What Happens When HTTP Adaptive Streaming Players Compete for Bandwidth?

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Objectives

- What performance issues arise when multiple adaptive streaming players compete for avail-bw?
- What is the root cause of the performance issues?
- What factors determine the stability of competing adaptive streaming players?

Outline

- Overview of adaptive streaming over HTTP
- Multiple player competition
- Experimental methodology
- Basic experiments and metrics
- Stability and affecting factors
- Conclusions

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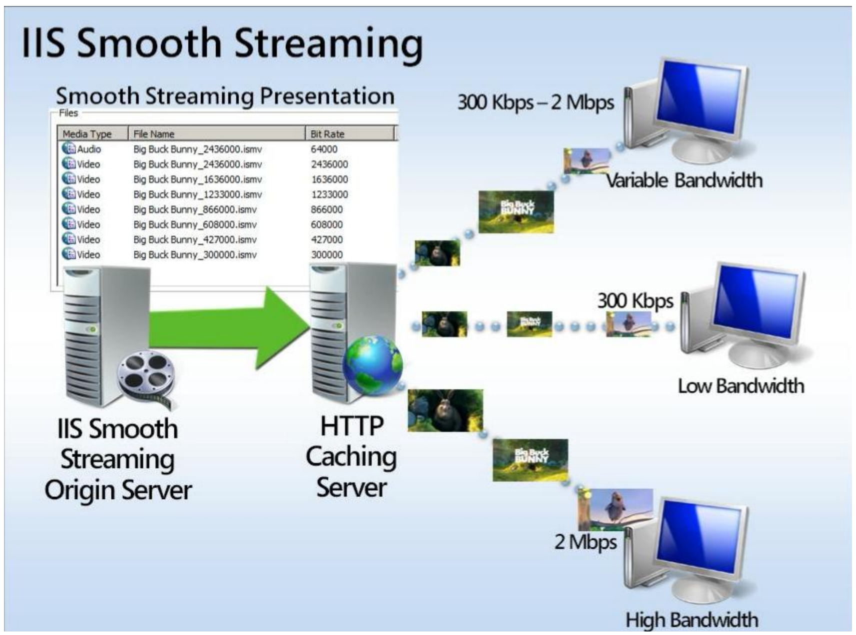
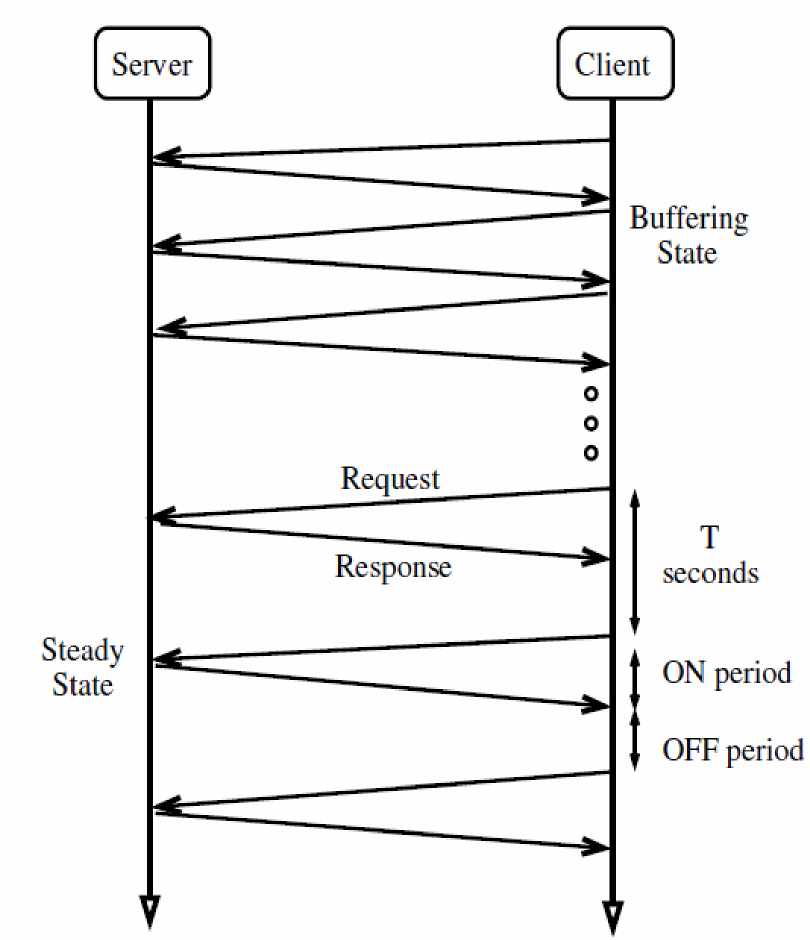
Adaptive Streaming over HTTP



