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

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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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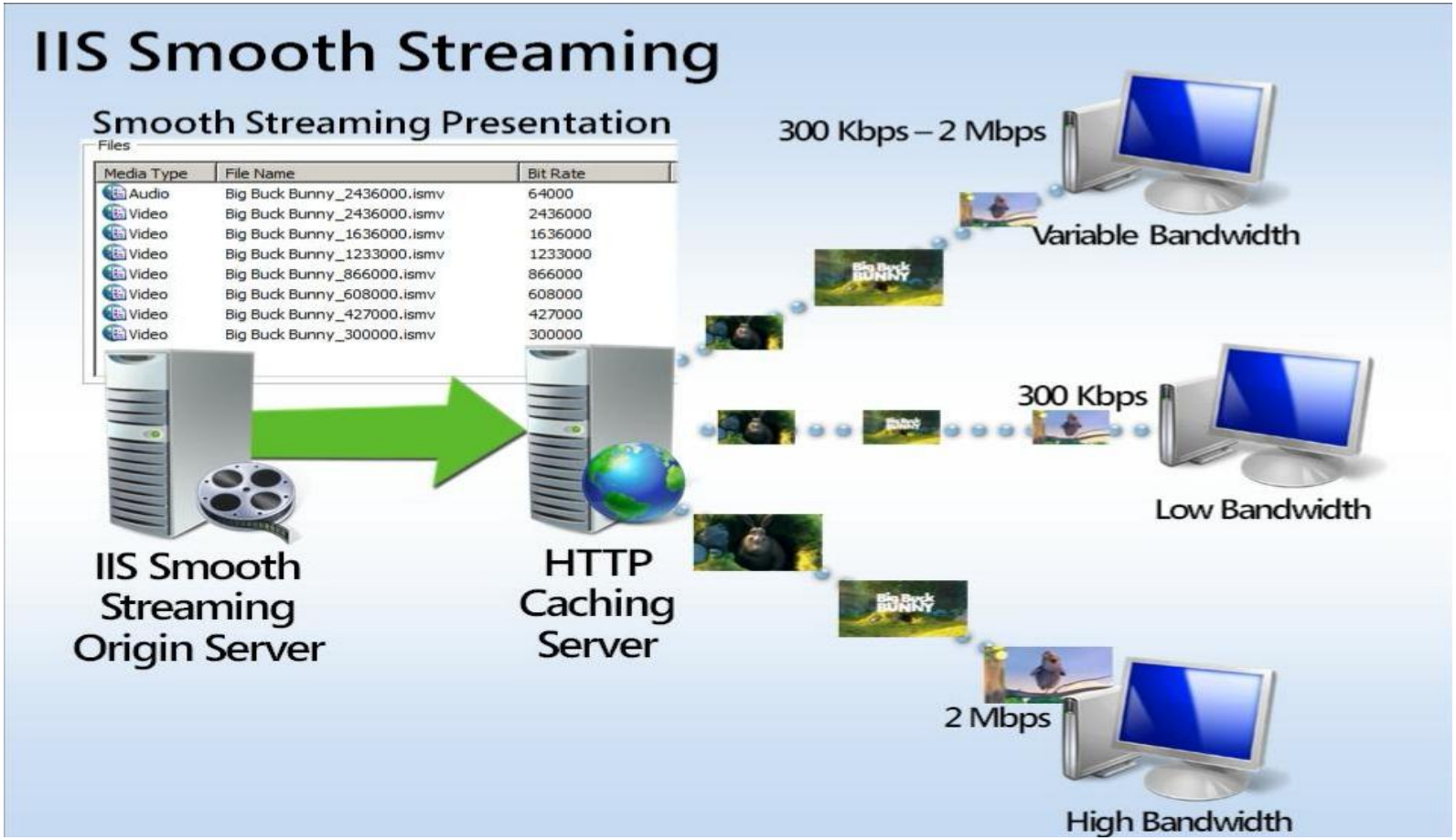
Adaptive Streaming over HTTP



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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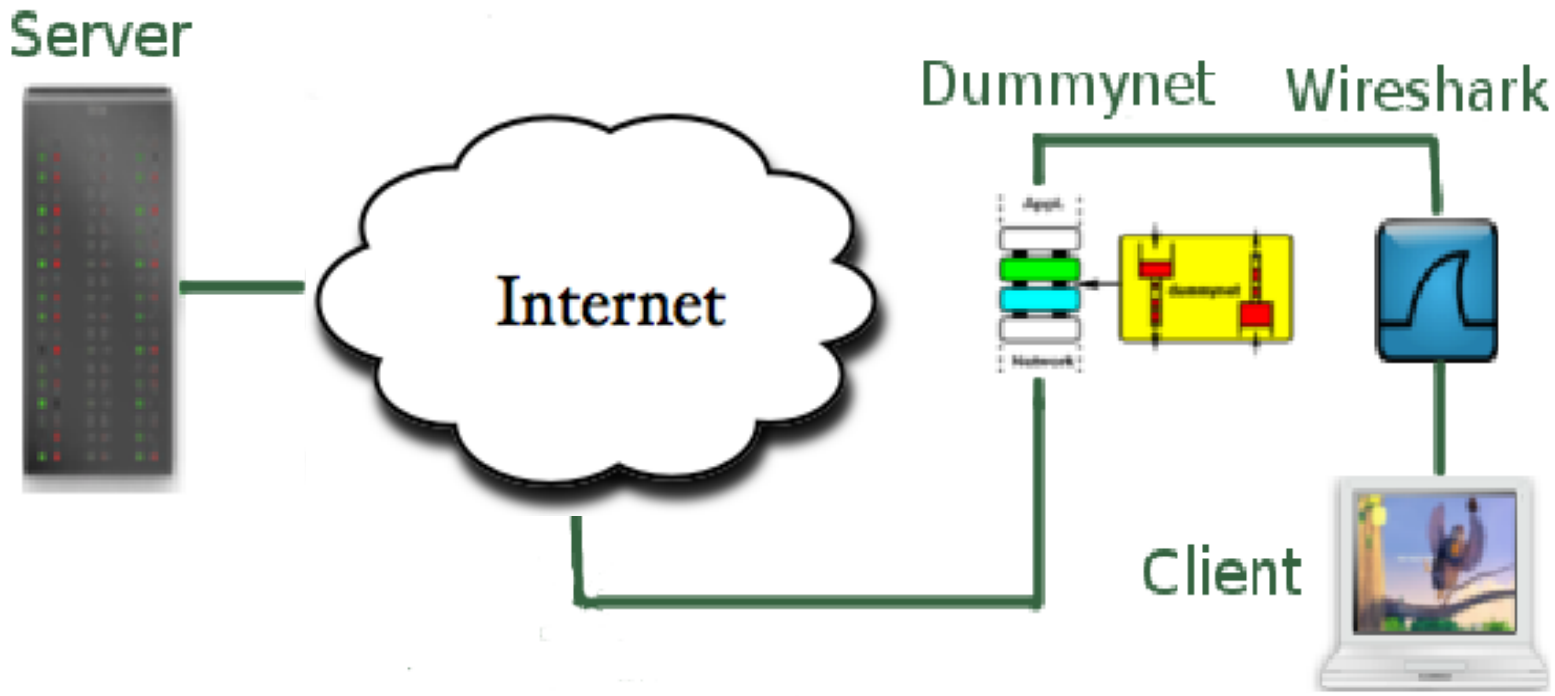
Experimental Methodology



