# Caching in HTTP Adaptive Streaming: Friend or Foe?

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# Objectives

- What happens when a cache lies between a content server and client?
- What is the simplest scenario that results in bitrate oscillations?
- How can we prevent bitrate oscillations in the presence of caching?

# Outline

- Overview of adaptive streaming over HTTP
- Oscillations due to interaction between cache and client
- A traffic shaping solution
- Simulation description
- Experiments and Results
- Conclusions

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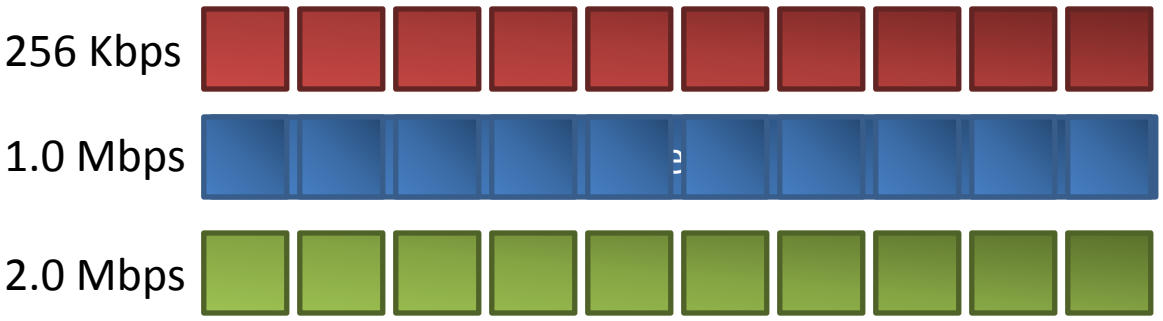
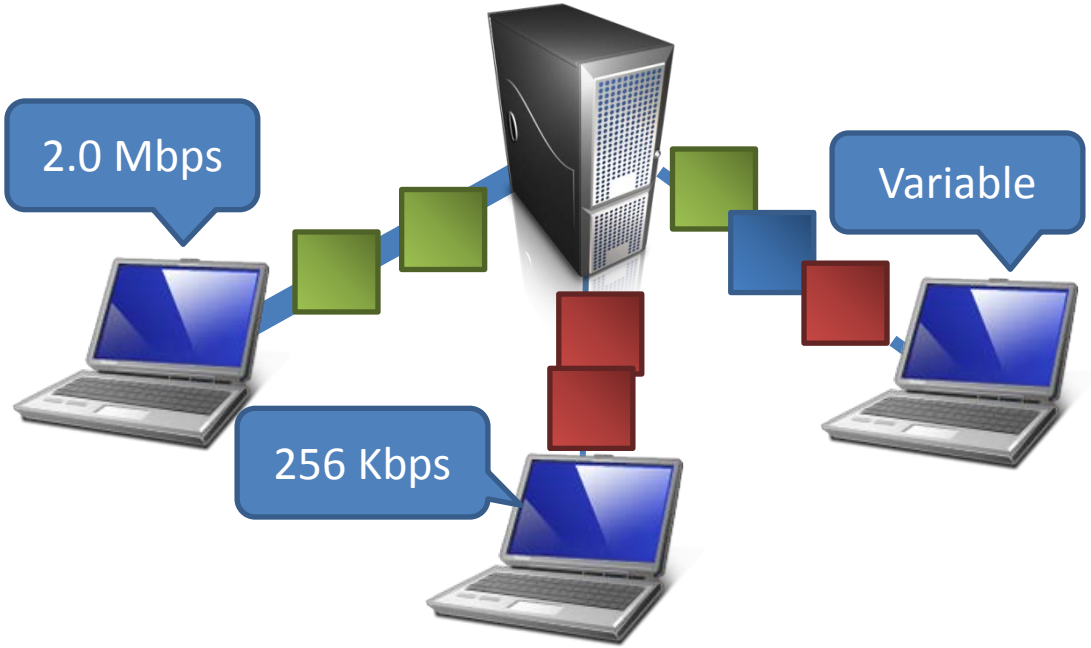
# Adaptive Streaming over HTTP




- Media is split into "segments", encoded in multiple bitrates




- Clients adaptively request segments based on their estimate of available bandwidth

