



HTTP Adaptive Streaming in practice

Mark Watson

(with thanks to the Netflix adaptive streaming team!)

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Netflix Overview



*Netflix corporate headquarters
Los Gatos, California*

- Started with DVD-by-mail, **now primarily Internet streaming**
- **20+ million¹ subscribers, growing rapidly** (*>15% of US households subscribe to Netflix*)
- USA-only for ten years, Canada in 2010, further expansion in 2011+
- Unlimited Streaming = \$7.99/month
 - Plus 1 DVD at a time = \$9.99/month

¹ subscriber reported 1/26/11

Partner Products

Roku Netflix Player by Roku



"My guess is that eventually, the streaming feature will be part of Blu-ray players and TVs. But for now, the Netflix Player by Roku strikes me as a great value for early adopters and film addicts alike."

POKMag.com, Tim Gibson May 25, 2009

URL Brand	Roku	Product Type	Set-top box
Model	HD (R1000)	Release Date	May 2009
Features	HD, Netflix, 1080p	Instant Streaming Ready	Yes

Microsoft Xbox 360



"It's high-def Netflix streaming, and it's coming first to Microsoft's Xbox 360. Yes friends, when the all new dashboard hits on November 23rd, with it will come HD Netflix streaming for Xbox Live Gold members."

Engadget, Simon Mugh October 26, 2008

URL Brand	Microsoft	Product Type	Game console
Model	Xbox 360	Release Date	May 2005
Features	HD, Netflix, 1080p	Instant Streaming Ready	Yes

LG BD390



"Streaming Netflix is one of the main selling points of the LG BD390."

LG BD390 for sale April, 2009

URL Brand	LG Electronics	Product Type	Blu-ray player
Model	BD390	Release Date	Apr. 2009
Features	BD, Netflix, 1080p	Instant Streaming Ready	Yes

Samsung BD-P1000



URL Brand	Samsung	Product Type	Blu-ray player
Model	BD-P1000	Release Date	May 2008
Features	BD, Netflix, 1080p	Instant Streaming Ready	Yes

LG BD370



URL Brand	LG	Product Type	Blu-ray player
Model	BD370	Release Date	May 2008
Features	BD, Netflix, 1080p	Instant Streaming Ready	Yes

LG LH8553



URL Brand	LG	Product Type	Blu-ray player
Model	LH8553	Release Date	May 2008
Features	BD, Netflix, 1080p	Instant Streaming Ready	Yes

LG 50P580



URL Brand	LG	Product Type	TV
Model	50P580	Release Date	May 2008
Features	HD, Netflix, 1080p	Instant Streaming Ready	Yes

Samsung HT-BD200



URL Brand	Samsung	Product Type	Blu-ray player
Model	HT-BD200	Release Date	May 2008
Features	BD, Netflix, 1080p	Instant Streaming Ready	Yes

LG BD390



URL Brand	LG Electronics	Product Type	Blu-ray player
Model	BD390	Release Date	Apr. 2009
Features	BD, Netflix, 1080p	Instant Streaming Ready	Yes

INSIGNIA NS-BRVD3



URL Brand	INSIGNIA	Product Type	Blu-ray player
Model	NS-BRVD3	Release Date	May 2008
Features	BD, Netflix, 1080p	Instant Streaming Ready	Yes

Sony PlayStation 3



URL Brand	Sony	Product Type	Game Console
Model	PS3	Release Date	Nov 6, 2006
Features	HD, Netflix, 1080p	Instant Streaming Ready	Yes

SONY KDL-XBR10



URL Brand	SONY	Product Type	TV
Model	KDL-XBR10	Release Date	May 2008
Features	HD, Netflix, 1080p	Instant Streaming Ready	Yes

SONY KDL-XBR9




URL Brand	SONY	Product Type	TV
Model	KDL-XBR9	Release Date	May 2008
Features	HD, Netflix, 1080p	Instant Streaming Ready	Yes

SONY KDL-XBR8



URL Brand	SONY	Product Type	TV
Model	KDL-XBR8	Release Date	May 2008
Features	HD, Netflix, 1080p	Instant Streaming Ready	Yes

INSIGNIA NS-BRVD3



URL Brand	INSIGNIA	Product Type	Blu-ray player
Model	NS-BRVD3	Release Date	May 2008
Features	BD, Netflix, 1080p	Instant Streaming Ready	Yes

