Multimedia content transmission

2024/25 Q2

Jaime Delgado *

DAC – UPC

* Part of the material comes from other sources.

Multimedia content transmission

- HTML5 support to MM transmission
- Streaming
- Original streaming protocols:
  - RTP, RTCP, RTSP, others
- Streaming with HTTP
  - DASH

HTML (*HTML4*): Tags

<!--->
<
<A>
<ABBREV>
<ACRONYM>
<ADDRESS>
<APPLET>
<AREA>
<AU>
<AUTHOR>
<B>
<BANNER>
<BASE>
<BASEFONT>
<BGSOUND>
<BIG>
<BLINK>
<BLOCKQUOTE>
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<ISINDEX>
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<LH>
<LI>
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<LISTING>
<MAP>
<MARQUEE>
<MATH>
<MENU>
<META>
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<NOFRAMES>
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<P>
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<PERSON>
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<PRE>
<Q>
<RANGE>
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<SPOT>
<STRIKE>
<STRONG>
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<TBODY>
<TD>
<TEXTAREA>
<TEXTFLOW>
<TFOOT>
<TH>
<THEAD>
<TITLE>
<TR>
<TT>
<U>
<UL>
<VAR>
<WBR>
<XMP>

HTML5

- Start with playing …

- http://www.w3schools.com/html/html5_**canvas**.asp
- http://www.w3schools.com/html/html5_**svg**.asp
- http://www.w3schools.com/html/html5_**video**.asp
- http://www.w3schools.com/html/html5_**audio**.asp

HTML history

- Introduced in early 90s.
- Some features in specifications, others in software.
- HTML4: W3C Recommendation in 1997.
- “HTML specification”: effort (since 2004) to study HTML implementations and Web content.
- The specification:
  - Defines a single language (“HTML”) that can be written in HTML and XML syntaxes.
  - Defines detailed processing models to foster interoperable implementations.
  - Improves markup for documents.
- *“Living standard”*

HTML5

www.w3.org/TR/html5/

Buscar

W3C Recommendation

HTML5

A vocabulary and associated APIs for HTML and XHTML

W3C Recommendation 28 October 2014

This Version:
http://www.w3.org/TR/2014/REC-html5-20141028/
Latest Published Version:
http://www.w3.org/TR/html5/
Latest Version of HTML:
http://www.w3.org/TR/html/
Latest Editor's Draft of HTML:
http://www.w3.org/html/wg/drafts/html/master/
Previous Version:
http://www.w3.org/TR/2014/PR-html5-20140916/
Previous Recommendation:
http://www.w3.org/TR/1999/REC-html401-19991224/
Editors:
WHATWG:
Ian Hickson, Google, Inc.
W3C:
Robin Berjon, W3C
Steve Faulkner, The Paciello Group
Travis Leithead, Microsoft Corporation
Erika Doyle Navara, Microsoft Corporation
Edward O'Connor, Apple Inc.
Silvia Pfeiffer

Please check the **errata** for any errors or issues reported since publication.
This specification is also available as a single page HTML document. See also **translations**.

HTML5


www.w3.org/TR/html5/
Buscar
W3C Recommendation
W3C
HTML5
A vocabulary and associated APIs for HTML and XHT
W3C Recommendation 28 October 2014
This Version:
http://www.w3.org/TR/2014/REC-html5-20
Latest Published Version:
http://www.w3.org/TR/html5/
Latest Version of HTML:
http://www.w3.org/T
Latest Editor's Dr
http://ww
Previous Versi
http://www.w
Previous Recom
http://www.w3.
Editors:
WHATWG:
Ian Hickson, Google
W3C:
Robin Berjon, W3C
Steve Faulkner, The Pa
Travis Leithead, Microsof
Erika Doyle Navara, Micros
Edward O'Connor, Apple Inc.
Silvia Pfeiffer
Please check the errata for any errors
sues reported since publication.
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Obsolete!