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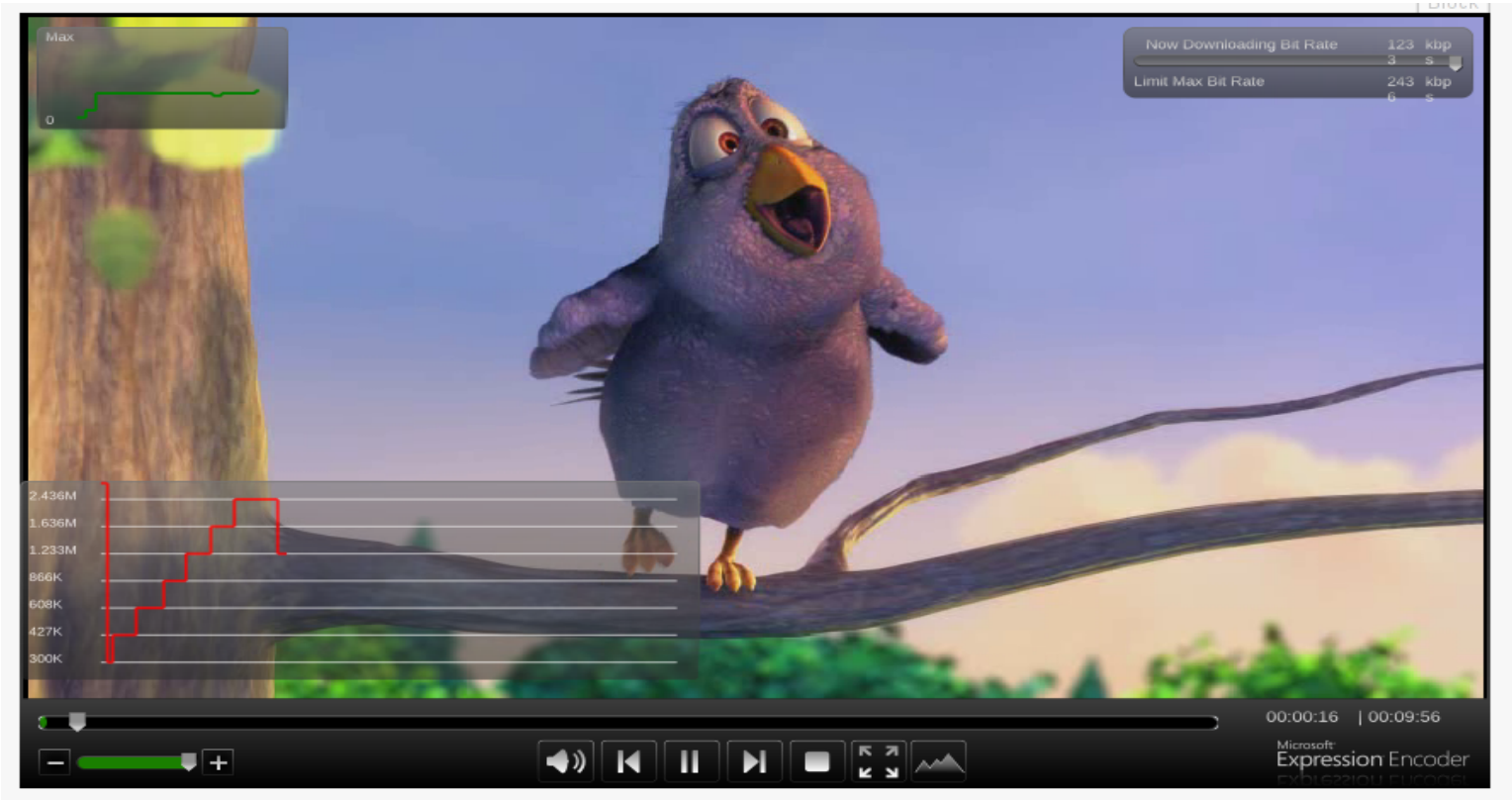
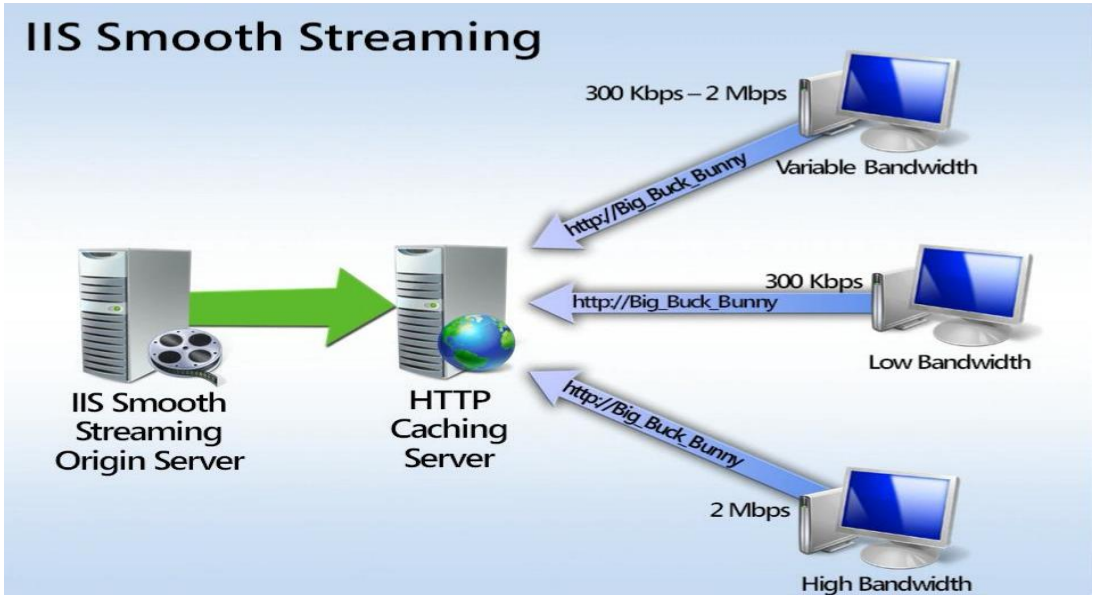
Smooth Streaming Player

