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National Tsing Hua University, Hsinchu, Taiwan

CS 5263: Wireless Multimedia Networking Technologies and Applications

Computer Networks: An Overview

Presenter: Chien-Chang Chen

Slides adopted from ACM Multimedia 2012 DASH Tutorial. We thank Christian and Carsten for sharing the slides

Dynamic Adaptive Streaming over HTTP: From Content Creation to Consumption

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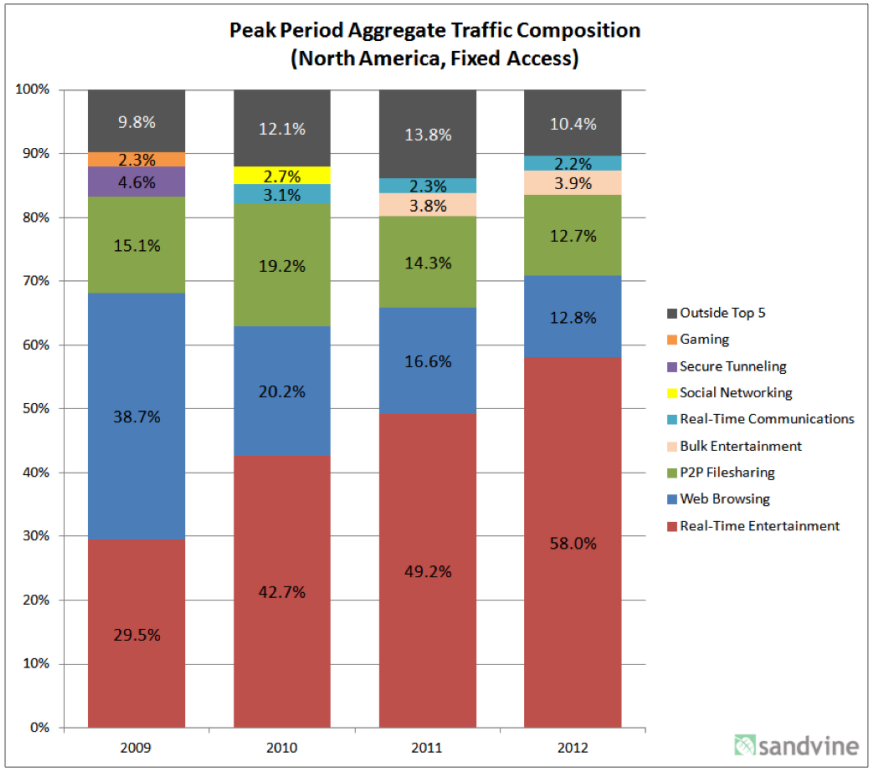
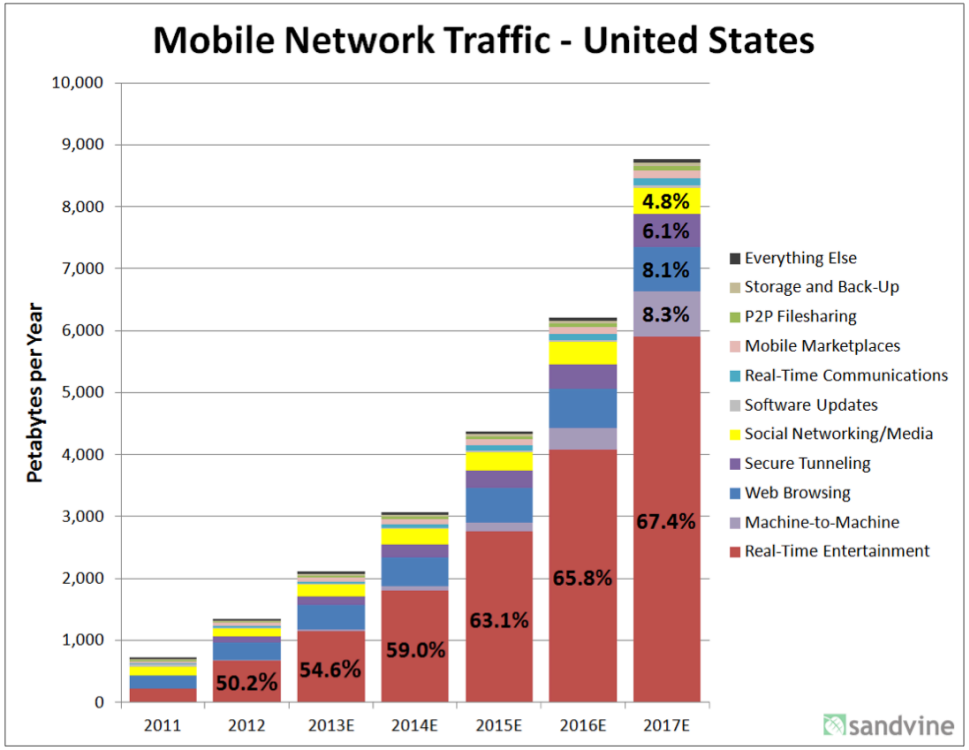
ACM Multimedia 2012, Nara, Japan
29th October, 2012

Video Predominant on the Internet

- Real-time video is more than 50% of the traffic at peak periods
- Mobile traffic is growing exponentially, all delivered over the top (OTT)





http://www.sandvine.com/downloads/documents/Phenomena_1H_2012/Sandvine_Global_Internet_Phenomena_Report_1H_2012.pdf

… but User Frustration is High!!!

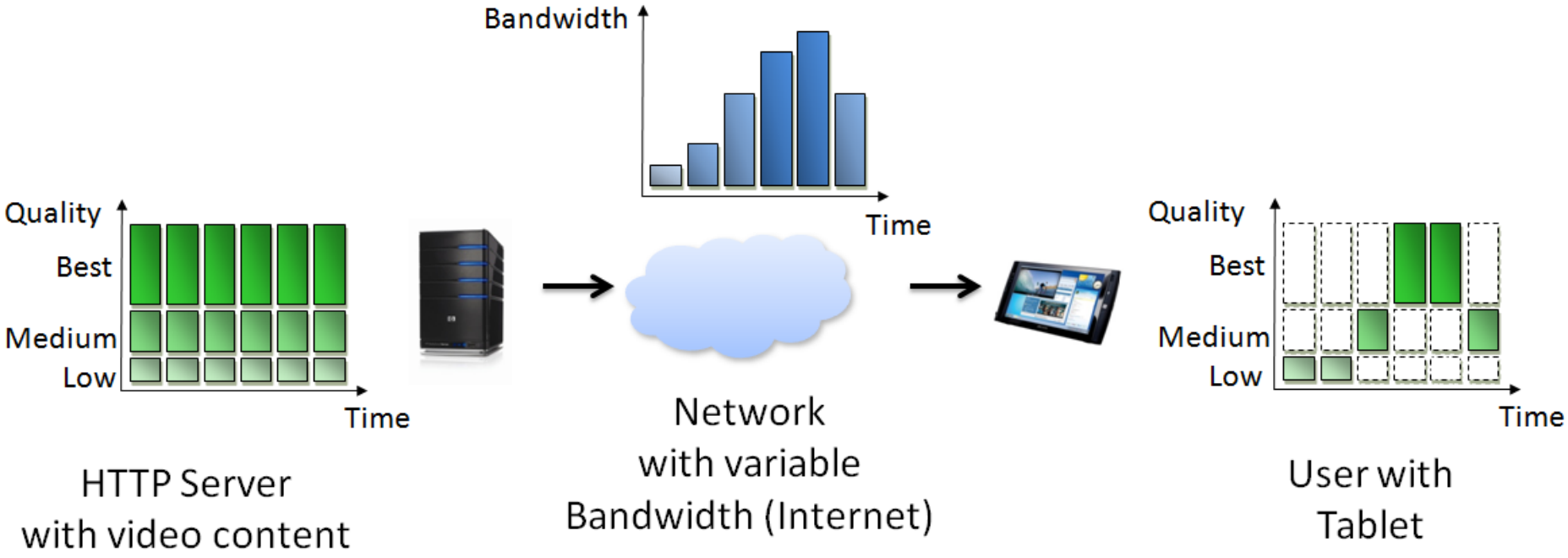
- Wrong format
- Wrong protocol
- Plugin required
- DRM issues
- Long start-up delay
- Low quality
- Frequent stalls
- Bitrate intense
- No DVD/PVR experience

Let's do something …

Ack: Thomas Stockhammer

Dynamic Adaptive Streaming over HTTP

- In a nutshell …



Ack & ©: Christopher Müller

Tutorial Outline

- **MPEG Dynamic Adaptive Streaming over HTTP (DASH)**
  - Scope and design principles
  - Data model
  - Profiles
- **DASH "Encoder", Dataset, and Players**
  - GPAC
  - VLC media player plugin, libdash
  - Javascript & HTML5 => DASH-JS
- **Evaluation of DASH**
  - Mobile, heterogeneous environments
  - Quality of Experience (QoE)
  - TCP interaction

Dynamic Adaptive Streaming over HTTP (DASH)

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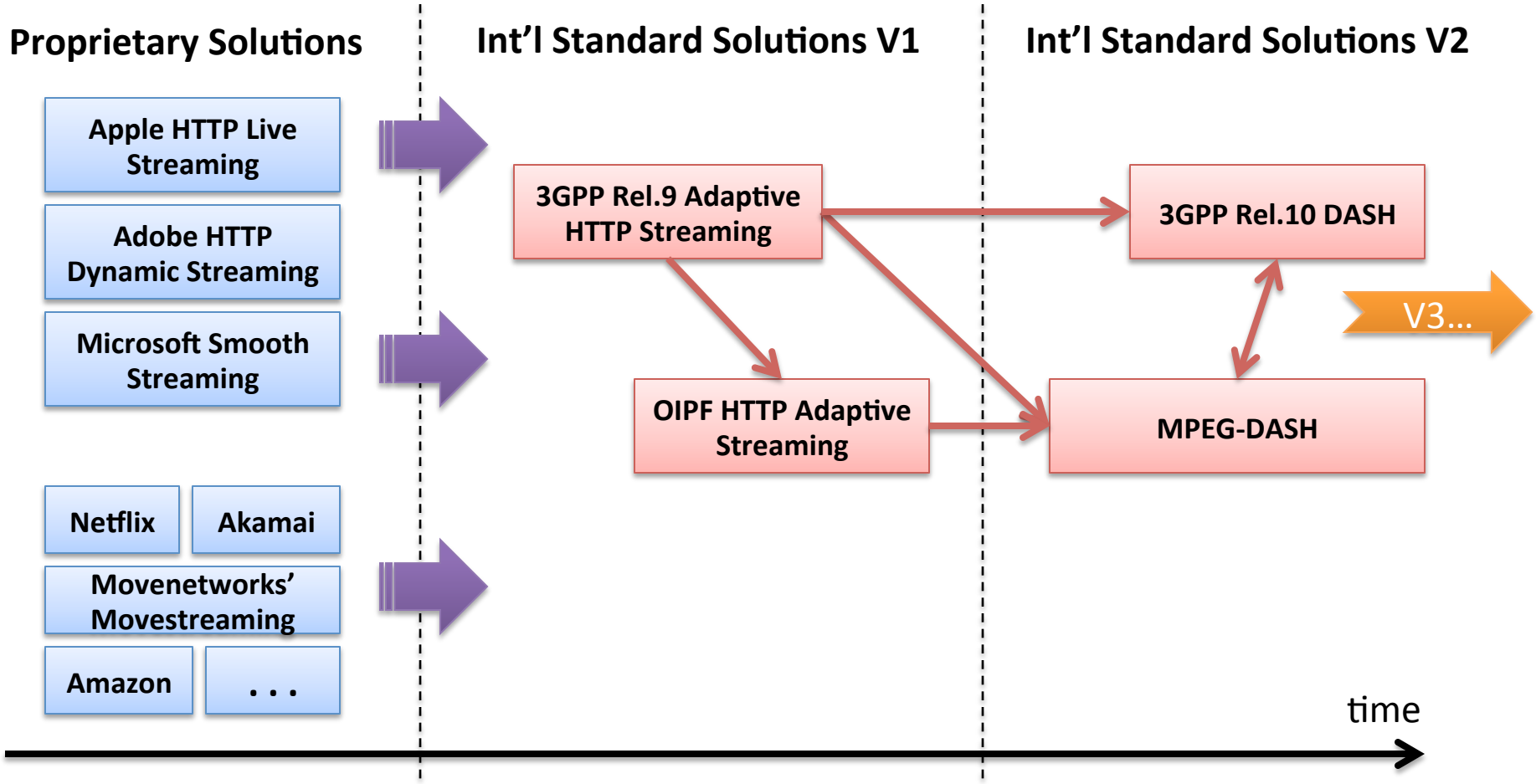
Acknowledgment: Thomas Stockhammer (QUALCOMM), Mark Watson (Netflix), Iraj Sodagar (Microsoft)

What is DASH?

http://en.wikipedia.org/wiki/Dash_(disambiguation)

Dynamic Adaptive Streaming over HTTP (DASH)