LG LH450



URL Brand	LG	Product Type	Blu-ray player
Model	LH450	Release Date	May 2008
Features	BD, Netflix, 1080p	Instant Streaming Ready	Yes

Nintendo Wii



URL Brand	Nintendo	Product Type	Game Console
Model	Wii	Release Date	Dec 25, 2006
Features	HD, Netflix, 1080p	Instant Streaming Ready	Yes

VIZIO SV422XVT



URL Brand	VIZIO	Product Type	TV
Model	SV422XVT	Release Date	Jan 2010
Features	HD, Netflix, 1080p	Instant Streaming Ready	Yes

Panasonic DMP-BD90



URL Brand	Panasonic	Product Type	Blu-ray player
Model	DMP-BD90	Release Date	May 2008
Features	BD, Netflix, 1080p	Instant Streaming Ready	Yes

Samsung LED C8000



URL Brand	Samsung	Product Type	TV
Model	LED C8000	Release Date	Mar 1, 2010
Features	HD, Netflix, 1080p	Instant Streaming Ready	Yes

Philips BDP1110



URL Brand	PHILIPS	Product Type	Blu-ray player
Model	BDP1110	Release Date	May 2008
Features	BD, Netflix, 1080p	Instant Streaming Ready	Yes

Samsung HT-C8500



URL Brand	Samsung	Product Type	Blu-ray player
Model	HT-C8500	Release Date	May 2008
Features	BD, Netflix, 1080p	Instant Streaming Ready	Yes

Apple iPad



URL Brand	Apple	Product Type	Tablet
Model	iPad	Release Date	Apr 3, 2010
Features	HD, Netflix, 1080p	Instant Streaming Ready	Yes

LG BX500



URL Brand	LG	Product Type	Blu-ray player
Model	BX500	Release Date	May 2008
Features	BD, Netflix, 1080p	Instant Streaming Ready	Yes

Netflix Ready Devices

From: May 2008
To: May 2010

Instant Streaming ready

NETFLIX

NETFLIX

Instant Queue

+ Movies You'll ❤️

New Arrivals

Movies

TV Shows

Search

Top 10 for Matt



Feel-good Movies



Underdog Movies



Movies Featuring a Strong Female Lead

Contents

- Why HTTP adaptive streaming ?
- Streaming approaches
- Measuring quality and the value of quality
- Adaptation algorithms and open problems

Why HTTP Adaptive Streaming ?