Microsoft® Silverlight™

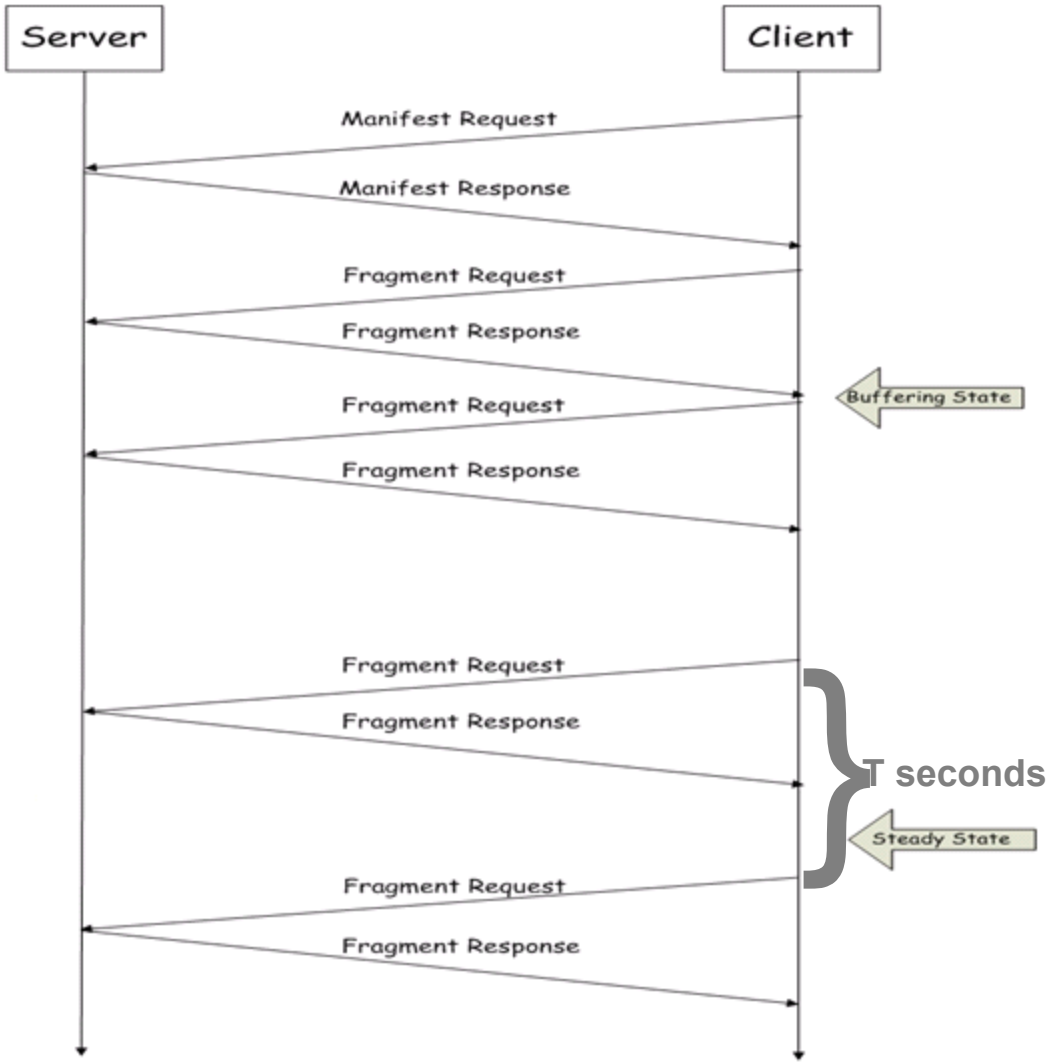


Smooth Streaming Player

- Sample HTTP Request:
  - GET /mediadl/iisnet/smoothmedia/Experience/BigBuckBunny720p.ism/QualityLevels(2040000)/Fragments(video=400000000) HTTP/1.1