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  - How does it cause problems?
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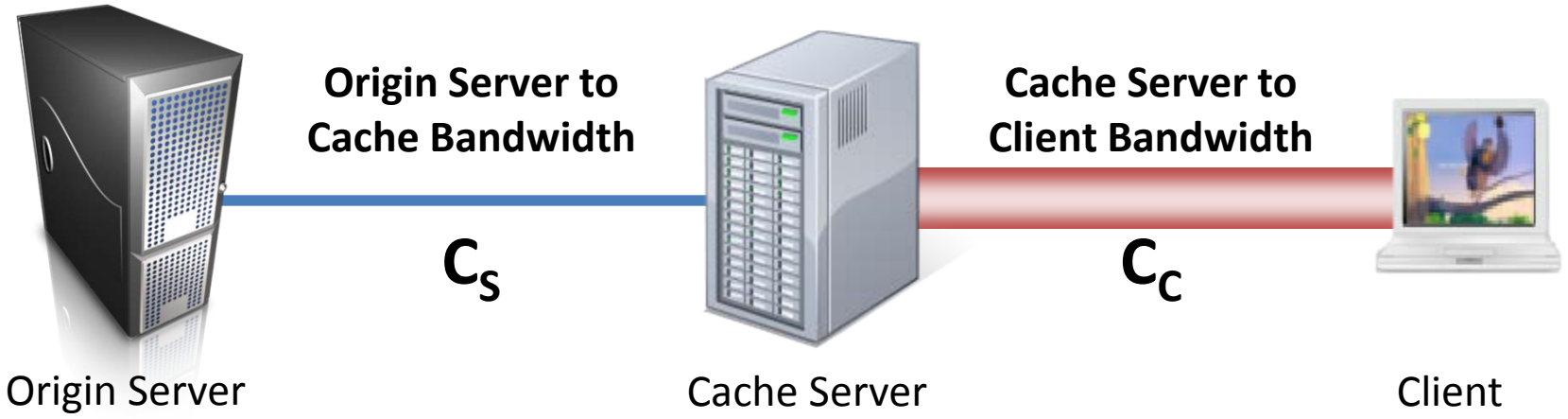
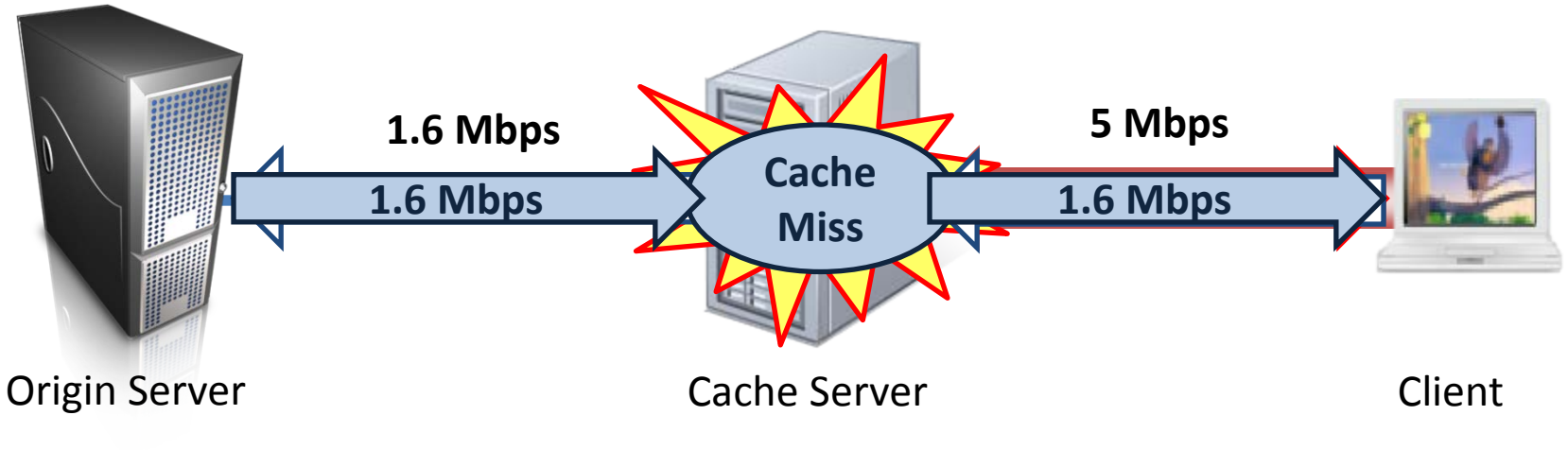
# Caching – A Simple Model




- Caches may be deployed to reduce upstream bandwidth usage, and provide better downstream latency and bandwidth to clients
- Media segments are transferred over HTTP, and may be cached in the cache server
- For a cache in an access network, typically $C_S < C_C$

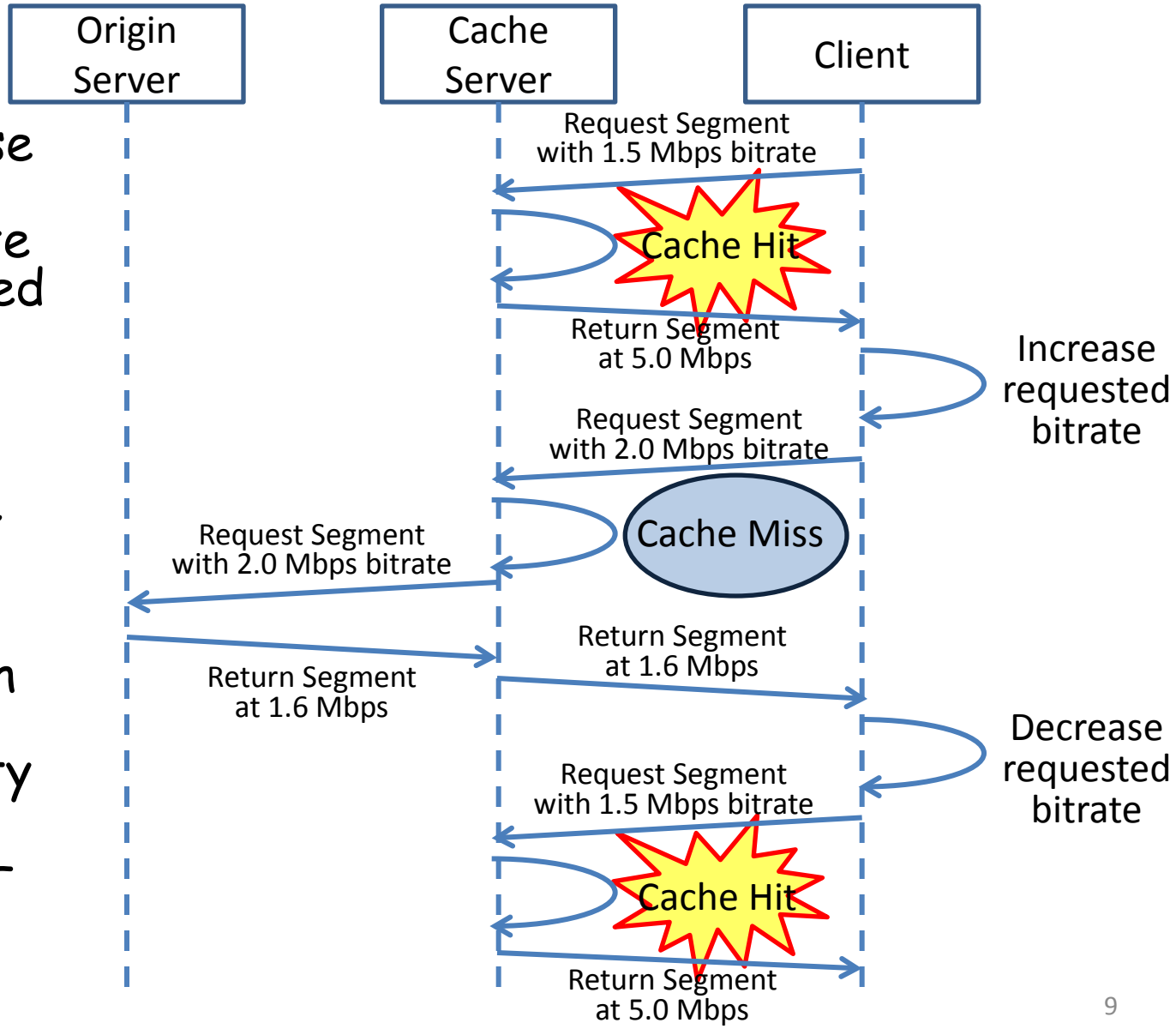
# Erroneous Bandwidth Estimation due to Cache Hit




- Clients retrieving cached segments will receive them at $C_C$
  - Causes an artificially high bandwidth estimation
- But faster is better, right?