Commodity service

Competing providers

Economies of scale

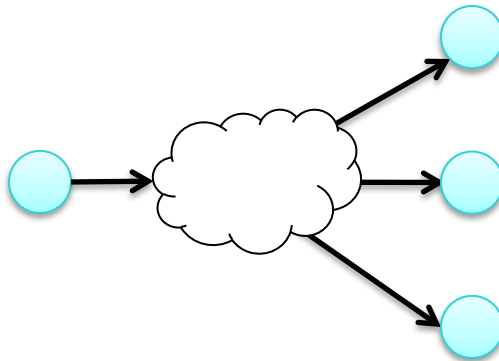


Netflix Confidential

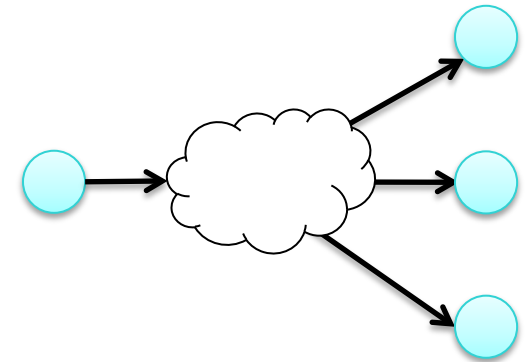
Unicast



Multicast



Synchronous



Asynchronous

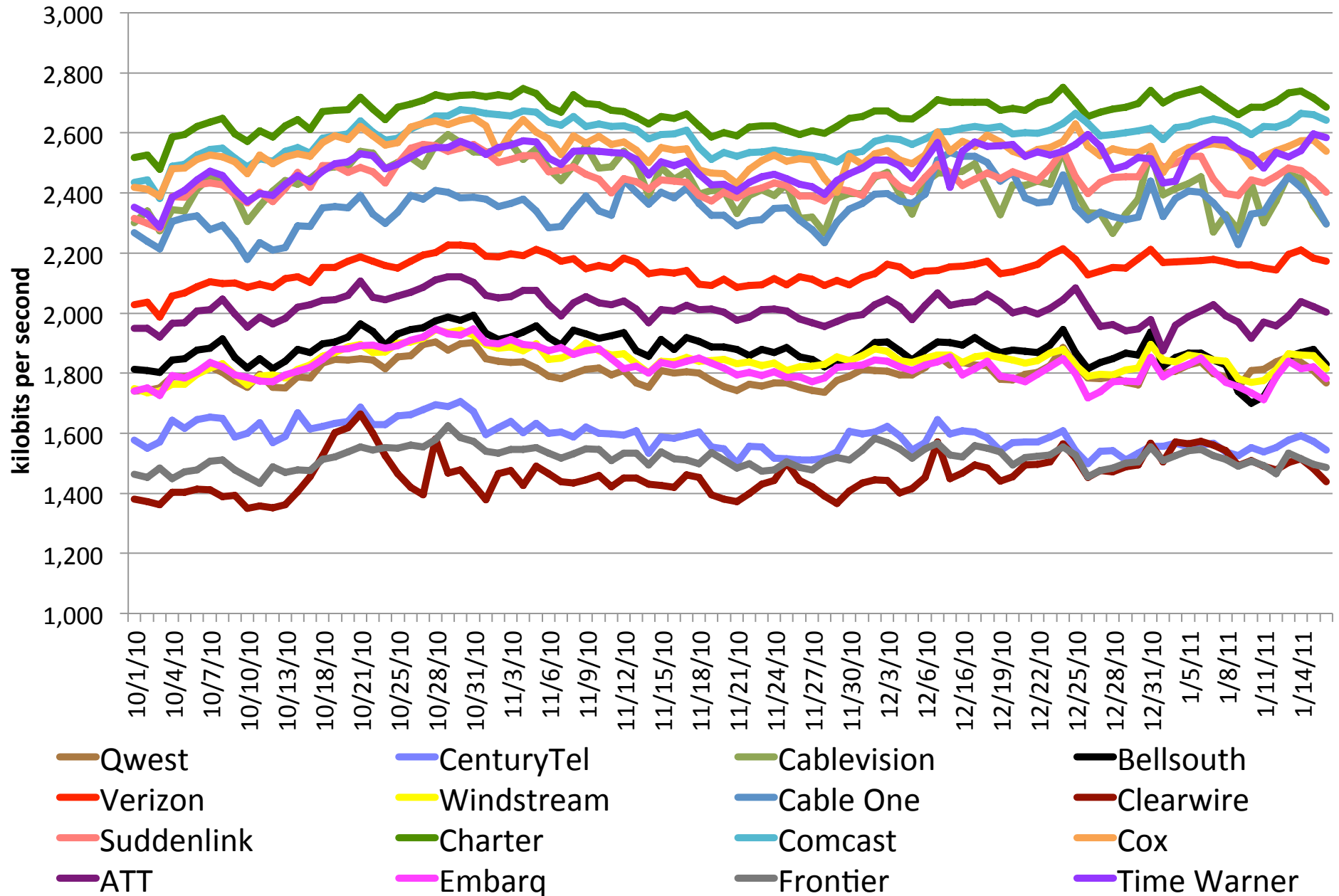
Client-centric approach

- Client has the best view of network conditions
- No session state in network
 - Redundancy
 - Scalability
- Faster innovation and experimentation
- BUT, relies on client for operational metrics
 - only the client knows what really happened anyway