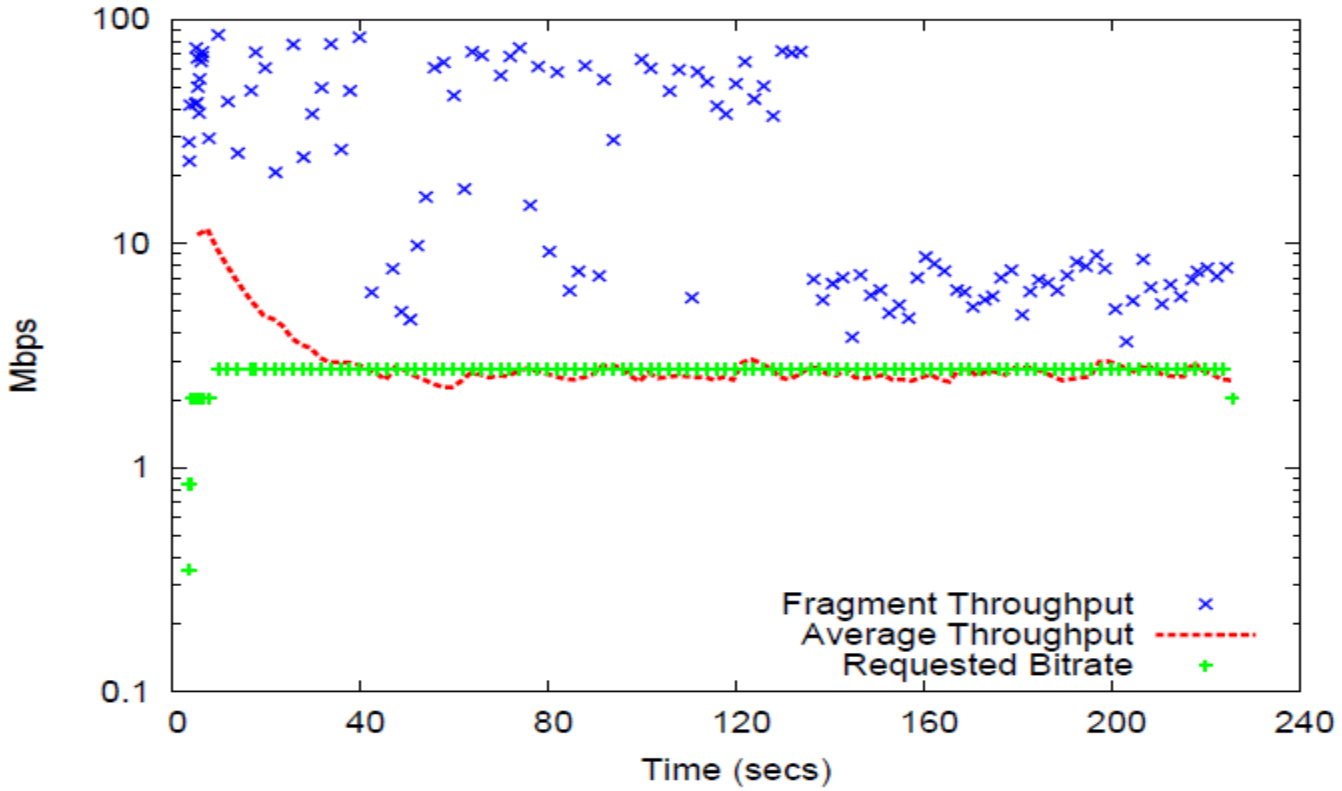


Smooth Streaming Player
Buffering and Steady State



- 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

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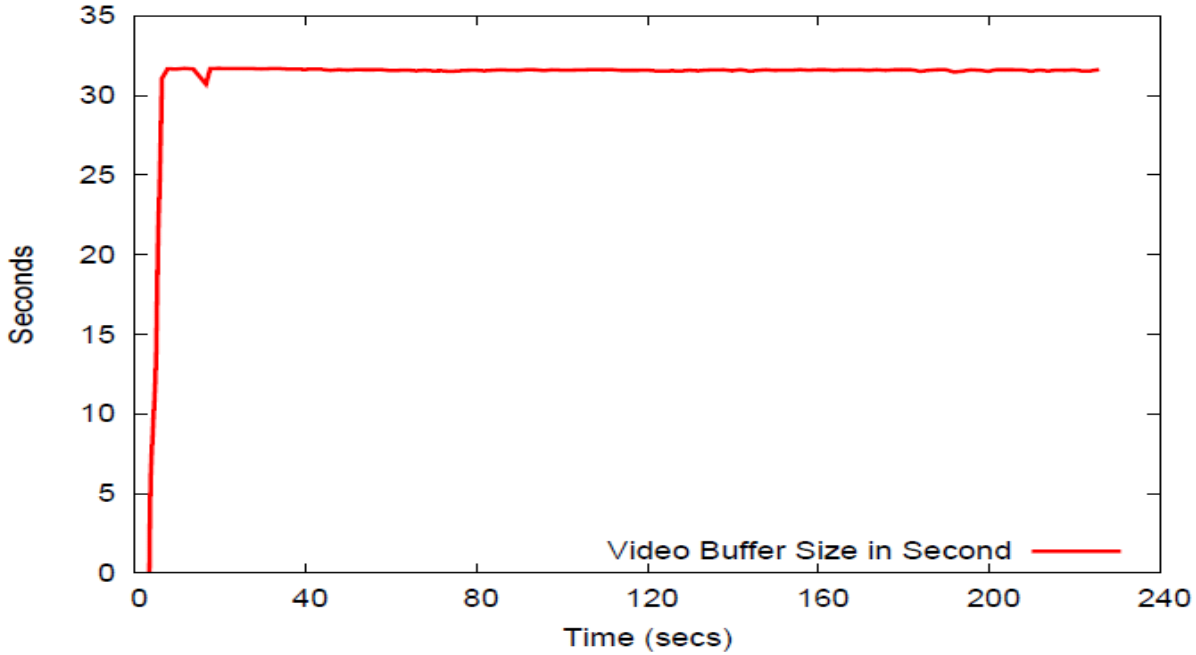
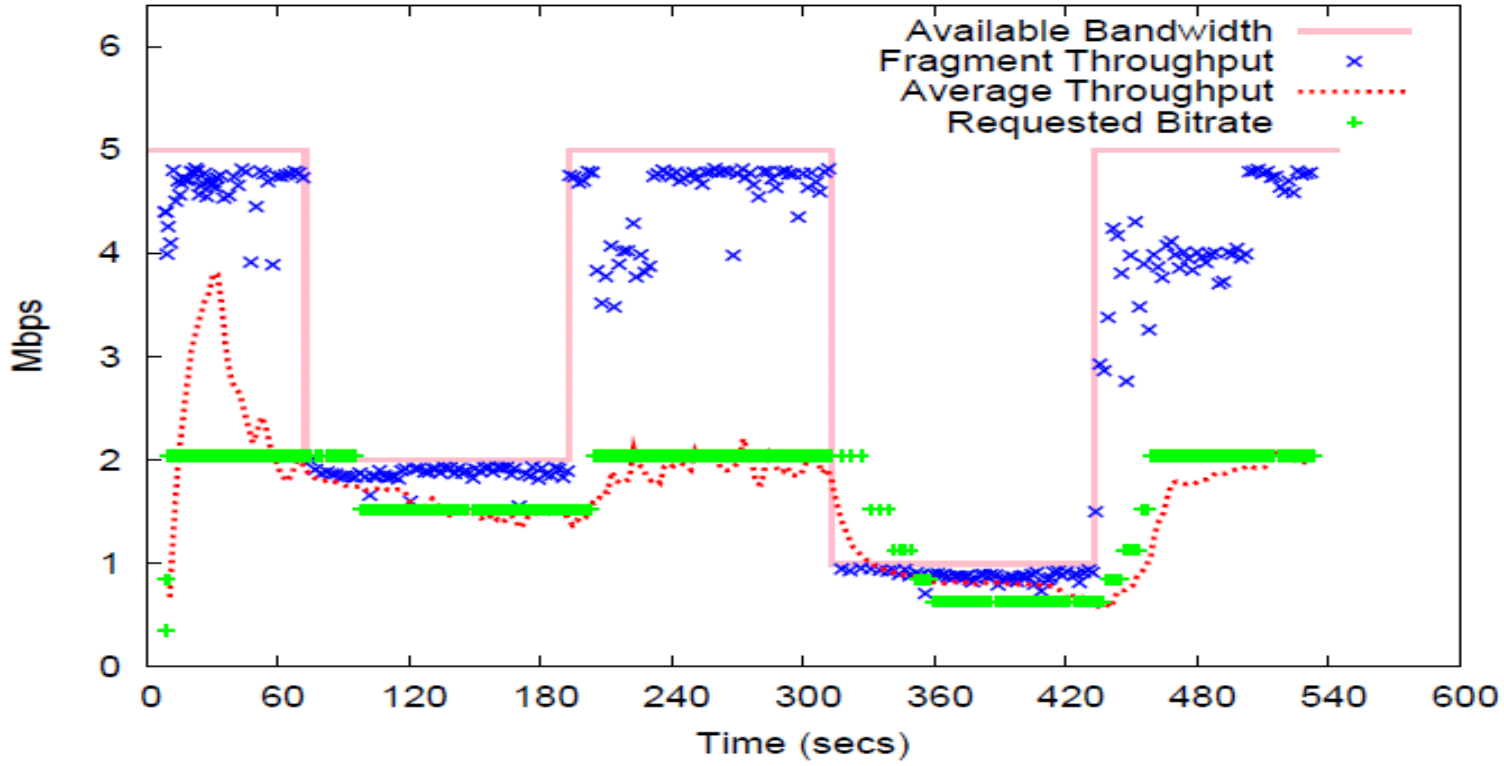


- Two successive, say video, requests sent at times t_1 and t_2 ($t_1<t_2$) with timestamps t'_1 and t'_2 ($t'_1 < t'_2$) respectively
- The playback buffer size (in seconds) for video at time t_2 is estimated as:

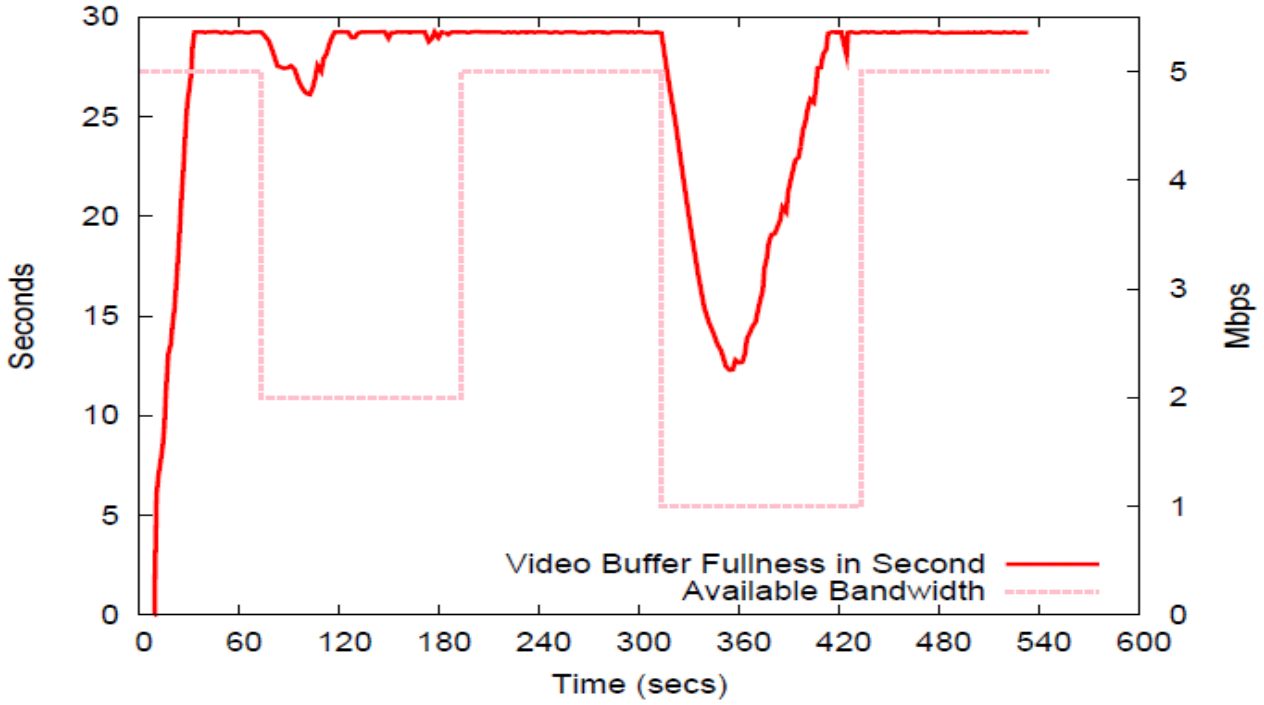
$$B(t_2) = B(t_1) - (t_2-t_1) + (t'_2 - t'_1)$$

