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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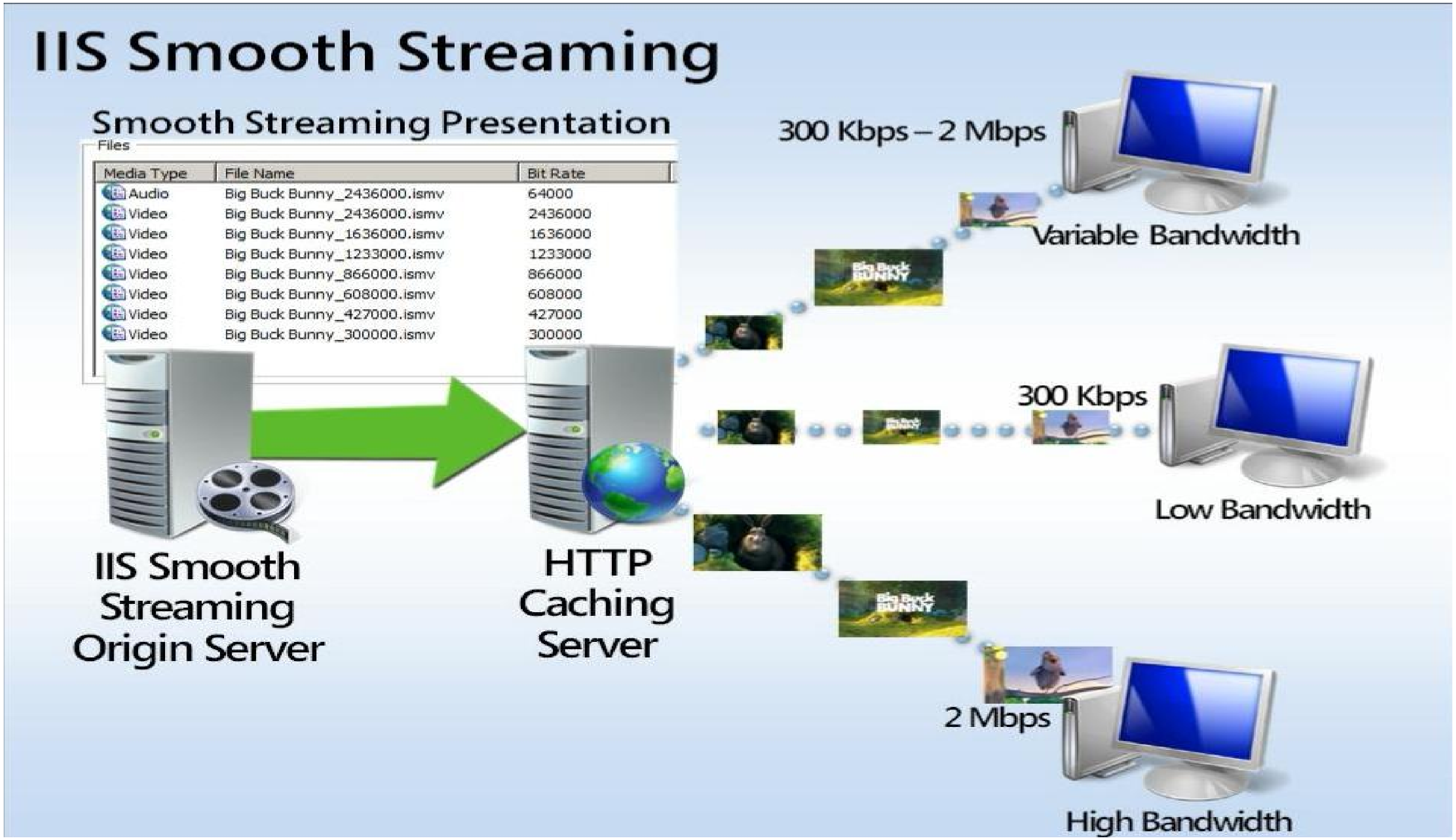
Adaptive Streaming over HTTP



IIS Smooth Streaming

Smooth Streaming Presentation

Files

Media Type	File Name	Bit Rate
Audio	Big Buck Bunny_2436000.ismv	64000
Video	Big Buck Bunny_2436000.ismv	2436000
Video	Big Buck Bunny_1636000.ismv	1636000
Video	Big Buck Bunny_1233000.ismv	1233000
Video	Big Buck Bunny_866000.ismv	866000
Video	Big Buck Bunny_608000.ismv	608000
Video	Big Buck Bunny_427000.ismv	427000
Video	Big Buck Bunny_300000.ismv	300000

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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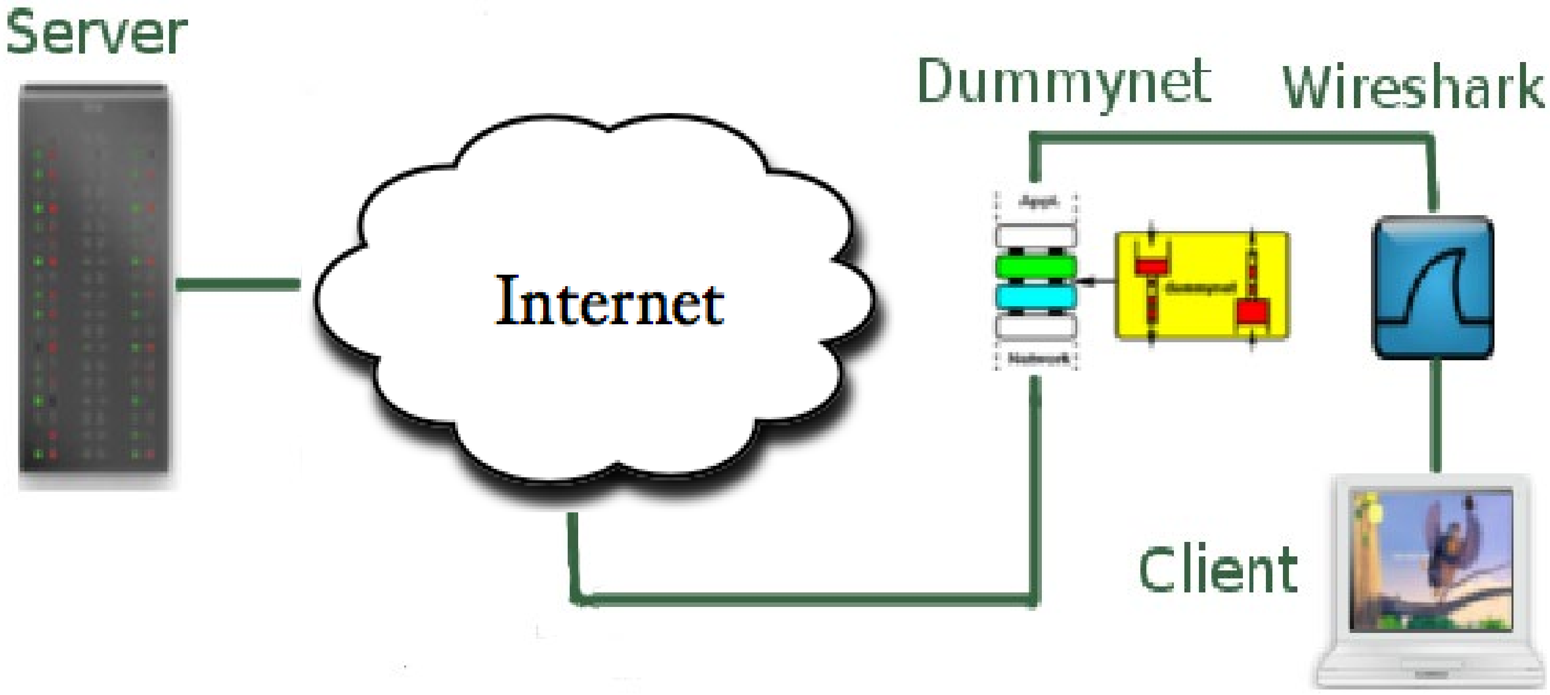
Experimental Methodology