# Bitrate Oscillations

- Problems arise when a mid-quality bitrate video is cached
- Typically, continuous segments are cached
- Clients switch between high and low quality video every few seconds – annoying!



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# Video Shaping Intelligent Cache (ViSIC)

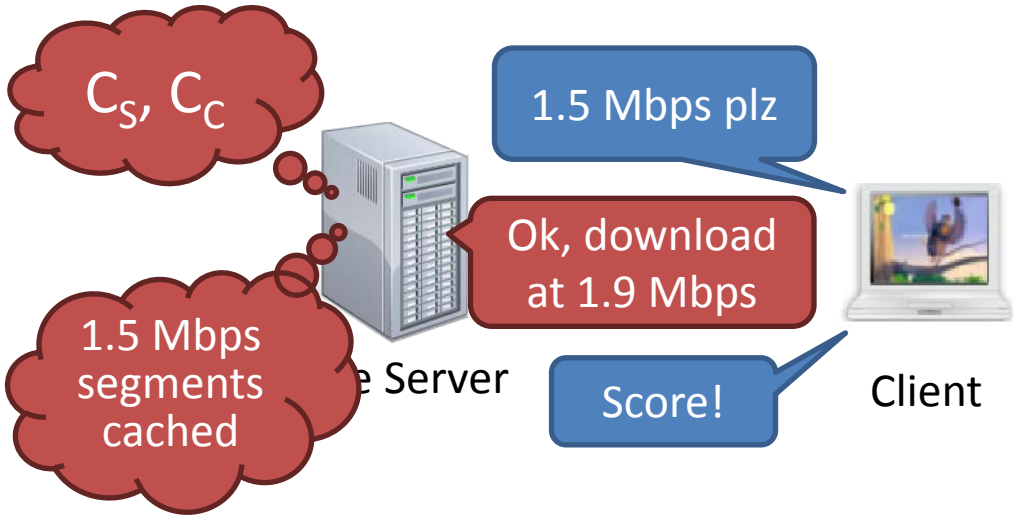
- Control the bitrates requested by the client by shaping the download speed
  - Prevent erroneous bandwidth estimates
  - Smooth fluctuations in available bandwidth
- Cache Server Implementation
  - Independent of client and origin server
  - Reduce upstream bandwidth usage
  - Serve cached segments faster than no-cache

# The Shaping Algorithm – High Level Description

- Estimate $C_S$ and $C_C$ from all traffic passing through cache server

- Select a target bitrate we want the client to use
  - Detect long duration changes in available bandwidth and allow increase/decrease in target bitrate
  - Otherwise favor bitrates of cached segments

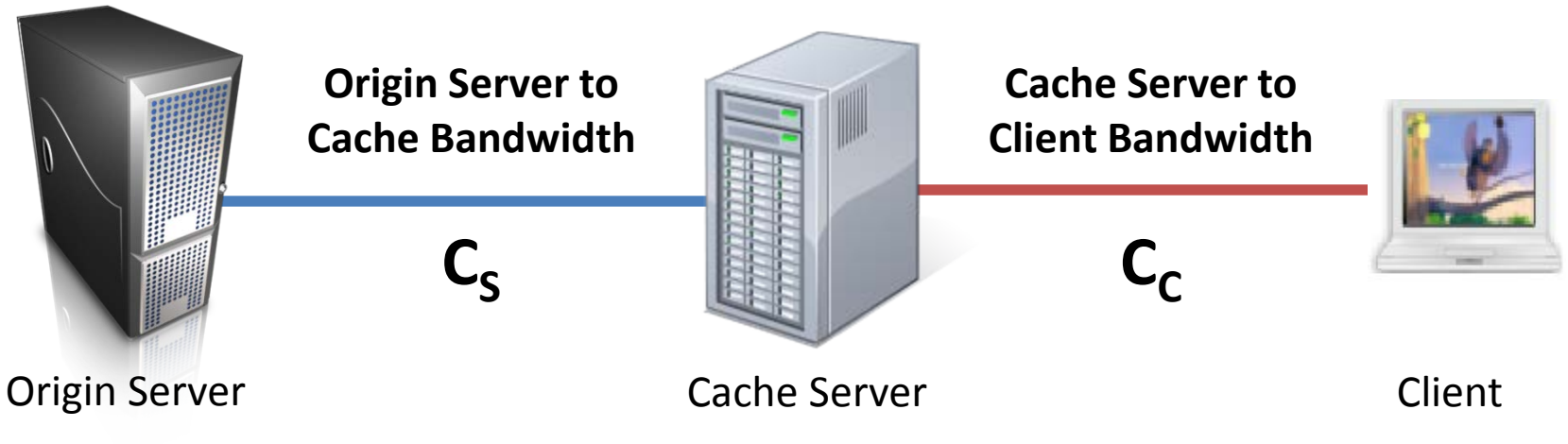
- Shape downloads from the cache
  - Use higher rate than target bitrate
  - But lower than what causes clients to switch rates



# Outline

- Overview of adaptive streaming over HTTP
- Interaction between cache and client
- A traffic shaping solution
- Simulation description
  - Setup
  - Client and Standard Cache
- Experiments and Results
- Conclusions