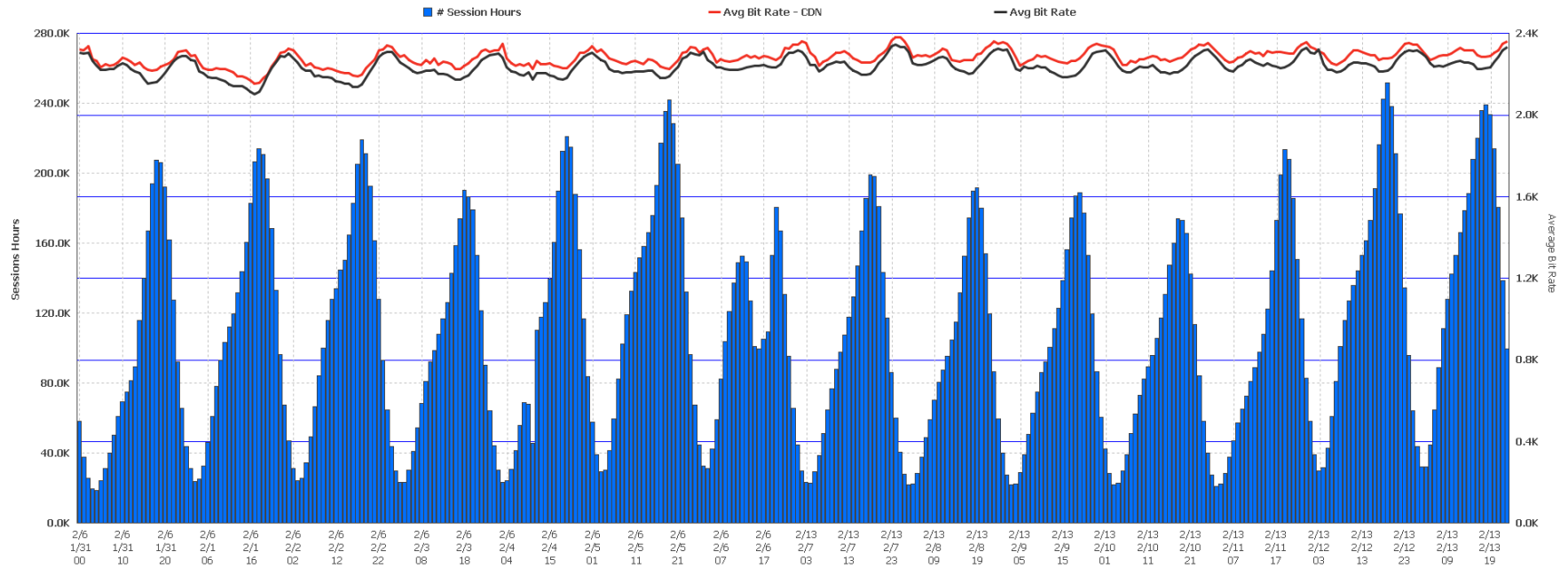
Scalability examples

- Microsoft streaming of 2008 Olympics
 - 4 Petabytes live & VoD content in one month
 - North America (av. user bandwidth 2Mbit/s)
 - Millions of simultaneous sessions
 - **Over existing infrastructure**
- Netflix
 - 20% of North American Internet traffic at peak hours
 - Millions of hours of content every day
 - Bitrates up to 4.8Mbit/s
 - Almost no dedicated infrastructure
 - Control servers in AWS
 - Content delivery through CDNs