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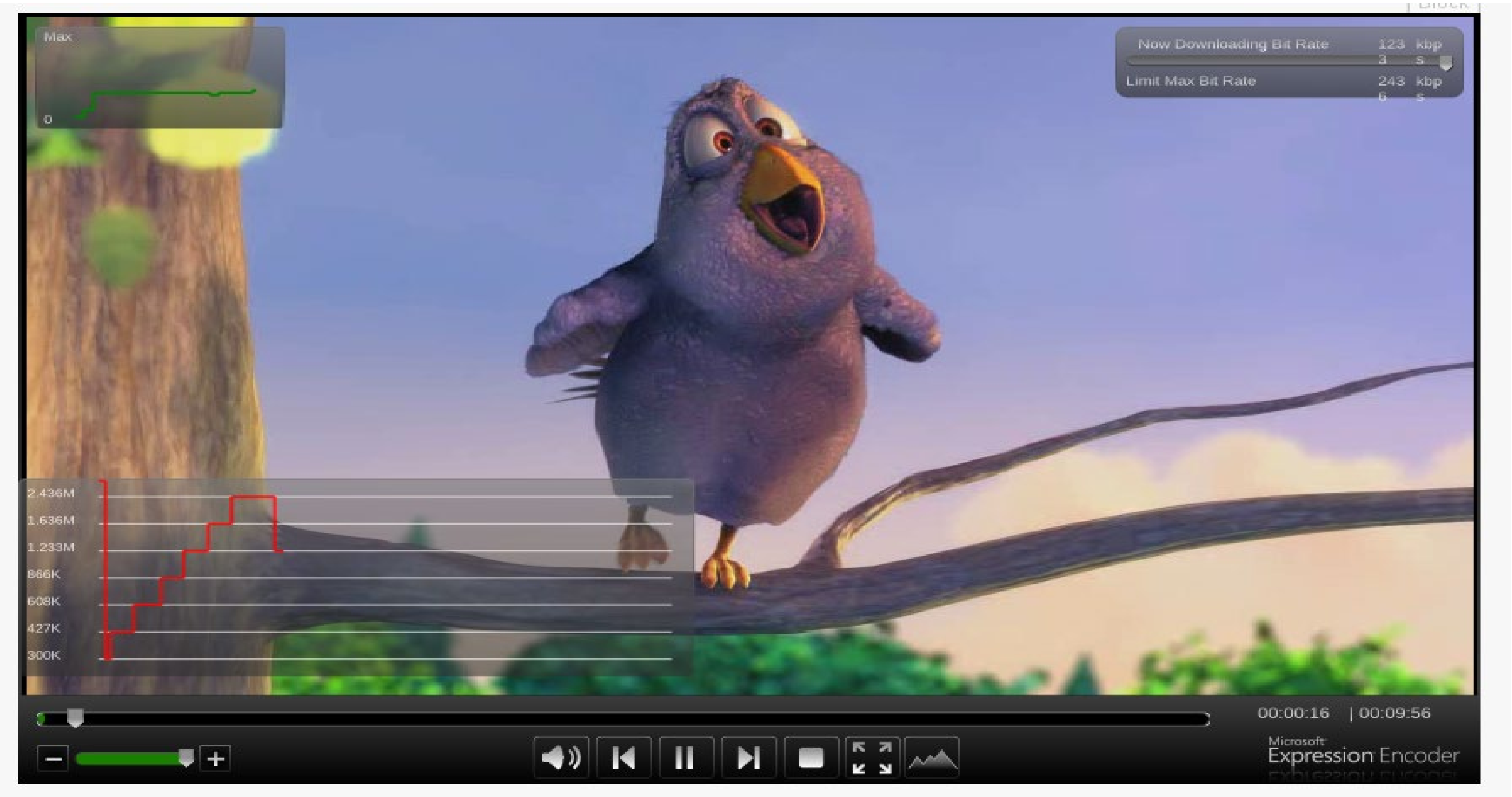
Smooth Streaming Player