Smooth Streaming Player Behavior Under Persistent Changes in Available Bandwidth



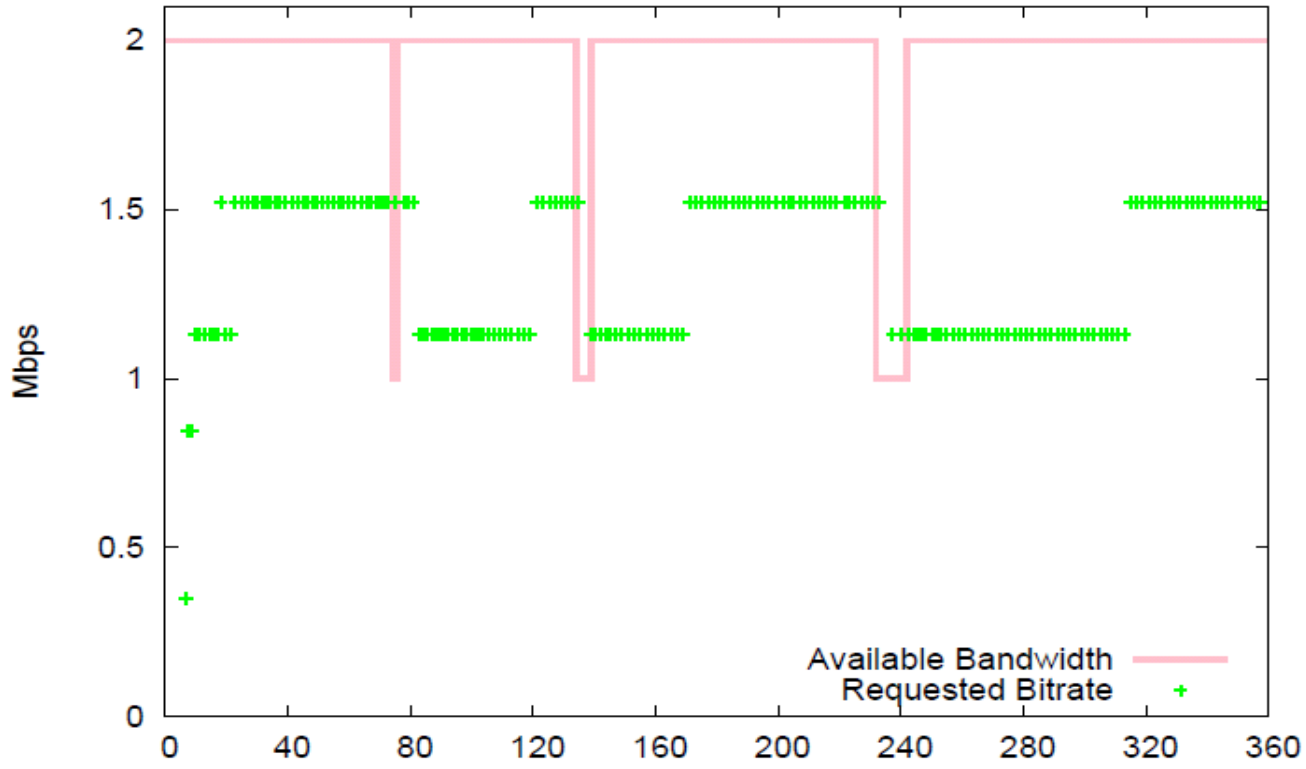
- Rate adaptation occurs after long delays
- The player estimates available bw using a running average of the per-fragment TCP throughput measurements

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

Smooth Streaming Player Behavior under Short Term Available Bandwidth Variations (Negative Spikes)