Netflix Performance on Top Networks - USA

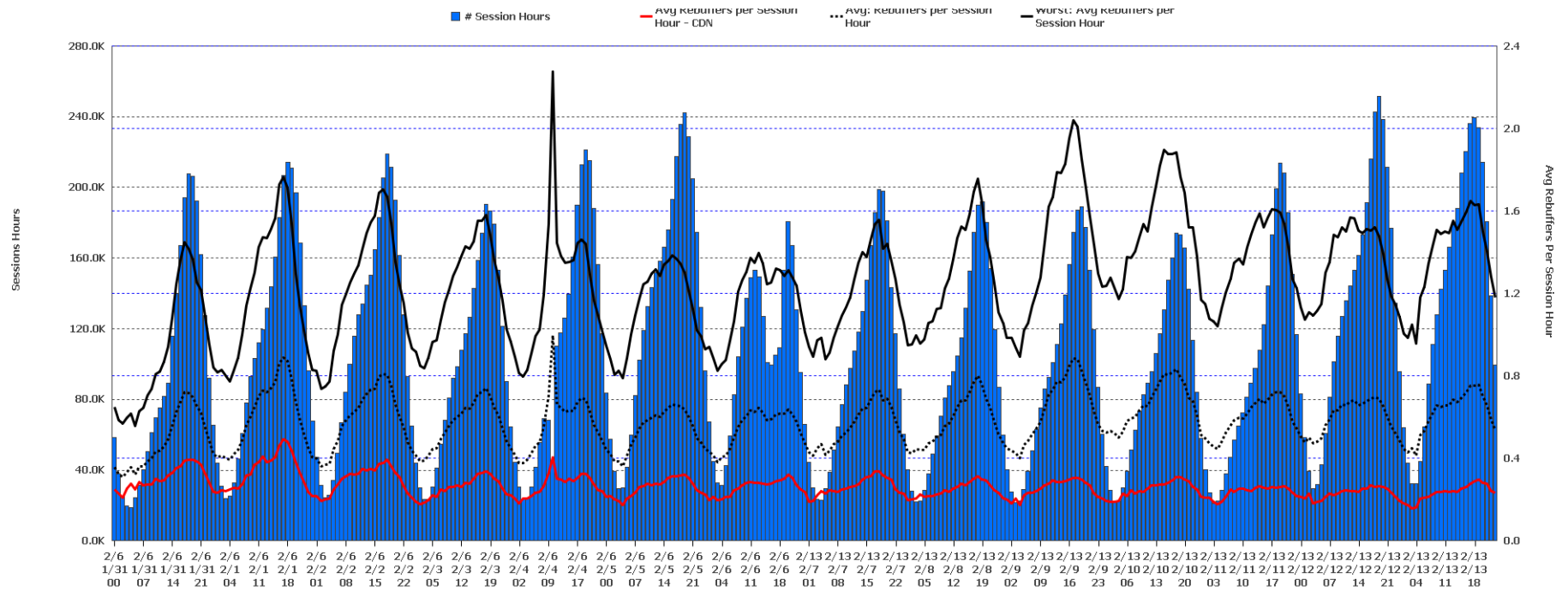


Streaming bitrate performance



(just one device type)

Streaming rebuffer rates



(just one device type)

Contents

- Why HTTP adaptive streaming ?
- **Streaming approaches**
- Measuring quality and the value of quality
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Adaptive streaming in practice



HTTP Live Streaming

Small media chunks
("streamlets")