Microsoft® Silverlight™

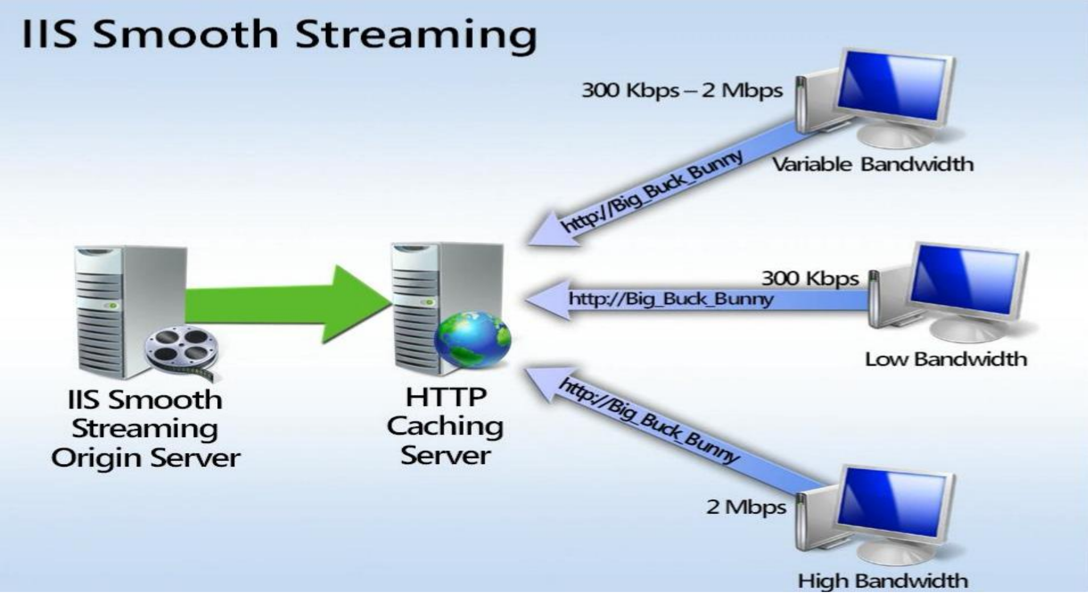


Now Downloading Bit Rate 1233 kbps

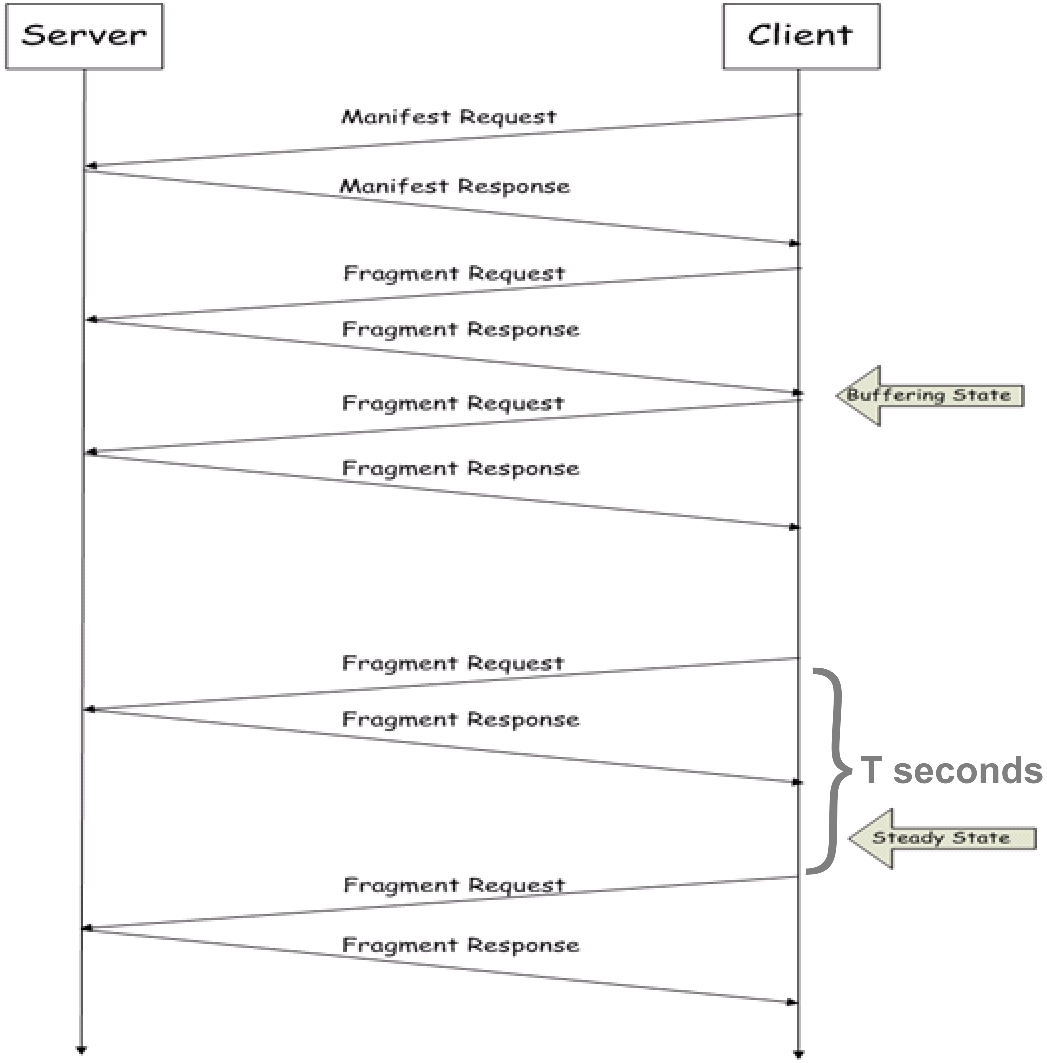
Limit Max Bit Rate 2436 kbps

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



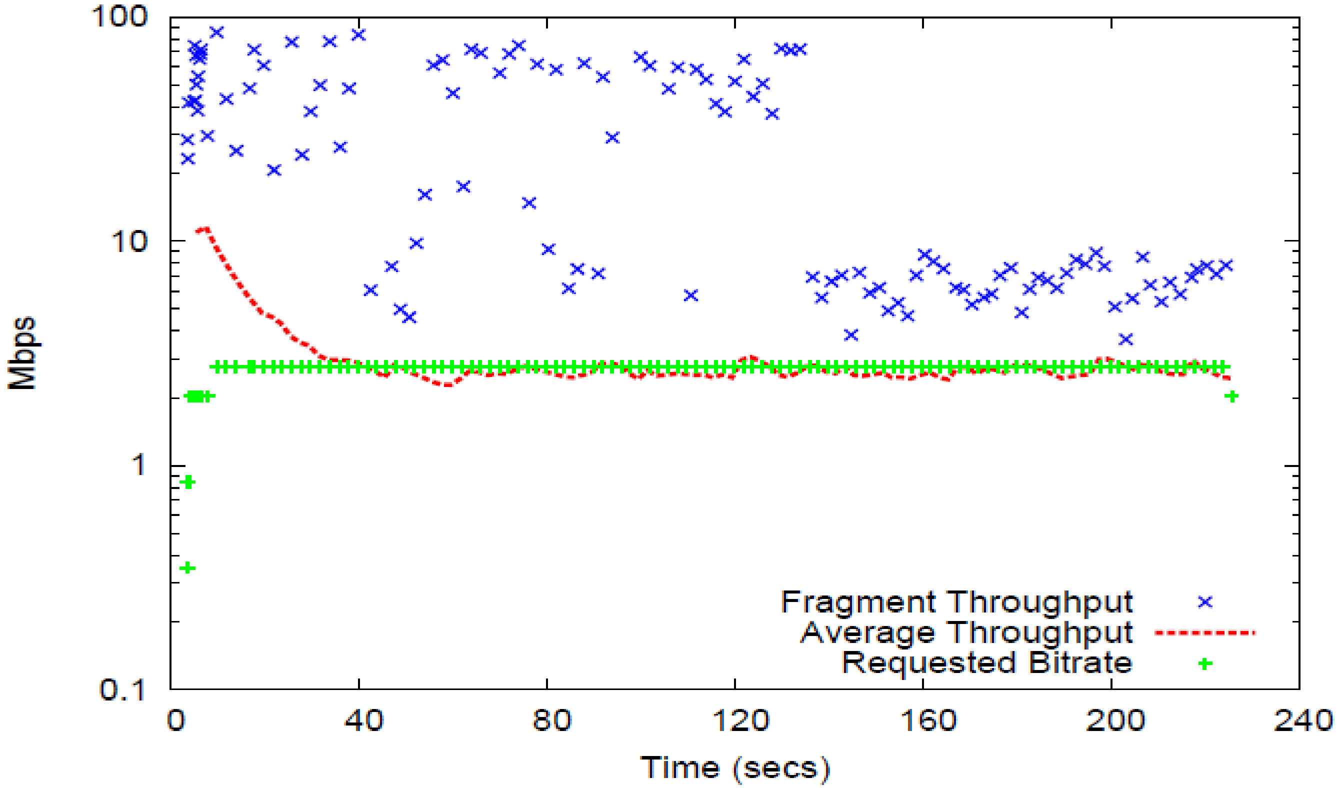
- One fragment per HTTP request

- No HTTP pipelining

- Two states:

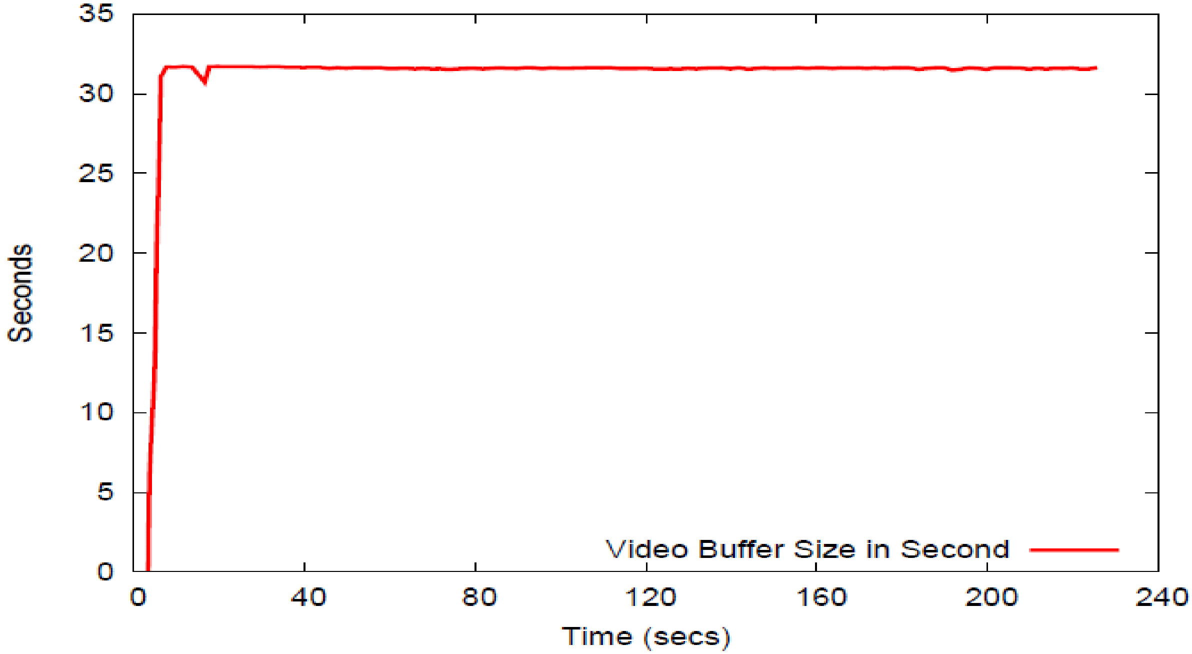
1. Buffering state
    - Request fragments as fast as possible
2. Steady-state
    - Request new fragment every T seconds

Smooth Streaming Player
Behavior under Unrestricted Available Bandwidth



- Average throughput: running average of *two-second* TCP throughput measurements.
- Fragment throughput: per-fragment throughput measurement

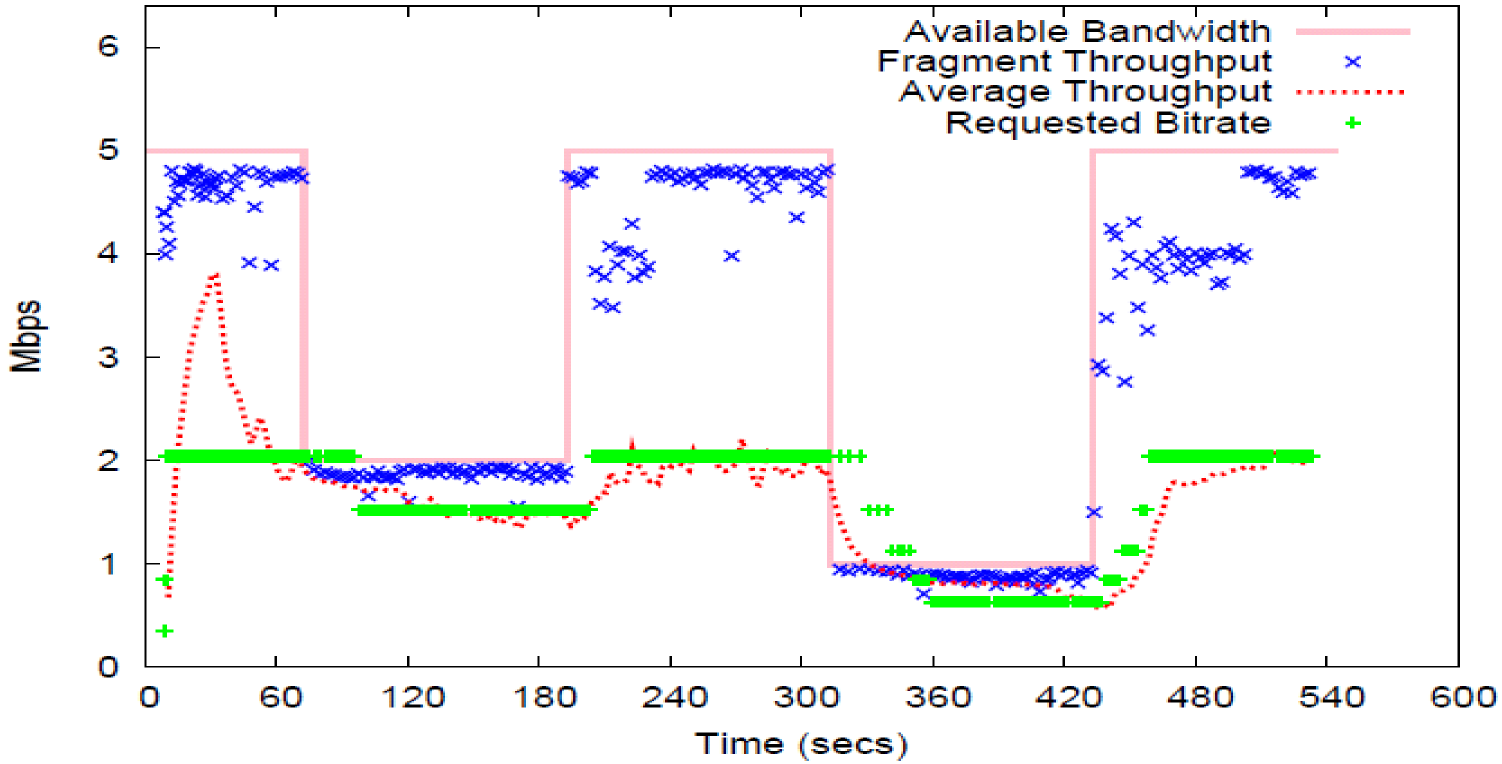
Smooth Streaming Player
Behavior under Unrestricted Available Bandwidth



- 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:

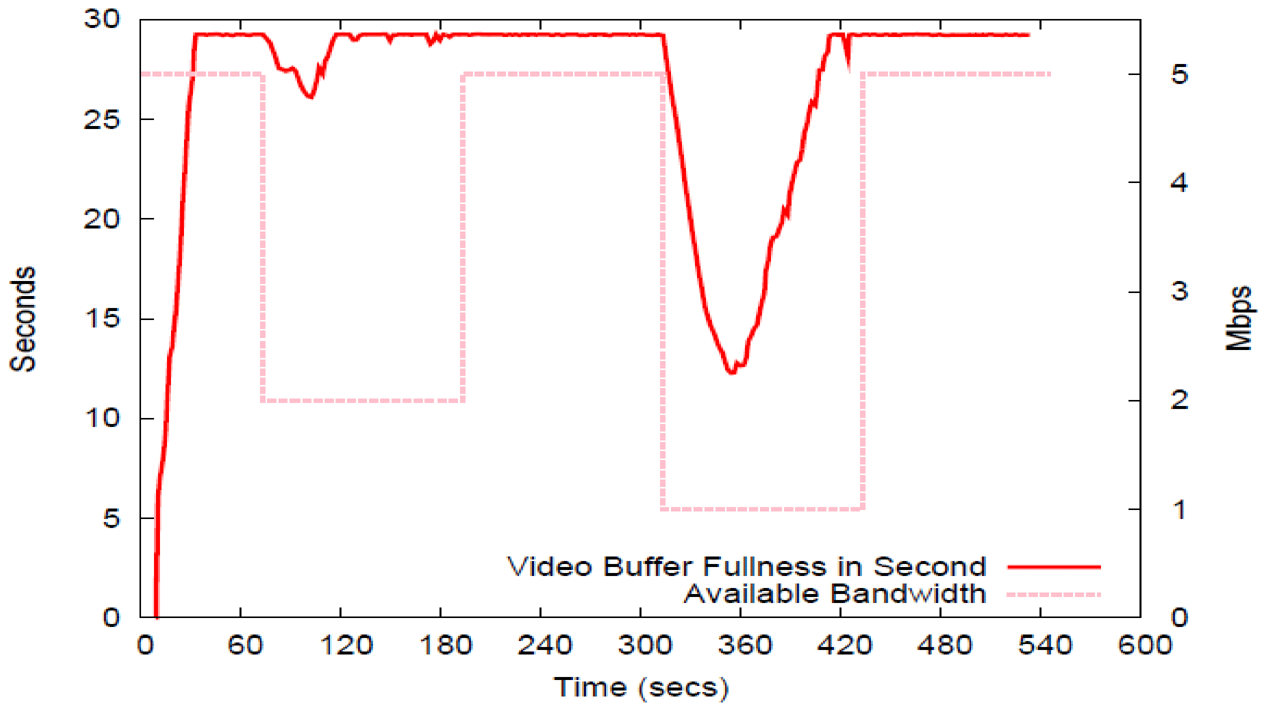
$$B(t_2) = B(t_1) - (t_2 - t_1) + (t'_2 - t'_1)$$

