Department of Computer Science
National Tsing Hua University

CS 5263: Wireless Multimedia Networking Technologies and Applications

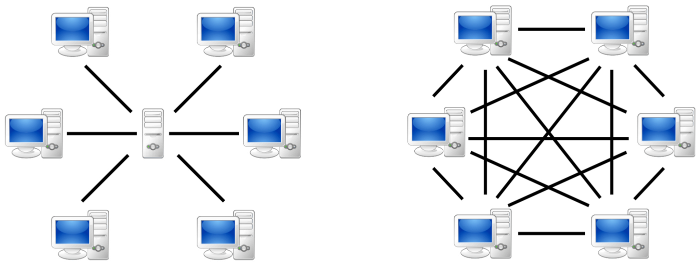
DASH Streaming and WebRTC

Instructor: Cheng-Hsin Hsu

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

Different Ways to Deliver Multimedia Contents

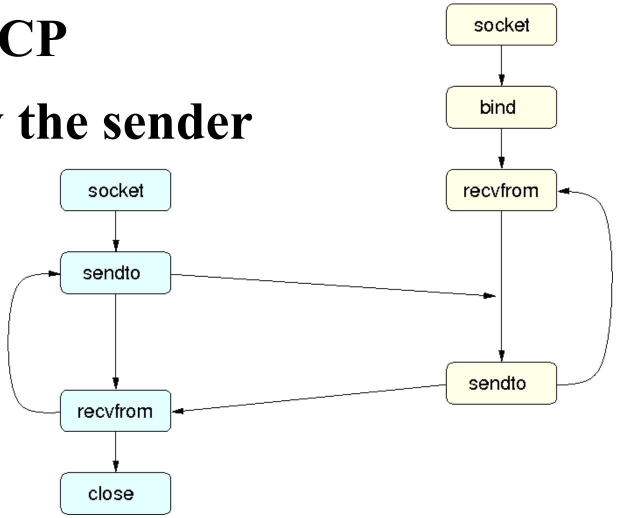
- **By network topologies**
  - Client/server
  - Peer-to-Peer (P2P)



Server-based

P2P-network

- **By transport protocols**
  - Reliable TCP ← rate is controlled by TCP
  - Unreliable UDP ← rate is controlled by the sender
- **By the location of adaptation logics**
  - Push-based → RTP streaming
  - Pull-based → DASH streaming



socket

bind

recvfrom

sendto

socket

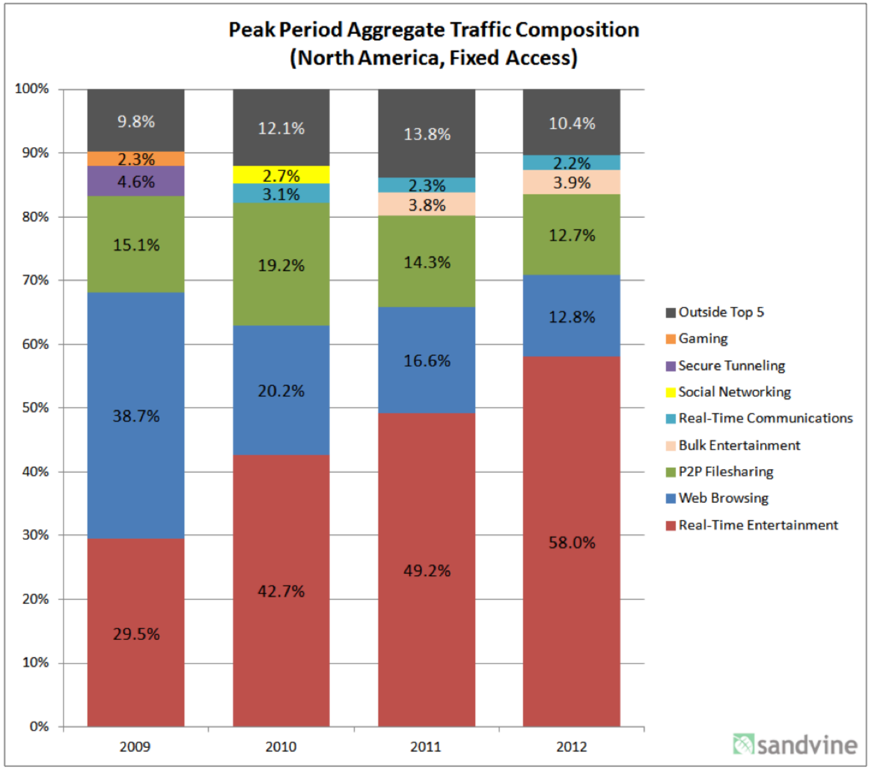
sendto

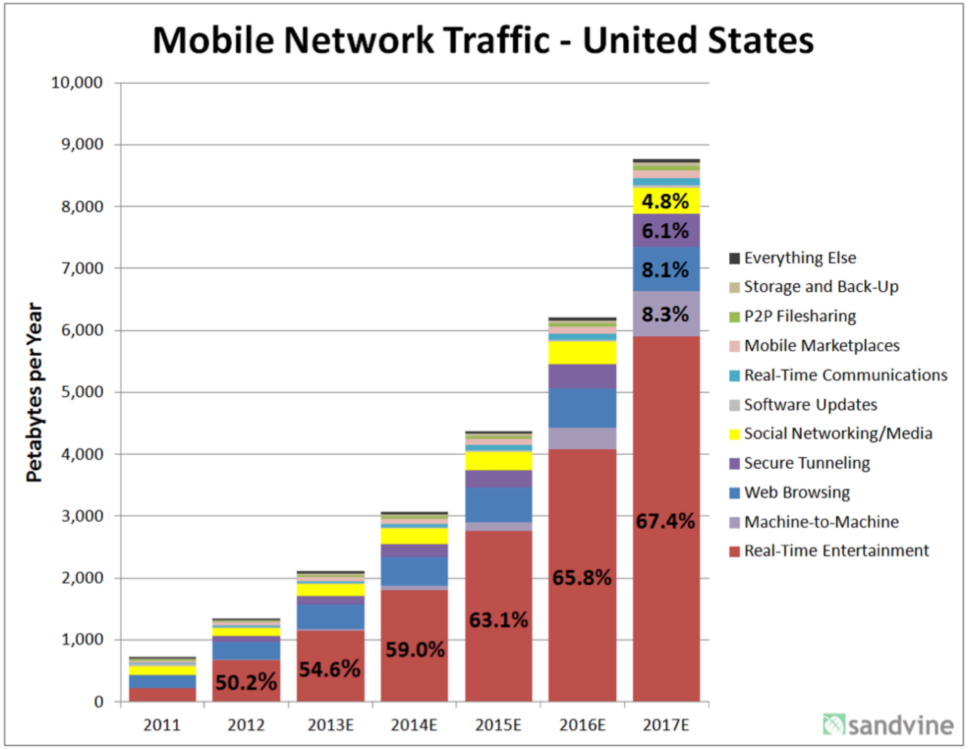
recvfrom

close

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)**

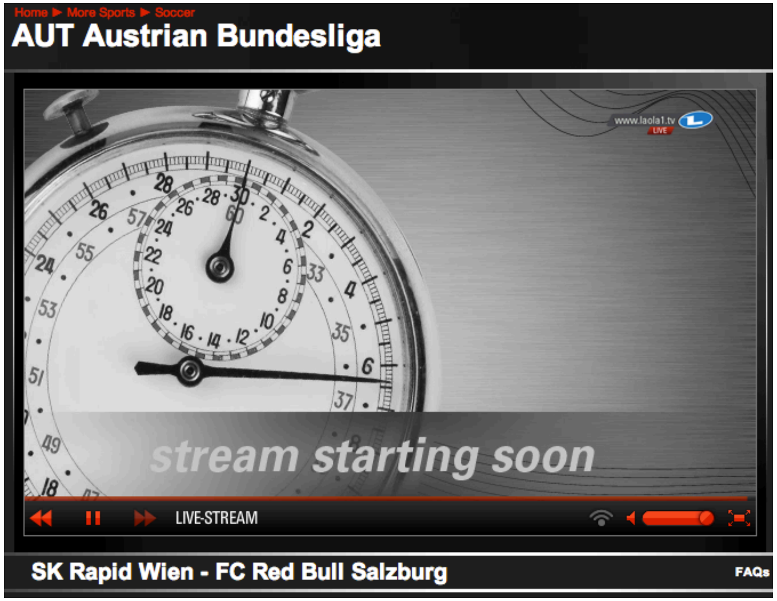




http://www.sandvine.com/downloads/documents/Phenomena_1H_2012/Sandvine_Global_Internet_Phenomena_Report_1H_2012.pdf

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

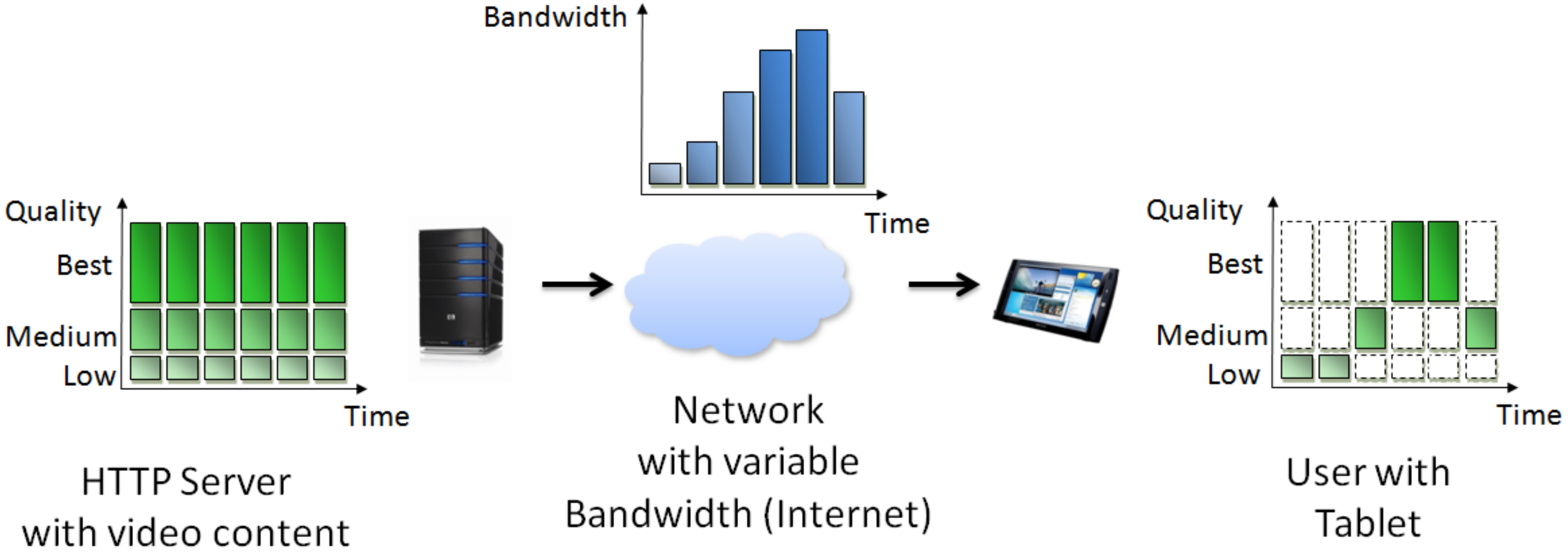

Home ▶ More Sports ▶ Soccer
AUT Austrian Bundesliga
www.laola1.tv
LIVE
LIVE-STREAM
SK Rapid Wien - FC Red Bull Salzburg
FAQs

stream starting soon

Dynamic Adaptive Streaming over HTTP

- Cut video into segments (each lasts for a few seconds)
  - Every segment is encoded in multiple quality (general sense) levels
- Receiver requests the quality level of each segment based on the network conditions and queue status
  - Scalable, as servers are stateless
- Video segments are sent over the HTTP connections
- Widely used nowadays for 3 main reasons
  - Enable NAT/Firewall traversals
  - Capitalize existing HTTP cache/CDNs
  - TCP streaming is no longer an issue because of broadband networks ← even if we can only use ½ of the capacity, we are fine