From IIS Smooth Streaming Website

- Media is split into “chunks”
- Each chunk corresponds to a certain amount of content (e.g. T seconds of content)
- Each chunk encoded in multiple bitrates
- Clients request the chunks based on their estimate of avail-bw (and other factors)

Typical Behavior of a Player



- One chunk per HTTP request
- Two states:
  - Buffering state
    - Request chunks as fast as possible
    - Build up the playback buffer
  - Steady-state
  - Request a new chunk every T seconds
  - Keep buffer constant
- ON-OFF download pattern
- Estimate the avail-bw by performing a running average on per-chunk TCP throughput measurements

Outline

- Overview of adaptive streaming over HTTP
- Multiple player competition
  - Three simple scenarios
- Experimental methodology
- Basic experiments and metrics
- Stability and affecting factors
- Conclusions

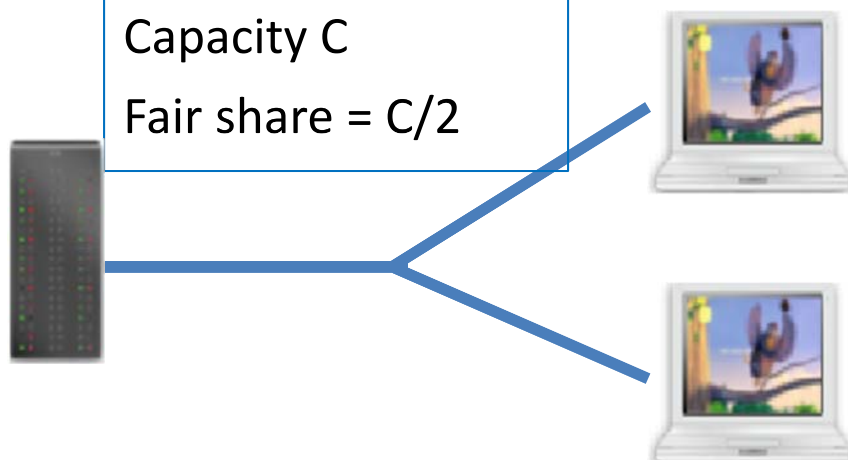
Multiple Competing Players
A Simple Model

- Ideal TCP
  - A single active connection gets the whole capacity C
  - Two active connections share the capacity fairly receiving C/2 each