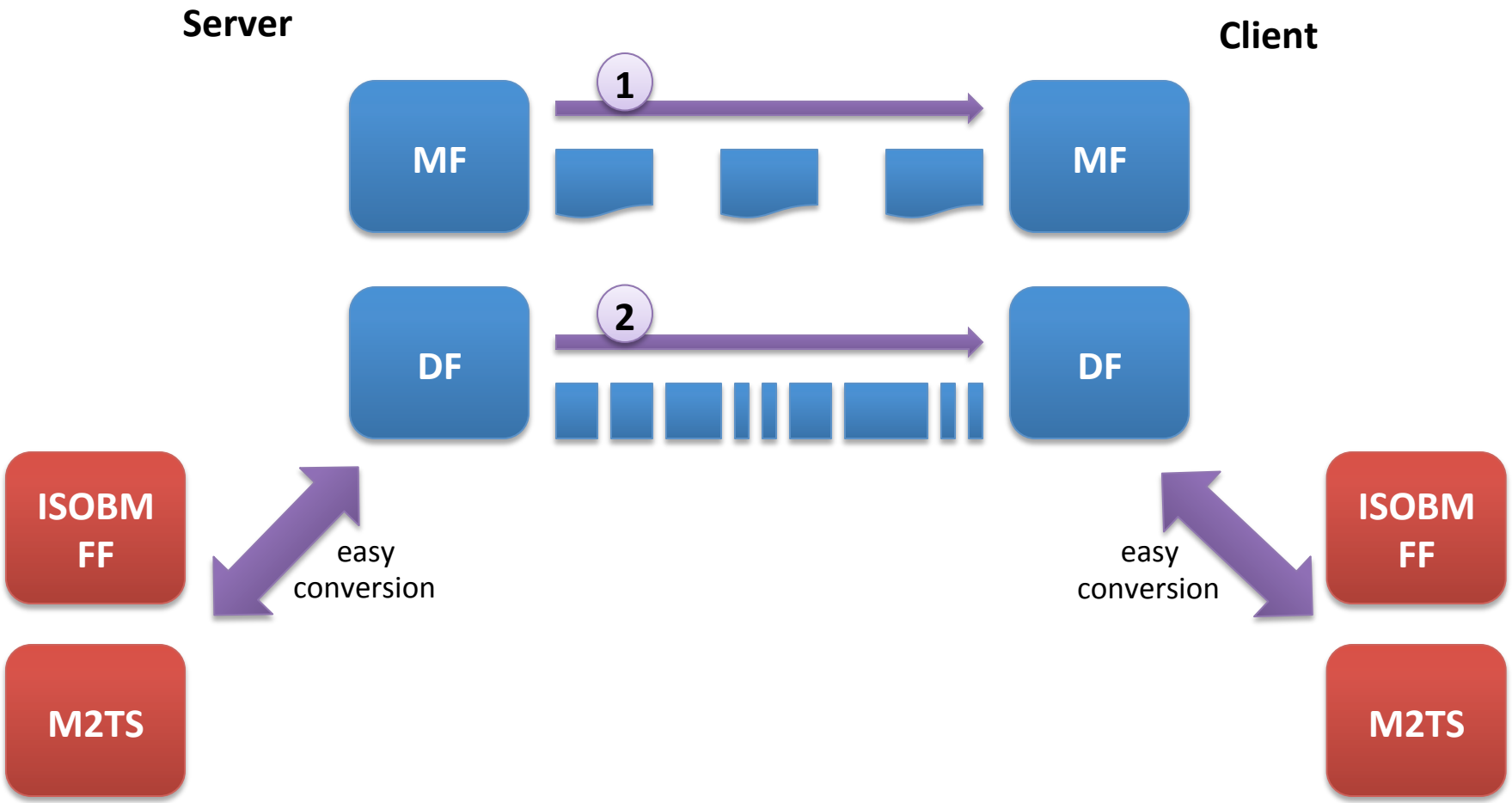


http://multimediacommunication.blogspot.com/2010/05/http-streaming-of-mpeg-media.html

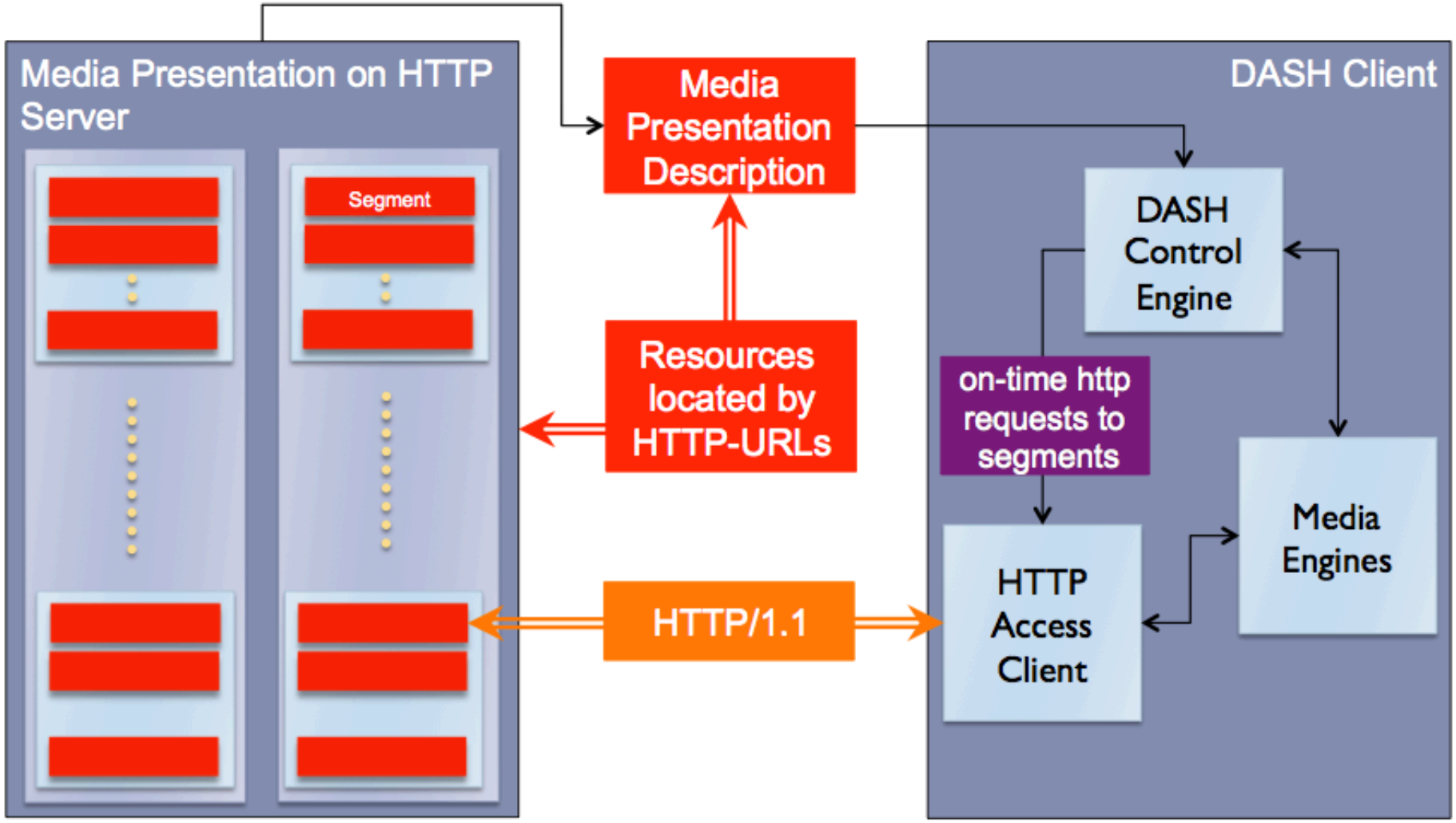
DASH Design Principles

- DASH is not
  - system, protocol, presentation, codec, interactivity, DRM, client specification
- DASH is an enabler
  - It provides formats to enable efficient and high-quality delivery of streaming services over the Internet
  - It is considered as one component in an end-to-end service
  - System definition left to other organizations (SDOs, fora, companies, etc.)
- Design choices
  - Enable reuse of existing technologies (containers, codecs, DRM etc.)
  - Enable deployment on top of HTTP-CDNs (Web Infrastructures, caching)
  - Enable very high user-experience (low start-up, no rebuffering, trick modes)
  - Enable selection based on network and device capability, user preferences
  - Enable seamless switching
  - Enable live and DVD-kind of experiences
  - Move intelligence from network to client, enable client differentiation
  - Enable deployment flexibility (e. g., live, on-demand, time-shift viewing)
  - Provide simple interoperability points (profiles)

Scope of DASH



What is specified – and what is not?



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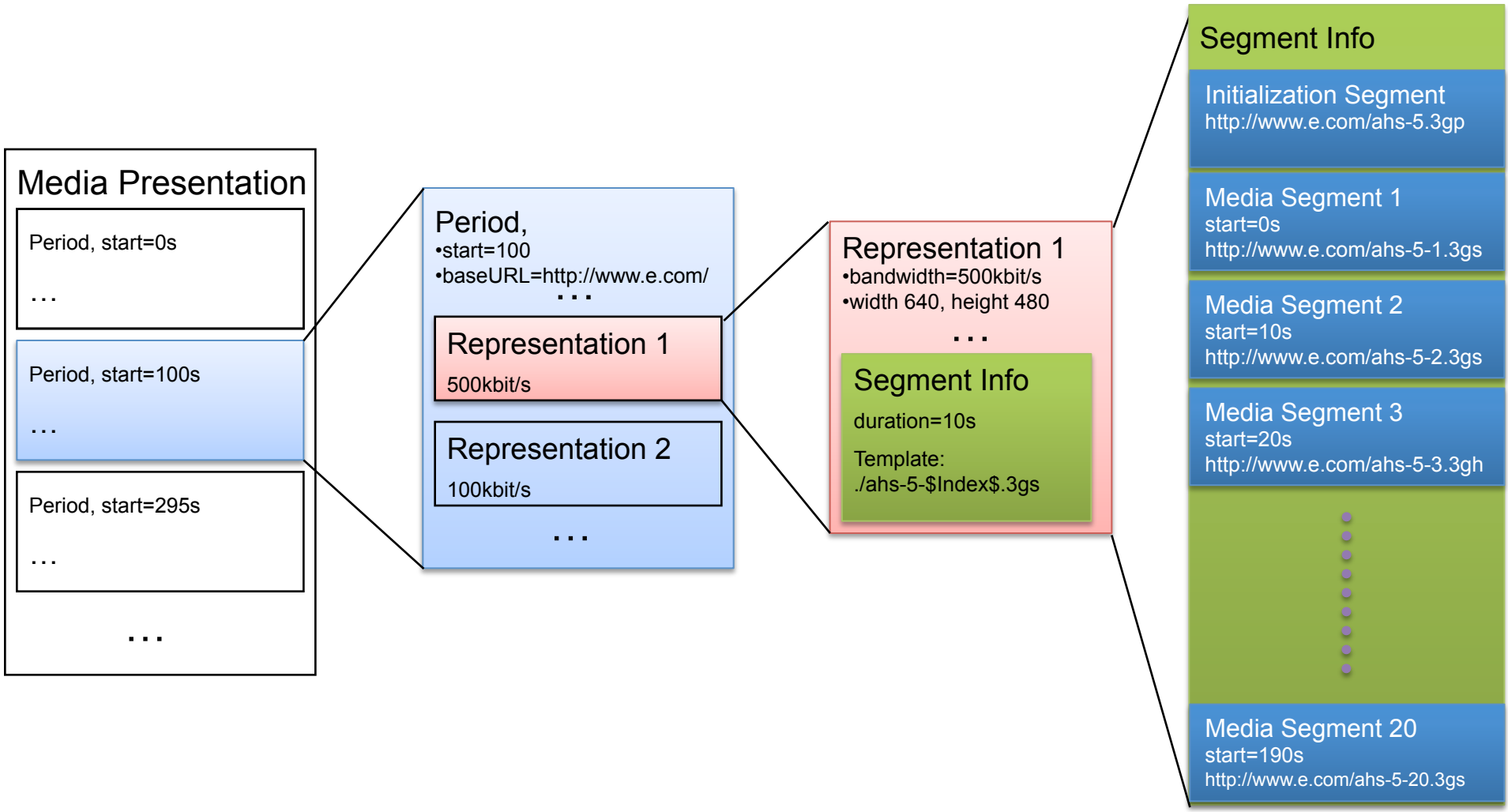
DASH Data Model