DASH in a Nutshell



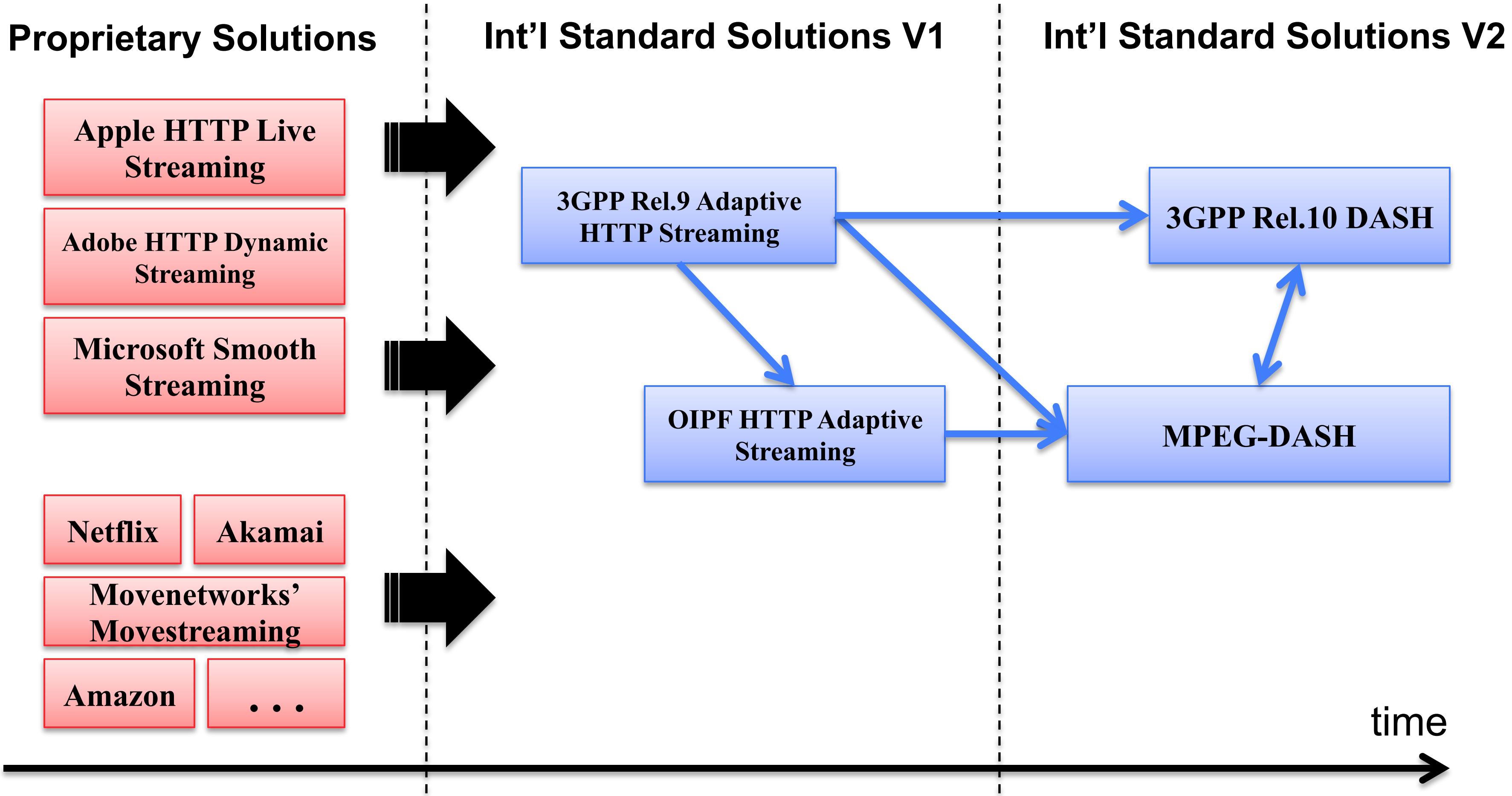
HTTP Server
with video content

Network
with variable
Bandwidth (Internet)

User with
Tablet

Ack & ©: Christopher Müller

History of DASH

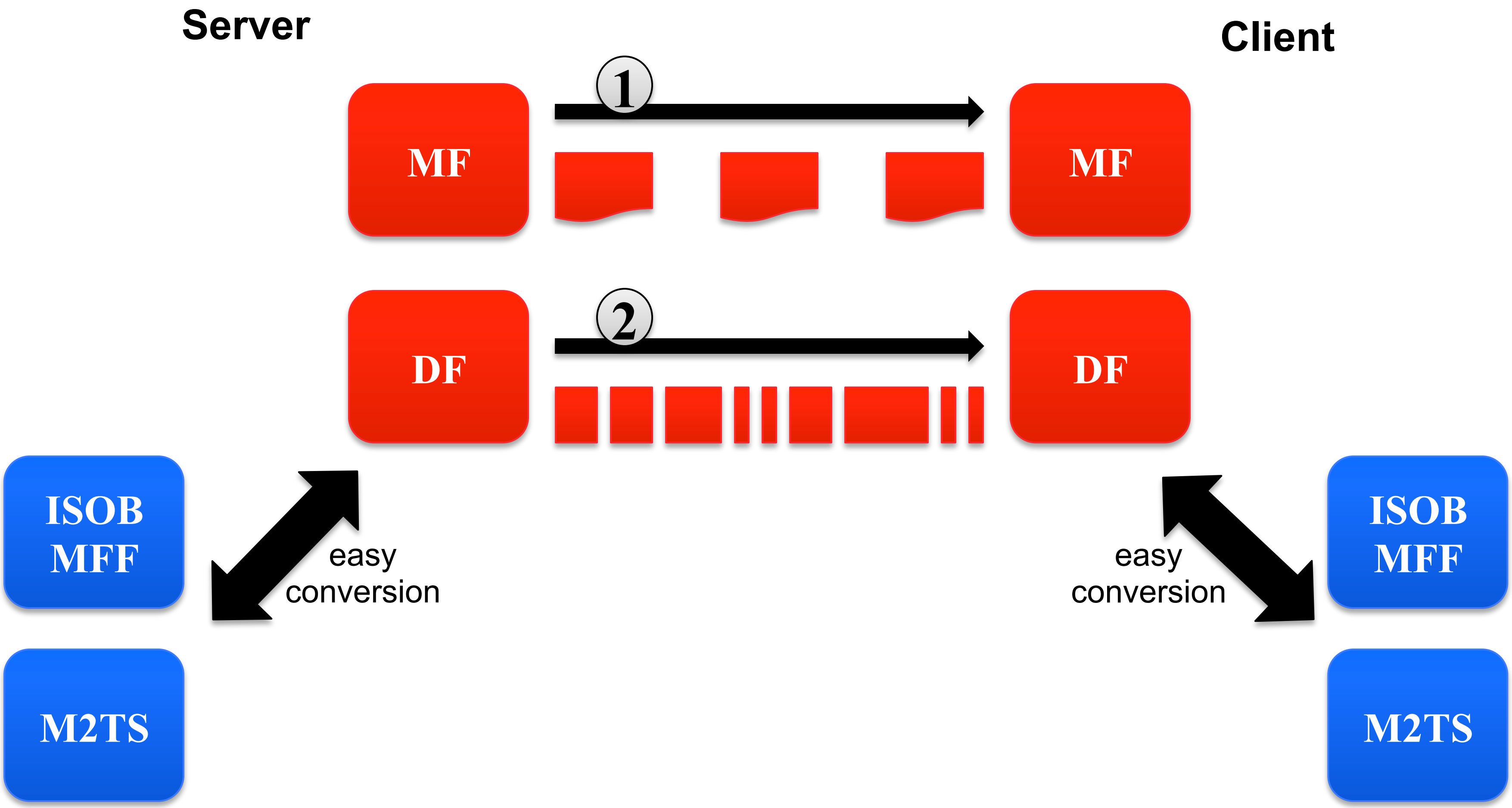

Proprietary Solutions
Int'l Standard Solutions V1
Int'l Standard Solutions V2
Apple HTTP Live Streaming
Adobe HTTP Dynamic Streaming
Microsoft Smooth Streaming
Netflix
Akamai
Movenetworks' Movestreaming
Amazon
. . .
3GPP Rel.9 Adaptive HTTP Streaming
OIPF HTTP Adaptive Streaming
3GPP Rel.10 DASH
MPEG-DASH
time

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

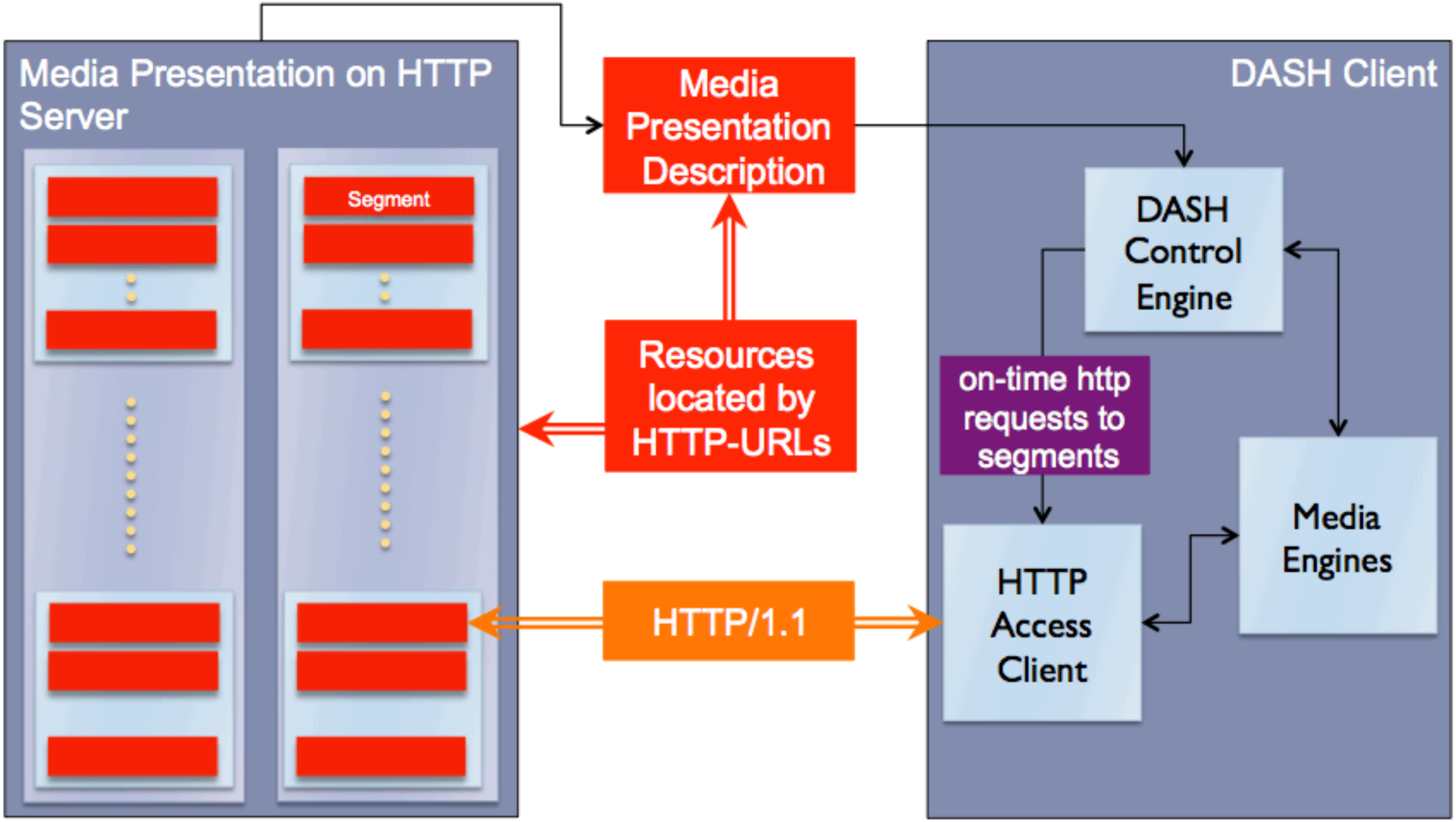
DASH Design Principles

- 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 (standardization bodies, forums, companies,…)
- 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)