Shared link

Capacity C

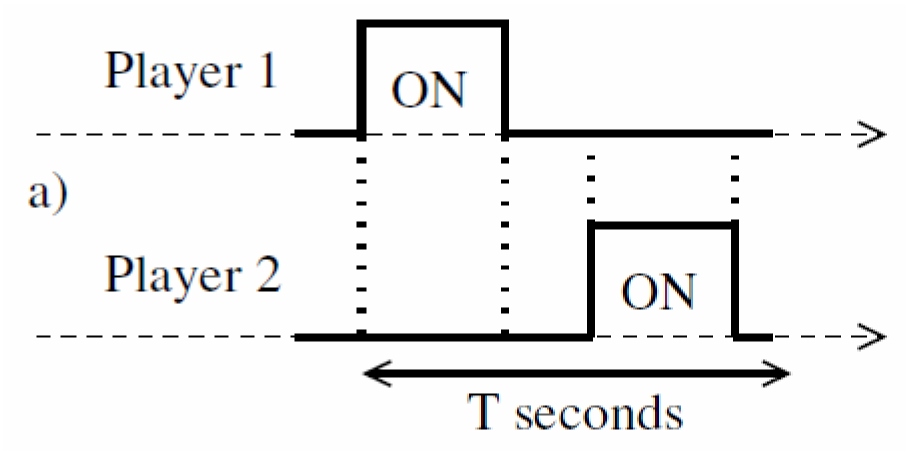
Fair share = C/2



- Two competing adaptive streaming players
- Steady-State
- Full buffers

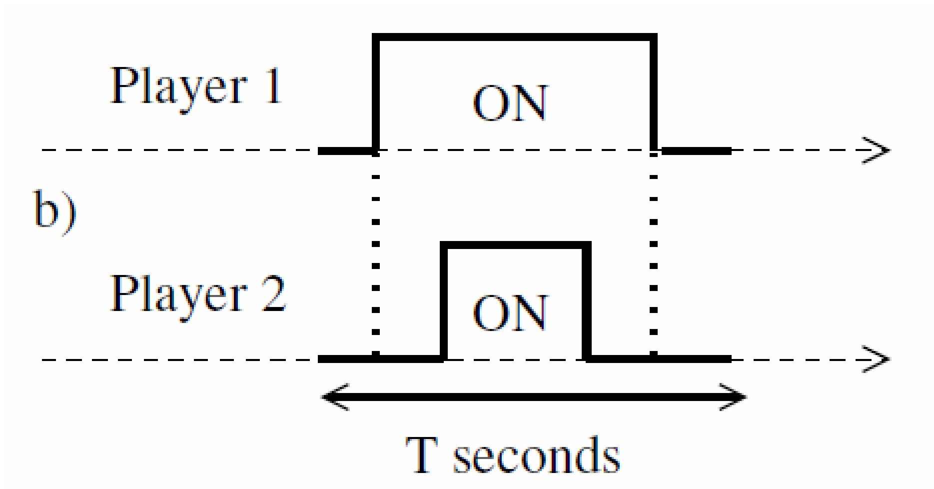
- Based on the temporal overlap of the ON-OFF periods of the players three performance problems can arise
  - Instability
  - Unfairness
  - Bandwidth underutilization

Case I: Non-Overlapping ON Periods



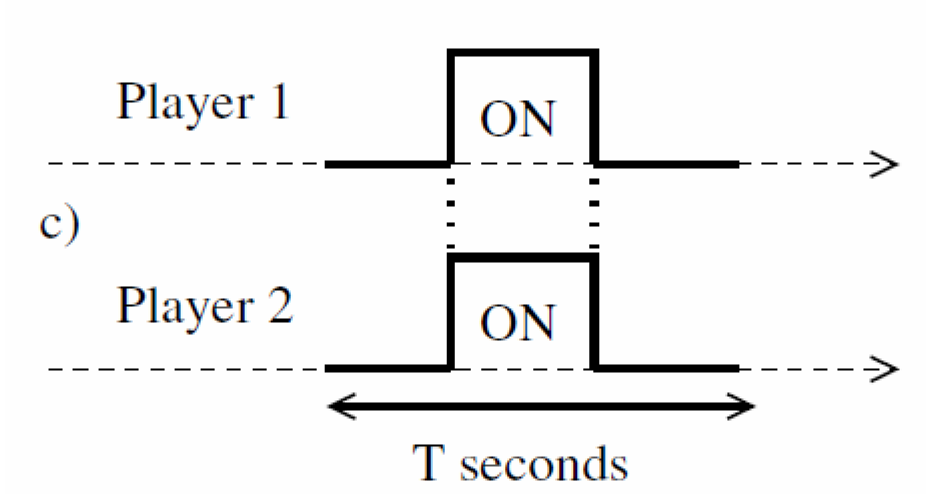
- Both players measure a per-chunk throughput of C
- Overestimate the fair share (f=C/2) by a factor of two
- They may request a bitrate greater than f
  - Congestions happen due to unsustainable requested bitrates
  - ON periods increase and overlap
  - Per-chunk throughputs decrease
  - Players switch back to a lower bitrate
- This oscillatory pattern can continue causing instability