- 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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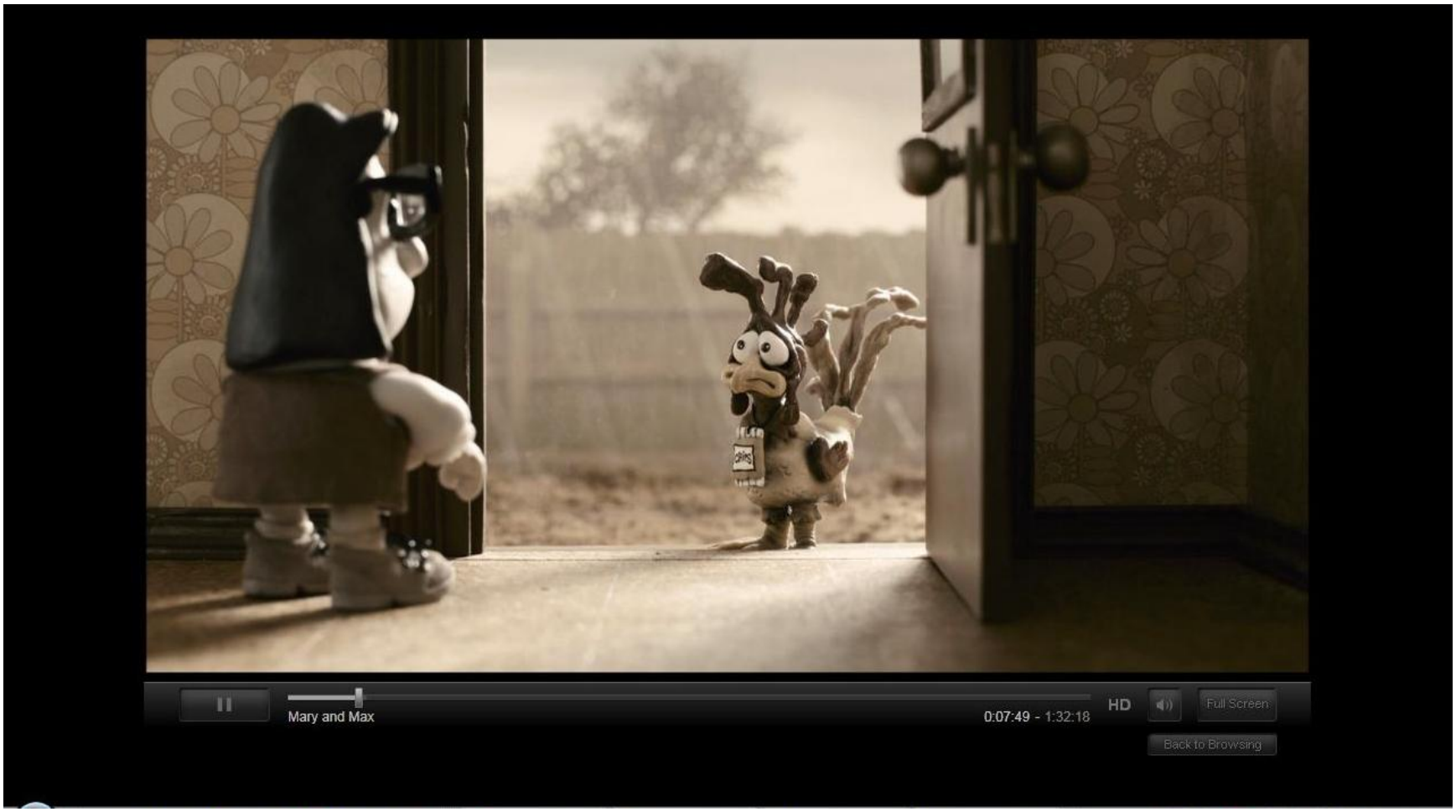
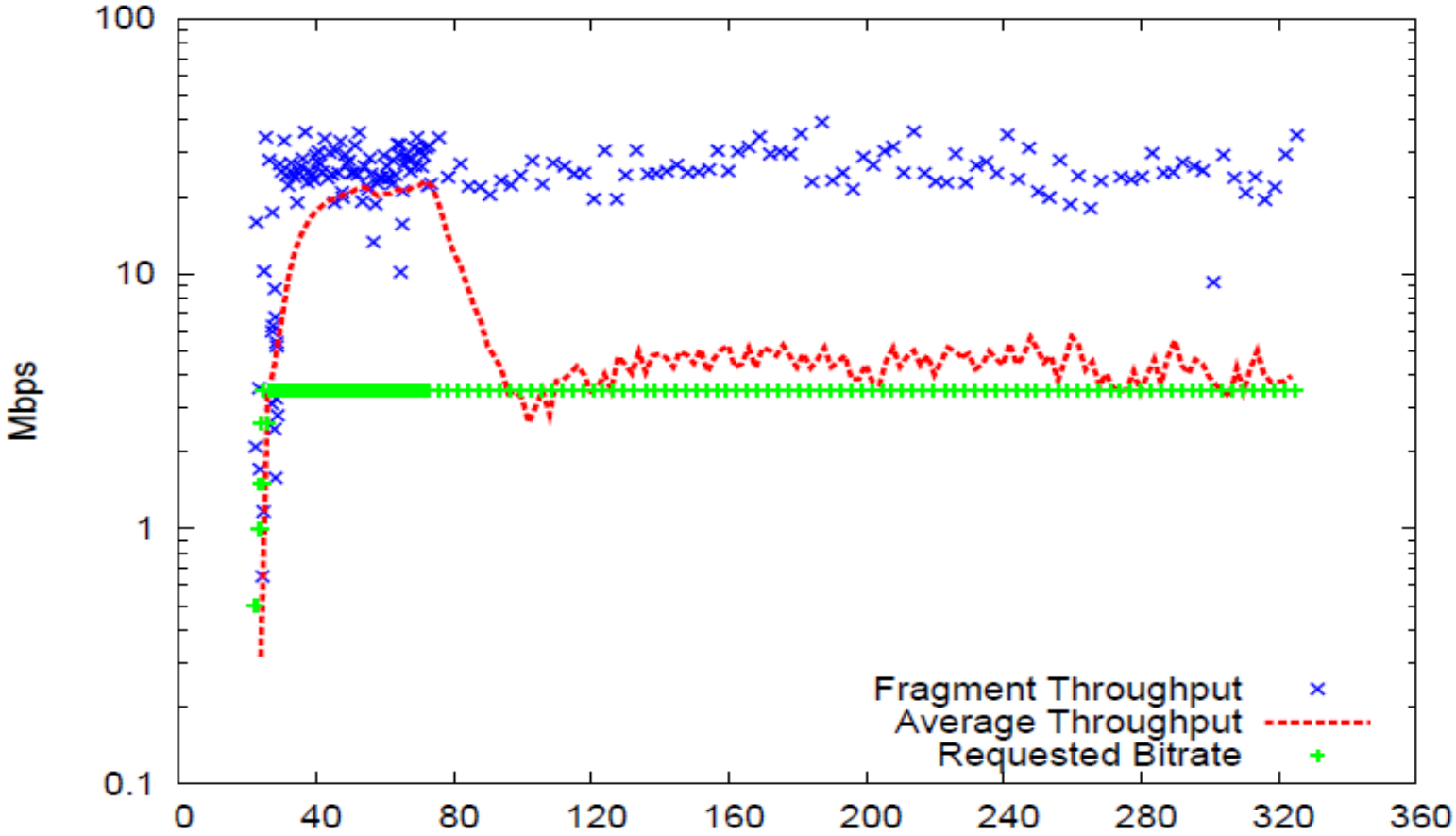
Netflix Player

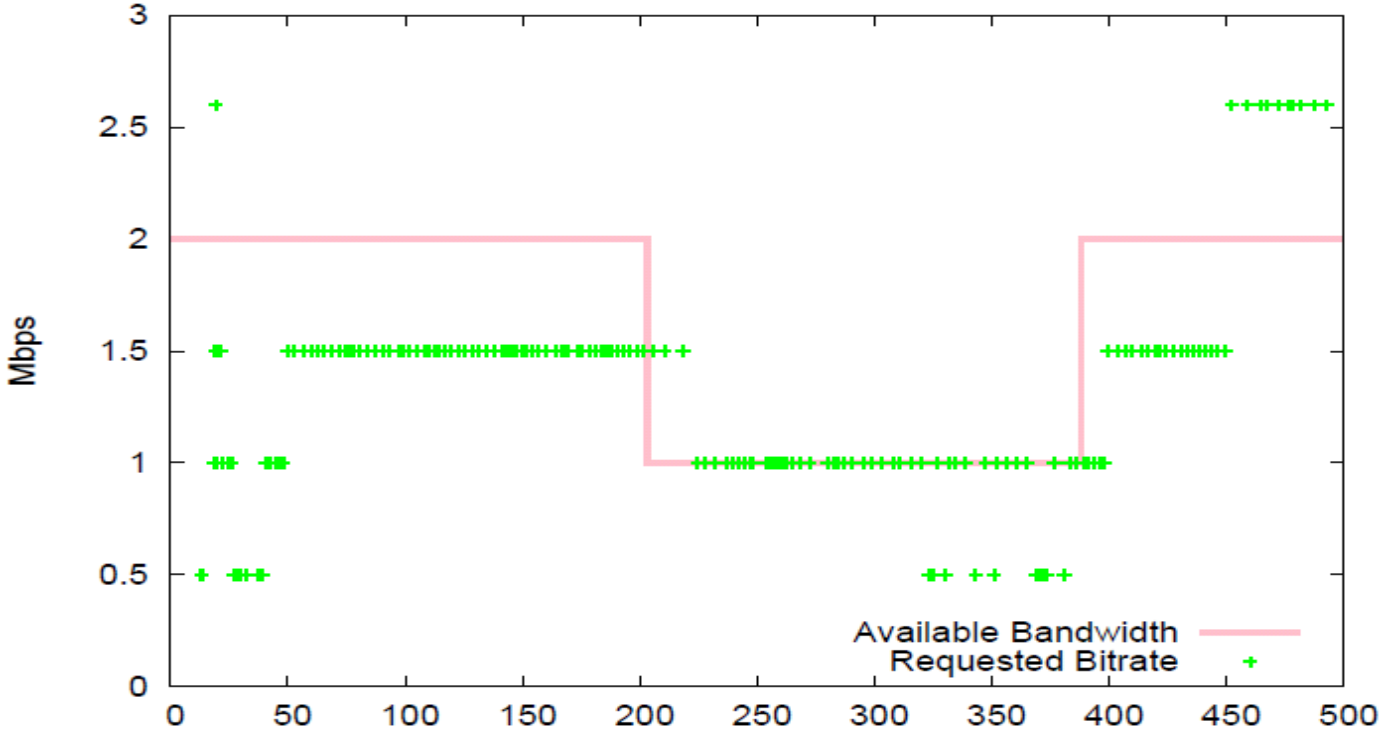


Netflix Player
Behavior under Unrestricted Available Bandwidth



- Player accumulates 5-min playback buffer!