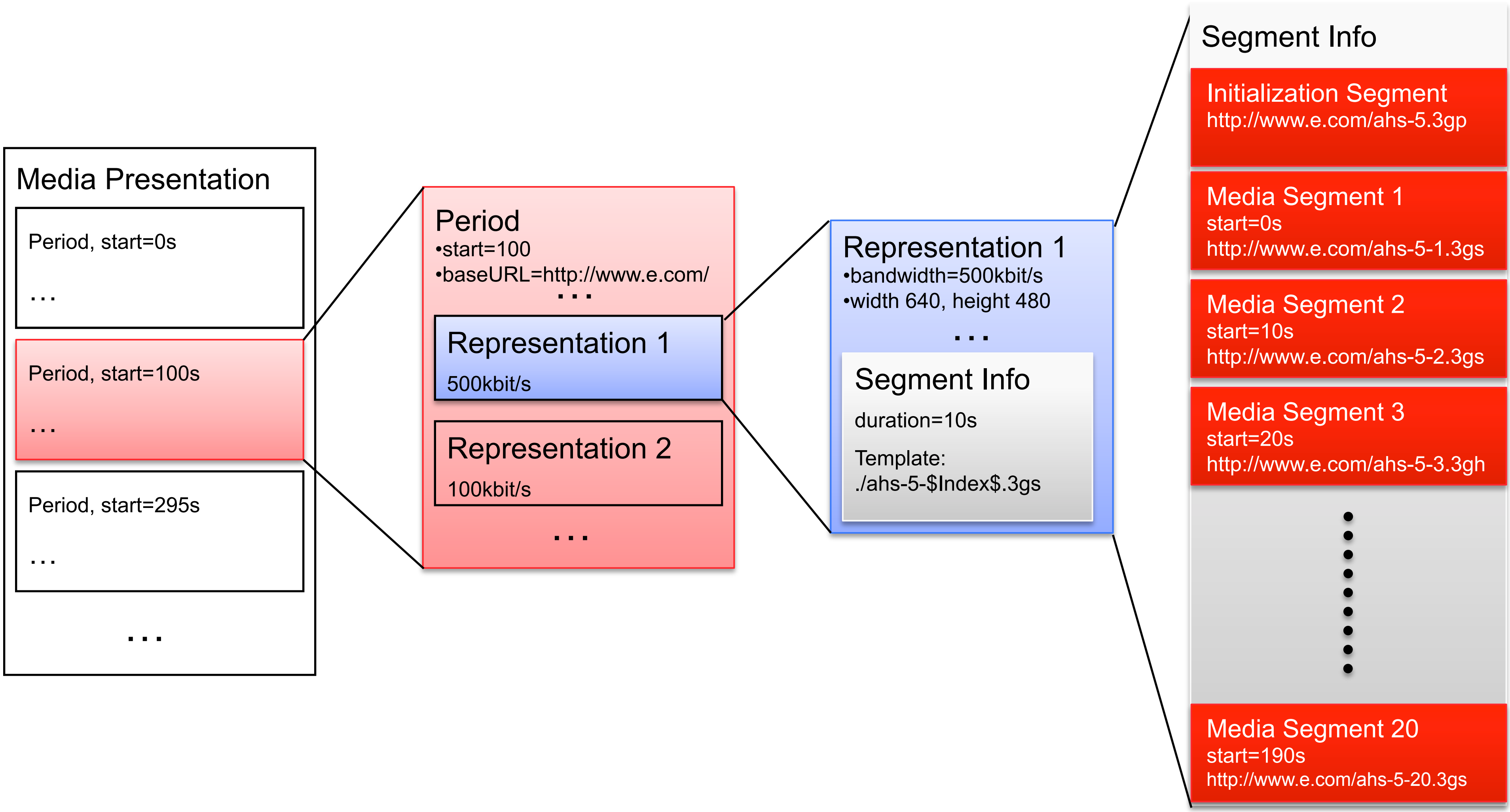
Manifest and Data Files



What is Specified – And What is Not?


Media Presentation on HTTP Server
Segment
Media Presentation Description
Resources located by HTTP-URLs
HTTP/1.1
DASH Client
DASH Control Engine
on-time http requests to segments
HTTP Access Client
Media Engines

DASH Data Model



Media Presentation

Period, start=0s

…

Period, start=100s

…

Period, start=295s

…

…

Period

•start=100

•baseURL=http://www.e.com/

…

Representation 1

500kbit/s

Representation 2

100kbit/s

…

Representation 1

•bandwidth=500kbit/s

•width 640, height 480

…

Segment Info

duration=10s

Template:
./ahs-5-$Index$.3gs

Segment Info

Initialization Segment
http://www.e.com/ahs-5.3gp

Media Segment 1
start=0s
http://www.e.com/ahs-5-1.3gs

Media Segment 2
start=10s
http://www.e.com/ahs-5-2.3gs

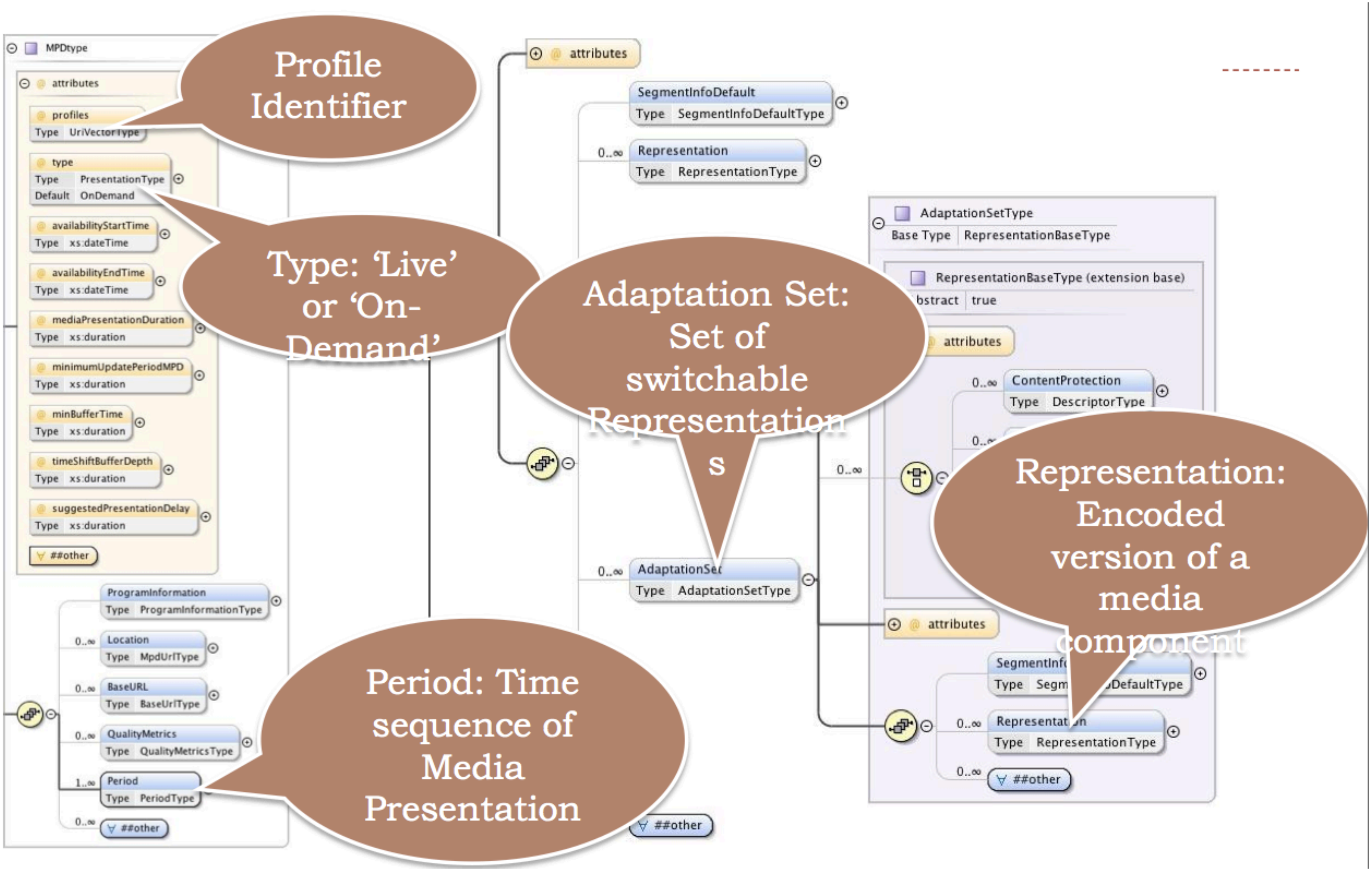
Media Segment 3
start=20s
http://www.e.com/ahs-5-3.3gh

Media Segment 20
start=190s
http://www.e.com/ahs-5-20.3gs

Media Presentation Description

- Meta 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
- Some other information

MPD Schema Overview



Profile Identifier

Type: 'Live' or 'On-Demand'

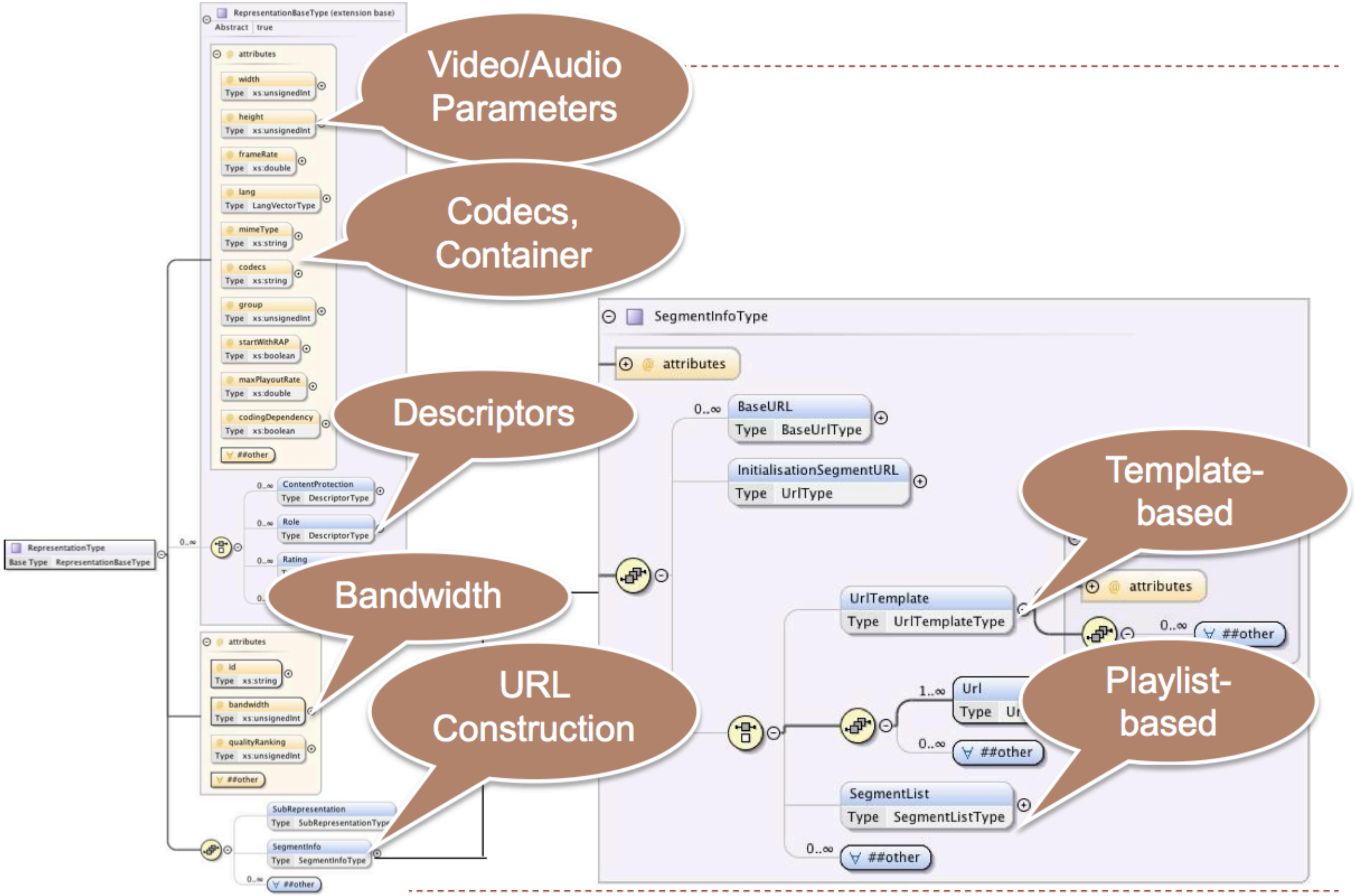
Adaptation Set: Set of switchable Representations