Smooth Streaming Player Behavior Under Persistent Changes in Available Bandwidth



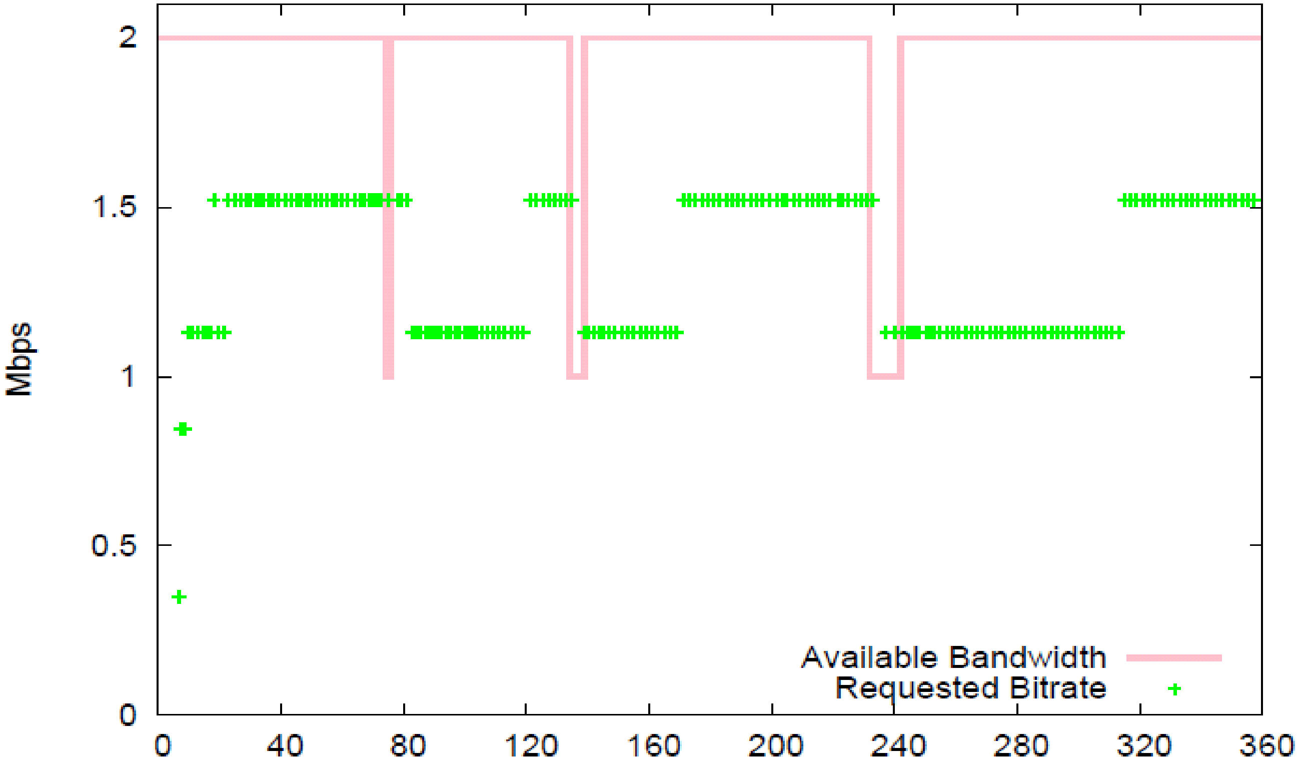
- Rate adaptation occurs after long delays
- The player estimates available bw using a running average of the per-fragment TCP throughput measurements