Netflix Player Behavior Under Persistent Changes in the Available Bandwidth



- Occasionally, the player requests a higher bitrate than available bw!
  - Utilize large playback buffer size to optimize video quality

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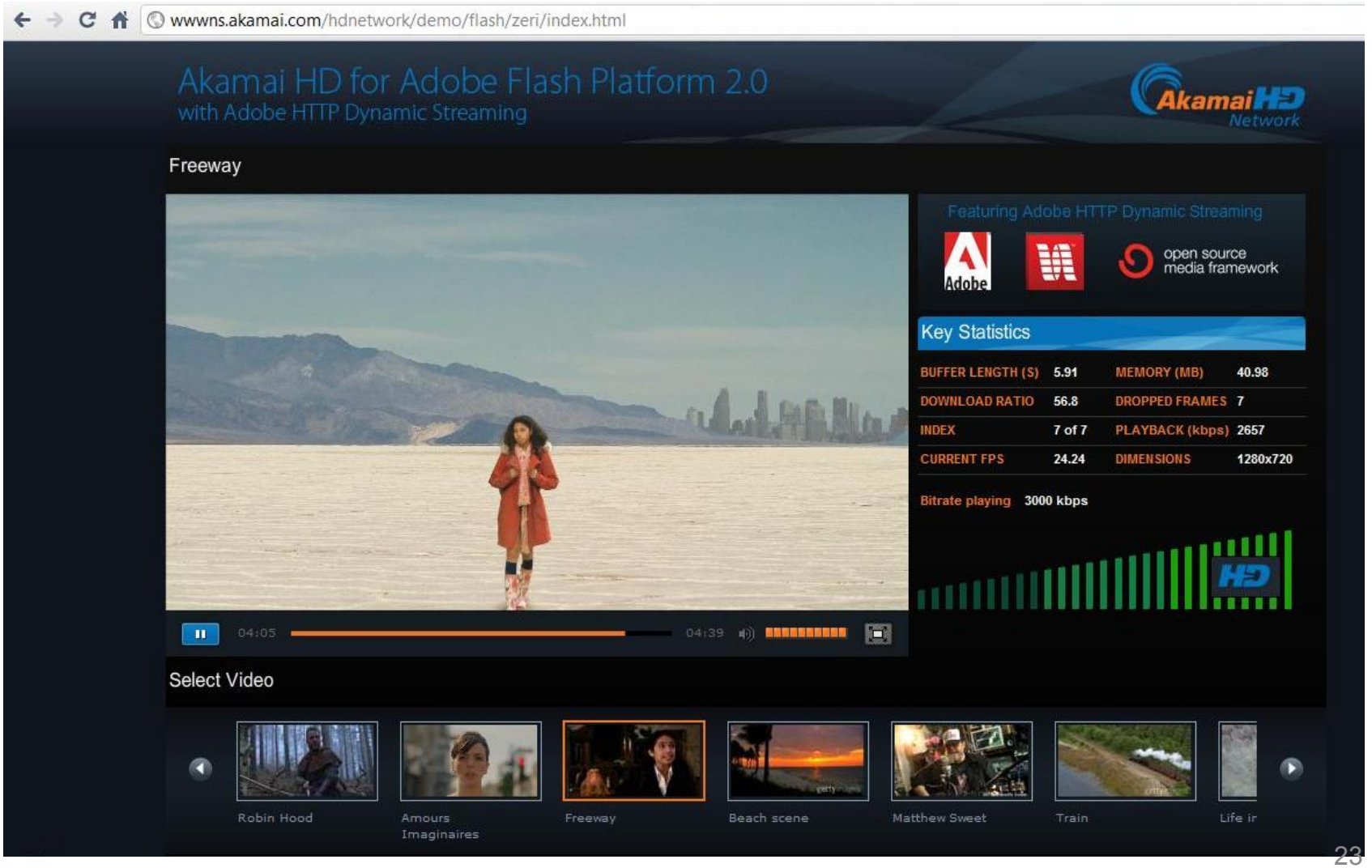
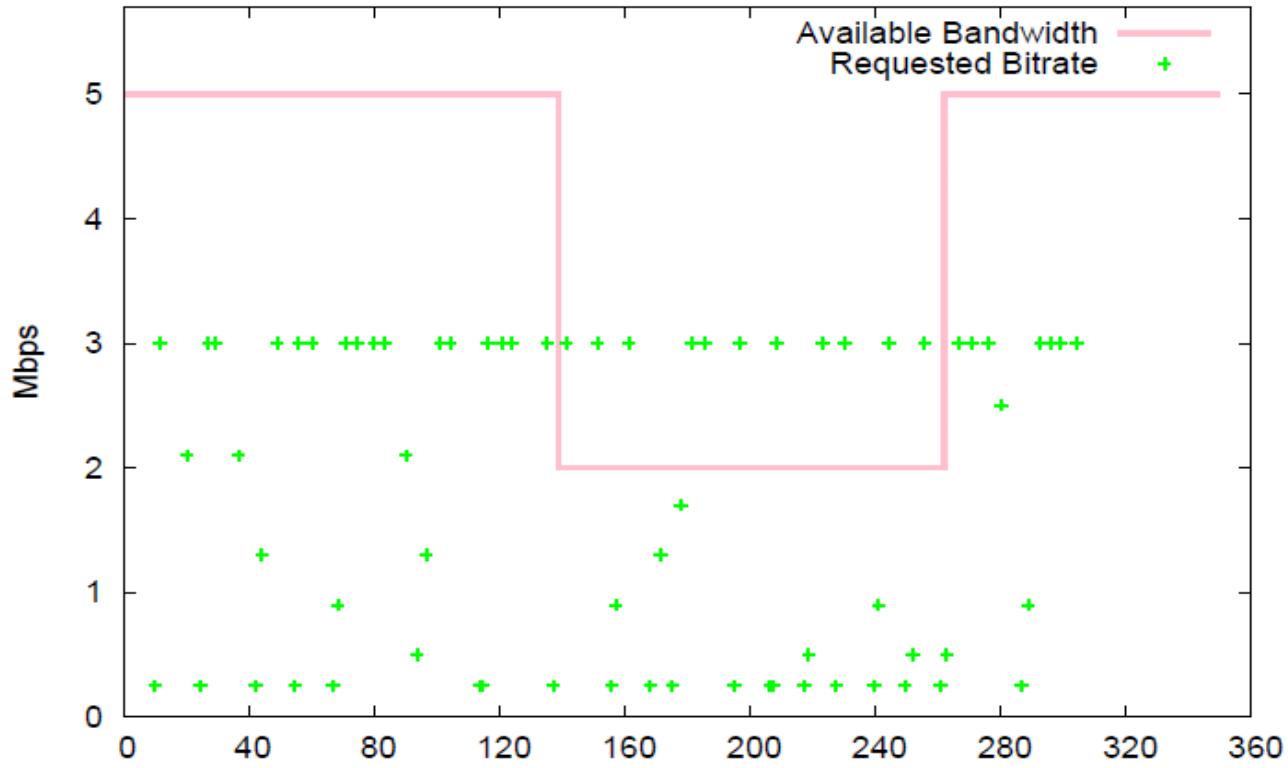
Adobe OSMF Player