Representation: Encoded version of a media component

Period: Time sequence of Media Presentation

Ack & ©: Iraj Sodagar

MPD Schema - Representation



Video/Audio Parameters

Codecs, Container

Descriptors

Bandwidth

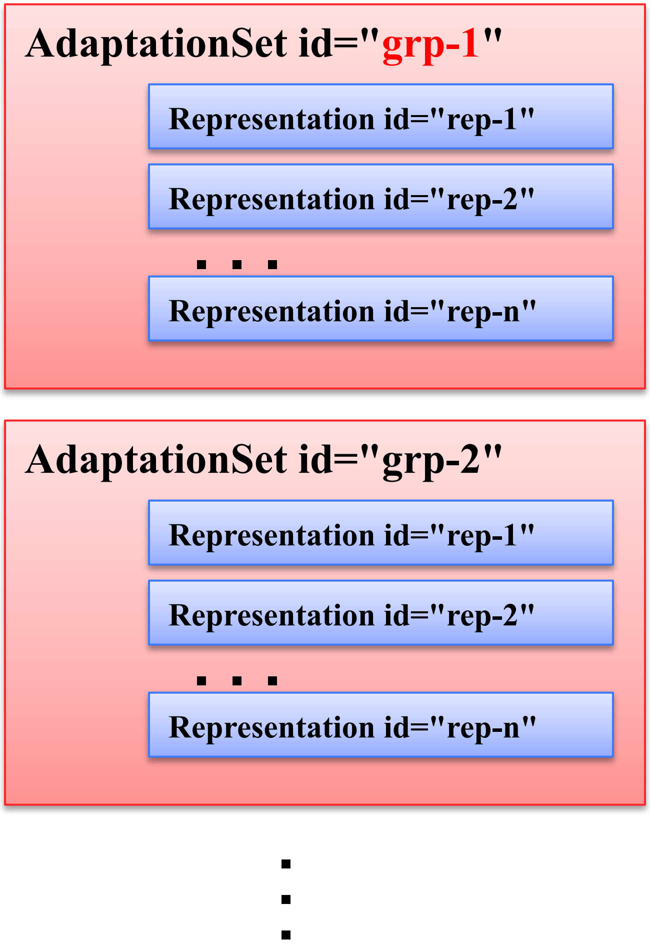
URL Construction

Template-based

Playlist-based

Ack & ©: Iraj Sodagar

DASH AdaptationSets & Subsets



AdaptationSet id="grp-1"

Representation id="rep-1"

Representation id="rep-2"

. . .

Representation id="rep-n"

AdaptationSet id="grp-2"

Representation id="rep-1"

Representation id="rep-2"

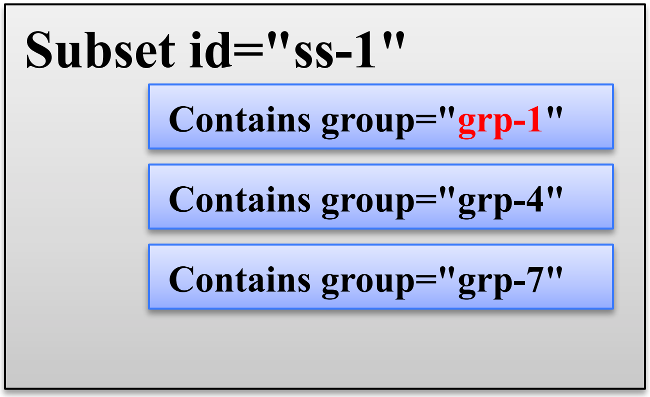
. . .

Representation id="rep-n"

.
.
.

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

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



Subset id="ss-1"

Contains group="grp-1"

Contains group="grp-4"

Contains group="grp-7"

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

Ack & ©: Thomas Stockhammer

Segment Indexing

Segment Index in MPD only

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

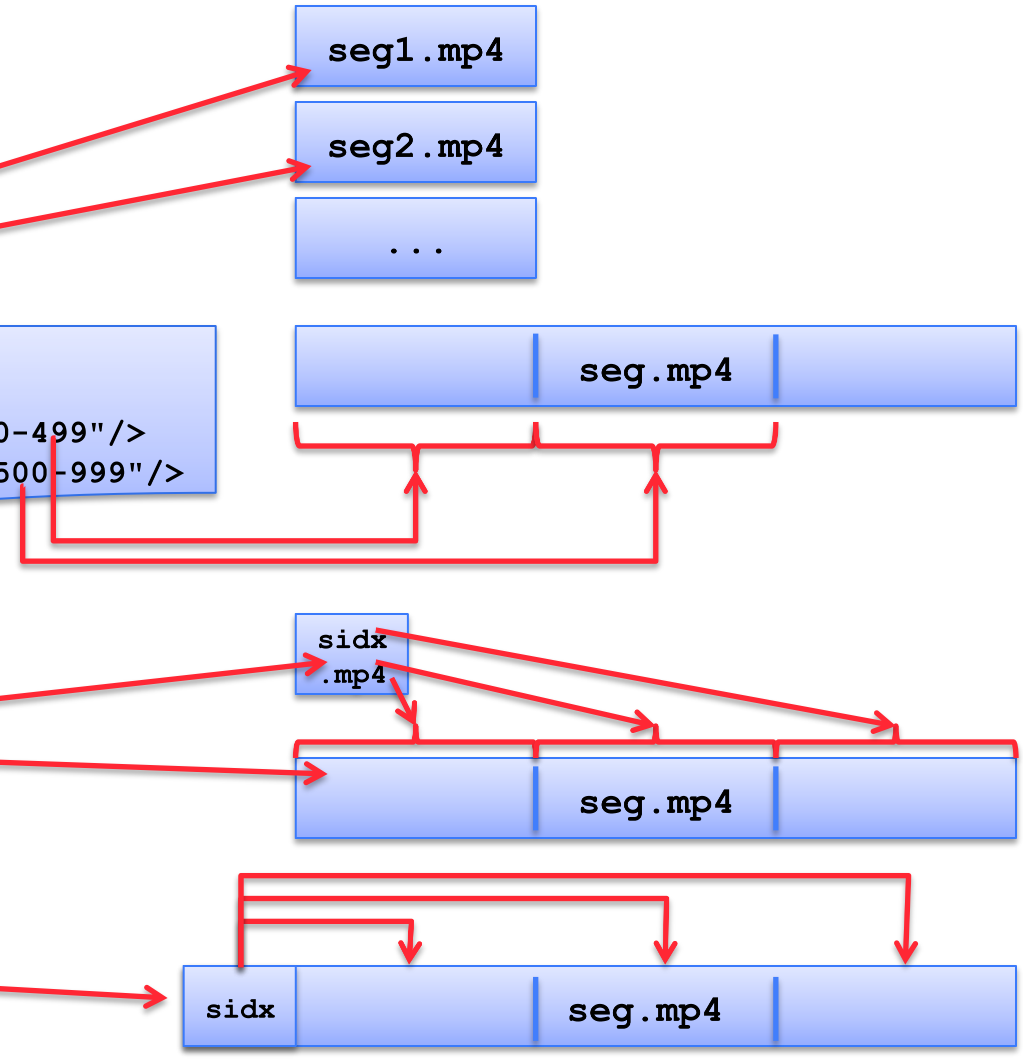
```
<MPD>
  ...
  <URL sourceURL="seg.mp4" range="0-499"/>
  <URL sourceURL="seg.mp4" range="500-999"/>
</MPD>
```