HTML5.x

https://www.w3.org/TR/html52/
(14th December 2017, W3C Rec.)

https://www.w3.org/TR/html53/
(18th October 2018, W3C WD)

New work going on!
“LIVING STANDARD”
https://w3c.github.io/html/
(Editor’s Draft)

HTML5.x

https://ww… …ml52/
(14th D… …Rec.)
…3/
…
…RD”
…ub.io/html/
…or’s Draft)

Work moved to whatwg.org

Web Hypertext Application Technology Working Group

(Apple, Google, Mozilla, Microsoft)

https://html.spec.whatwg.org/

HTML5

- New version of HTML:
  World Wide Web Consortium (W3C) +
  Web Hypertext Application Technology Working Group (WHATWG)
  "This document covers the W3C HTML5 specification, W3C HTML5.1 specification, and the WHATWG HTML standard. For readability, these are referred to as if they were a single specification: "the HTML specification" or simply "HTML" when something applies equally to all of them; otherwise, they are called out explicitly."
- W3C Rec. Oct. 2014, but still new developments!
- Browsers support some of its new features
- Basic ideas:
  - Based on HTML, CSS, DOM, Javascript
  - Reduce the need of external plug-ins
  - Improve error management
  - More markup to reduce scripting
  - Device independent

HTML5 new elements

- `<canvas>` to draw 2D elements
- Multimedia: `<video>`, `<audio>`, `<source>`, `<embed>`, `<track>`
- Content specific element:

  `<figure>`, `<footer>`, `<header>`, `<nav>`, `<section>`, …
- Other elements:

  `<output>`, new values for `<input>` (`date`, `email`, `url`, `search`), `<time>`, …
- Obsoleted elements:

  `<big>`, `<center>`, `<font>`, `<frame>`, ...
- Support for inline MathML and SVG.

HTML5

http://w3c.github.io/html-reference/elements.html

HTML5 support

VIDEO

BROWSER	MP4	WebM	Ogg
Edge/IE	Yes	Yes	Yes
Chrome	Yes	Yes	Yes
Firefox	Yes	Yes	Yes
Safari	Yes	Yes	No
Opera	Yes	Yes	Yes

AUDIO

BROWSER	MP3	Wav	Ogg Vorbis
Edge/IE	Yes	Yes	Yes
Chrome	Yes	Yes	Yes
Firefox	Yes	Yes	Yes
Safari	Yes	Yes	No
Opera	Yes	Yes	Yes

Multimedia containers

REMINDER

- **Proprietary**
  - Microsoft/IBM: RIFF (Resource Interchange FF)
  - Microsoft: ASF, AVI, …
  - Adobe: Flash video, …
- **Open**
  - Matroska (.mkv) [*Very much used for video*]
  - Google: WebM (VP8+Vorbis for HTML5). (Based on Matroska)
    (**Now**: VP9+Opus)
  - Xiph.org: ogg (Theora+Vorbis for HTML5)
  - …

WebP uses RIFF as container
WAV, AVI, etc. are derived from RIFF

Multimedia containers

REMINDER

- **Proprietary**
  - Microsoft/IBM: RIFF (Resource Interchange FF)
  - [illegible]

Audio specific:
WAV (Microsoft/IBM), **Ogg Vorbis**, …

- **Open**
  - Matroska (.mkv) [*Very much used for video*]
  - Google: **WebM** (VP8+Vorbis for HTML5). (Based on Matroska)
    (Now: VP9+Opus)
  - Xiph.org: **ogg** (Theora+Vorbis for HTML5)
  - …

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WAV, AVI, etc. are derived from RIFF

Multimedia content transmission

- HTML5 support to MM transmission
- Streaming
- Original streaming protocols:
  - RTP, RTCP, RTSP, others
- Streaming with HTTP
  - DASH

MM content transmission

- “Stored” / “pre-published” / “On demand”
  - Transfer (File)
  - **Streaming** *(rendering while downloading)*
- “Creating” / “live”
  - Interactive (*more than one transmitter*)
  - **Streaming**
- More on streaming …

MM content transmission

- "Stored" / "pre-published" / "On demand"
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First definition

- "Creating" / "live"
  - Interactive (*more than one transmitter*)
  - **Streaming**

- More on streaming …

Streaming

More definitions of "Streaming media":

- "Video or audio content sent in compressed form over the Internet and played immediately" – techtarget.com
- "Multimedia that is constantly received by and presented to an end-user while being delivered" – wikipedia.org (some year ago)