# Simulation Description – Setup




- Compare different Cache Server scenarios: ViSIC, Standard Cache and No-cache

- We varied $C_S$ and $C_C$

- Representation Bitrates:
  256 Kbps, 768 Kbps, 1.5 Mbps, 2.8 Mbps, 4.5 Mbps

# Simulation Description – Client and Cache

- Client
  - Simulates a typical adaptive streaming player
  - Adjusts requested bitrates based on average segment throughput
  - If video buffer level falls below a low threshold, engage "panic mode"

- Standard Cache
  - Simulates a traditional Web cache
  - Cache hit: Serve files at maximum speed
  - Cache miss: Serve files at upstream speed

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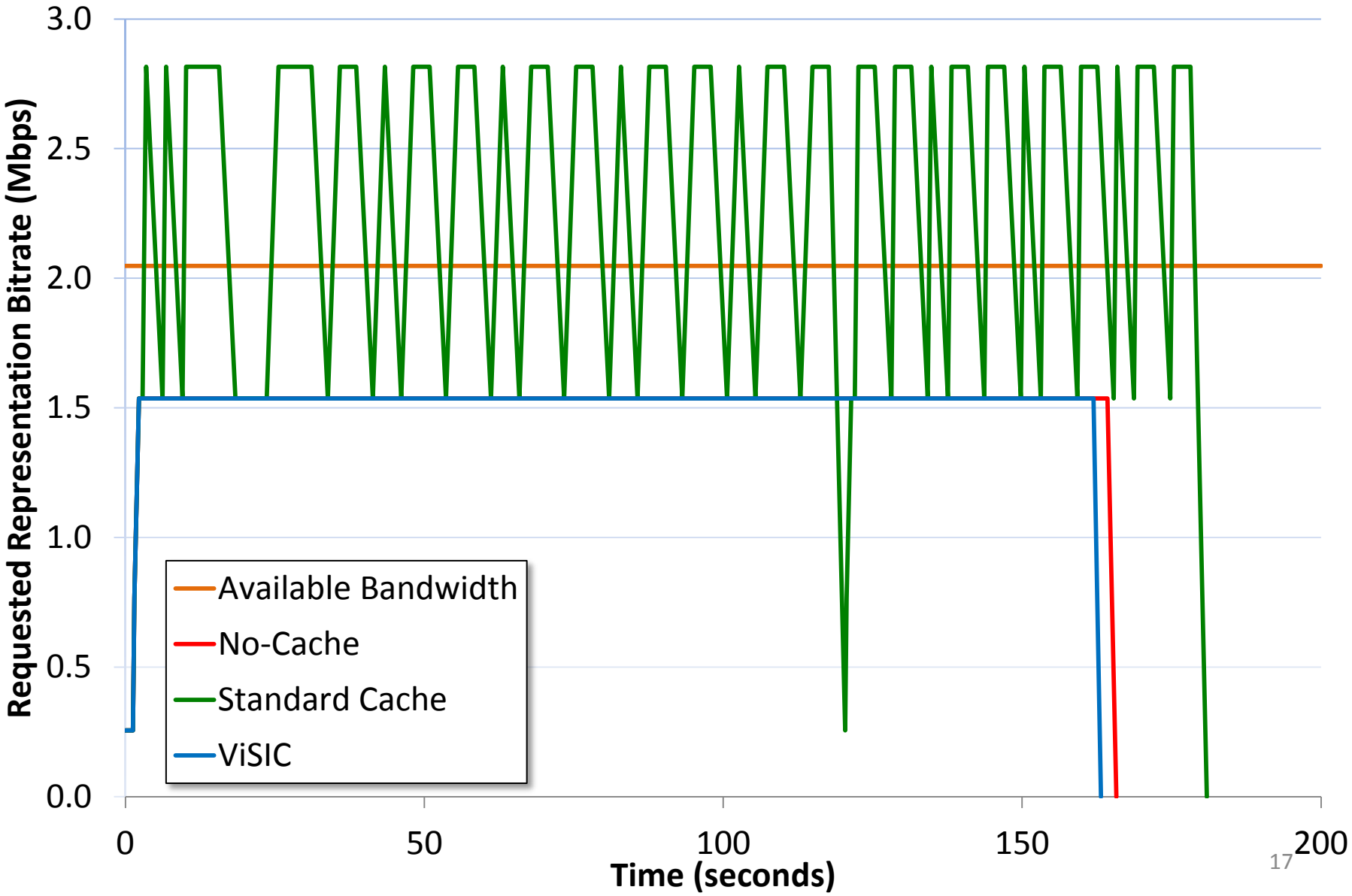
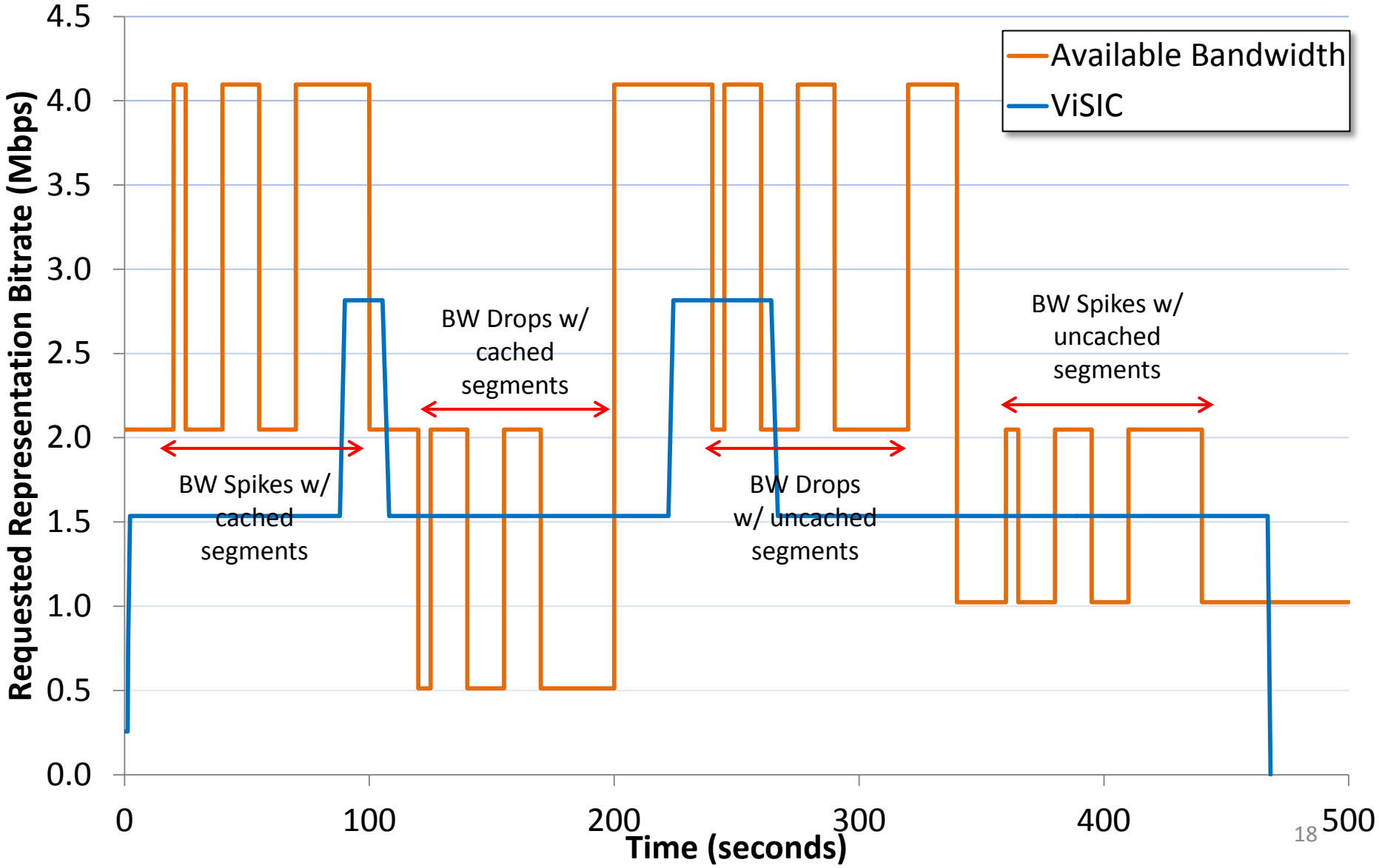
  - Constant Bandwidth
  - Fluctuating Bandwidth
- Conclusions