Segment Index in MPD + Segment

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

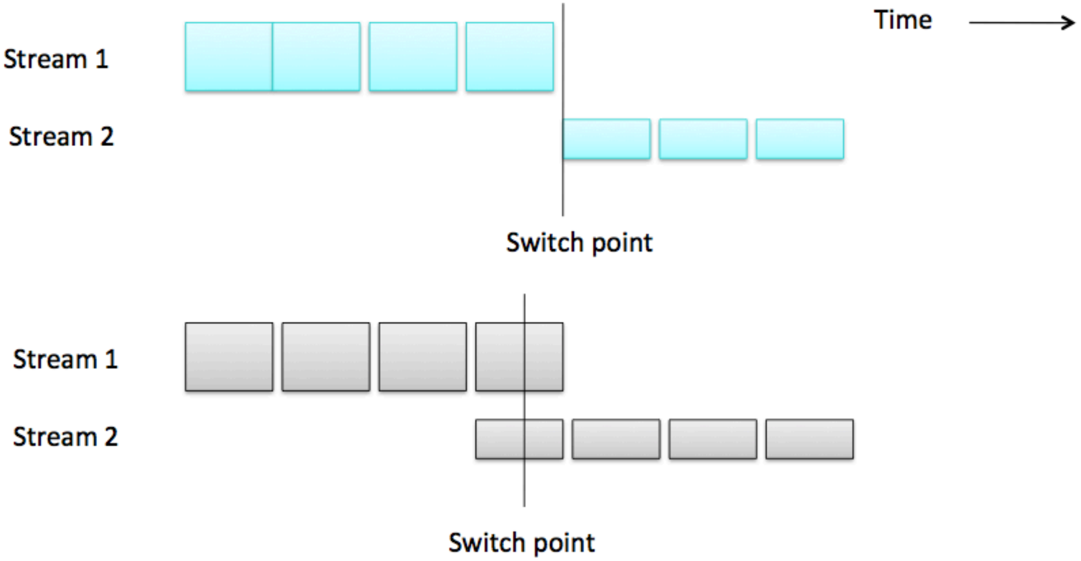
Segment Index in Segment only

```
<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



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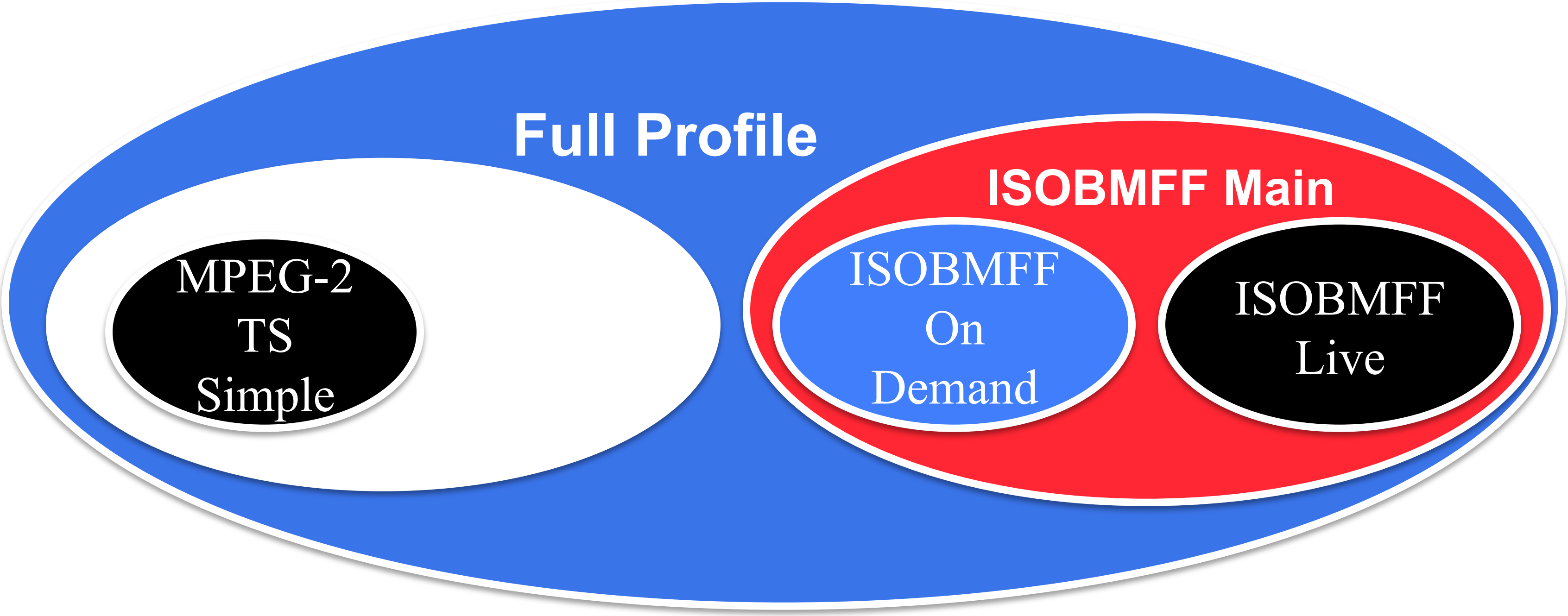
Profiles

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



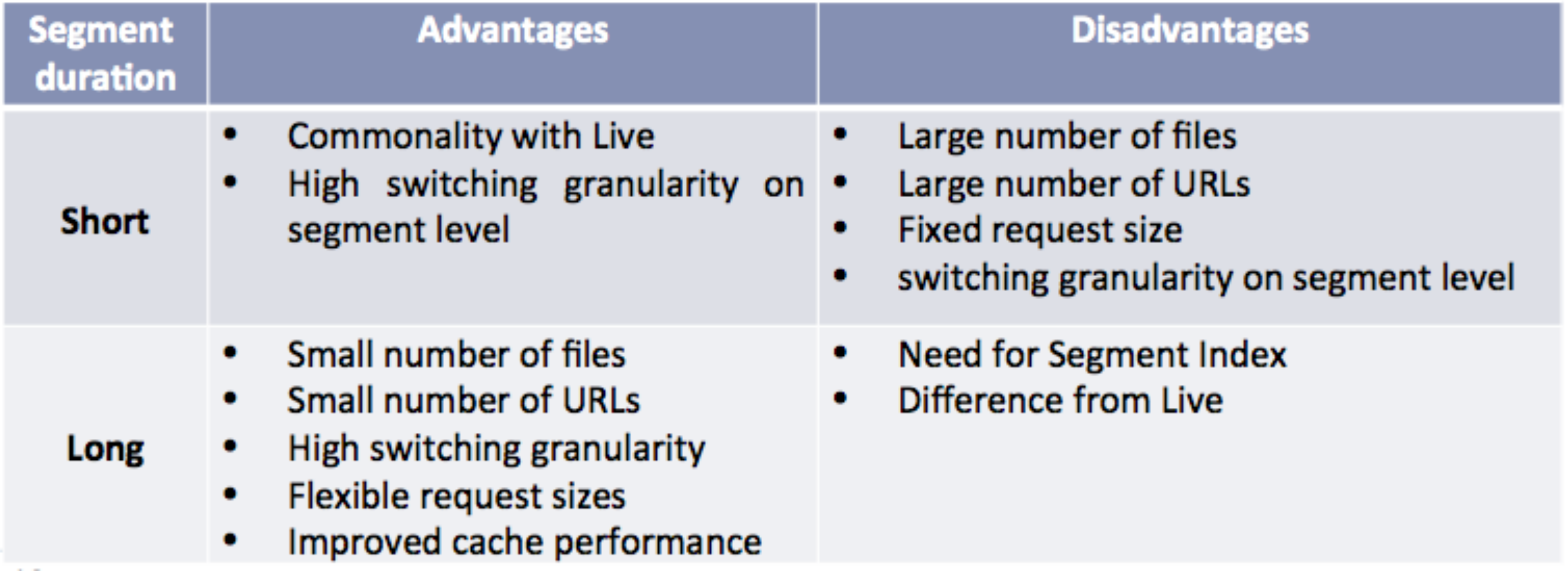
- More restrictions may be added

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 both
  - Switch point alignment required for most consumer electronics decoders

- For live
  - Chunks are unavoidable
  - Still value in decoupling request size from chunk size
  - Multiple language audio tracks are rare
  - May need manifest updates

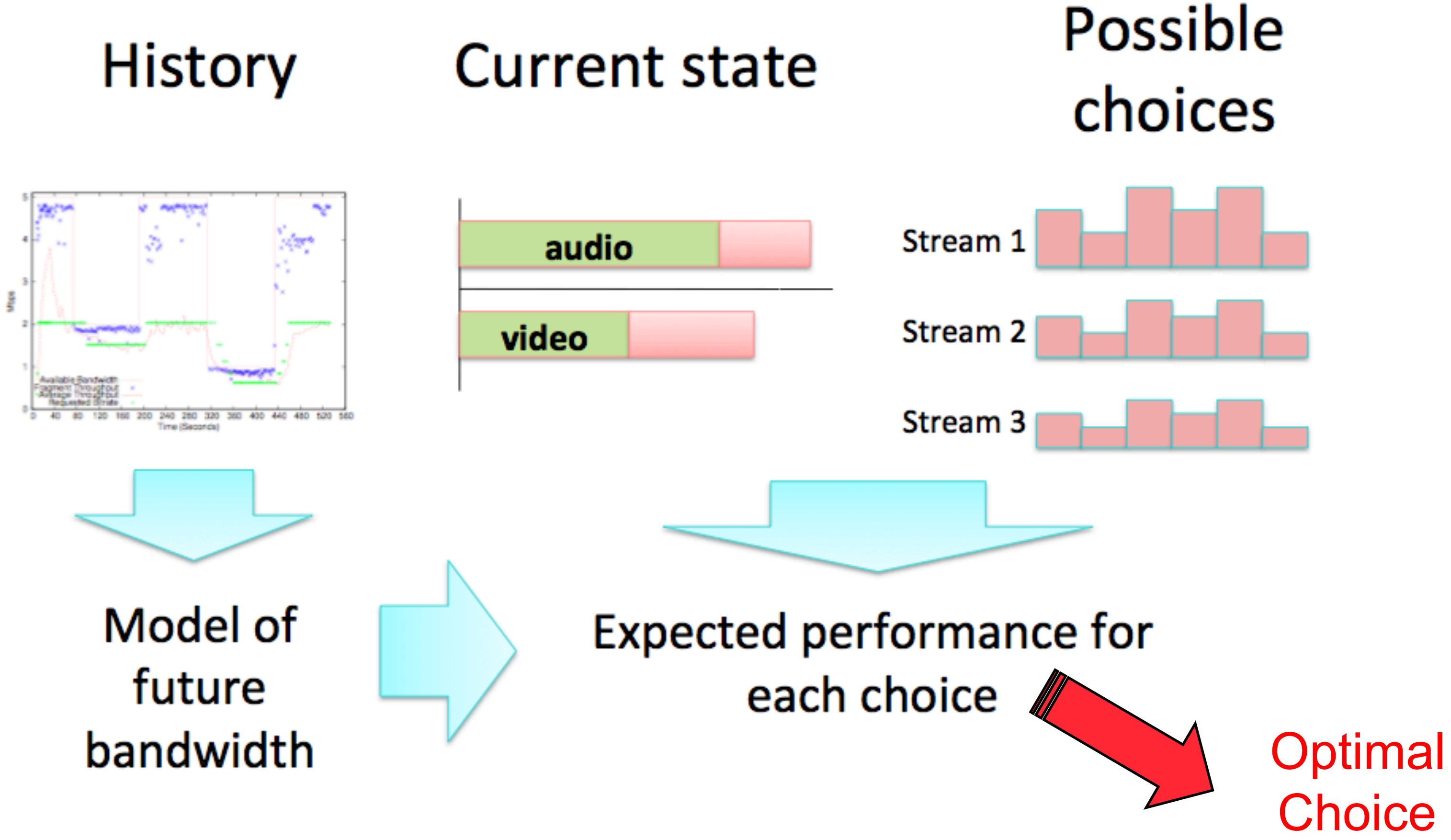


Segment duration	Advantages	Disadvantages
Short	• Commonality with Live • High switching granularity on segment level	• Large number of files • Large number of URLs • Fixed request size • switching granularity on segment level
Long	• Small number of files • Small number of URLs • High switching granularity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

Ack & ©: Mark Watson and Thomas Stockhammer

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

Optimal Choice

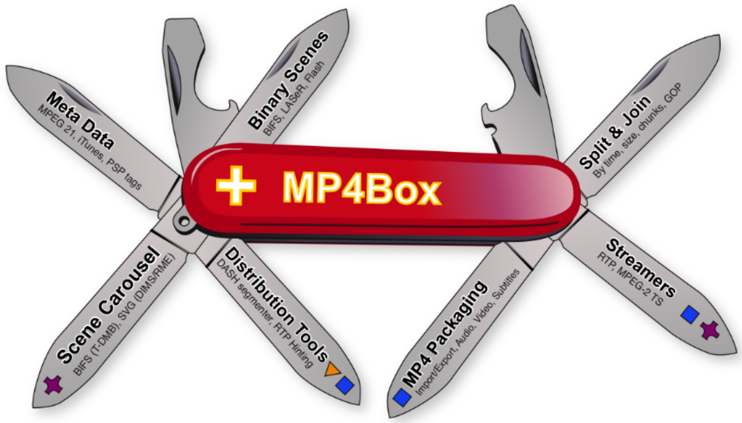
Ack & ©: Mark Watson

DASH Encoders, Datasets, and Players

- “Encoder”: GPAC
- Datasets: Big Buck Bunny and so on…
- Players: VLC media player plugin, libdash

DASH@GPAC: MP4Box & MP42TS

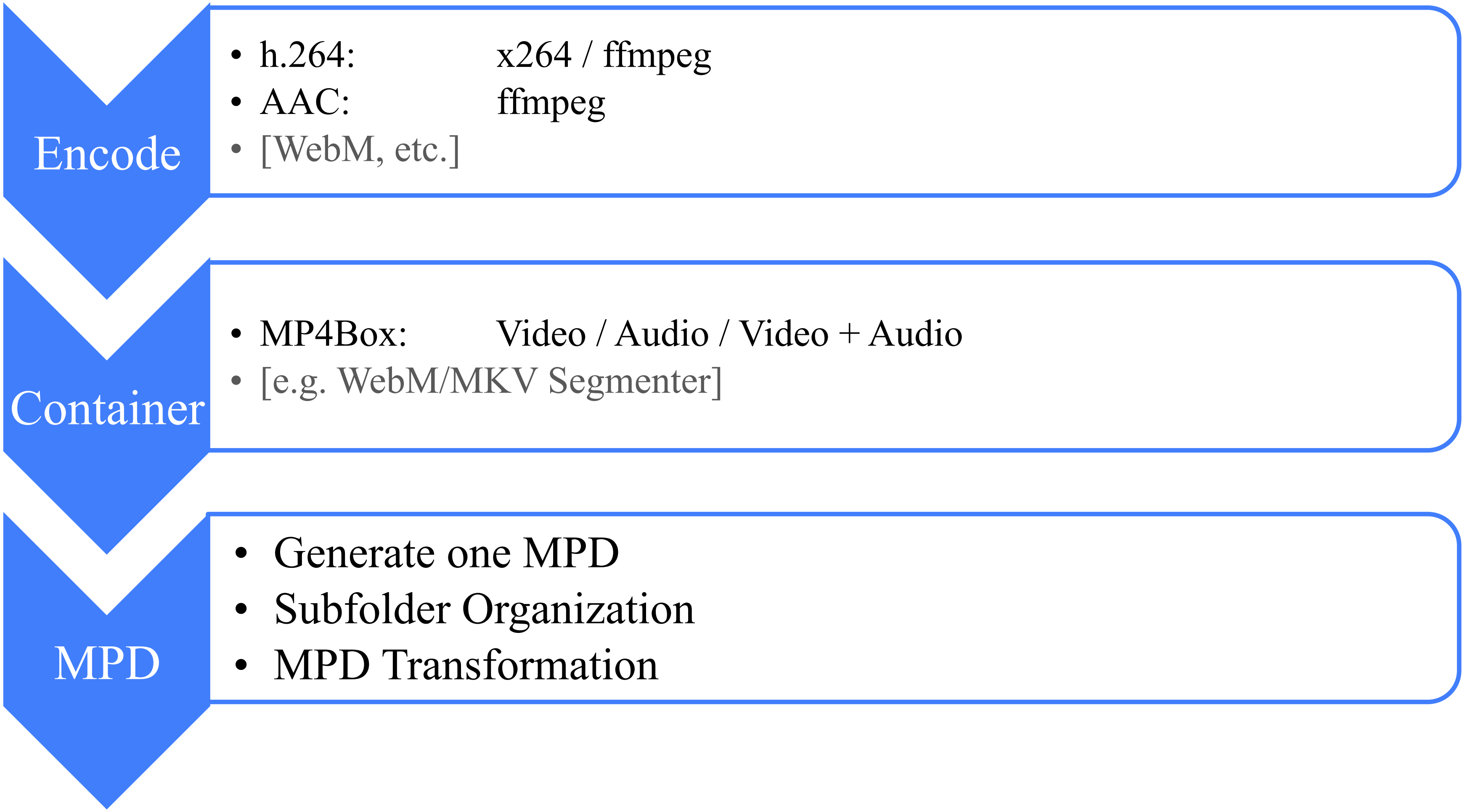
- **Multimedia Packagers**
  - MPEG-2 TS for DASH profiles
  - ISOBMFF Packager & Analyser
- **DASH Segmenter**
  - ISOBMFF and M2TS segments
    - All DASH profiles supported
    - URL-template naming scheme
  - Segment indexing (*SIDX*)
  - GOP-align segments or fragments (*MediaSourceExtension*)