Microsoft
Silverlight

Smooth Streaming



Adobe HTTP Dynamic
Streaming

Chunks created at
origin server



MPEG DASH

HTTP Byte Range
requests

Adaptive streaming in practice



HTTP Live Streaming



Microsoft®
Silverlight™

Smooth Streaming



Adobe HTTP Dynamic
Streaming

Combined A/V
streams only



MPEG DASH

Separate Audio/Video

Adaptive streaming in practice



HTTP Live Streaming

No switchpoint alignment



Microsoft®
Silverlight™

Smooth Streaming



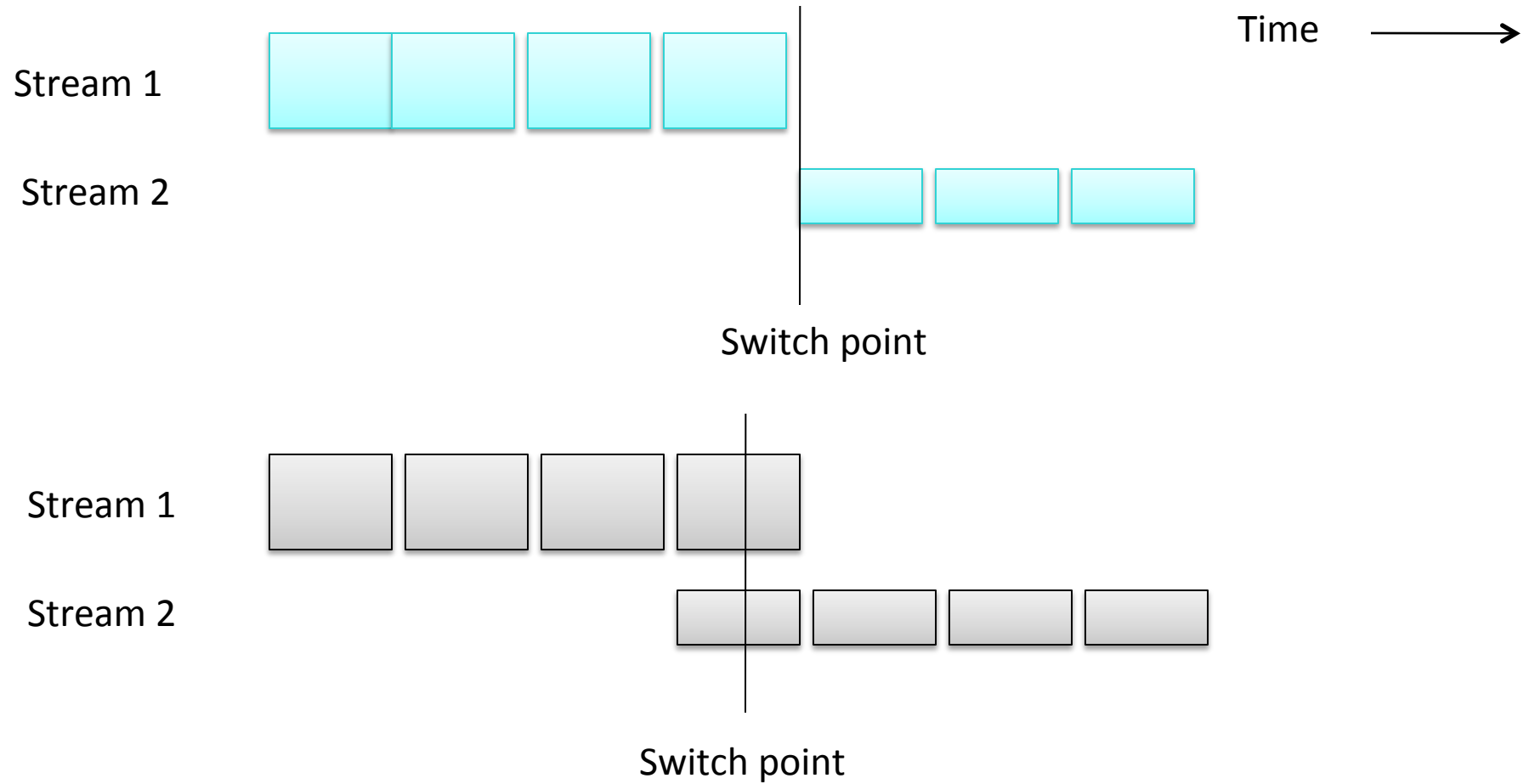
Adobe HTTP Dynamic
Streaming



MPEG DASH

Switchpoint
alignment
(optional)

Switchpoint Alignment



Adaptive streaming summary

- For On Demand
 - Chunks are unnecessary and costly
 - Byte Range requests have caching and flexibility advantages
 - Separate audio/video essential for language support
- For Live
 - Chunks are unavoidable
 - Still value in decoupling request size from chunk size
 - Multiple language audio tracks are rare
 - May need manifest updates
- For both
 - Switch point alignment required for most CE decoding pipelines

MPEG DASH

- Supports both unchunked & chunked
- Supports both separate & combined A/V
- Index formats for efficient byte range operation
- ISO Base Media File Format w/common encryption
- Rigorous definition of stream alignment requirements
- Signaling of different alignment modes
- Many useful stream and track annotations

Currently the best candidate for an open standard for adaptive streaming

Contents

- Why HTTP adaptive streaming ?
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- **Measuring quality and the value of quality**
- Adaptivity algorithms and open problems

Measuring quality

- Reliable transport => all-or-nothing delivery
- Quality characterized by
 - Video quality
 - At startup, average and variability
 - Re-buffer rate
 - Re-buffers per viewing hour, duration of re-buffer pauses
 - Startup delay
 - Time from user action to first frame displayed

Importance of client metrics

- Metrics are operationally essential
 - Detecting and debugging failures
 - Managing performance
 - Experimentation
- Absence of server-side metrics places onus on client
- What do we need ?
 - Reports of what the user did (or didn't) see
 - Which part of which stream presented when
 - Reports of what happened on the network
 - Requests sent, responses received, timing, throughput

Contents

- Why HTTP adaptive streaming ?
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- Measuring quality and the value of quality
- **Adaptivity algorithms and open problems**