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

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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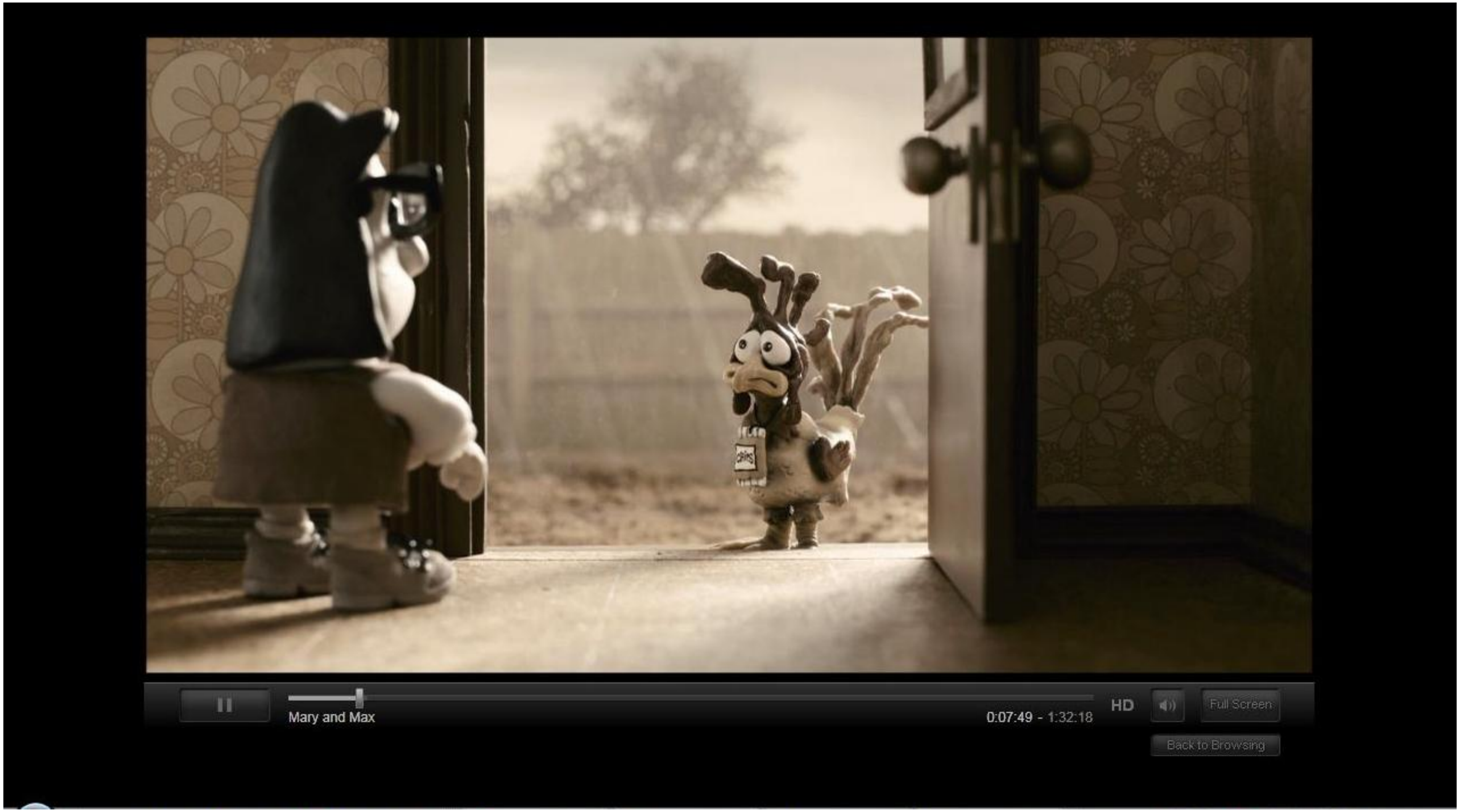
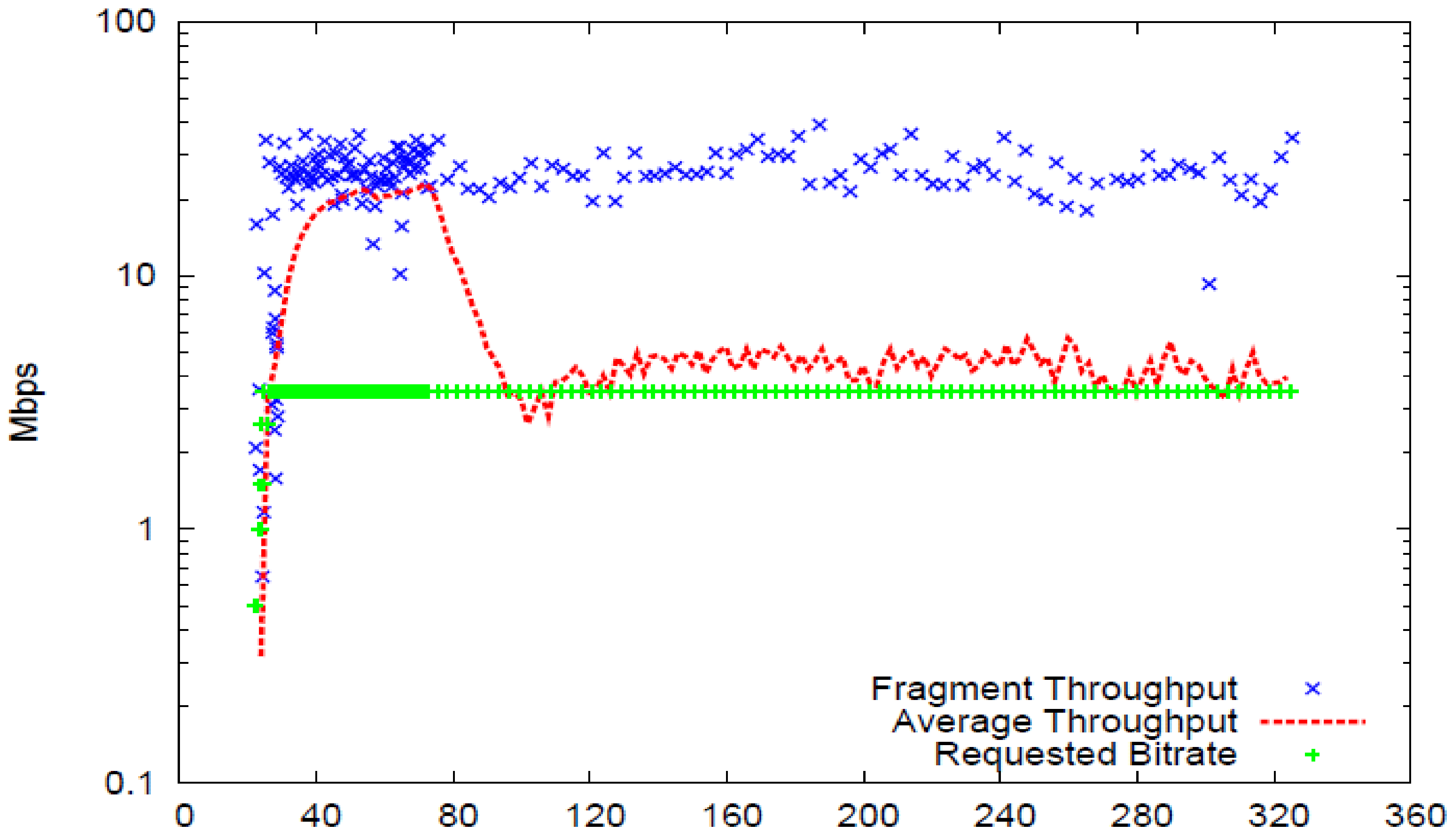
Netflix Player