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


MP4Box
Meta Data
MPEG 21, iTunes, PSP tags
Binary Scenes
BIFS, LASeR, Flash
Split & Join
By time, size, chunks, GOP
Scene Carousel
BIFS (T-DMB), SVG (DIMS/RME)
Distribution Tools
DASH segmenter, RTP Hinting
MP4 Packaging
Import/Export, Audio, Video, Subtitles
Streamers
RTP, MPEG-2 TS

DASH Encoder

- **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/

Three Steps of DASH Encoder



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

Datasets

- **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**

Popular 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

Popular Sequences (cont.)

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 Clients

DASHClient

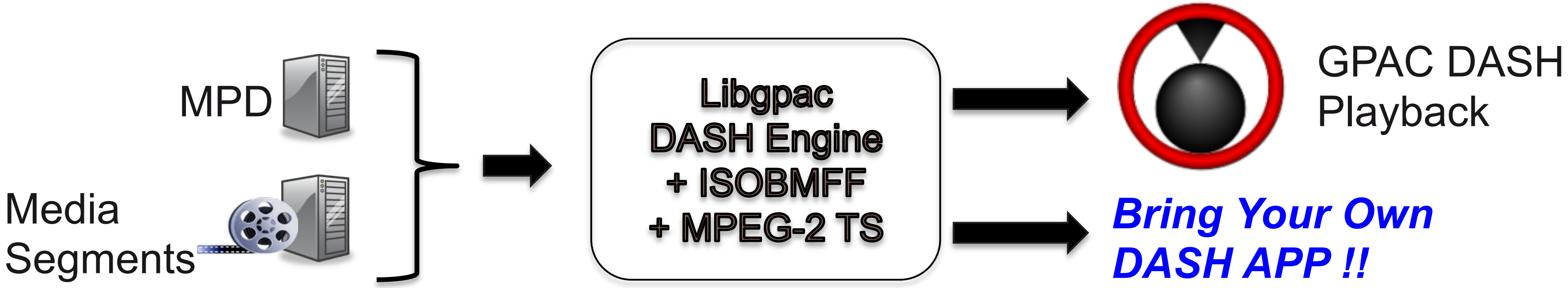
- DASH ISOBMFF, M2TS (+ HLS)
  - With or without bitstreamSwitching
  - Support for multiple Periods
- All profiles except *onDemand* (ongoing)
  - VoD through « live » or « main »
- Local files and http(s) playback
- Various download policies

Integrated in Osmo4

- Many input formats and codecs
- Composition engine (SVG, BIFS, X3D)

Try it!

- Included in libgpac
- Independent from player



MPD

Media Segments

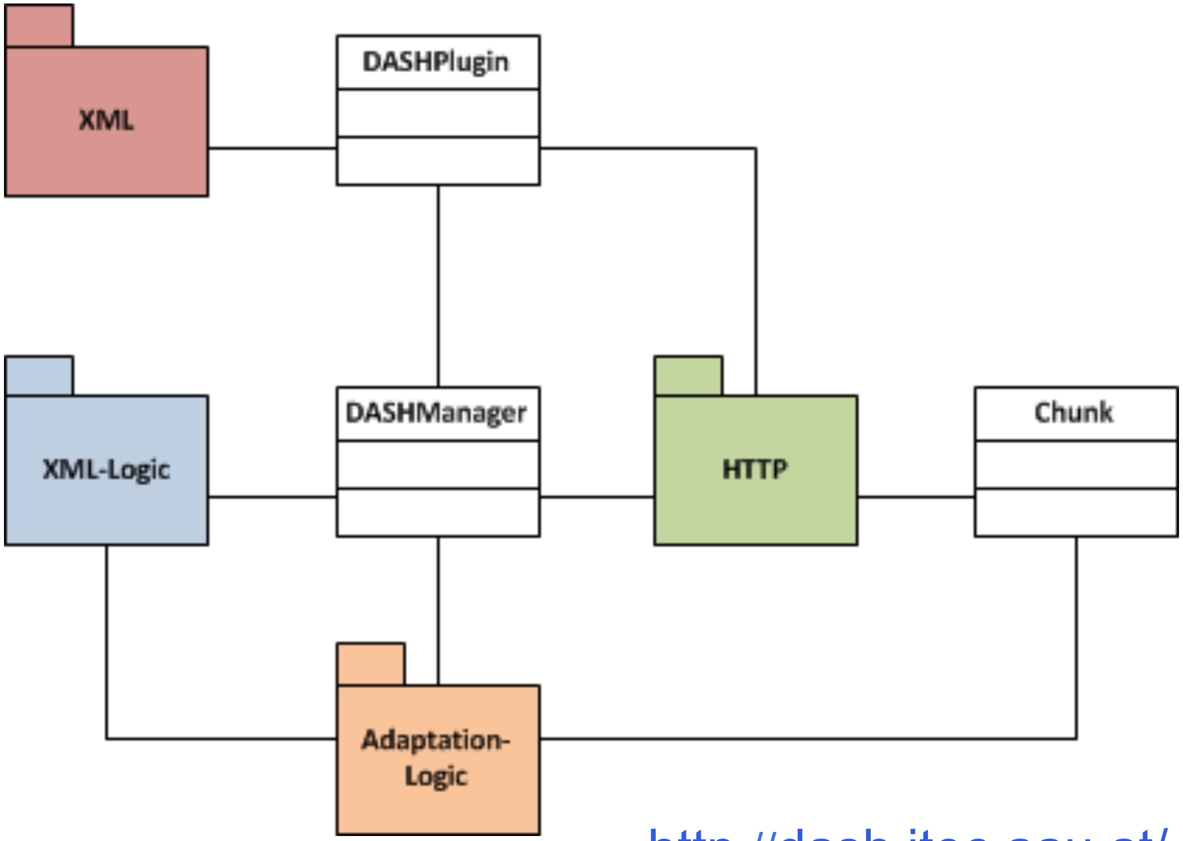
Libgpac
DASH Engine
+ ISOBMFF
+ MPEG-2 TS

GPAC DASH Playback

Bring Your Own DASH APP !!

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/

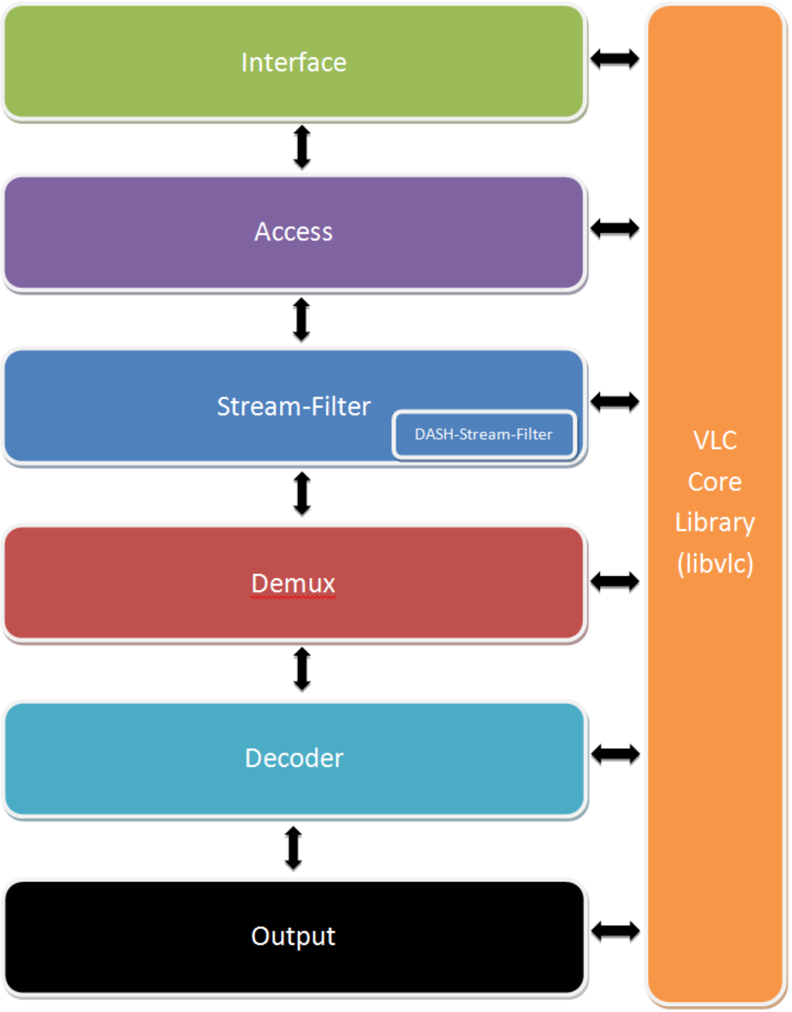
DASH VLC Plugin Features

- 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.**



Summary: Pull-Based DASH Streaming

- **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**

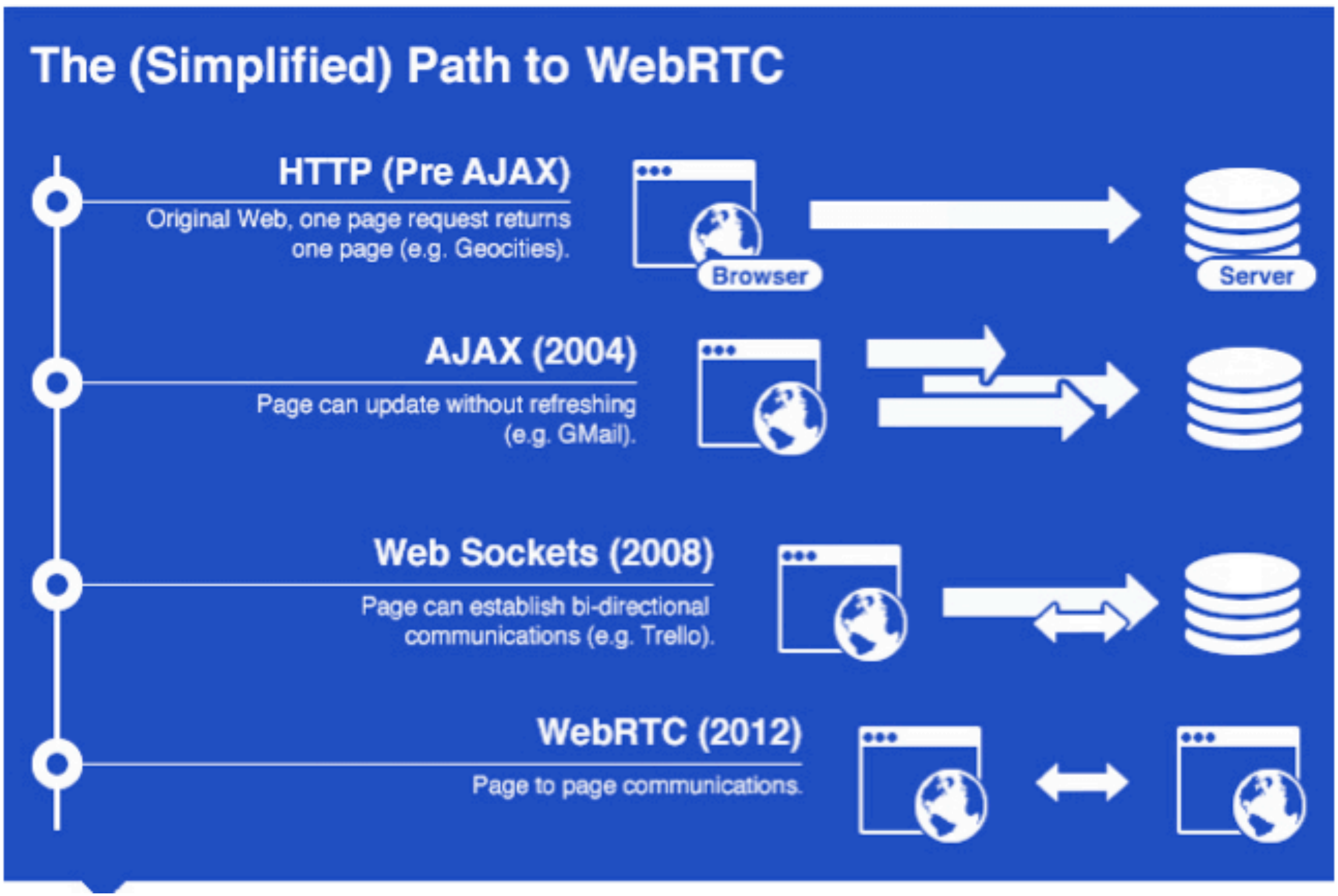
WebRTC: Real-Time Communications

Web Browsers with Real-Time-Communication

- Audio/Video Chat on the web
- Accessed through Javascript API