Streaming

- Streaming features:
  - Continuous transmission, but in fact: **Continuous rendering**
  - Control *("interactivity")* (pause, resume, fast forward, rewind, forward to, back to)
    (Pre-published vs. live)
  - Jitter → Buffering
  - Network quality vs. Content quality

Streaming

- Streaming features:
  - Continuous transmission, but in fact:
    Continuous rendering
    Simple definition!
  - Control *("interactivity")*
    (Pre-published vs. live)
    (pause, resume, fast forward, rewind, forward to, back to)
  - Jitter → Buffering
  - Network quality vs. Content quality

Audio and video streaming

- Audio and video “streaming” transmission through Internet:
  - TV and radio
  - On-line newspapers
  - Music: Spotify, …
  - Video: Youtube, Netflix, movistarplus, …
  - Advertisements in regular web sites
  - Interaction (online conferencing): Skype, Google Chat/meet, Zoom, Webex, Teams, GoToMeeting, …
  - Etc…

Streaming requirements

- Multimedia data streaming transmission requirements:
  - Sensible to end-to-end delay
  - *Occasional delay tolerance* (more for “stored”)
  - Sensible to delay variability
  - *Occasional losses tolerance* (more for “live”)

  - Contrary requirements for file transfer applications:
    - no losses allowed,
    - but delay is not a problem

“Old” streaming products

- “Classic” commercial products (“only” since 1995) (“**true**” **streaming**):
  - Real Media (Real Networks).
  - Windows Media (Microsoft).
  - Adobe Flash Video (.flv).
  - Quick Time Movie (Apple).
  - Macromedia (bought by Adobe).
  - …

Types of streaming

- **“Original”**
- **HTTP-based**
- **HTTP → Adaptive (bit rate) streaming**

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RTP

- **Real time Transport Protocol**
  (A Transport Protocol for Real-Time Applications)
- IETF: RFC1889 (1996) → RFC3550 (2003)
- Over UDP
- Real time encapsulation
- Recovering correct signal at reception:
  - Payload type: GSM, MPEG audio, H.261, MPEG-1 video, MPEG-2 video, …
  - Timestamps
  - Sequence numbers
  - SSRC: Synchronization Source identifier

RTCP

- **RTP Control Protocol**
  - Sends (with RTP) periodic control packets to session participants
- Basic functions
  - Inform about the quality of the distributed data
  - Keep a persistent identifier of a RTP source (to recover session participants)
  - Control sending rate of RTP participants
  - Communicate session control information (e.g. to show user identification)

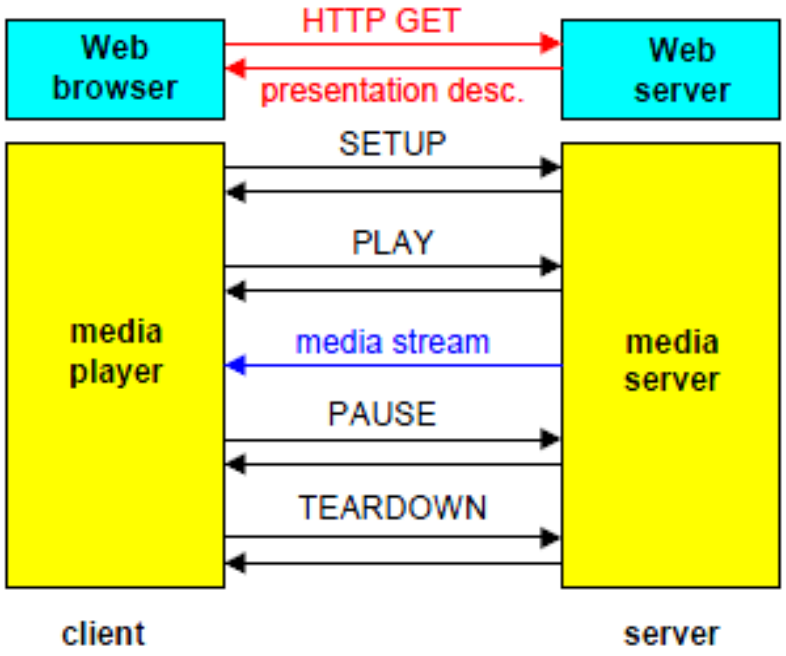
RTSP

- **Real Time Streaming Protocol**
  - Establishes & controls one or more synchronized multimedia streams (e.g. audio & video).
  - Does not send data. Only controls information of transmitted data.
  - No connections but sessions, kept by the server. Identifier per session not linked to TCP connection.
  - Over TCP, but UDP also possible.
  - Normally combined with RTP to send the *streams.*
  - IETF: RFC2326 (1998).