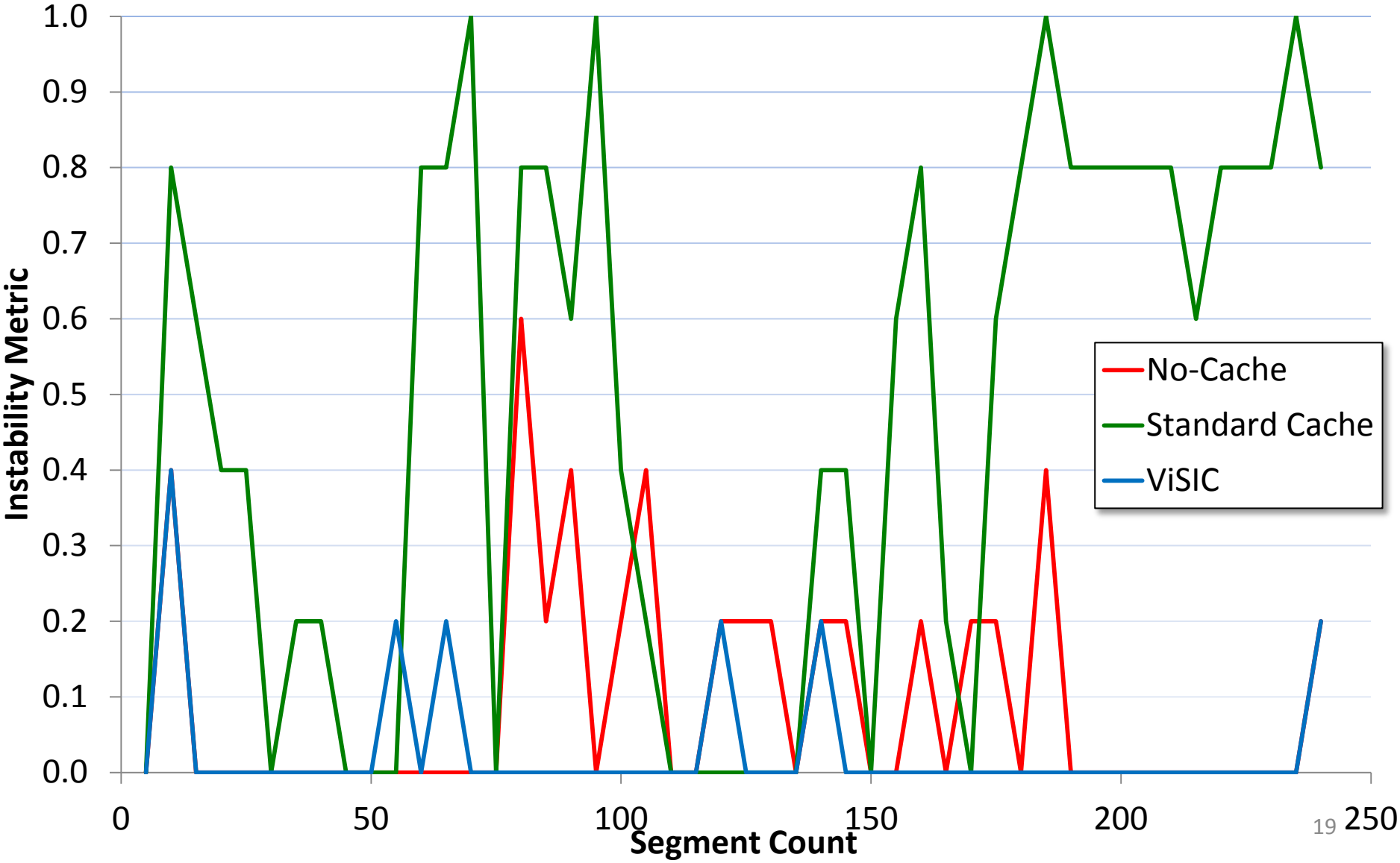
# Constant Bandwidth



# Fluctuating Bandwidth - ViSIC



# Fluctuating Bandwidth – Stability



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# Conclusions

- A cache server in the path of an HTTP adaptive streaming client can cause problems
  - Bitrate oscillations, buffer draining
- Cause: Cache hits cause erroneous bandwidth estimations
  - Clients overestimate actual path bandwidth
  - Clients request segments that are unsustainable
- Traffic shaping at the cache can prevent oscillations and buffer drains
  - Maintains cache benefits over no-cache