- Does not require plugins, downloads or installs
- Multiple browsers, multiple platforms
- Good NAT/Firewall traversal supports
- Based on UDP streaming

http://www.webrtc.org/faq

The Origin of WebRTC



The (Simplified) Path to WebRTC

HTTP (Pre AJAX)

Original Web, one page request returns one page (e.g. Geocities).

AJAX (2004)

Page can update without refreshing (e.g. GMail).

Web Sockets (2008)

Page can establish bi-directional communications (e.g. Trello).

WebRTC (2012)

Page to page communications.

Source: jimmylee.info

WebRTC Lowers the Barriers

- PSTN

  - Circuit-switched
  - Electronic devices
  - Dedicated lines

- VOIP

  - SIP and IP
  - Standard protocols
  - IMS core for carriers
  - Complex infrastructure

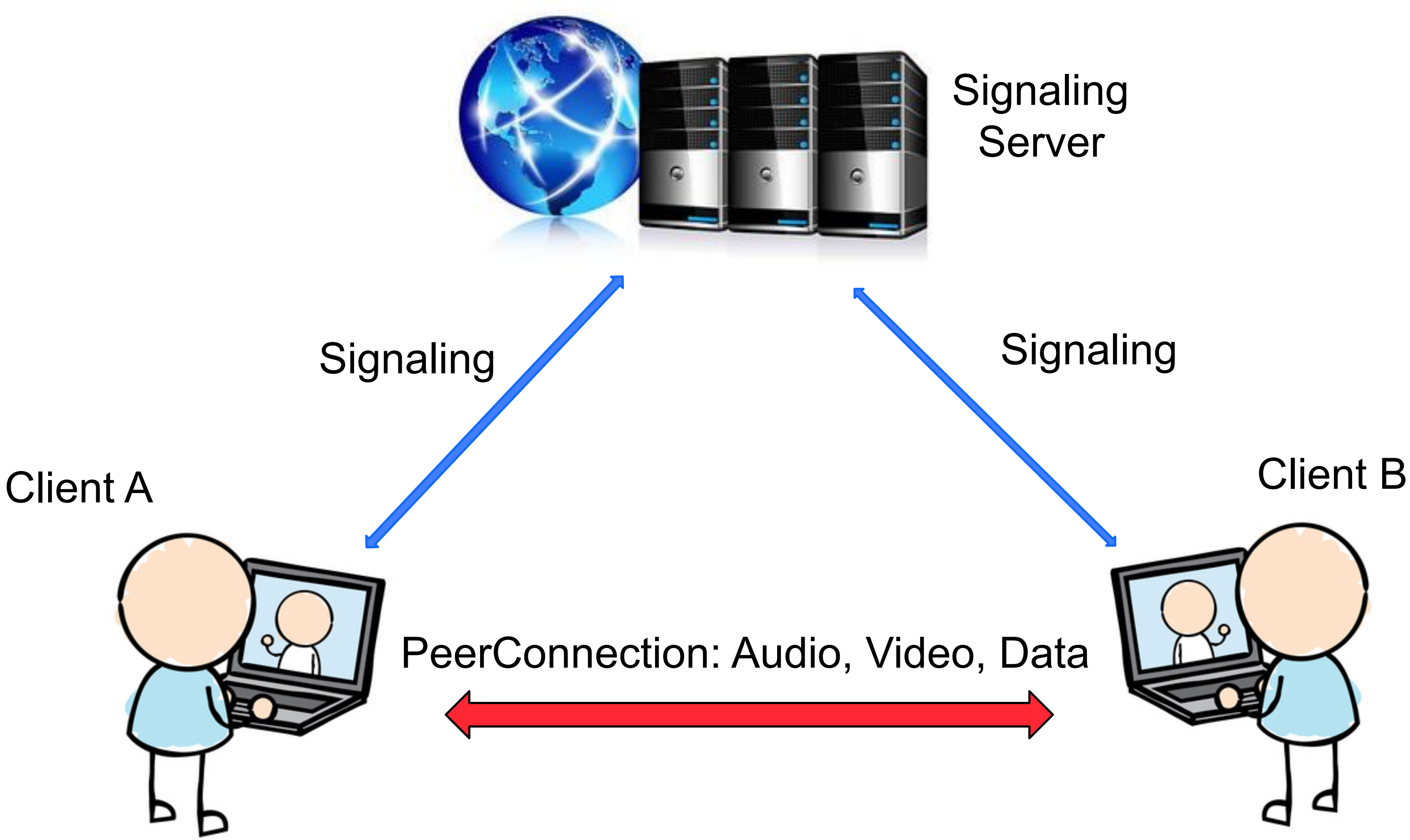
- P2P

  - IP
  - Client software
  - Walled garden

- WebRTC

  - HTML5
  - No plug-in
  - No client software
  - Hopefully interoperate

WebRTC Signaling Triangle



Signaling Server

Signaling

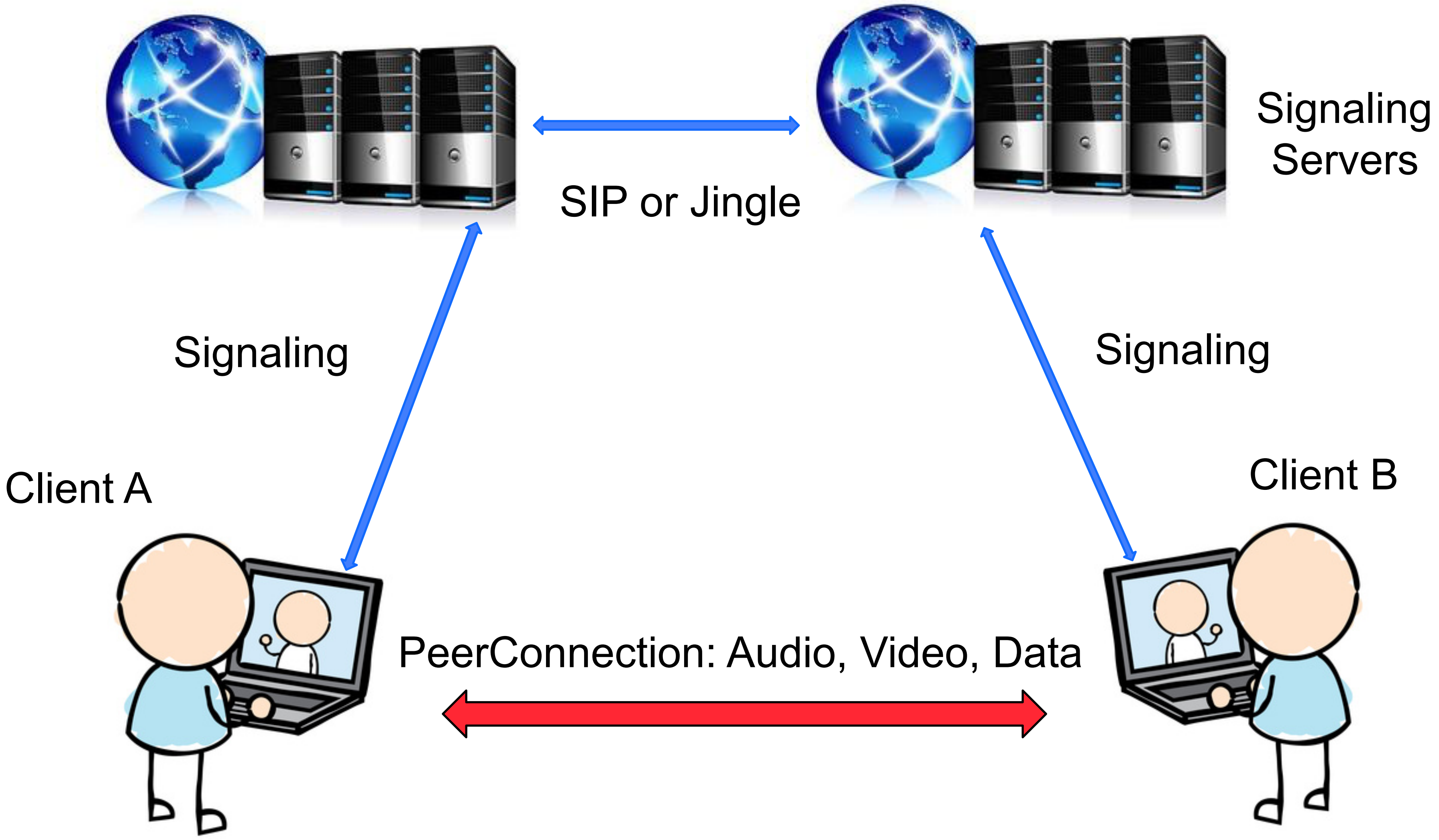
Signaling

Client A

Client B

PeerConnection: Audio, Video, Data

WebRTC Signaling Trapezoid



Signaling Servers

SIP or Jingle

Signaling

Signaling

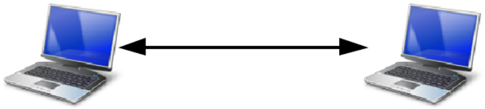
Client A

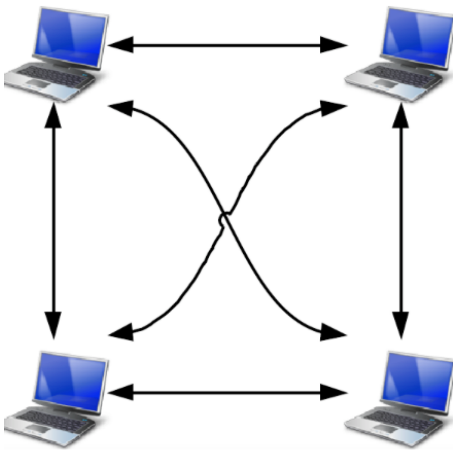
Client B

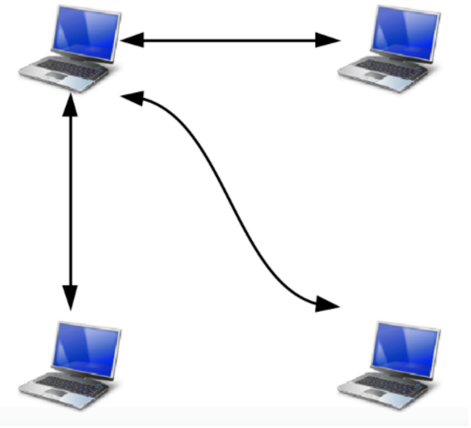
PeerConnection: Audio, Video, Data

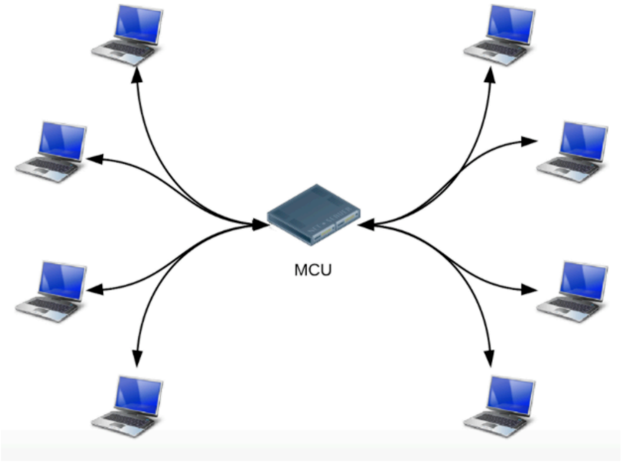
Architectures

- Peer-to-peer: phone call
- Full mesh: (small) conference call
- Star: (medium) conference call
- MCU: (large) conference call

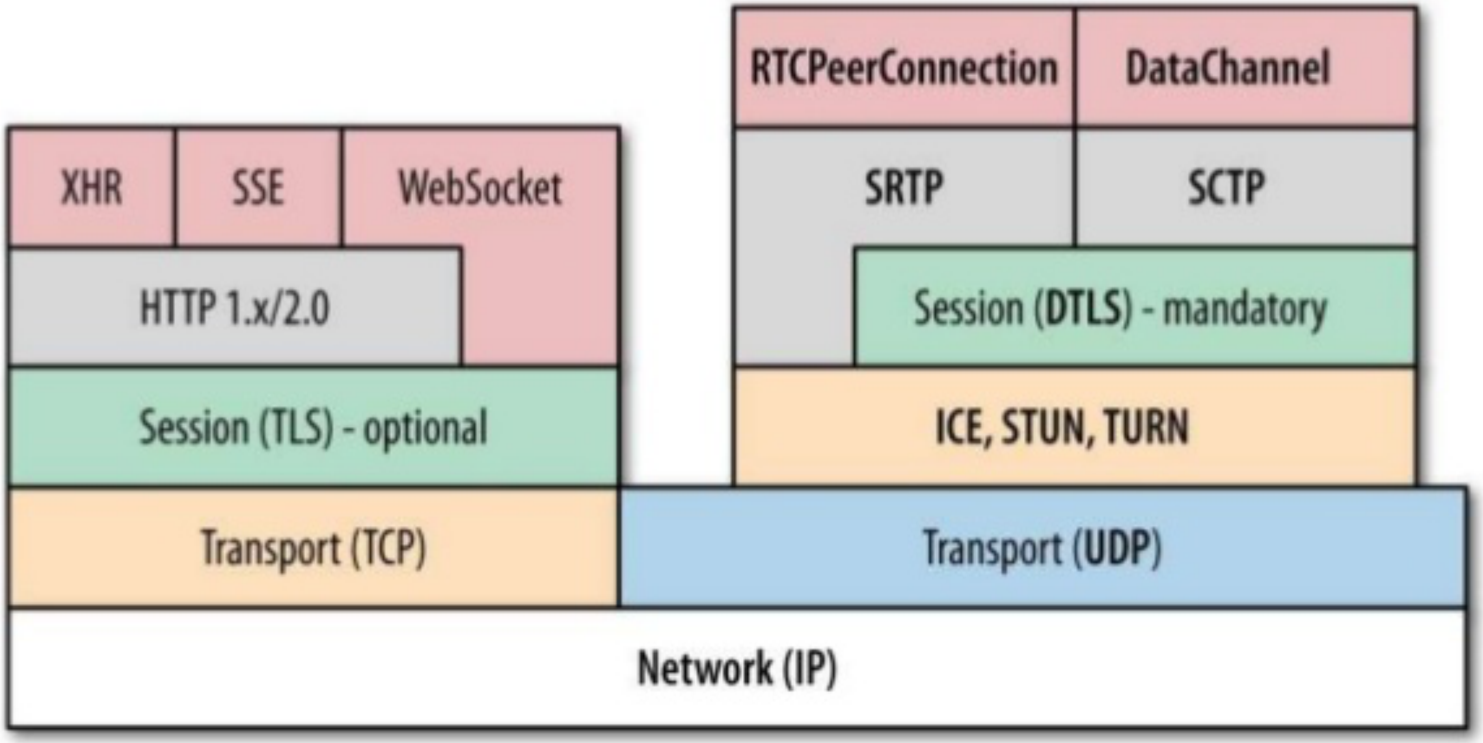








WebRTC Protocols

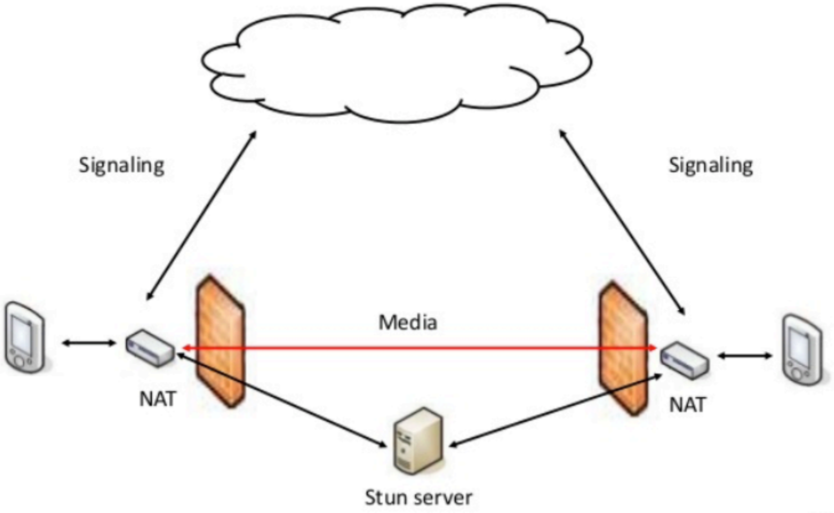


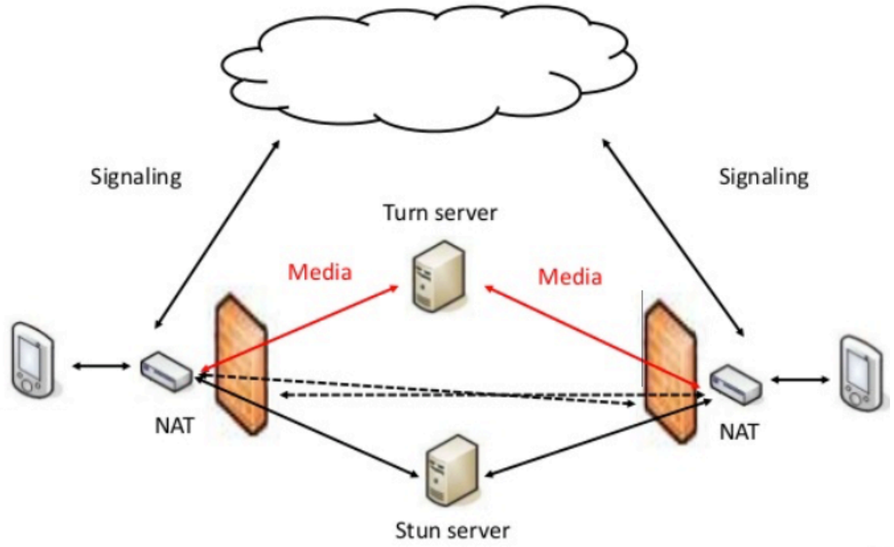
WebRTC Related RFCs

- ICE: Interactive Connectivity Establishment (RFC 5245)
- STUN: Session Traversal Utilities for NAT (RFC 5389)