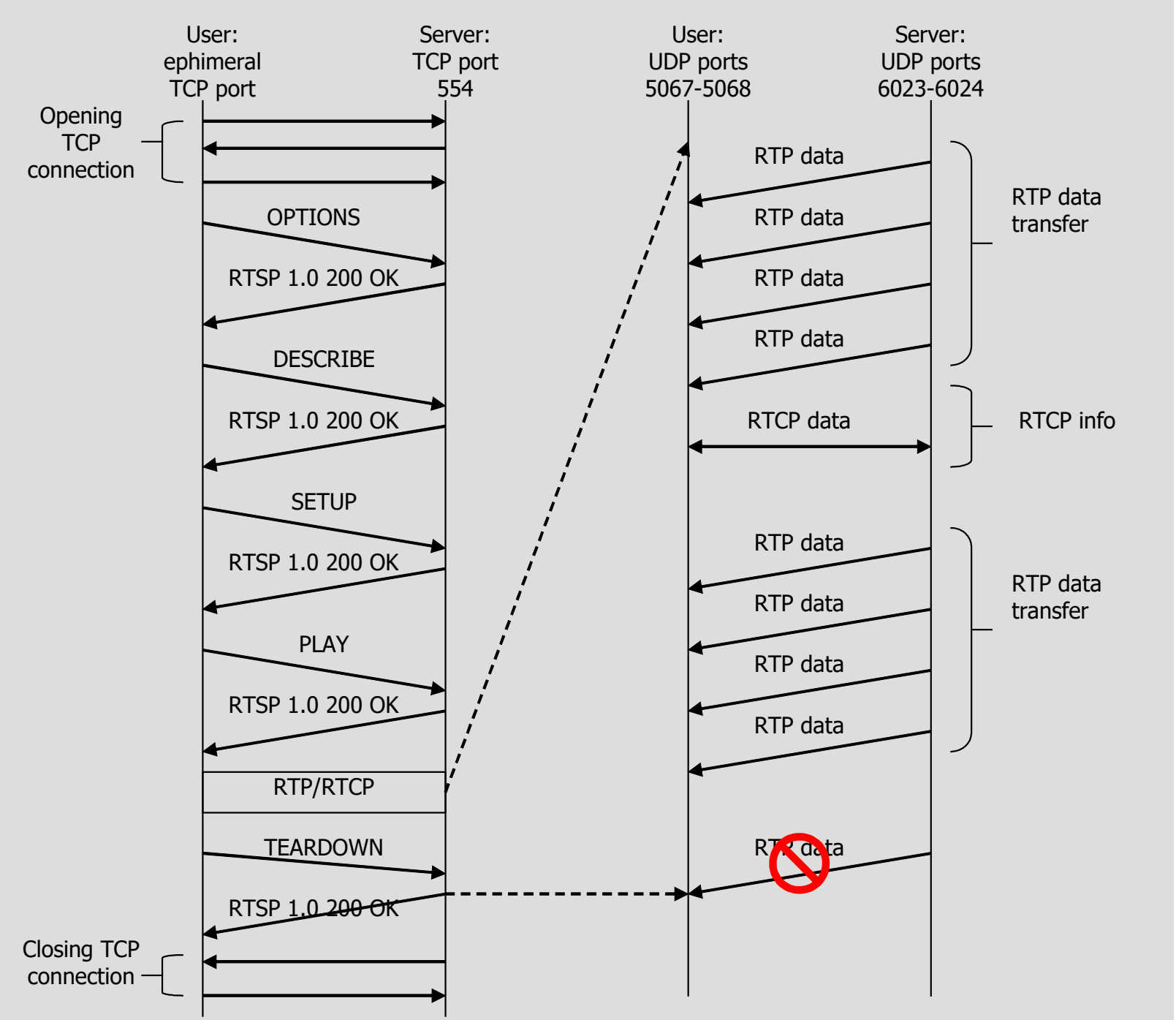
RTSP: Methods

- **SETUP**: Server reserves resources for a stream and initiates a RTSP session
- **PLAY**, **RECORD**: Starts data transmission of a stream initialized with SETUP
- **PAUSE**: Temporarily stops the data transmission without releasing the server resources
- **TEARDOWN**: Releases the resources associated to the stream. The RTSP session is removed from the server