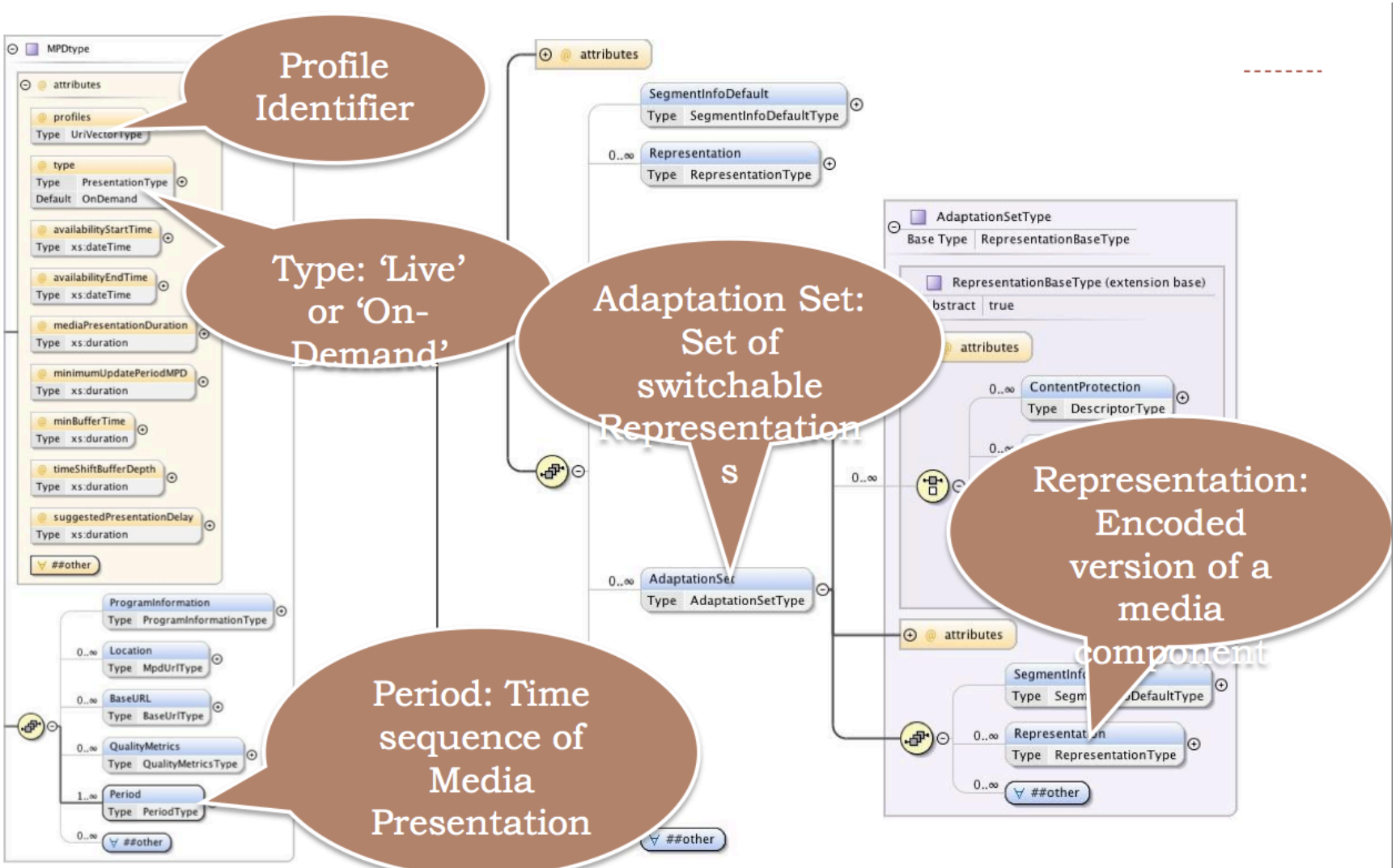


Ack & ©: Thomas Stockhammer

Media Presentation Description

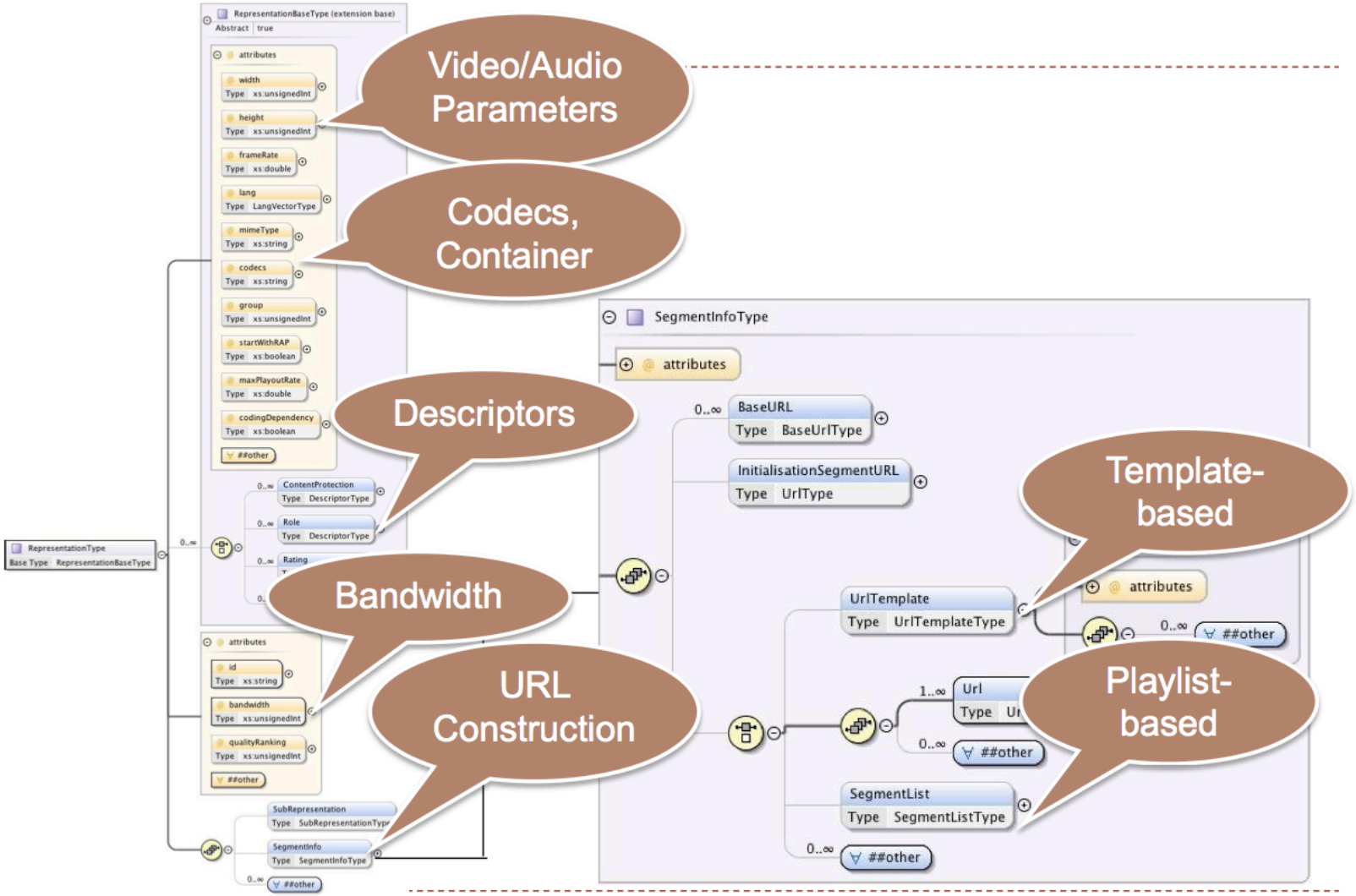
- Redundant information of Media Streams for the purpose to initially select or reject AdaptationSets of Representations
  - Examples: Codec, DRM, language, resolution, bandwidth
- Access and Timing Information
  - HTTP-URL(s) and byte range for each accessible Segment
  - Earliest next update of the MPD on the server
  - Segment availability start and end time in wall-clock time
  - Approximated media start time and duration of a Media Segment in the media presentation timeline
  - For live service, instructions on starting playout such that media segments will be available in time for smooth playout in the future
- Switching and splicing relationships across Representations
- Relatively little other information

MPD Schema Overview



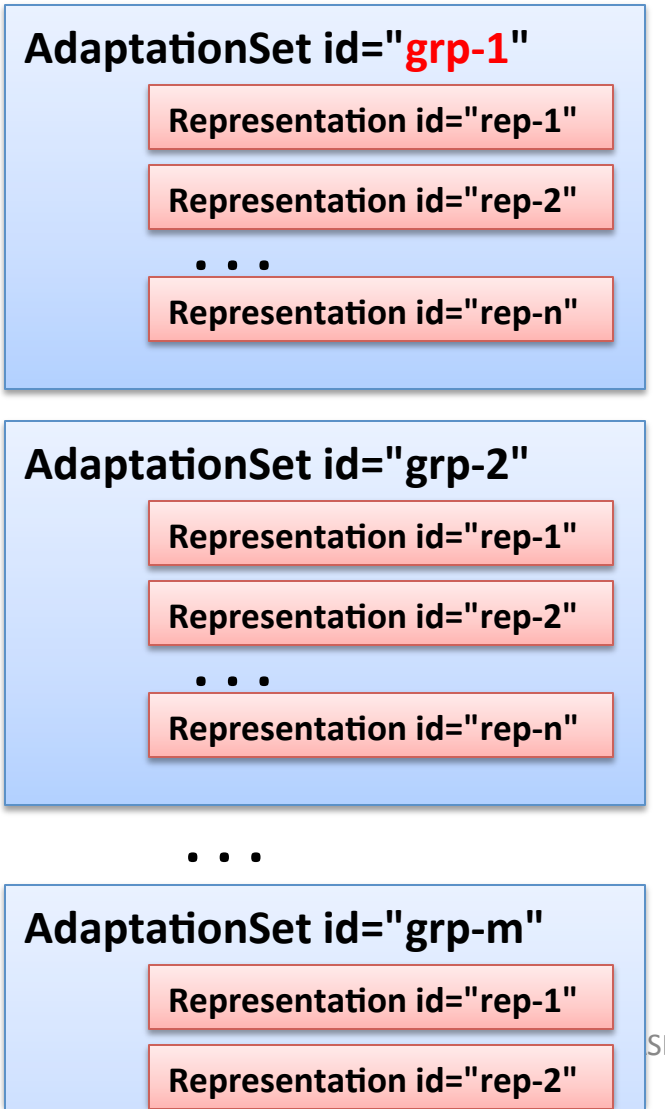
Ack & ©: Iraj Sodagar

MPD Schema - Representation



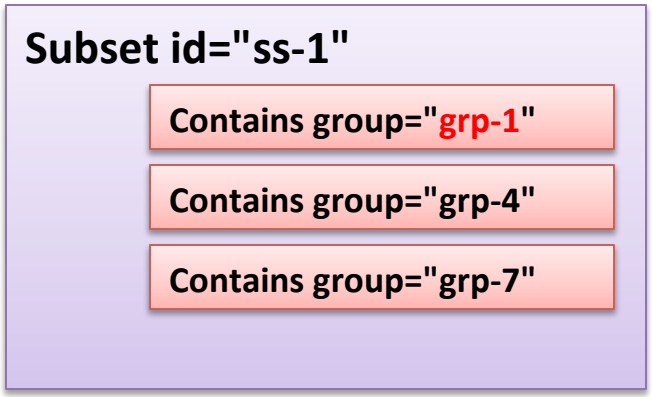
Ack & ©: Iraj Sodagar

DASH AdaptationSets & Subsets



AdaptationSet by codec, language, resolution, bandwidth, views, etc. – very flexible (in combination with xlink)!

- Ranges for the @bandwidth, @width, @height and @frameRate



Subsets

- Mechanism to restrict the combination of *active* Groups
- Expresses the intention of the creator of the Media Presentation

Segment Indexing

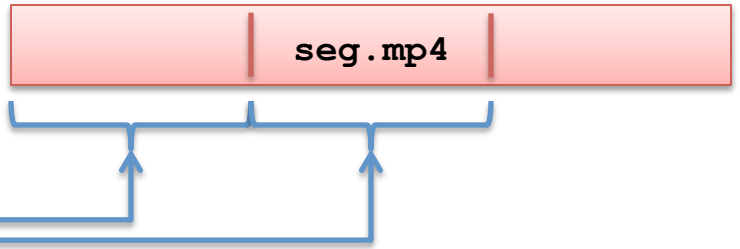
- Provides binary information in ISO box structure on
  - Accessible units of data in a media segment
  - Each unit is described by
    - Byte range in the segments (easy access through HTTP partial GET)
    - Accurate presentation duration (seamless switching)
    - Presence of representation access positions, e.g. IDR frames
- Provides a compact bitrate-over-time profile to client
  - Can be used for intelligent request scheduling
- Generic Data Structure usable for any media segment format, e.g. ISO BMFF, MPEG-2 TS, etc.
- Hierarchical structuring for efficient access
- May be combined with media segment or may be separate

Segment Indexing

Segment Index in MPD only

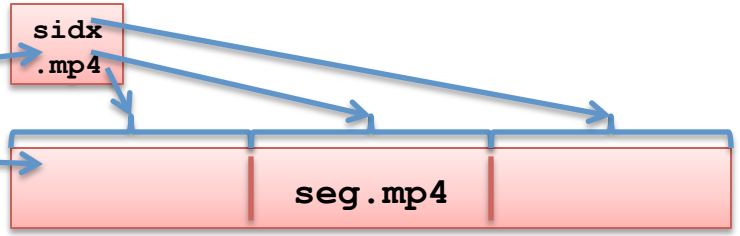
```
<MPD>
  ...
  <URL sourceURL="seg1.mp4"/>
  <URL sourceURL="seg2.mp4"/>
</MPD>
```


```
<MPD>
  ...
  <URL sourceURL="seg.mp4" range="0-499"/>
  <URL sourceURL="seg.mp4" range="500-999"/>
</MPD>
```