- TURN: Traversal Using Relays around NAT (RFC 5766)
- SDP: Session Description Protocol (RFC 4566)
- XMPP: Extensible Messaging and Presence Protocol (RFC 3921)
- DTLS: Datagram Transport Layer Security (RFC 6347)
- SCTP: Stream Control Transport Protocol (RFC 4960)
- SRTP: Secure Real-Time Transport Protocol (RFC 3711)

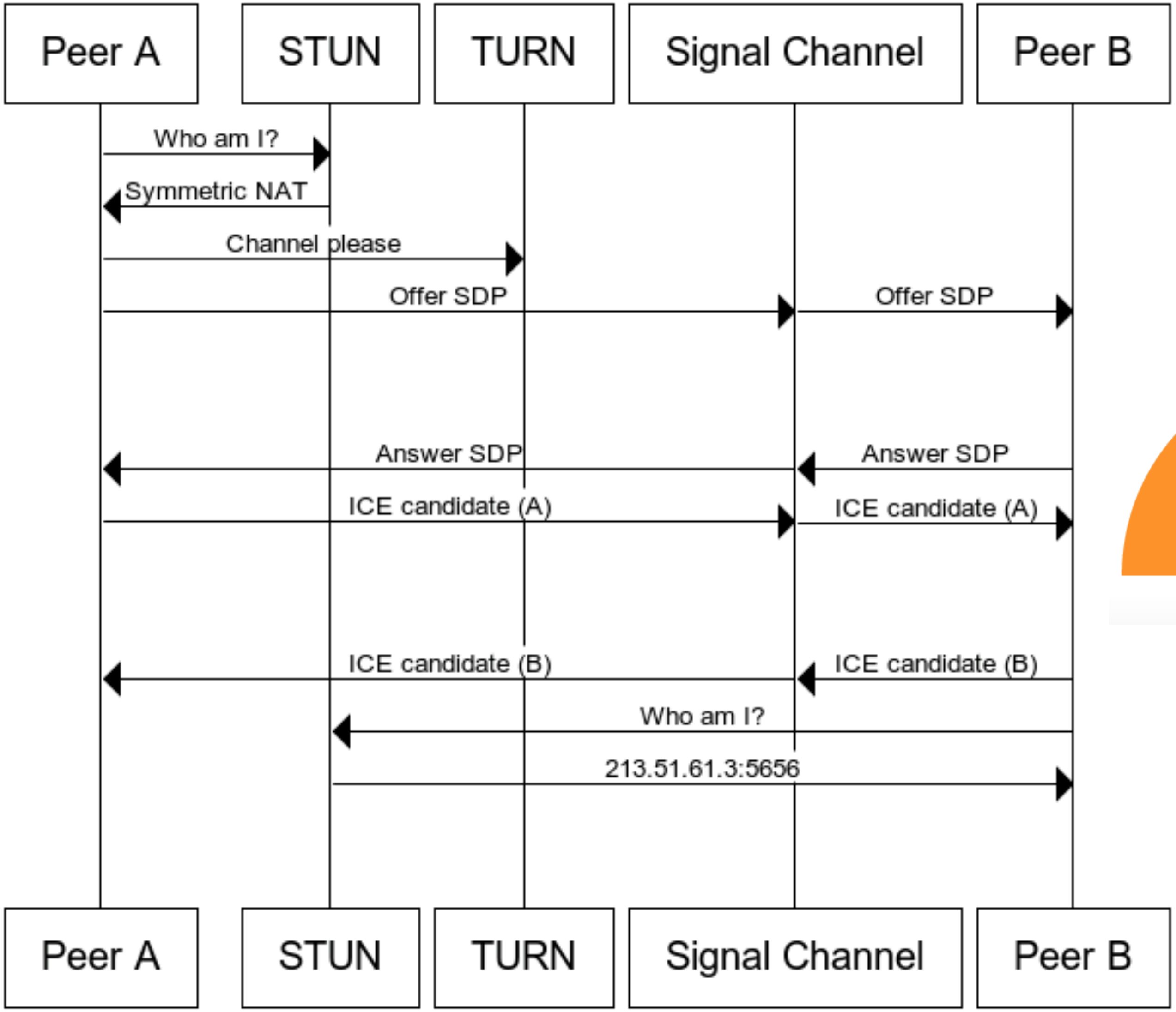
Interactive Connectivity Establishment: ICE

- A framework for connecting peers, it tries to find the best path for each call
  - Direct
  - STUN (Session Traversal Utilities for NAT)
  - TURN (Traversal Using Relays around NAT)





How NAT Traversal Works



Peer A

STUN

TURN

Signal Channel

Peer B

Who am I?

Symmetric NAT

Channel please

Offer SDP

Offer SDP

Answer SDP

Answer SDP

ICE candidate (A)

ICE candidate (A)

ICE candidate (B)

ICE candidate (B)

Who am I?

213.51.61.3:5656

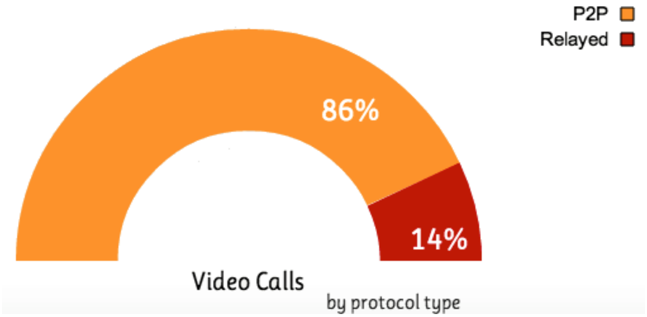
Peer A

STUN

TURN

Signal Channel

Peer B



Source: http://www.innoarchitech.com/what-is-webrtc-and-how-does-it-work/

Three Main Tasks and JavaScript APIs

- Main Tasks
  - Acquire audio and video
  - Transferring audio and video
  - Transferring arbitrary data
- JavaScript APIs
  - MediaStream (getUserMedia)
  - RTCPeerConnection
  - RTPDataChannel
- Details on APIs are left as exercise….

Summary: Push-Based WebRTC

- **Web Real-Time Communications**
- **Standards to enable browser based sessions (voice, video, collaborations, …) without the need of custom clients or plugins**
- **Builds on HTLM5 capabilities with JavaScript**
- **Standardized by W3C and IETF**
  - **IETF RTCWeb WG (Internet world, IP protocols)**
  - **W3C WebRTC WG (web world, Browsers etc.)**
- **Intended for all browsers to support**
  - **Microsoft being problematic**
    - **Have their own CU-RTC-Web framework**
  - **Apple (Safari) not at the table**