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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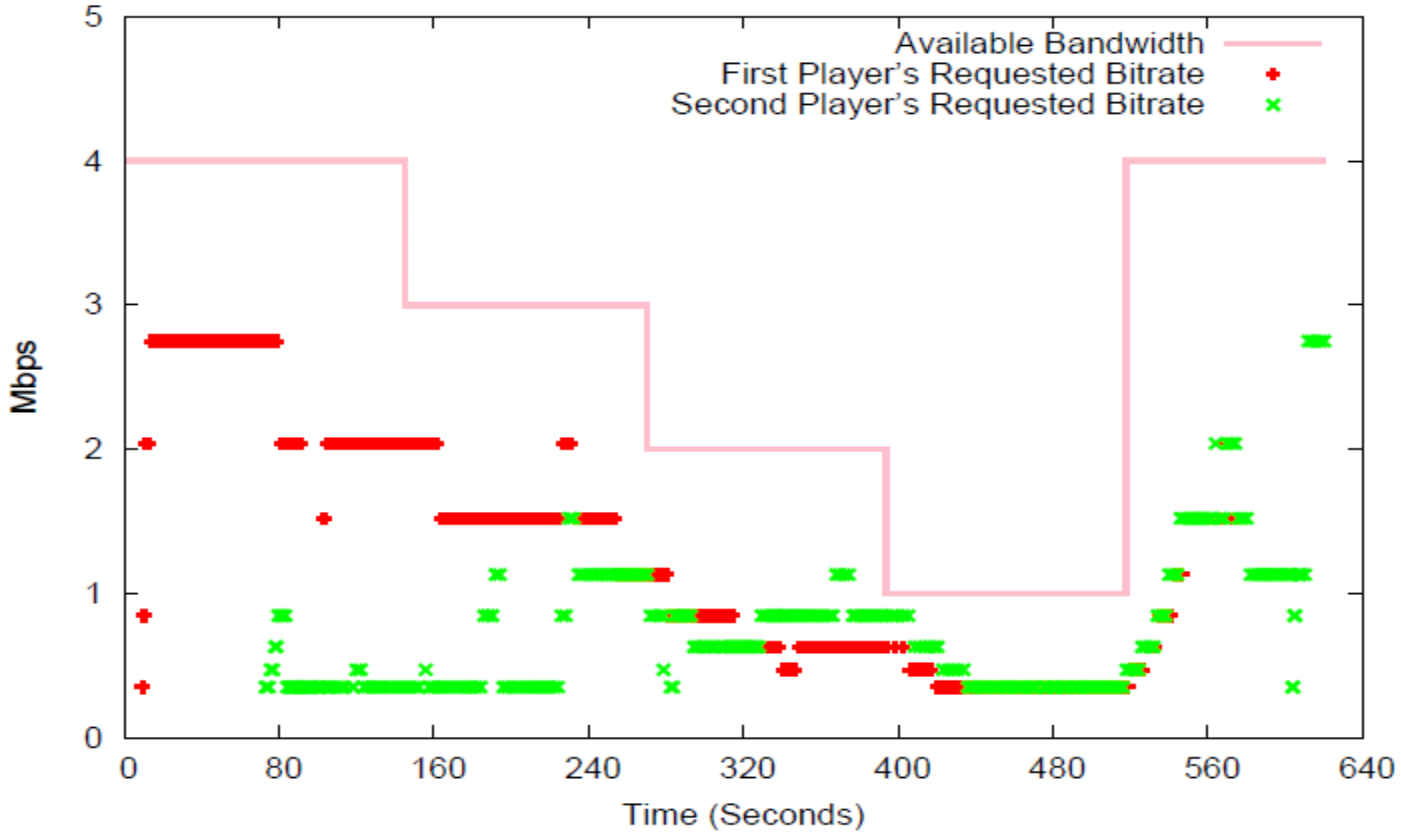
Two Smooth Streaming Players Compete



- 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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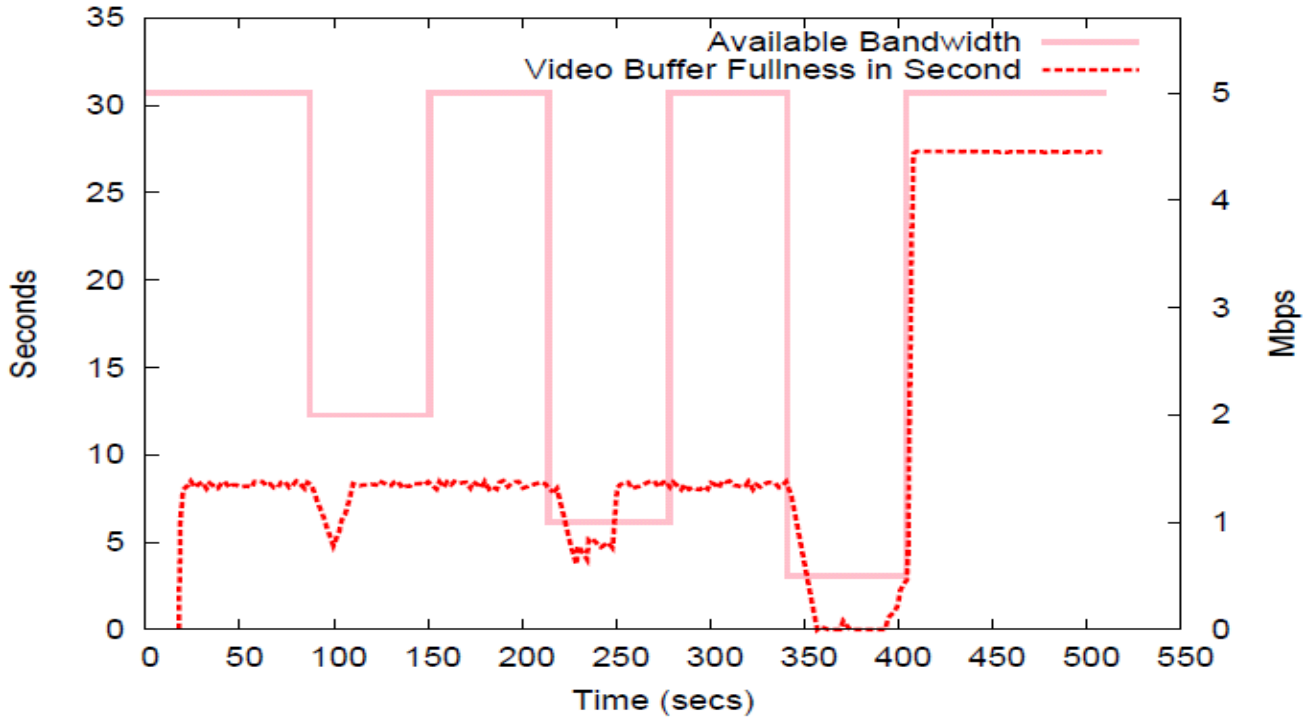
Smooth Live Streaming Playback Buffer Size



- 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