# Acknowledgments

Ashok Narayanan

Ashok presented the cache-induced instability problem at the Adaptive Media Transport Workshop, organized by Cisco, in June 2012

# In Memory Of

Saamer Akhshabi

1 April 1987 – 6 March 2014

# Thanks

# Typical Behavior of a Player

- Estimates available bandwidth using running average of per-segment TCP throughput measurements
- Adaptive segment bitrate selection
  - Increase if throughput is high (i.e., can support higher bitrate segments)
  - Decrease if throughput is lower than current bitrate (i.e., transfer is slower than real time)
- Client buffer levels affect the state
  - "Panic mode" to recover from low buffer situation

# Selecting the Target Bitrate – More Details (i)

- By shaping the download speed, we can cause the client to select specific bitrates – Target Bitrate

- Two possibilities:
  1. Stay at current segment bitrate
     - Cache Hit: Avoid erroneous high-bandwidth estimation
     - Absorb short term $C_S$ bandwidth fluctuations
     - Guard against $C_S$ bandwidth decreases when serving cached segments

  2. Change to bitrate supported by available path bandwidth
     - Allow client to adapt to long term bandwidth increases/decreases

# Selecting the Target Bitrate – More Details (ii)

Case I: When $C_S \leq C_C$

- For a cache hit
  - If $C_S$ has a long term increase, use current path bw
  - Else shape at current segment bitrate
- For a cache miss
  - If $C_S$ has a long term increase or decrease, use current path bw
  - Else shape at current segment bitrate

Case II: When $C_S > C_C$

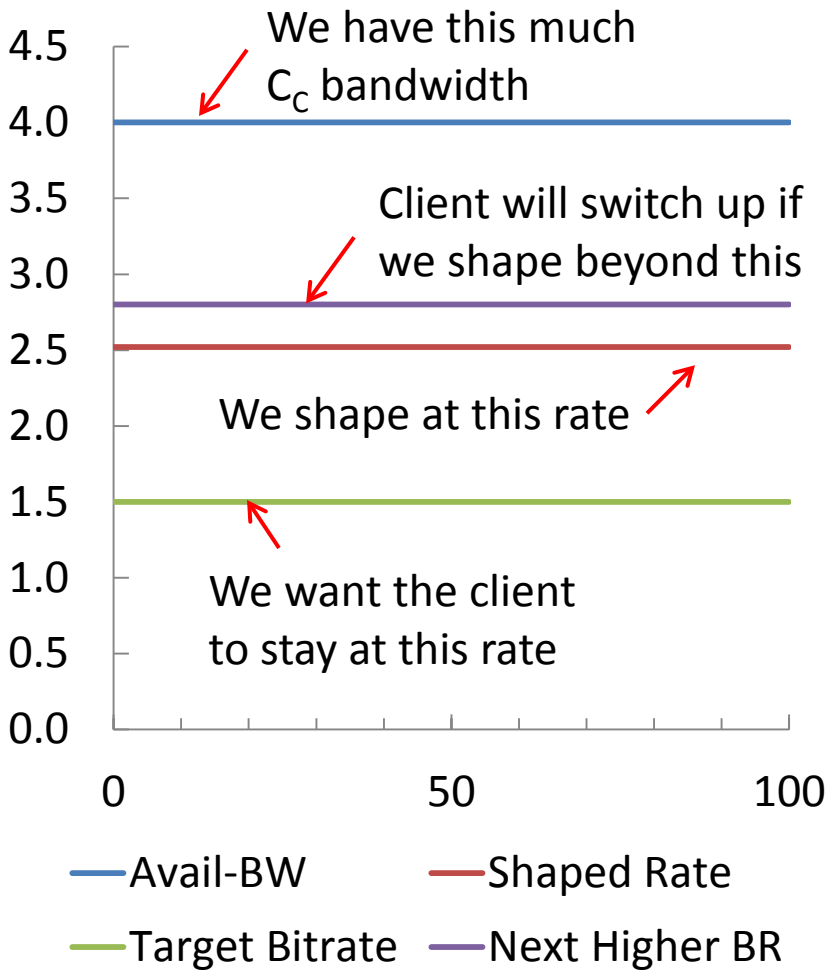
- Whether cache hit or miss
  - If $C_C$ has a long term increase, use current path bw
  - Else shape at current segment bitrate

# The Shaping Algorithm - More Details

- Make use of higher available bandwidth between cache server and client
  - Serve a segment at a higher speed than the target bitrate
- Solution:
  1. Select the next higher representation bitrate
  2. Multiply it by a factor $\beta$ (we used 0.9)
- Shape at a higher speed than current bitrate but lower than the next higher representation
  - Make use of $C_S < C_C$
  - Better performance than No-Cache