Adaptation problem

Choose sequence and timing of requests

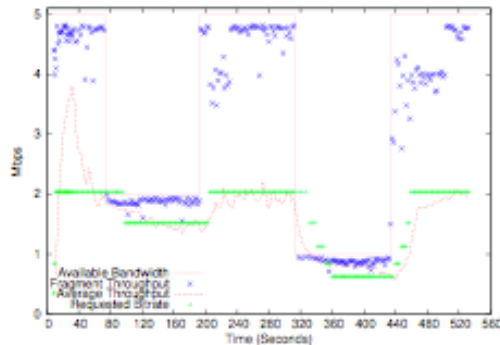
to

Minimize probability of re-buffers

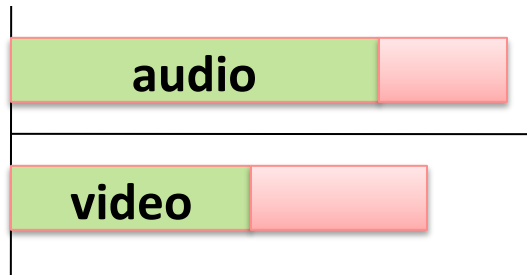
Maximize quality

Adaptation problem: Inputs

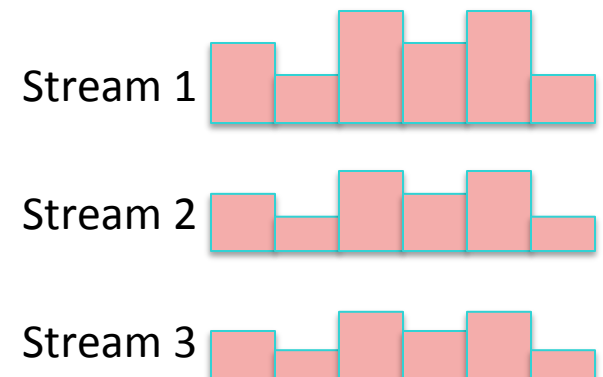
History



Current state



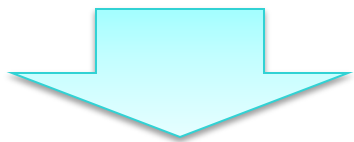
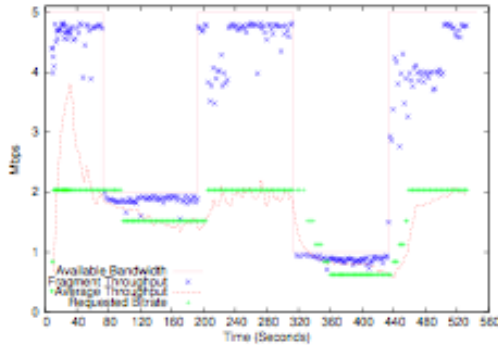
Possible choices



Capturing and representing all this information is not easy!

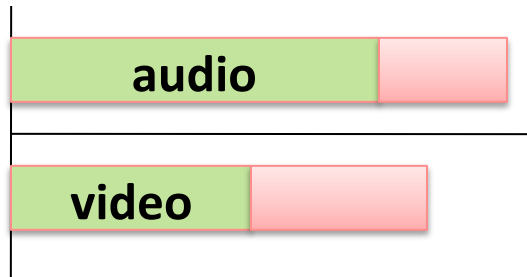
Adaptation problem: logic

History



Model of
future
bandwidth

Current state



Expected performance for
each choice

Possible
choices



Adaptation problem: example

- Model of future bandwidth
 - Constant
 - Equal to average over last 10s
- Analysis of choices
 - Construct “plan” for each choice
 - Determine re-buffers for each plan

Adaptation problem: future work

- Good models of future bandwidth based on history
 - Short term history
 - Long term history (across multiple sessions)
- Tractable representations of future choices
 - Including scalability, multiple streams
- Convolution of future bandwidth models with possible plans

Conclusions

- Asynchronous delivery of same content to many users is a first-class network service
 - HTTP CDNs may not be the “perfect” architecture, but it’s working pretty well at scale
- Many variations on HTTP Adaptive Streaming theme in deployed systems and emerging standards
 - MPEG DASH provides sufficient flexibility here
- Adaptation is not straightforward
 - How to model bandwidth future based on history ?
 - How to efficiently search choice space to maximise quality goals ?
 - What are the quality goals ?

Questions ?

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