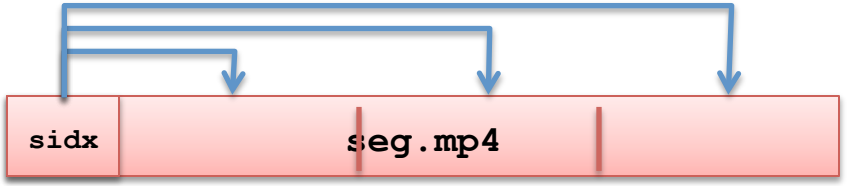
Segment Index in MPD + Segment

```
<MPD>
  ...
  <Index sourceURL="sidx.mp4"/>
  <URL sourceURL="seg.mp4"/>
</MPD>
```



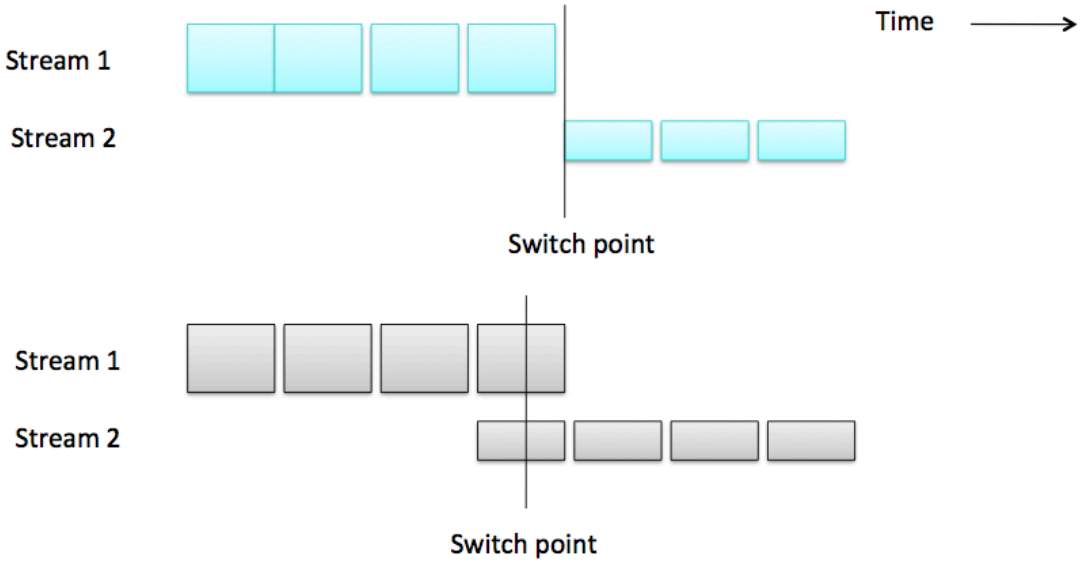
Segment Index in Segment only

```
<MPD>
  ...
  <BaseURL>seg.mp4</BaseURL>
</MPD>
```



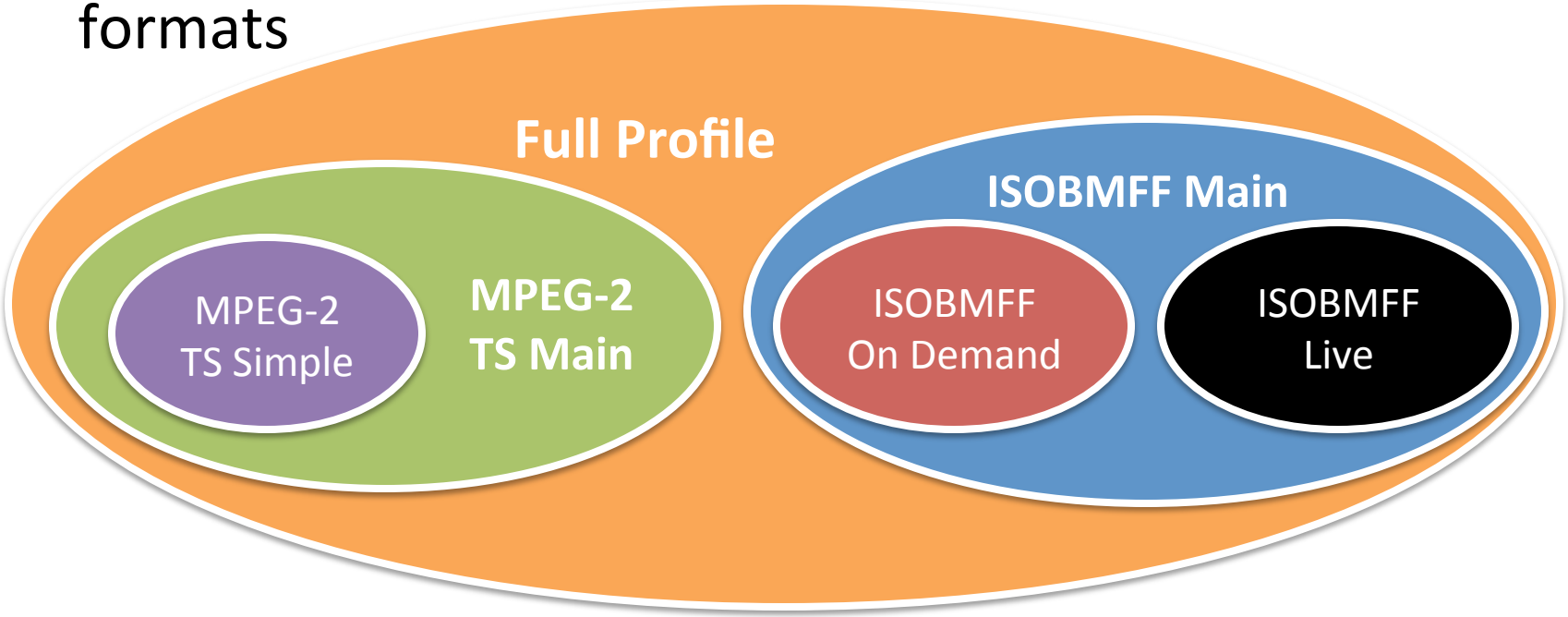
Switch Point Alignment

- Segment alignment
  - Permits non-overlapping decoding and presentation of segments from different representations
- Stream Access Points (SAPs)
  - Presentation time and position in segments at which random access and switching can occur
- Bitstream Switching
  - Concatenation of segments from different representations results in conforming bitstream
- Alignment and SAPs can also apply for subsegments
- Preferable switching points are segment/subsegment boundaries for which
  - Alignment holds across representations
  - The switch-to representation starts with a SAP



Profiles

- Subset (restrictions) of the functionality
- Target specific applications/domains
- As of now, mainly related to supported segment formats



- More restrictions may be added

Ack: Thomas Stockhammer

Adaptive Streaming Summary

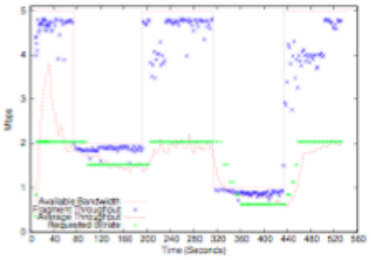
- For on demand
  - Chunks are unnecessary and costly
  - Byte range requests have caching and flexibility advantages
  - Separate audio/video essential for language support
- For live
  - Chunks are unavoidable
  - Still value in decoupling request size from chunk size
  - Multiple language audio tracks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

Segment duration	Advantages	Disadvantages
Short	• Commonality with Live • High switching granularity on segment level	• Large number of files • Large number of URLs • Fixed request size • switching granularity on segment level
Long	• Small number of files • Small number of URLs • High switching granularity • Flexible request sizes • Improved cache performance	• Need for Segment Index • Difference from Live

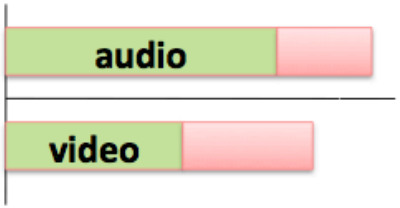
Adaptation Problem

Choose sequence and timing of requests to minimize probability of re-buffers and maximize quality

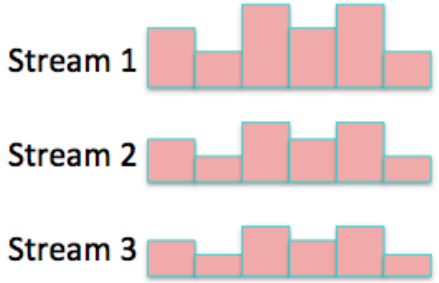
History



Current state



Possible choices



Model of future bandwidth

Expected performance for each choice

Ack & ©: Mark Watson

Potential Future Work Items

- MMSys'11 Keynote
  - HTTP Adaptive Streaming in Practice by Mark Watson (Netflix)
  - Future work
    - Good models for future bandwidth
    - Tractable representations of future choices - how to efficiently search the 'choice space'
    - What are the quality goals?
- Call for adaptation logics
  - Efficient implementations of the actual adaptation logic which is responsible for the dynamic and adaptive part of DASH

http://multimediacommunication.blogspot.com/2011/02/beta-version-of-vlc-dash-plugin.html

- Get it deployed and adopted (e.g. W3C, DVB – what is necessary?)
- Join this activity, everyone is invited – get involved in and exited about DASH!

DASH “Encoder”, Dataset, and Players

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ACM Multimedia 2012, Nara, Japan
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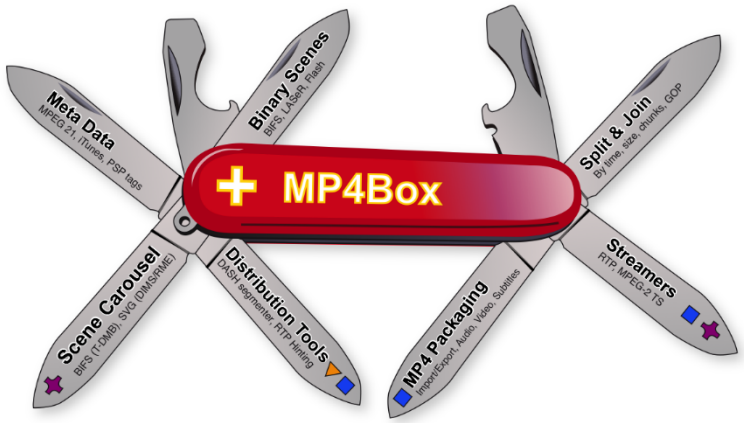
DASH@GPAC: MP4Box & MP42TS

- **Multimedia Packagers**
  - MPEG-2 TS for DASH profiles
  - ISOBMFF Packager & Analyser
- **DASH Segmenter**
  - ISOBMFF and M2TS segments
    - All DASH profiles supported
    - URL-template naming scheme
  - Segment indexing (*SIDX*)
  - GOP-align segments or fragments (*MediaSourceExtension*)
  - Automatic *AdaptationSet* selection
    - Media type, codec, language, PAR
    - Handle groups (same media but not switchable)
- **DASH live simulator**
  - Manages MPD update and timeline continuity



DASHEncoder

- DASH Content Generation Tool
  - Encoding + Multiplexing + MPD generation
  - Generates isoffmain profile compliant MPDs
  - Fully configurable using a config-file
  - Enables batch processing
  - Currently uses x264 and GPAC‘s MP4Box
  - Easy extensible to further encoders & multiplexers
  - http://dash.itec.aau.at/

DASHEncoder

Encode

- h.264: x264 / ffmpeg
- AAC: ffmpeg
- [WebM, etc.]

Container

- MP4Box: Video / Audio / Video + Audio
- [e.g. WebM/MKV Segmenter]

MPD

- Generate one MPD
- Subfolder Organization
- MPD Transformation

Dataset

- **Dataset with DASH Content**
  - Long sequences in high quality
  - Various segment-length versions
  - Free available for DASH experiments
  - PSNR values per frame

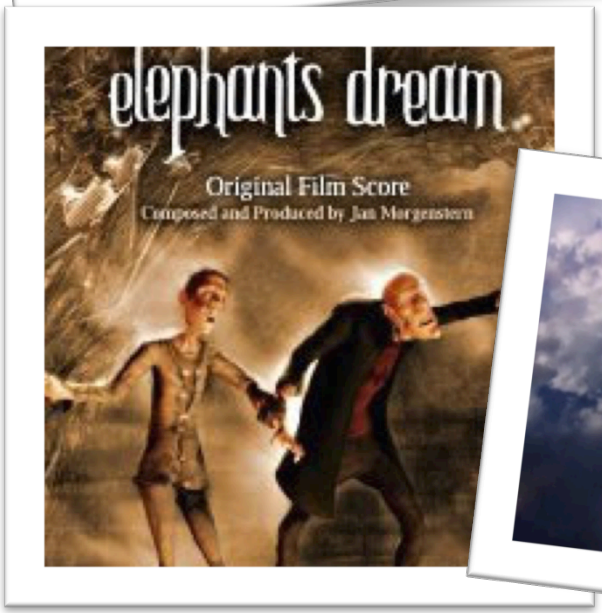
- **Problem: Content Rights**
  - CC-Attribution 2.0 Generic (**CC-BY 2.0**) License or similar
  - Free to Share, Free to Remix
  - **Note**: YouTube introduces CC-BY in June 2011!