Case II: Nested ON Periods



- ON period of player 2 falls within the ON period of player 1
- Player 1 requests a higher bitrate than player 2
- Player 1 observes a throughput larger than C/2
- Player 2 observes a throughput of C/2
- This configuration might be stable but is unfair

Case III: Fully Overlapping ON Periods



- ON periods are perfectly aligned
- Both players see a throughput of C/2
- Players share the capacity fairly and can be stable
- Bandwidth underutilization can occur due to periods of link inactivity

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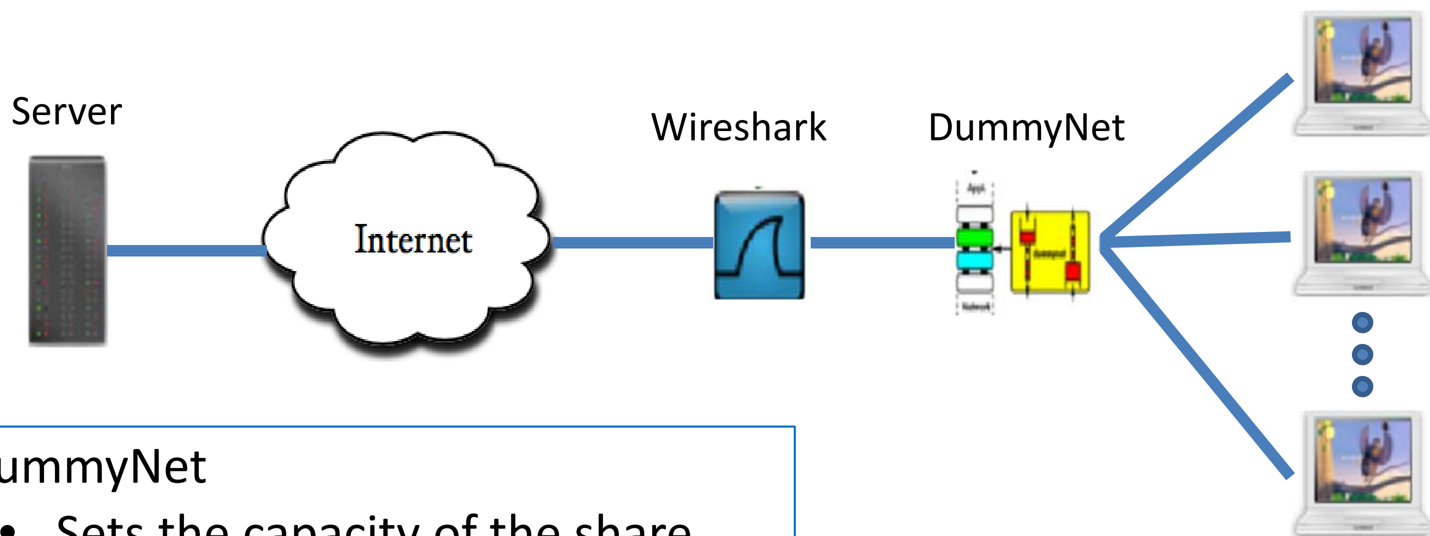
Experimental Methodology



- DummyNet
  - Sets the capacity of the share bottleneck
- Wireshark
  - Captures the traffic for offline analysis
- Server
  - Hosts the video content in multiple bitrates

- Clients on a host machine
  - Smooth Streaming player
  - AdapTech player
    - Logs internal parameters
    - Does not render video