# The Shaping Algorithm - Example

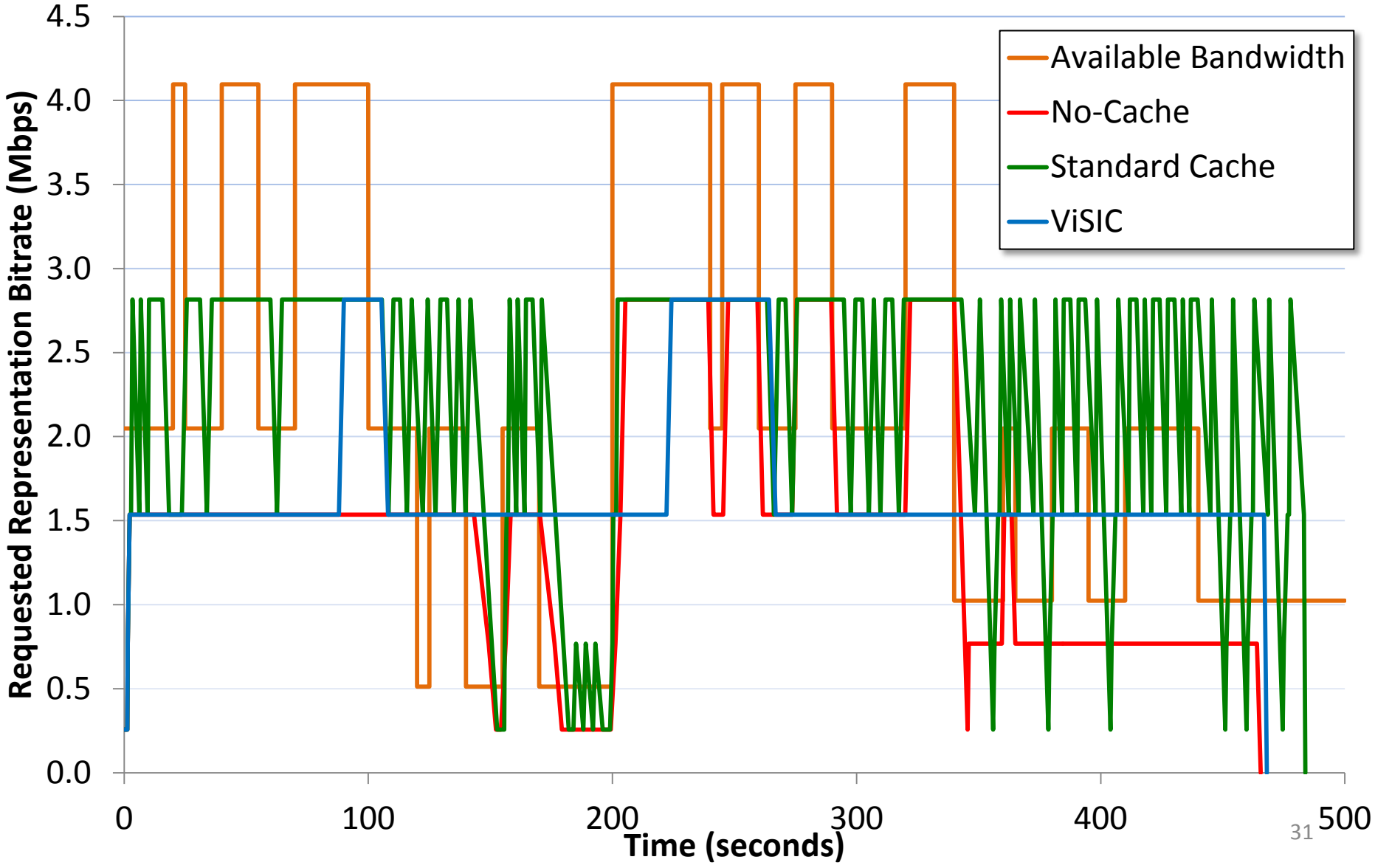
- Representation Bitrates:
  256 Kbps, 768 Kbps,
  1.5 Mbps, 2.8 Mbps, 4.5 Mbps
- $C_C$: 4.0 Mbps
- Target Bitrate: 1.5 Mbps
- Shaped Bitrate:
  0.9 * 2.8 Mbps = 2.52 Mbps
- Client will continue to request 1.5 Mbps segments, but receive them at a higher rate!



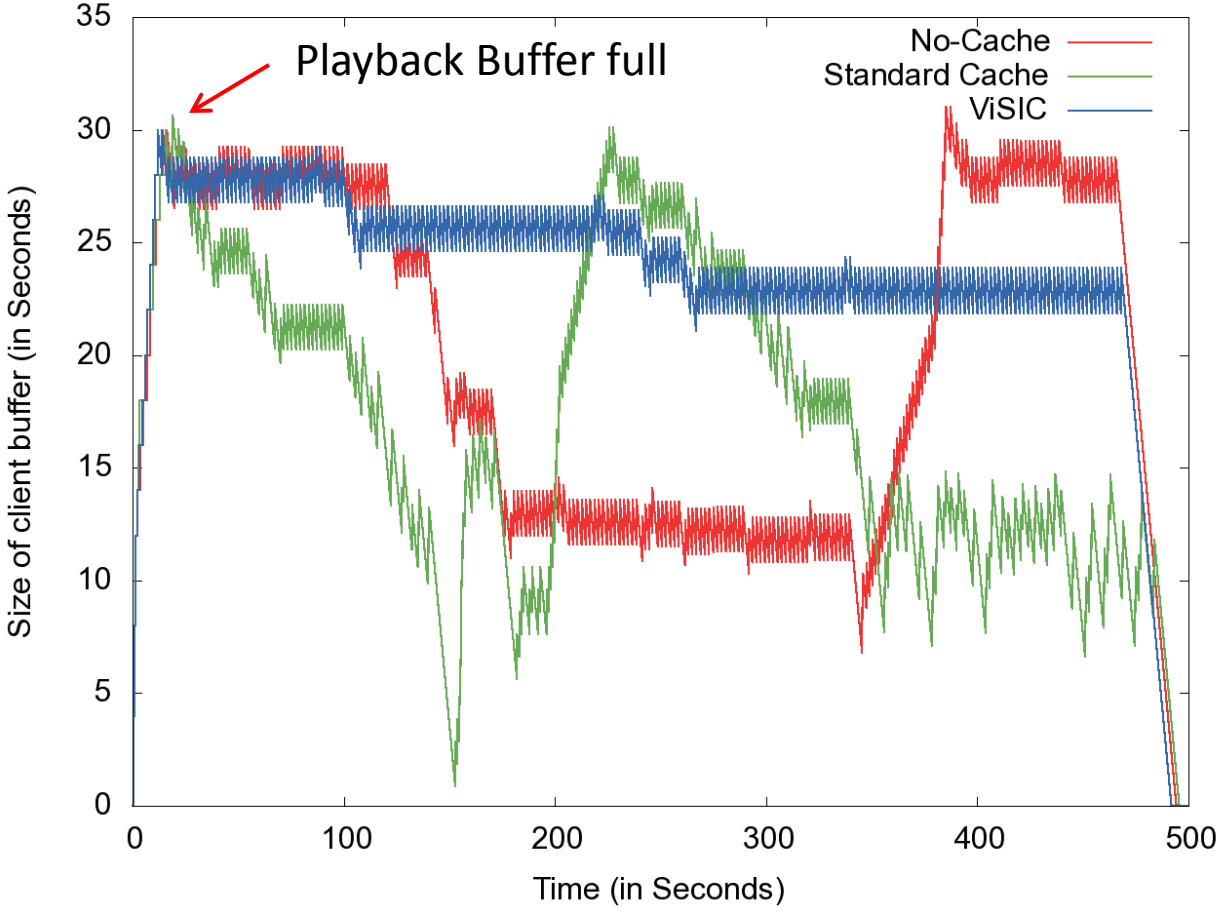
# Simulation Description – Standard Cache