- **Negotiation with content owner**

Dataset Sequences

Name	Source Quality	Length	Genre
Big Buck Bunny	1080p YUV	09:46	Animation
Elephants Dream	1080p YUV	10:54	Animation
Red Bull Playstreets	1080p, 6 Mbit H.264	01:37:28	Sport
The Swiss Account	1080p, 6 Mbit H.264	57:34	Sport
Valkaama	1080p, 6 Mbit H.264	01:33:05	Movie
Of Forest and Men	SD	10:53	Movie

DASH Dataset Sequences



Bitrates and Resolutions

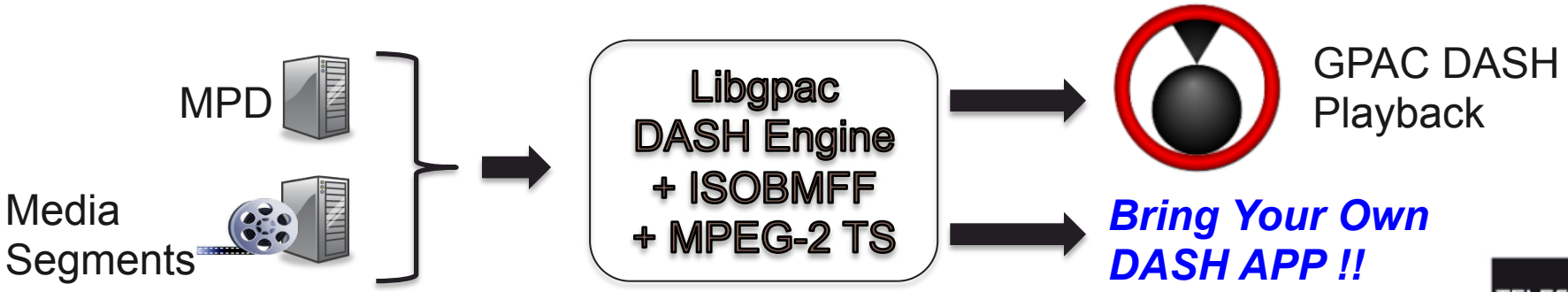
#	Animation	Sport	Movie
1	50 kbit/s, 320x240	100 kbit/s, 320x240	50 kbit/s, 320x240
2	100 kbit/s, 320x240	150 kbit/s, 320x240	100 kbit/s, 320x240
3	150 kbit/s, 320x240	200 kbit/s, 480x360	150 kbit/s, 320x240
4	200 kbit/s, 480x360	250 kbit/s, 480x360	200 kbit/s, 480x360
5	250 kbit/s, 480x360	300 kbit/s, 480x360	250 kbit/s, 480x360
6	300 kbit/s, 480x360	400 kbit/s, 480x360	300 kbit/s, 480x360
7	400 kbit/s, 480x360	500 kbit/s, 854x480	400 kbit/s, 480x360
8	500 kbit/s, 480x360	700 kbit/s, 854x480	500 kbit/s, 854x480
9	600 kbit/s, 854x480	900 kbit/s, 854x480	600 kbit/s, 854x480
10	700 kbit/s, 854x480	1,2 Mbit/s, 854x480	700 kbit/s, 854x480
11	900 kbit/s,1280x720	1,5 Mbit/s,1280x720	900 kbit/s,1280x720
12	1,2 Mbit/s,1280x720	2,0 Mbit/s,1280x720	1,2 Mbit/s,1280x720
13	1,5 Mbit/s,1280x720	2,5 Mbit/s,1280x720	1,5 Mbit/s,1280x720
14	2,0 Mbit/s,1280x720	3,0 Mbit/s,1920x1080	2,0 Mbit/s,1920x1080
15	2,5 Mbit/s,1920x1080	4,0 Mbit/s,1920x1080	2,5 Mbit/s,1920x1080
16	3,0 Mbit/s,1920x1080	5,0 Mbit/s,1920x1080	3,0 Mbit/s,1920x1080
17	4,0 Mbit/s,1920x1080	6,0 Mbit/s,1920x1080	4,0 Mbit/s,1920x1080
18	5,0 Mbit/s,1920x1080		5,0 Mbit/s,1920x1080
19	6,0 Mbit/s,1920x1080		6,0 Mbit/s,1920x1080
20	8,0 Mbit/s,1920x1080		

DASH Content Types

- **Segment Size**:
  - Seconds: 1, 2, 4, 6, 10, 15
- **File Organization**
  - Segmented
  - One file per representation, Byte Range Requests
- **e.g.: Big Buck Bunny**
  - **120 Encodings** needed
  - Only **6 DASH Encoder** runs

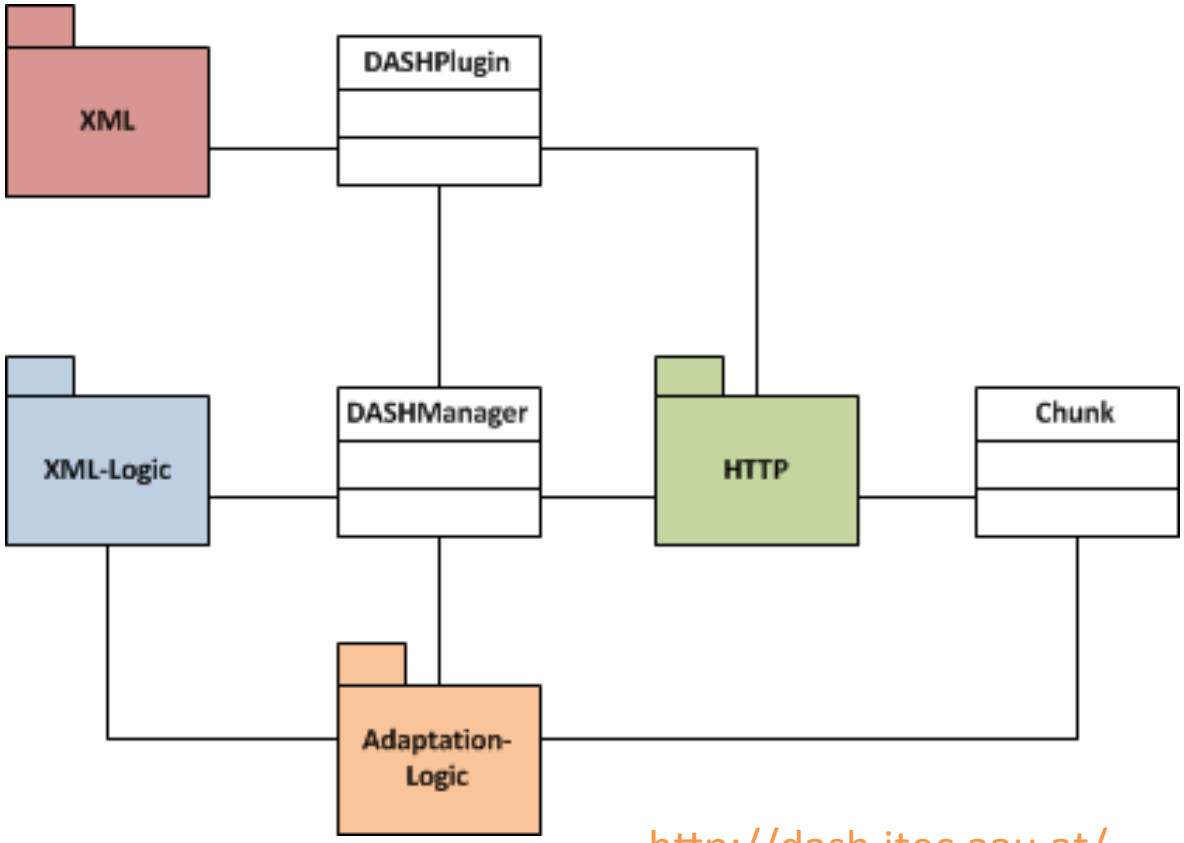
DASH@GPAC: Playback

- **DASHClient**
  - DASH ISOBMFF, M2TS (+ HLS)
    - With or without bitstreamSwitching
    - Support for multiple Periods
  - All profiles except *onDemand* (ongoing)
    - VoD through « live » or « main »
  - Local files and http(s) playback
  - Various download policies
- **Integrated in Osmo4**
  - Many input formats and codecs
  - Composition engine (SVG, BIFS, X3D)
- **Try it!**
  - Included in libgpac
  - Independent from player



DASH VLC Plugin Architecture

- Four major components and two controller classes
- Easy Adaptation Logic Interface for Researchers and Developers
- Flexible HTTP structure for further improvements e.g. persistent connections



http://dash.itec.aau.at/

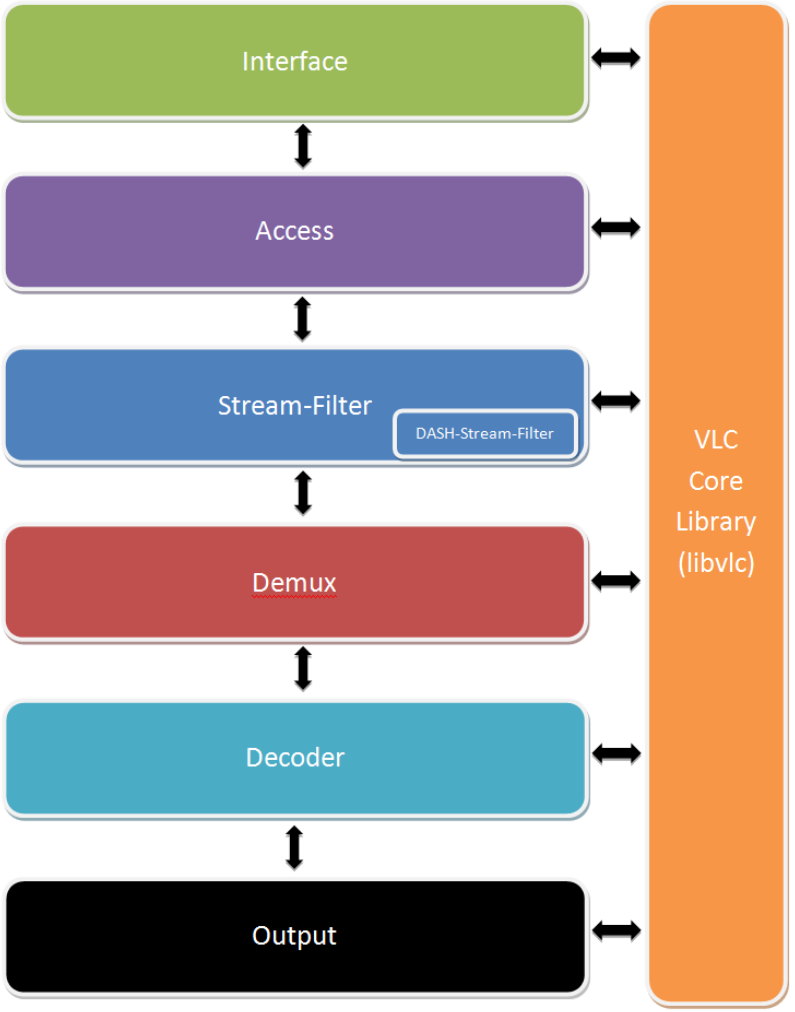
DASH VLC Plugin Features

- Officially part of VLC and as library (libdash)
- Provides a simple interface to integrate new Adaptation Logics
- Dynamic adaptation to the available bandwidth
- Flexible for further improvements, e.g., profiles, persistent connections and pipelining
- Source code is available through the VLC git repository and at:

http://www-itec.aau.at/dash

VLC Architecture

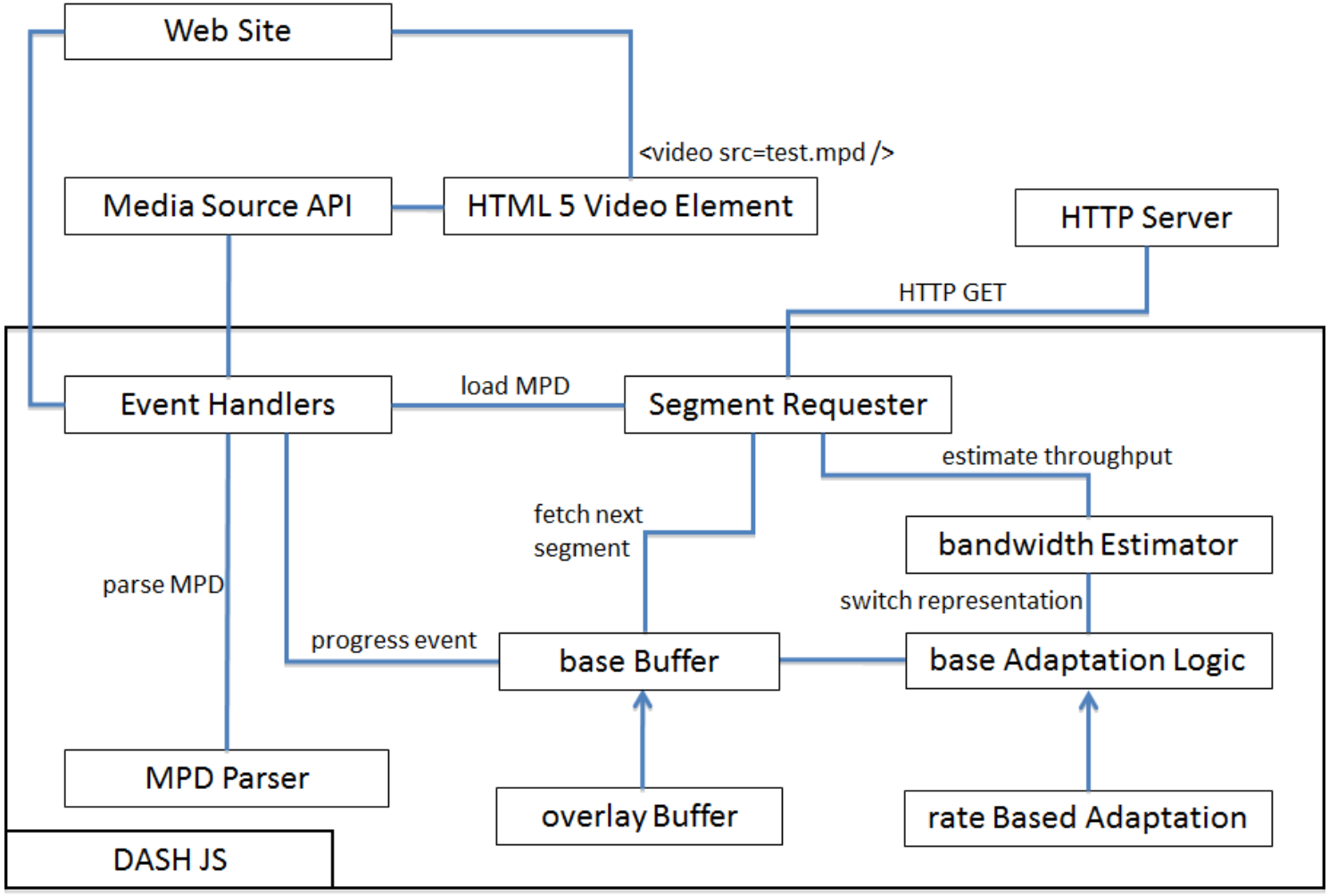
- Interface: User interaction e.g. stop, play etc.
- Access: HTTP, RTP etc.
- Stream-Filter: Recording, Dynamic Streaming
- Demux: MP4, M2TS, MKV
- Decoder: H264, VP8 etc.



DASH in JavaScript (DASH-JS)

- Completely implemented in JavaScript – no (3rd party) plugins required
- Makes use of the Media Source API provided by Google Chrome
  - Support for WebM and ISOBMFF
- Provides time based and byte based buffers
  - E.g., use as input for adaptation logics
- Flexible adaptation logics
  - Easy to extend existing ones or integrate your own

DASH-JS Architecture



DASH-JS (cont'd)

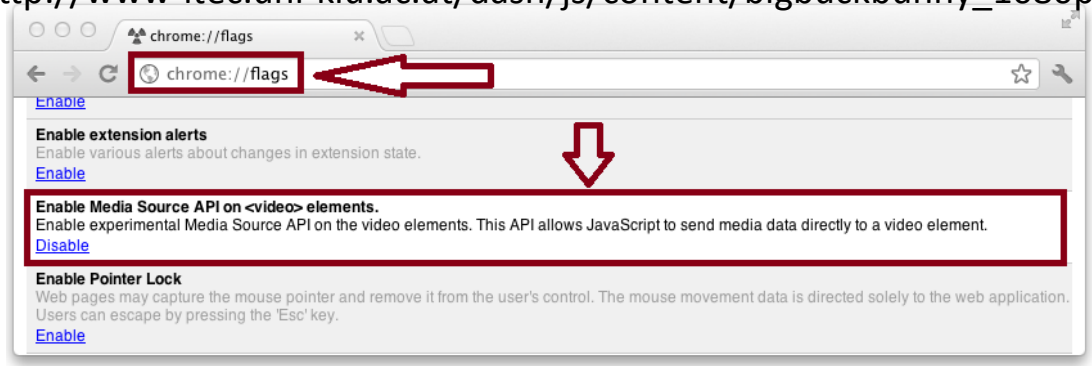
- Bandwidth / throughput estimation
  - … is done each time a segment is retrieved
  - At the beginning the MPD is used to have an educated guess on the bandwidth
  - To bypass proxy caching "no-cache" is set in the HTTP Request Header (will influence the throughput estimation)
- Representation selection is based on:

$$b_n = \frac{w_1 b_{n-1} + w_2 b_m}{w_1 + w_2}$$

  - b_{n-1} denotes the throughput calculated at the n-1th segment
  - b_m depicts the throughput measured with the nth segment
  - b_n is used to decide which representation should be selected
  - The weights (w_1 and w_2) are used to mimic optimistic or pessimistic behavior
- Simple adaptation logic, easy to extend, modify…

Showcases

- Sintel Trailer @ 480p
  - 5 representation from 200 kbps to 2000 kbps video bitrate
  - 128 kbps audio for all representations
  - Showcase: http://www-itec.uni-klu.ac.at/dash/js/dashtest.html
  - MPD: http://www-itec.uni-klu.ac.at/dash/js/content/sintel_multi_rep.mpd
- Big Buck Bunny @ 480p
  - 7 representations from 200 kbps to 4700 kbps video bitrate
  - 128 kbps audio for all representations
  - Showcase: http://www-itec.uni-klu.ac.at/dash/js/dashtest-bunny.html
  - MPD: http://www-itec.uni-klu.ac.at/dash/js/content/bigbuckbunny.mpd
- Big Buck Bunny @ 1080p
  - 7 representations from 1000 kbps to 8000 kbps
  - 128 kbps audio for all representations
  - Showcase: http://www-itec.uni-klu.ac.at/dash/js/dashtest-bunny1080p.html
  - MPD: http://www-itec.uni-klu.ac.at/dash/js/content/bigbuckbunny_1080p.mpd



Conclusions

- End-to-end DASH tools available
  - GPAC provides support for ISOBMFF, M2TS, and beyond
  - DASH VLC plugin and libdash (world first DASH player)
  - DASH-JS for easy Web integration (HTML5, Javascript)
- Flexible architecture, easy to extend, e.g.:
  - Add your own profile (!!!)
  - Add your own buffer model
  - Add your own bandwidth estimation, adaptation logic
- Open source: http://dash.itec.aau.at | http://gpac.sourceforge.net
  - Feel free to use it, please acknowledge/reference us

An Evaluation of Dynamic Adaptive Streaming over HTTP in Vehicular Environments

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ACM Multimedia 2012
29th October, 2012

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Methodology

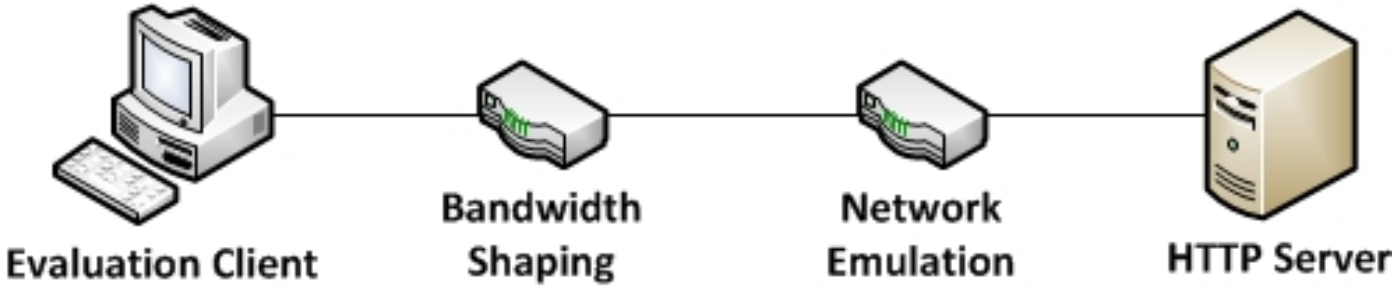
- **Experiment 1 / Track 1 (601 seconds)**
  - Drive on the freeway A2, passing by the city of Villach in the direction to Klagenfurt.
- **Experiment 2 / Track 2 (575 seconds)**
  - From the Alpen-Adria-Universität Klagenfurt on the freeway A2 until the service area around Techelsberg.
- **Experiment 3 / Track 3 (599 seconds)**
  - From the service area around Techelsberg on the freeway A2 to the exit of Klagenfurt.

Metrics

- Average bitrate
  - Overall performance for the entire session
- Number of quality switches
  - Different representation due available bandwidth
- Buffer level
  - Estimated with download timestamp (DTS) and presentation timestamp (PTS)
- Number of unsmooth seconds
  - Buffer empty

Experimental Setup

- Bandwidth Shaping
  - Ubuntu 11.04 w/ Linux hierarchical token bucket (htb)
  - Available bandwidth will be adjusted every 2s due to the recorded traces and 2s segment length
- Network Emulation
  - Emulates a round trip time of 150ms
- HTTP Server
  - Server based on Windows Server 2008 and IIS / Ubuntu 11.04 and Apache Web Server
- Evaluation Client
  - Windows or Linux depending on the evaluation system



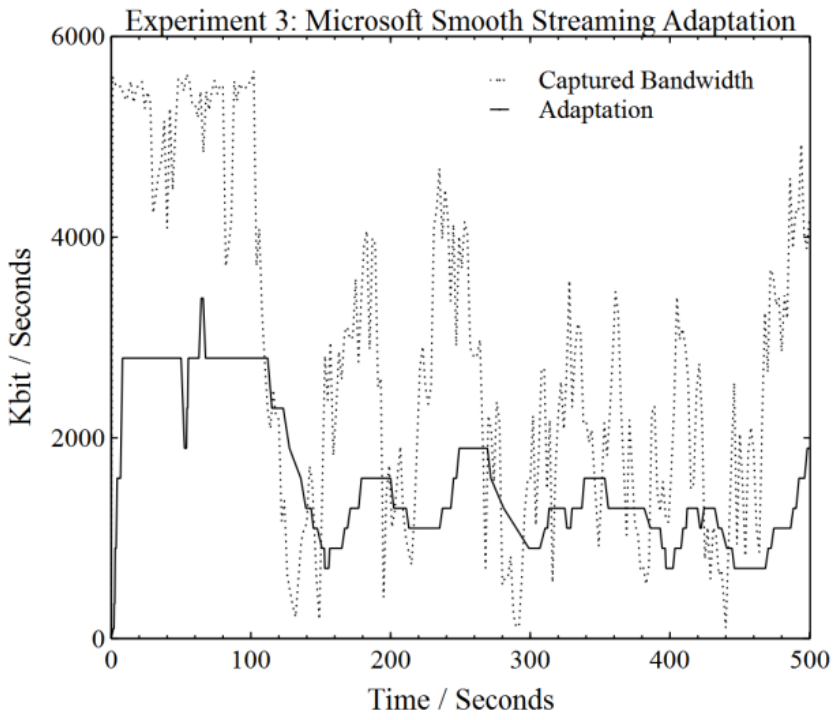
Dataset

- All experiments have been performed with the same content based on [Lederer2012]
- The content has been encoded with x264
- 14 different bitrates from 100kbps to 4500kbps
- Segments with a length of 2 seconds
  - Restricted by Microsoft Smooth Streaming
- That content has been used for all three scenarios

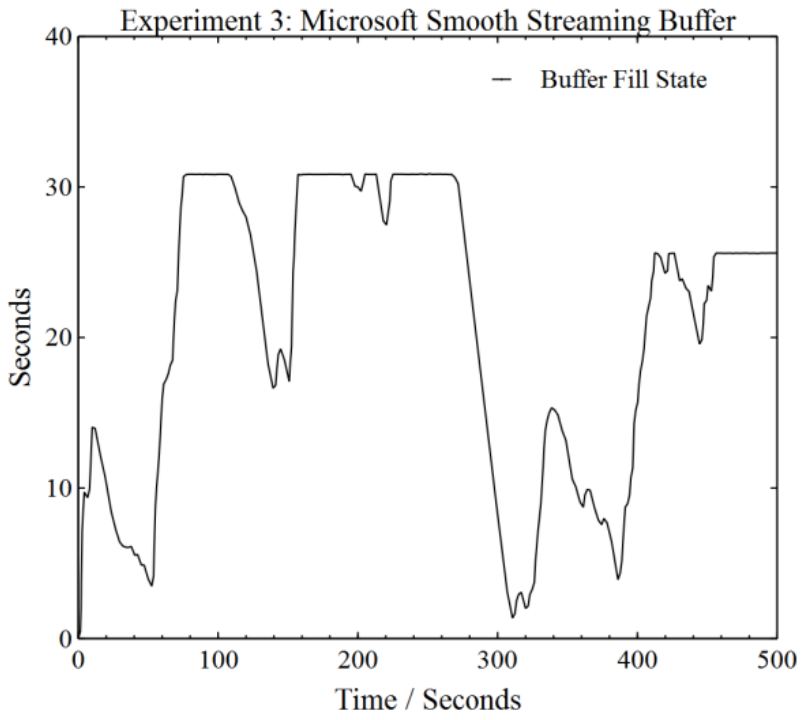
Microsoft Smooth Streaming

- Client based on Windows 7, Microsoft Silverlight and Firefox 7
- Server based on Windows Server 2008 and IIS with Media Services 4.0
- Content has been multiplexed with IIS Transform Manager 1.0 Beta
- PTS has been taken from the request URL
- DTS comes from the bandwidth emulation node