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  - Smooth Streaming player
  - Simpler player
  - Metrics
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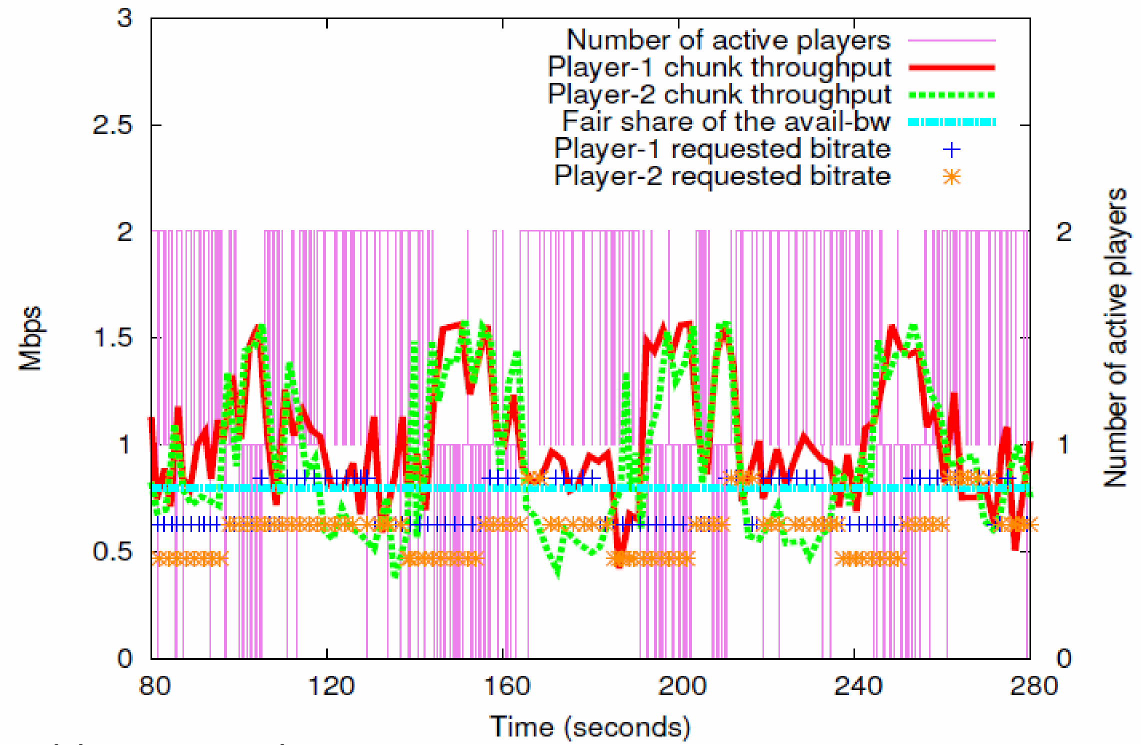
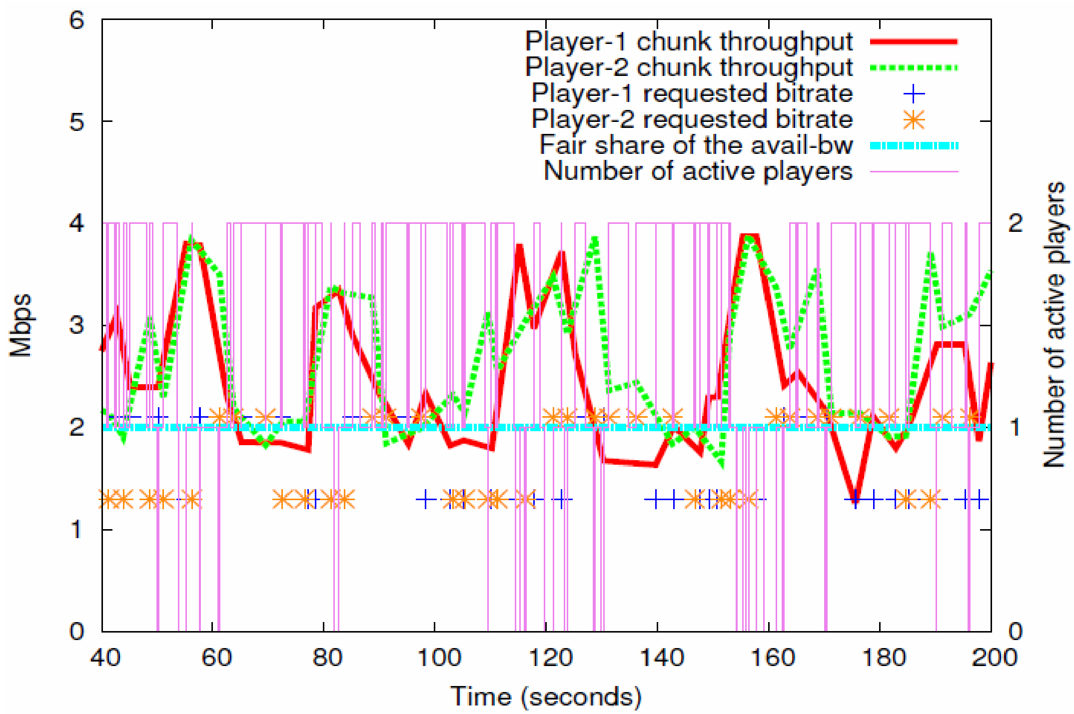
Two Competing Smooth Streaming Players