- Functions as a cut-through cache
  - Intercepts HTTP requests to the server
  - Files not in cache don't need to be fully downloaded to be served
- List of files that represents cached segments
- If a file exists on disk, cache hit: served at $C_C$
- Cache miss
  - Starts a new transfer, serves file one RTT later
  - Effective bandwidth is $C_S$

# Fluctuating Bandwidth – Full Results



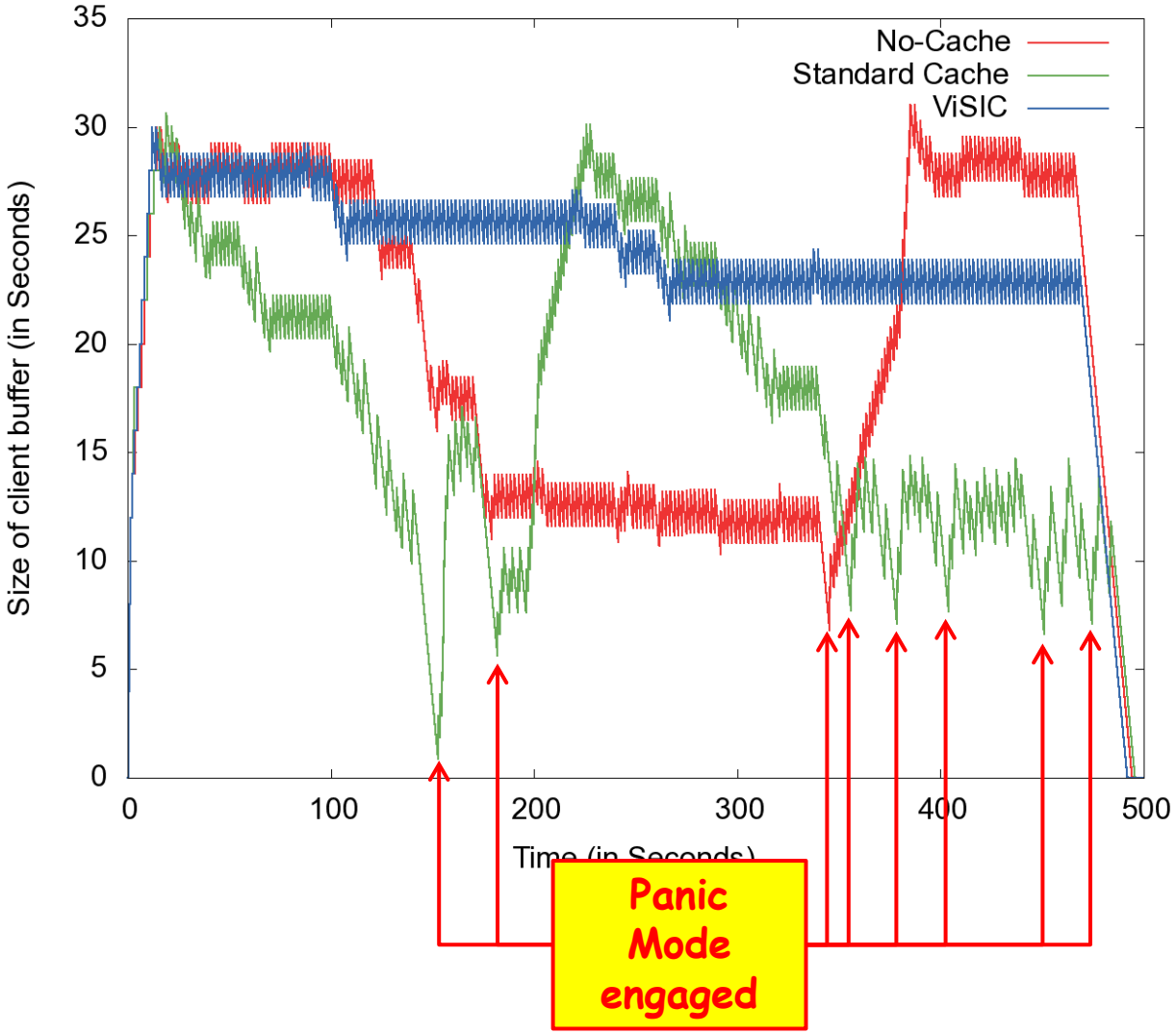
# Fluctuating Bandwidth – Playback Start Time




- Playback starts after client buffer is full

| Scenario | Playback Start (sec) |
|---|---|
| ViSIC | 11.954 |
| No-cache | 14.258 |
| Standard Cache | 15.664 |

# Fluctuating Bandwidth – Buffer Fullness




We aim to keep the buffer full

- Allows user to seek in buffered region
- Minimal quality disruptions during playback

Playback buffer is near full for ViSIC in all scenarios

Panic Mode engaged multiple times for no-cache and standard cache