Microsoft Smooth Streaming (cont'd)



(a)



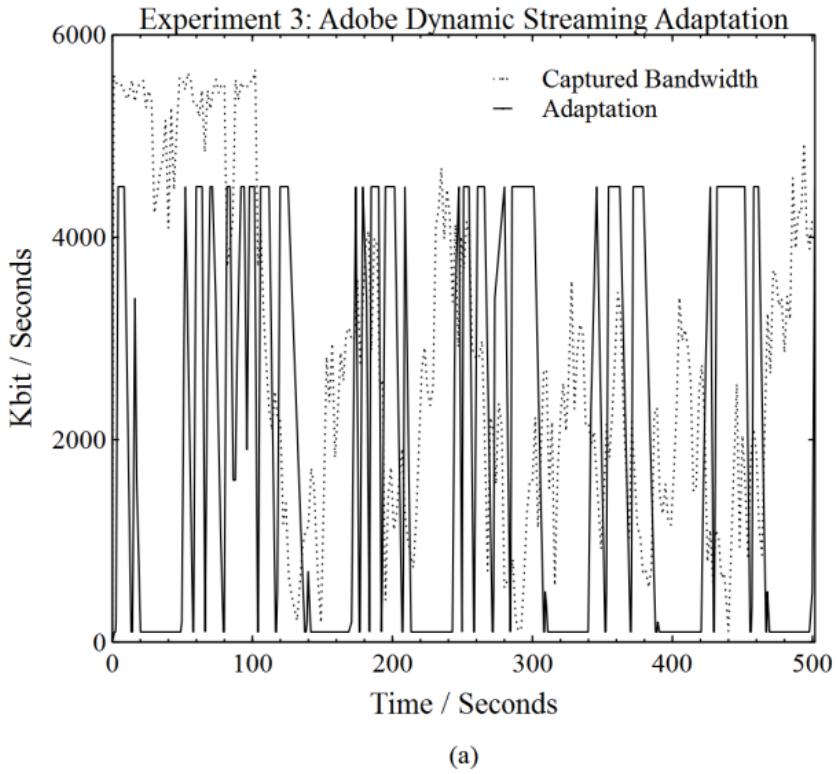
(b)

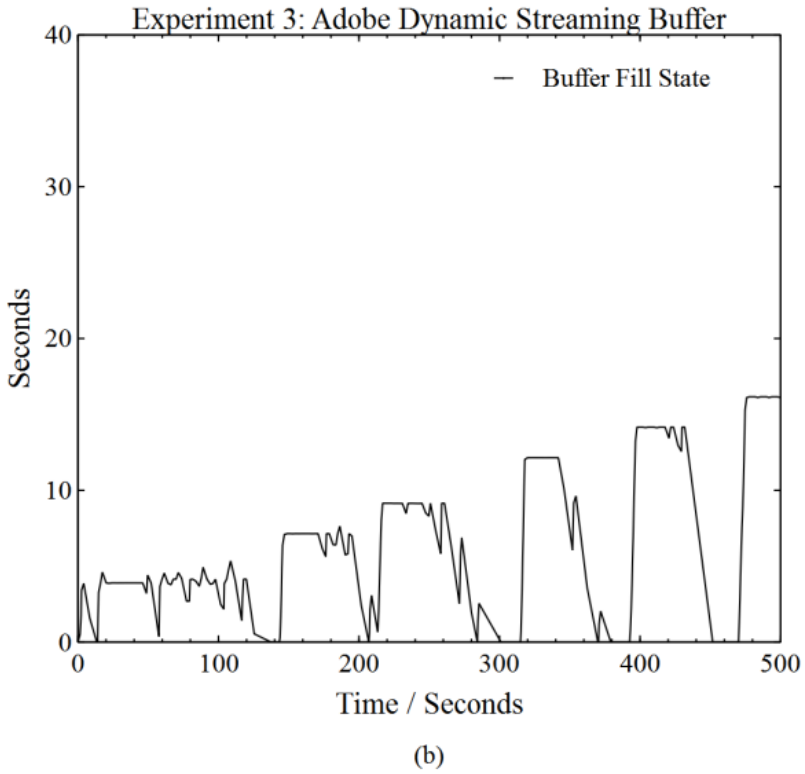
- Few switches with a good average bitrate
- Nevertheless close to unsmoothness at second 300

Adobe Dynamic HTTP Streaming

- Client is based on Ubuntu 11.04, Firefox 7 and the Open Source Media Framework player
- The server component hosts the Flash Media Server in development edition
- The content has been generated with the Adobe File Packager for Adobe Dynamic Streaming

Adobe Dynamic HTTP Streaming (cont'd)



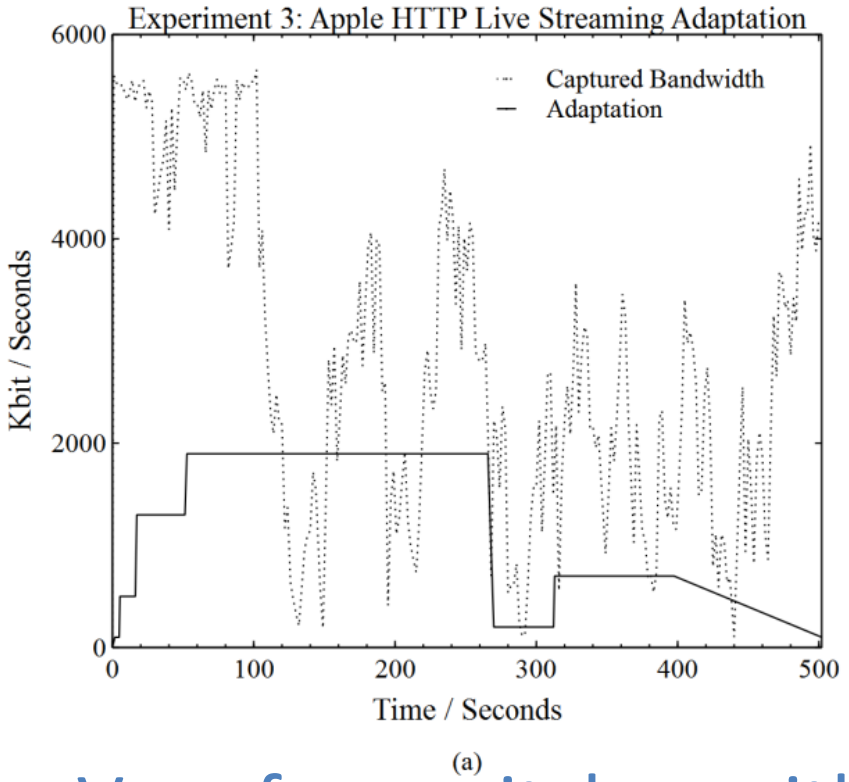


- High number of unsmooth seconds
- Rather binary and unpredictable

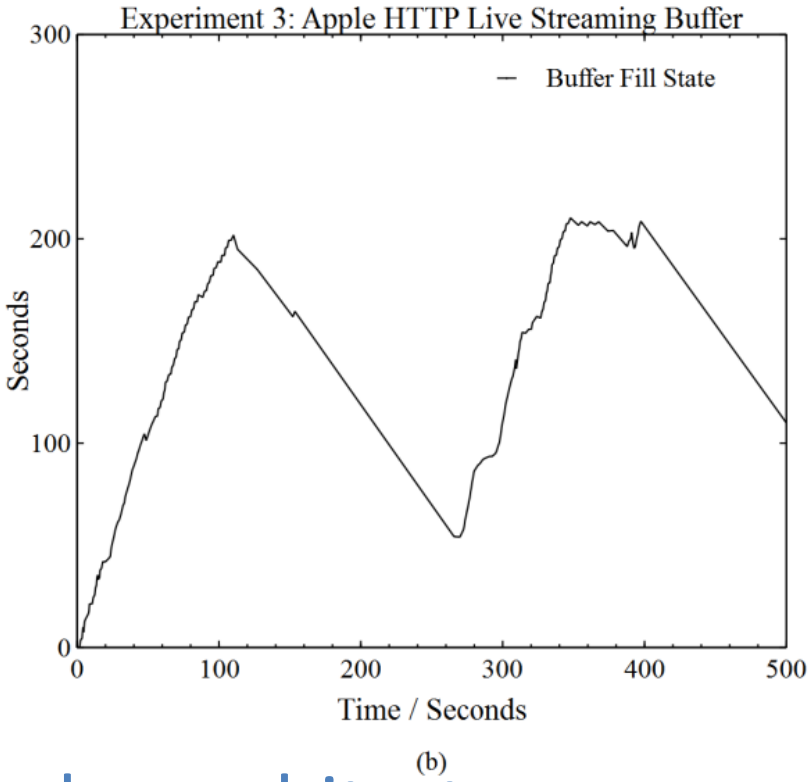
Apple HTTP Live Streaming

- Client is based on Mac OS X Snow Leopard 10.6 and Safari 5
- Content has been generated with Microsoft Transform Manager
  - Transmultiplexing of mp4 to MPEG-2 TS
  - Chops the transport stream into segments of 2 seconds length
- The only system that uses MPEG-2 TS

Apple HTTP Live Streaming (cont'd)



(a)



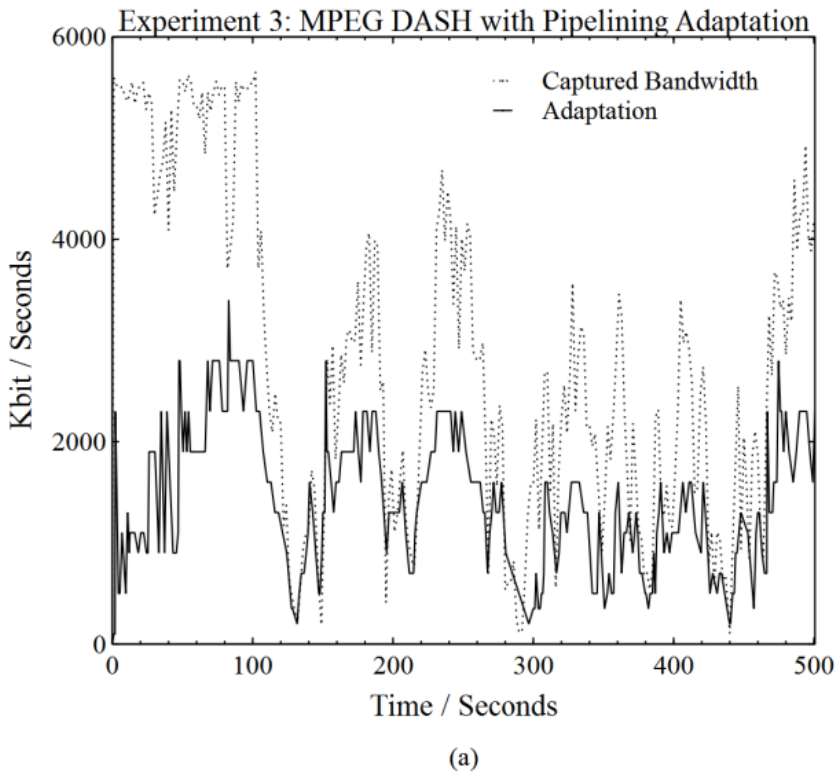
(b)

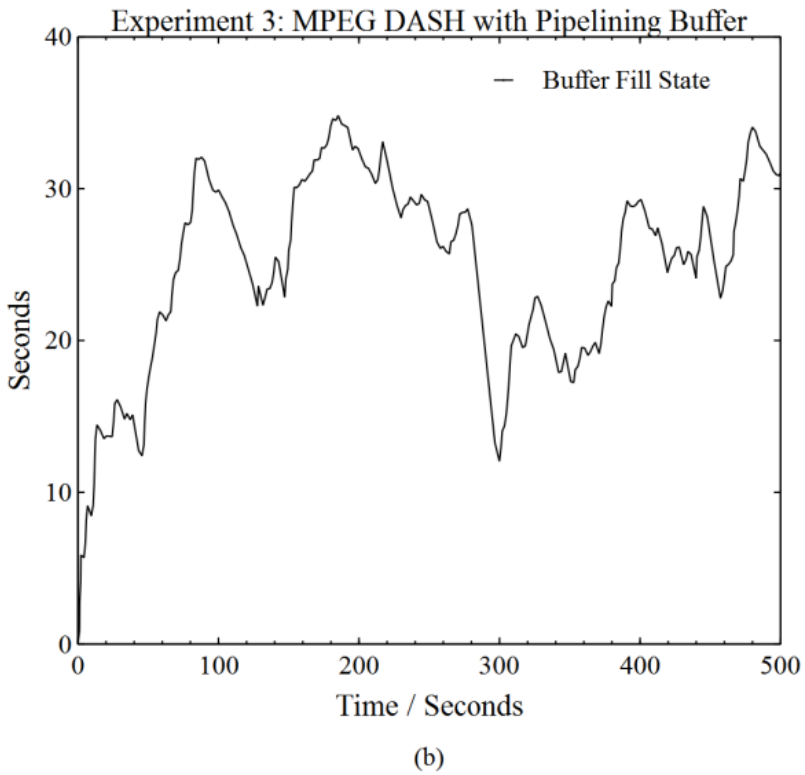
- Very few switches with a lower bitrate
- Large buffer for energy awareness