- Fair share avail-bw = 800 Kbps
- Players show an oscillatory pattern in their requested bitrate and per-chunk throughput
- When only a single player is active (ON) it overestimates the fair share and tries to switch to an unsustainable bitrate

A Simpler Player



- Based on AdapTech streaming player (built on OSMF player)
- Performs qualitatively similar to Smooth (similar pattern of instability)
- Does not render and display video
- Used to run several instances of the player on our host machine

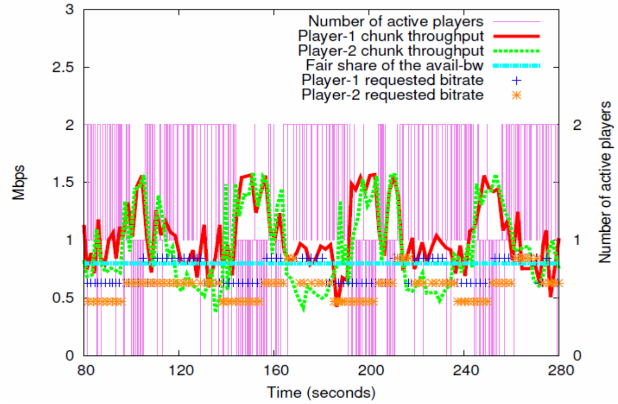
Performance Metrics

- Instability
  - Fraction of successive chunk requests by a player in which the requested bitrate does not remain constant
- Unfairness (for two players)
  - Average of the absolute bitrate differences between the corresponding chunks requested by each player
- Utilization
  - Aggregate throughput during an experiment (measured from the Wireshark captures) divided by the avail-bw in that experiment