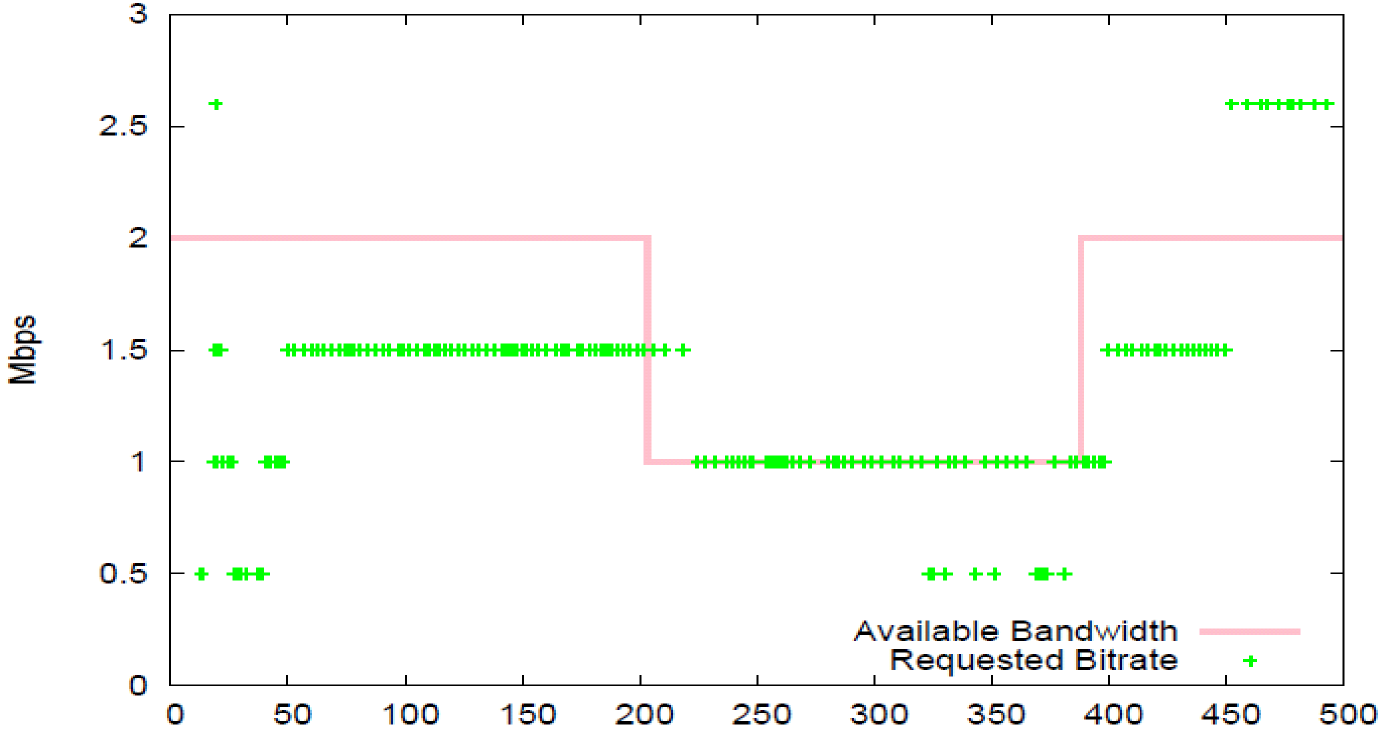


Netflix Player
Behavior under Unrestricted Available Bandwidth



- 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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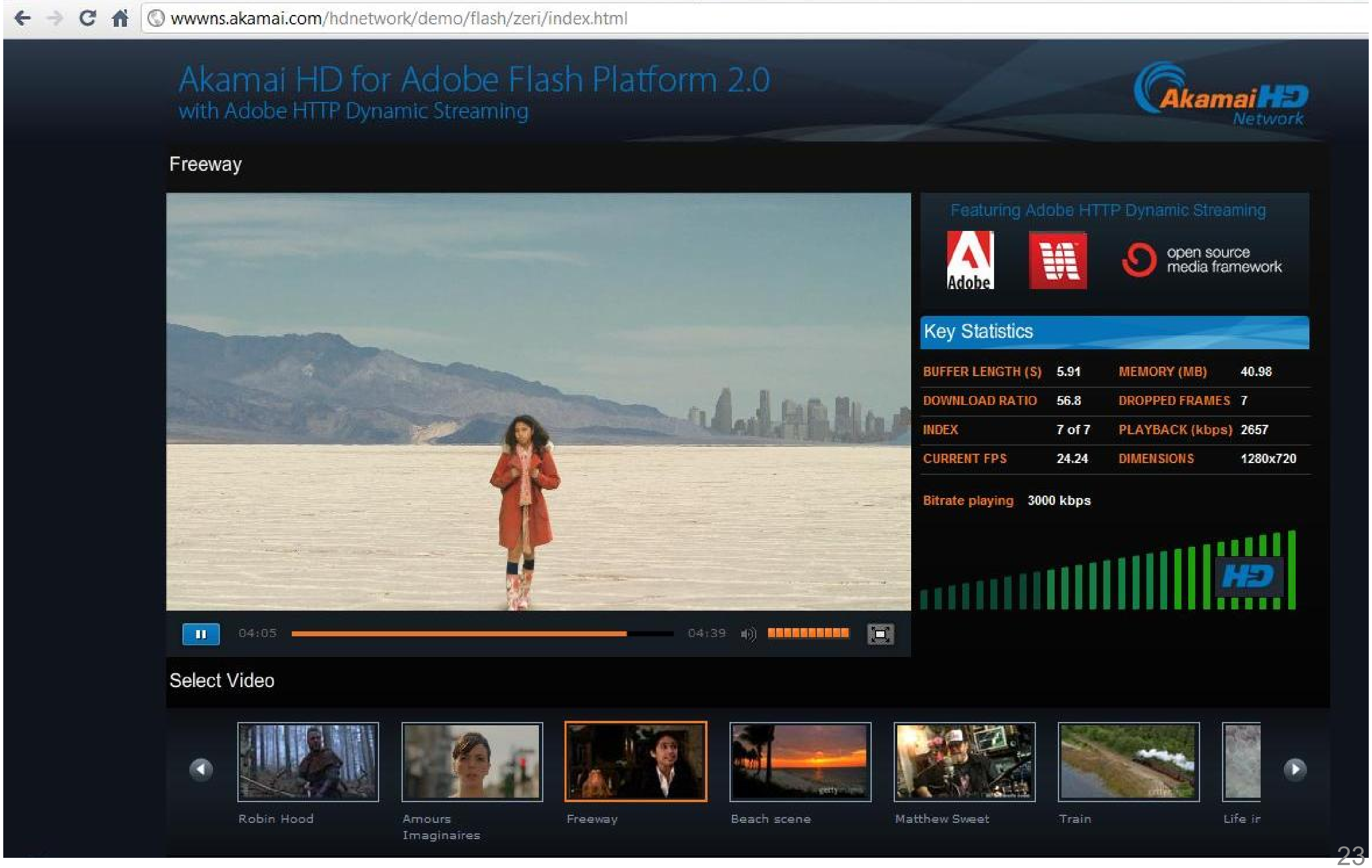
Adobe OSMF Player



wwwns.akamai.com/hdnetwork/demo/flash/zeri/index.html

Akamai HD for Adobe Flash Platform 2.0
with Adobe HTTP Dynamic Streaming

Freeway

Featuring Adobe HTTP Dynamic Streaming

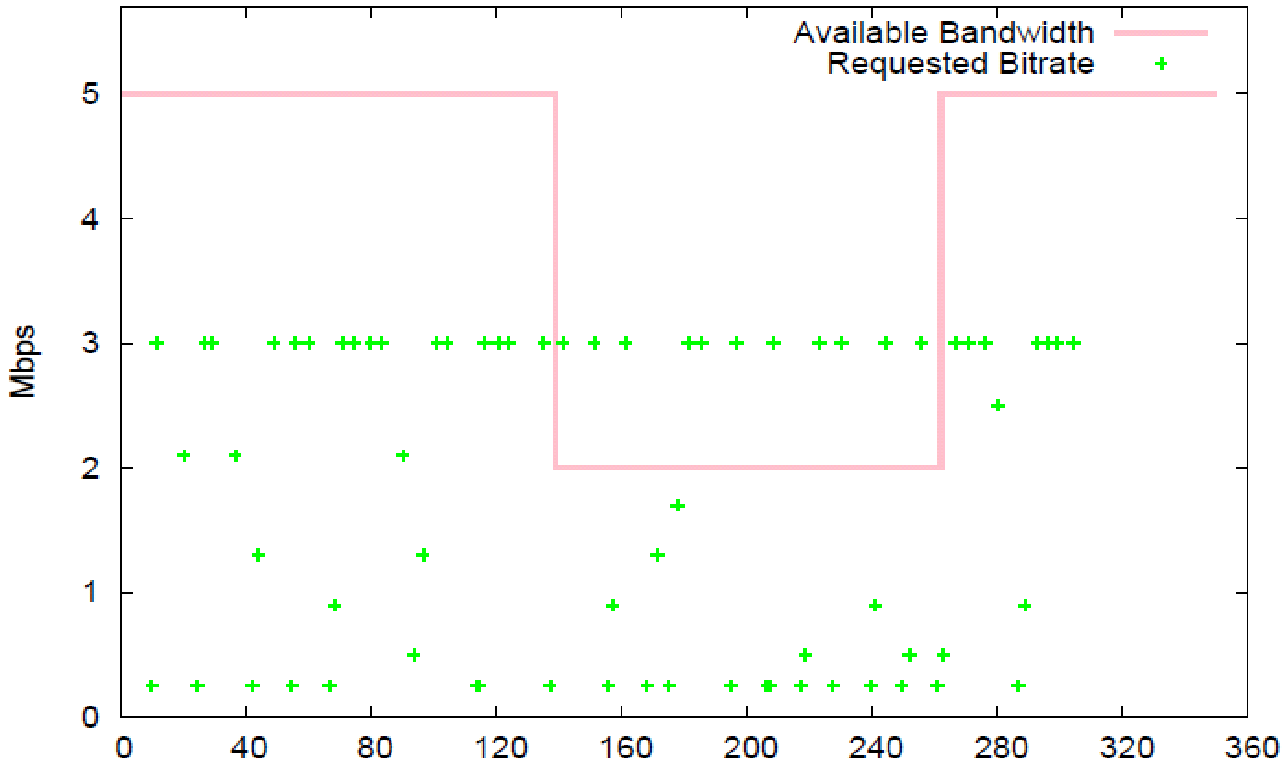
Key Statistics

BUFFER LENGTH (S)	5.91	MEMORY (MB)	40.98
DOWNLOAD RATIO	56.8	DROPPED FRAMES	7
INDEX	7 of 7	PLAYBACK (kbps)	2657
CURRENT FPS	24.24	DIMENSIONS	1280x720