Our MPEG-DASH Implementation

- Client: DASH VLC Plugin [Mueller2011] on Ubuntu 11.04
- Server: Ubuntu 11.04 which hosts an Apache Web server
- Content based on DASH dataset generated with DASHEncoder
- Simple (naïve) adaptation logic

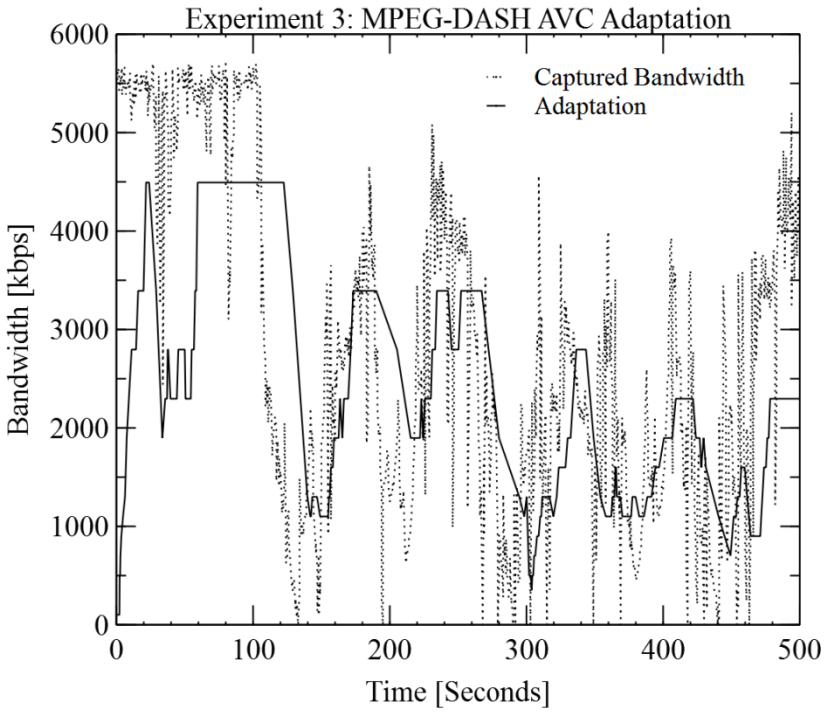
Our MPEG-DASH Implementation (cont'd)



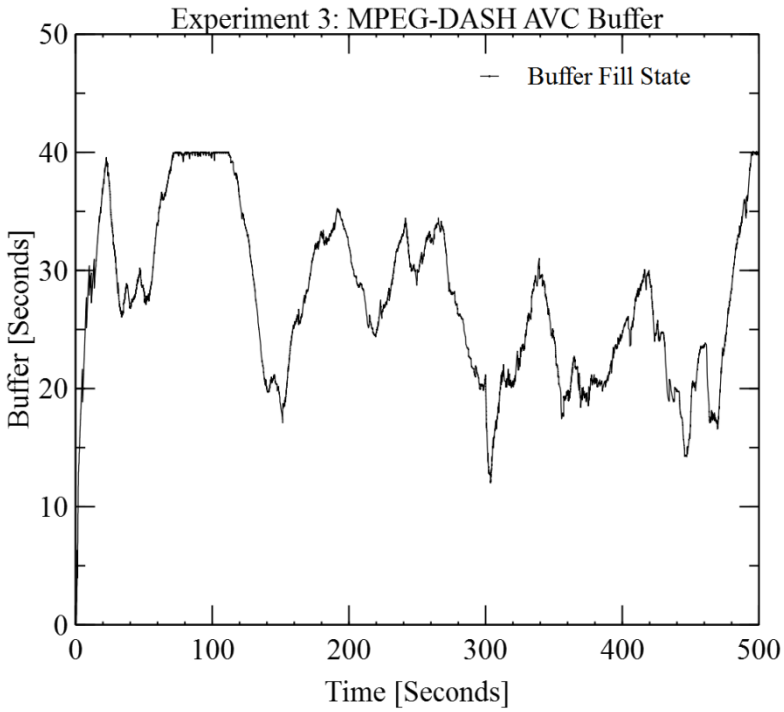


- Non stepwise switching
- Good average bitrate and stable buffer

MPEG-DASH AVC

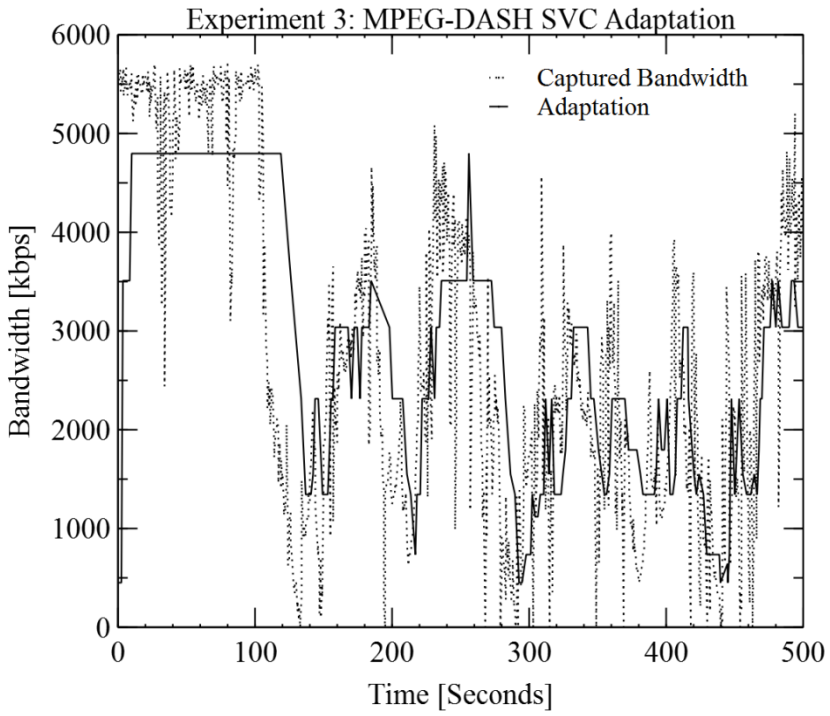


(a)

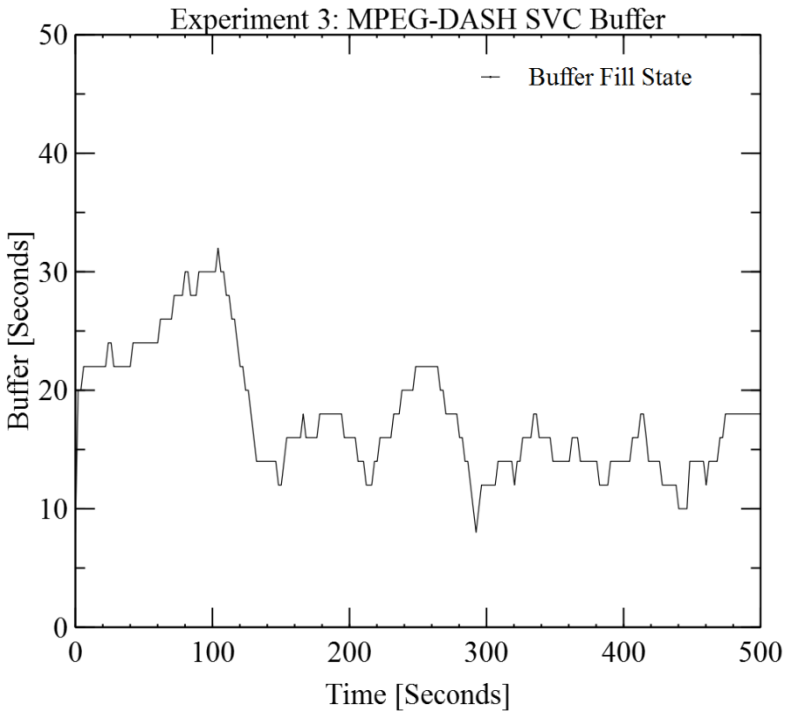


(b)

MPEG-DASH SVC



(a)



(b)

Summary

Name	Average Bitrate [kbps]	Average Switches [Number of Switches]	Average Unsmoothness [Seconds]
Microsoft	1522	51	0
Adobe	1239	97	64
Apple	1162	7	0
MPEG-DASH Naïve*	1045	141	0
MPEG-DASH Pipelined*	1464	166	0
MPEG-DASH AVC**	2341	81	0
MPEG-DASH SVC**	2738	101	0

* … MoVid/MMSys, February 2012

** … EUSIPCO, August 2012

Conclusions

- Microsoft Smooth Streaming
  - Performs very well w.r.t. average bitrate
  - Yes, deserves the name smooth streaming
- Apple HLS
  - Less quality switches due to large buffer
  - Designed for mobile devices, energy awareness
- Adobe HDS
  - Binary decision between the highest and the lowest representation
  - Stalls, re-buffering => low QoE
- Our MPEG-DASH implementation
  - Achieves a good/superior average bitrate
  - In striking distance to the top, space for improvements though (e.g., buffer management)
- Disclaimer: comparison of specific client implementations, not formats (manifest/segment), not technology

DASH @ AAU/ITEC

http://dash.itec.aau.at/

DASH VLC Plugin

DASHEncoder

libdash

Dataset

DASH-JS

Join this activity, everyone is invited – get involved in and exited about DASH!

Acknowledgments

- EC projects for partially funding this activity
  - ALICANTE project (FP7-ICT-248652)
    - http://www.ict-alicante.eu
  - SocialSensor project (FP7-ICT-287975)
    - http://www.socialsensor.org
  - COST ICT Action IC1003
    - QUALINET – European Network on Quality of Experience in Multimedia Systems and Services
    - http://www.qualinet.eu/
- DASH Industry Forum
  - http://www.dashif.com
- Christopher Müller: VLC Plugin, libdash
- Stefan Lederer: DASHEncoder, dataset, DASH-JS
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IEEE JSAC: Adaptive Media Streaming

- Guest Editors
  - Christian Timmerer, Alpen-Adria-Universität Klagenfurt, Austria
  - Ali C. Begen, CISCO, Canada
  - Thomas Stockhammer, QUALCOMM, USA
  - Carsten Griwodz, Simula Research Laboratory, Norway
  - Bernd Girod, Stanford University, USA
- Important Dates
  - 1st Submission: Apr 1, 2013
  - Reviews Available: Jul 1, 2013
  - 2nd Submission: Aug 31, 2013
  - Final Acceptance Decision: Oct 31, 2013
  - Camera-ready: Dec 1, 2013
  - Publication: 2nd quarter 2014

http://multimediacommunication.blogspot.com/2012/07/jsac-special-issue-adaptive-media.html

Special Issue on Adaptive Media Streaming

IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS

Guest Editors

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Recently, traditional TV services, Internet TV and mobile streaming services have started converging, and it is expected that this convergence trend will continue with other services. Additionally, new emerging multimedia services are being introduced. These developments in the multimedia arena mean that various content and services will be delivered over different networks, and the users expect to consume these services using those networks, depending on the availability and reach of the network at the time of consumption. This massive heterogeneity in terms of terminal/network capabilities and user expectations requires efficient solutions for the transport of modern media in an interoperable and universal fashion. In particular, in recent years, the Internet has become an important channel for the delivery of multimedia. The Hypertext Transfer Protocol (HTTP) is widely used on the Internet and it has also become a primary protocol for the delivery of multimedia content.

Additionally, standards developing organizations (SDOs) such as MPEG have developed various technologies for multimedia transport and encapsulation, e.g., MPEG2-TS (Transport Stream) and MPEG4 file format. These technologies have been widely adopted and are heavily deployed by various providers and in different applications and services, such as digital broadcasting, audio and video transport over the Internet and streaming to mobile phones, etc. At the same time, many other SDOs such as the IETF, IEEE, and 3GPP have provided various protocols to deliver multimedia content packetized or packaged by such MPEG transport technologies.

This special issue solicits novel contributions and breaking results on all aspects of Adaptive Streaming of Multimedia.

The main objectives of this special issue are (but not limited to):

- *Efficient delivery of multimedia content in an adaptive, progressive download/streaming fashion (incl. over HTTP);*
- *Support for streaming of live multimedia, to mobile users, low-capacity channels, bandwidth variations, as well as multipoint streaming over heterogeneous channels or paths;*
- *Efficient and ease of use of existing content distribution infrastructure components such as CDNs, proxies, caches, NATs and firewalls;*
- *Efficient content generation (encoding) techniques for content delivery (e.g., segmentation);*
- *Detailed performance analyses of deployed standard technologies or that uncover and rectify major problems in the behavior of such technologies;*
- *Measurement techniques for collecting consumption data (both application and transport-level performance metrics, viewer behavior, etc.) in content delivery;*
- *The effects of adaptation techniques on the end-user quality of experience;*
- *Viewer experiences from large-scale experiments and events (such as Olympics, World Cup, etc.).*

Submission Procedure

Prospective authors should prepare their submissions in accordance with the rules specified in the 'Information for Authors' section of the JSAC guidelines (http://www.jsac.ucsd.edu/Guidelines/info.html). Papers should be submitted through EDAS (http://www.edas.info). Prior to submitting their papers for review, authors should make sure that they understand and agree to adhere to the over-length page charge policy presented in the JSAC guidelines.

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Thank you for your attention

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