Metrics Values - Previous Experiments

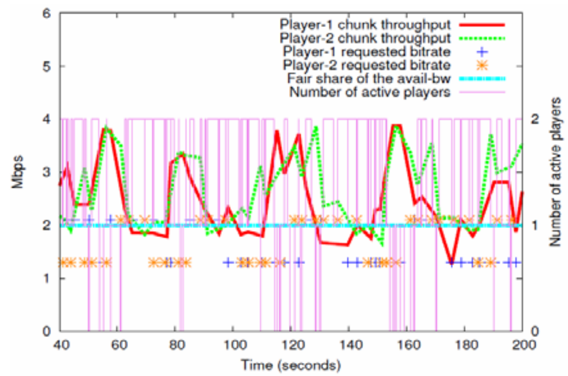
Smooth Streaming Player

- Instability: 12%
- Unfairness: 85 Kbps
- Utilization: 94 %



Simpler Player

- Instability: 16%
- Unfairness: 270 Kbps
- Utilization: 92 %



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  - Duration of ON-OFF periods
  - Fair share and available profiles
  - Number of competing players
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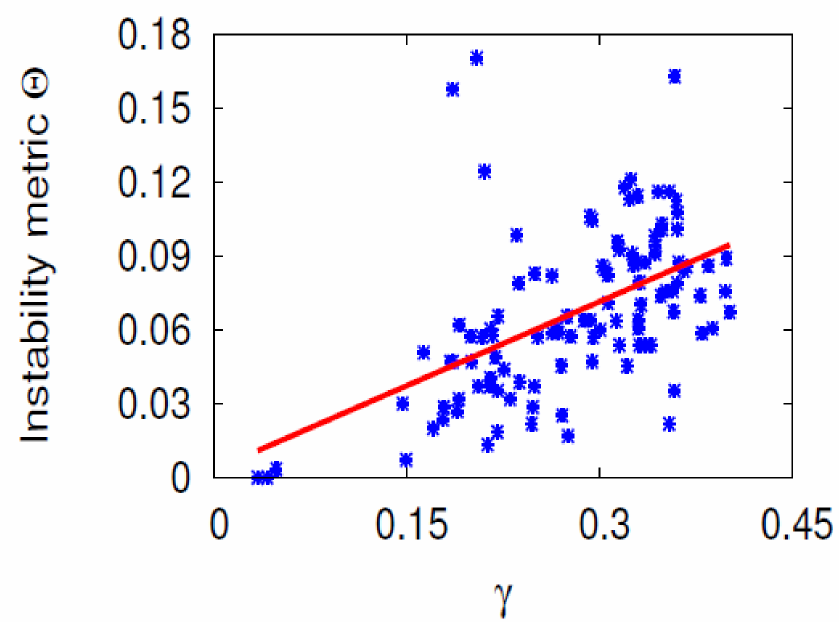
Stability

- Players often do a reasonable job regarding fairness and utilization
- However, the root cause of the instability problem still exists
- What factors affect stability of adaptive streaming players?

Duration of ON-OFF Periods

- Consider two competing Smooth players
- Increase fair share f from 400 Kbps to 3 Mbps in steps of 100 Kbps (repeating four times for each value of f)
- Denote by γ the fraction of time exactly one player is OFF
  - γ =1 if all the time exactly one player is ON and the other OFF (so both see the whole link capacity)

Effect of γ on Instability

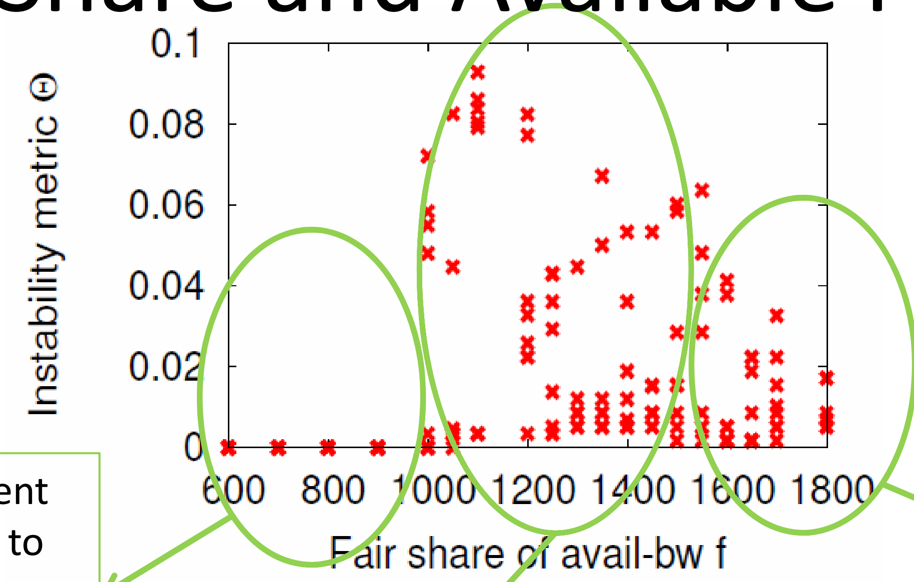


- The higher γ the higher instability
- When exactly one player is ON, it will see the whole link capacity and overestimate its fair share.
- It can switch to a higher but unsustainable bitrate as a result causing instability