Bitrate playing 3000 kbps

Select Video

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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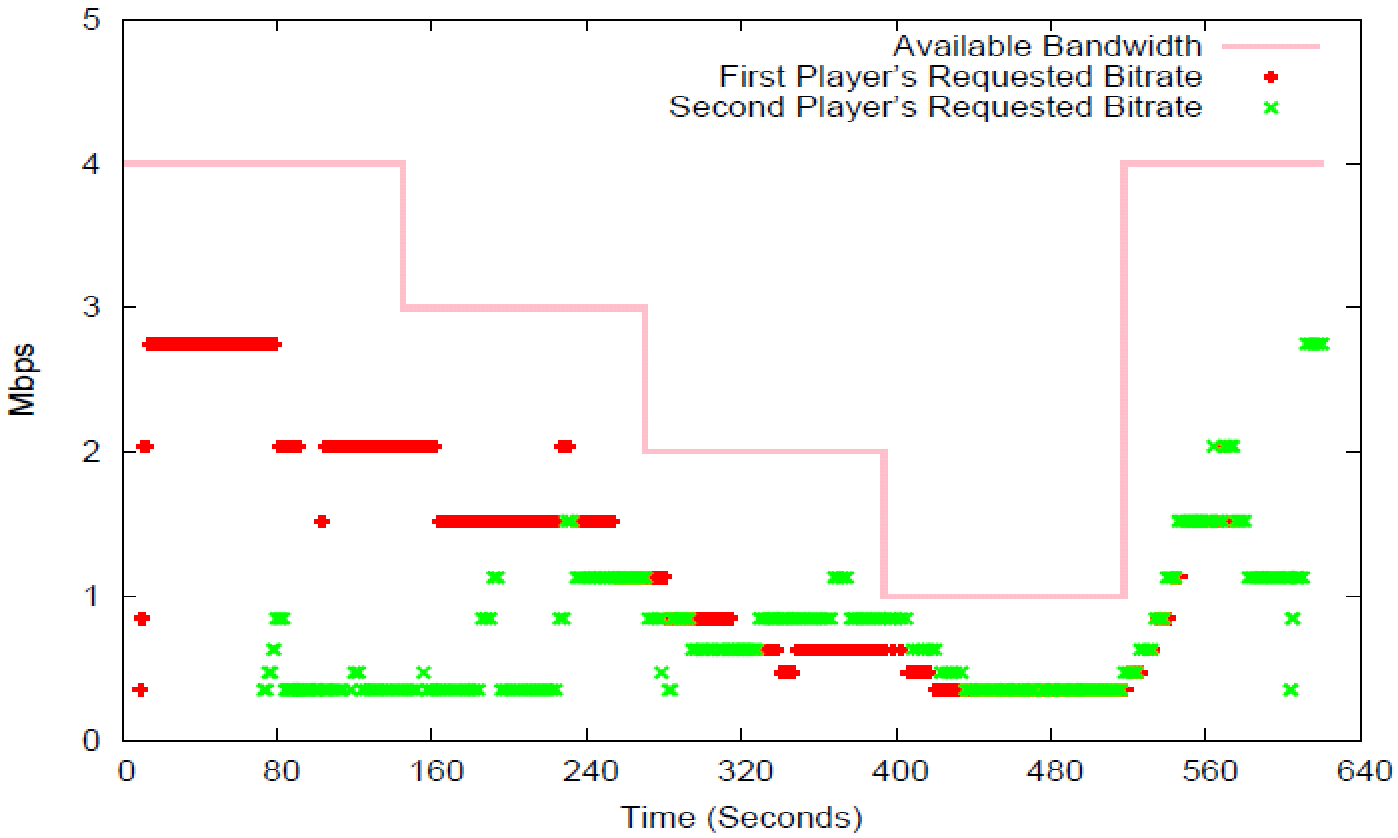
Two Smooth Streaming Players Compete



- 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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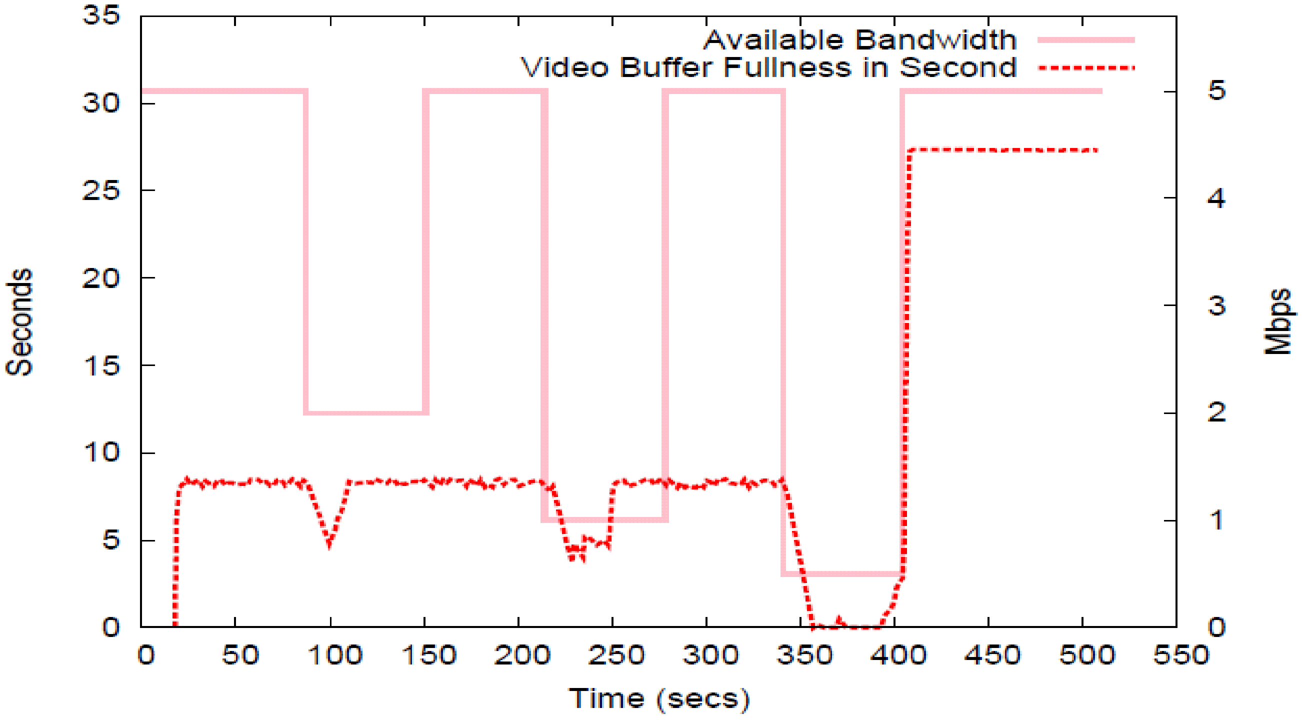
Smooth Live Streaming Playback Buffer Size



- 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