The player estimates available bw using a running average of the per-fragment TCP throughput measurements
Smooth Streaming Player
Playback Buffer Size under Persistent Changes in the Available Bandwidth

- Playback buffer size decreases when available bandwidth is less than the requested bitrate.
- Playback buffer size increases when player goes into “buffering state” requesting fragments as fast as possible.
  - Together with switching to bitrate < available bw.
The client reacts to the spikes by switching to a lower bitrate too late

Stays at that bitrate for long after the spike has passed
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Player accumulates 5-min playback buffer!
Occasionally, the player requests a higher bitrate than available bw!

Utilize large playback buffer size to optimize video quality
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Adobe OSMF Player
OSMF Player
Behavior under Persistent Changes in the Available Bandwidth

- The client often fails to select the highest possible bitrate for the given available bandwidth
- Also, player often oscillates between bitrates, mostly the lowest and the highest bitrates
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Two Smooth Streaming Players Compete

- Fairness issue: one stream may get much lower bitrate than the other
- Players can get into oscillation between bitrates even when available bw is constant
- Synchronization can cause simultaneous bitrate drops
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Smooth Live Streaming

Playback Buffer Size

- Player starts streaming with 8-seconds delay
- Playback delay increases over time whenever playback buffer gets empty
  - Player does not skip fragments
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Summary of the Key Differences Between Players

- Smooth Streaming player
  - Playback buffer size of 10s of seconds
  - Conservative in selecting bitrate
    (bitrate < available bw)

- Netflix player
  - Playback buffer size of few minutes
  - More aggressive than Smooth player
    (sometimes bitrate > available bw)

- OSMF player
  - Erratic bitrate selection
  - Is open source and requires customization
Research Challenges for Adaptive Streaming over HTTP

- Reducing the large delay in responding to persistent available bw variations
- Correcting erratic rate adaptations under short-term variations
- Avoiding oscillations and unfairness when multiple players compete
- Improving the performance of live streaming
Ongoing Work

• Continue the analysis of commercial players to understand how they work
  – And identify weaknesses
• Expand study of multiple player competition
• Design and implement an adaptive steaming adaptation logic that can address all previous issues
Questions