Fair Share and Available Profiles

- Consider two competing Smooth players and two available profiles (470 Kbps and 1.52 Mbps)
- Increase fair share f from 470 Kbps to 1.8 Mbps in steps of 50 Kbps (repeating eight times for each value of f)
- Calculate the fraction of the ON duration of one player in which the other player is also ON
- Denote by λ (overlap factor) the maximum fraction of that value among the two players
  - λ=1 if the ON period of one player always falls within the ON period of the other player

Fair Share and Available Profiles



- Avail-bw not sufficient for even one player to switch to the higher profile
- Instability close to 0

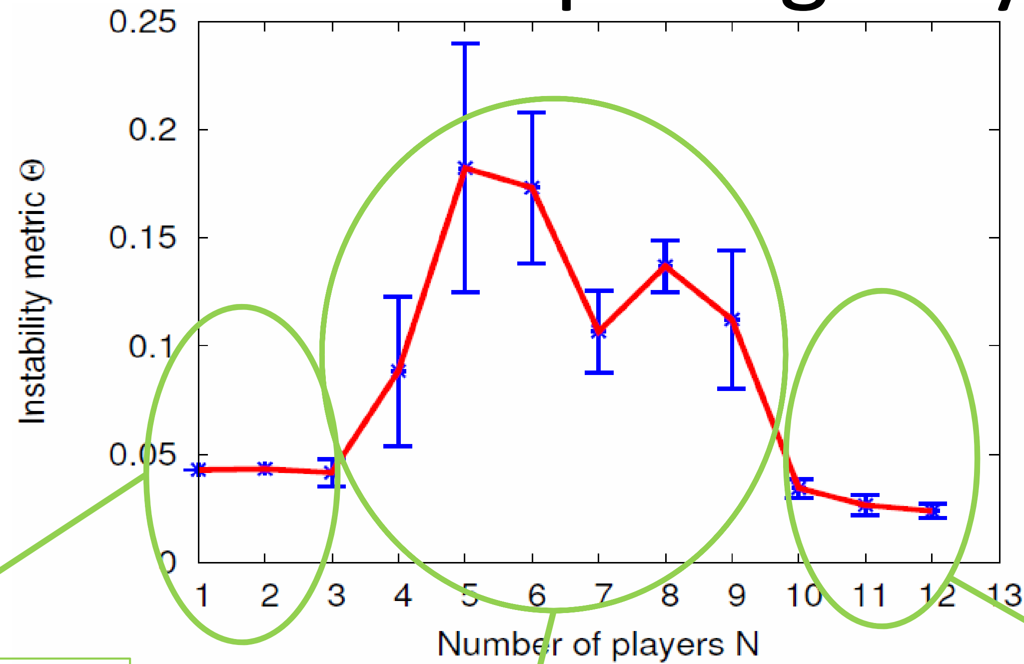
- Avail-bw sufficient for both players to switch to the higher profile
- Instability close to 0

- At least one of the players can switch to the higher bitrate
- High variation in instability
- Instability negatively correlated with the overlap factor λ
- The more overlapped the ON periods, the better the estimate of the fair share and so the smaller the instability

Number of Competing Players

- Consider a varying number of the Simpler players
- Set avail-bw at the bottleneck to constant value
  - 11 Mbps
- Increase the number of competing player from 1 to 12 repeating each experiment four times

Number of Competing Players



- Avail-bw sufficient for all players to switch to the highest bitrate
- Instability close to 0

- Fair share f falls within the highest and lowest profiles
- Players mostly in Steady-Sate going through ON-OFF periods
- Instability is peaked almost halfway between the lowest and highest bitrates

- Avail-bw barely sufficient for the players to request the lowest bitrate
- Always in Buffering-State
- Instability close to 0

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Conclusions

- Competition between HTTP adaptive streaming players can lead to performance problems
    - Instability
    - Unfairness
    - Bandwidth underutilization
- Root cause is the behavior of the players in their Steady-State
    - Periods of activity (ON periods) followed by periods on inactivity (OFF periods)
    - Players overestimate their fair share of avail-bw
- Several factors affect the stability of players
    - Duration of ON-OFF periods
    - Fair share and available profiles
    - Number of competing players