RTSP working: example



- Client obtains a description of the multimedia presentation, which can consist of several media streams.
- The browser invokes media player (helper application) based on the content type of the presentation description.
- Presentation description includes references to media streams, using the URL method rtsp://
- Player sends RTSP SETUP request; server sends RTSP SETUP response.
- Player sends RTSP PLAY request; server sends RTSP PLAY response.
- Media server pumps media stream.
- Player sends RTSP PAUSE request; server sends RTSP PAUSE response.
- Player sends RTSP TEARDOWN request; server sends RTSP TEARDOWN response.


User:
ephimeral
TCP port
Server:
TCP port
554
User:
UDP ports
5067-5068
Server:
UDP ports
6023-6024
Opening
TCP
connection
OPTIONS
RTSP 1.0 200 OK
DESCRIBE
RTSP 1.0 200 OK
SETUP
RTSP 1.0 200 OK
PLAY
RTSP 1.0 200 OK
RTP/RTCP
TEARDOWN
RTSP 1.0 200 OK
Closing TCP
connection
RTP data
RTP data
RTP data
RTP data
RTP data transfer
RTCP data
RTCP info
RTP data
RTP data
RTP data
RTP data
RTP data transfer
RTP data

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Streaming and HTTP

Reasons for moving to HTTP:

- Streaming media protocols designed for media delivery
  BUT
  Internet built and optimized on HTTP
- Streaming protocols: problems getting around firewalls and routers (based on UDP, unusual port numbers, …)
  WHILE
  this is not a problem for HTTP-based delivery (firewalls and routers know how to pass HTTP through port 80!)
- HTTP media delivery does not require special proxies or caches. A media file is just like any other file to a Web cache.

HTTP-based streaming

- **“Just” download:** Rendering afterwards

  No interest!

- **Progressive:** Rendering while downloading
  - Features:
    - *Metafile*: Description
    - Download, buffering. Control, “segmenting”
- **Adaptive (bit rate) streaming**
  - Client adapting to existing bandwith

Adaptive (bit rate) streaming

- **Commercial**
  - HTTP Dynamic Streaming (Adobe HDS)
  - HTTP Live Streaming (Apple HLS)
  - IIS (Internet Information Services) Smooth Streaming (Microsoft)
- **Standard**
  - MPEG-DASH
    (Dynamic Adaptive Streaming over HTTP)

Adaptive (bit rate) streaming

- **Commercial**
  - HTTP Dynamic Streaming (Adobe HDS)
  - HTTP Live Streaming (Apple HLS)
  - IIS (Internet Information Services) Smooth Streaming (Microsoft)
- **St**
  -

Apple: ***HTTP Live Streaming***
- Published as RFC8216
- Dec. 2015:
  RFC Independent Stream Editor (ISE)
  → informational (non-standard) RFC,
  (outside of the IETF consensus process).
- Aug. 2017: Version 7

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- Streaming with HTTP:
  - **DASH**

Standardization (ISO/IEC process)

REMINDER

- **Steps** (all of them could be repeated)**:**
  - Requirements
  - Call for Proposals
  - **WD** (Working Draft) - WG level
  - **NP** (New Proposal)
  - **CD** (Committee Draft) → consultation
  - **DIS** (Draft International Standard) → ballot SC level
  - **FDIS** (Final Draft International Standard) → ballot TC level (optional)
  - **IS (International Standard)**
  - *Corrigenda and amendments*

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Example: MPEG DASH (Streaming over HTTP)

ballot SC level

tandard)

→ ballot TC level

(optional)

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Standardization – DASH example

Apple HTTP Live Streaming	Adobe HTTP Dynamic Streaming	Microsoft Smooth Streaming	Others

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Standardization – DASH example

Apple HTTP Live Streaming	Adobe HTTP Dynamic Streaming	Microsoft Smooth Streaming	Others

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Experts agree!

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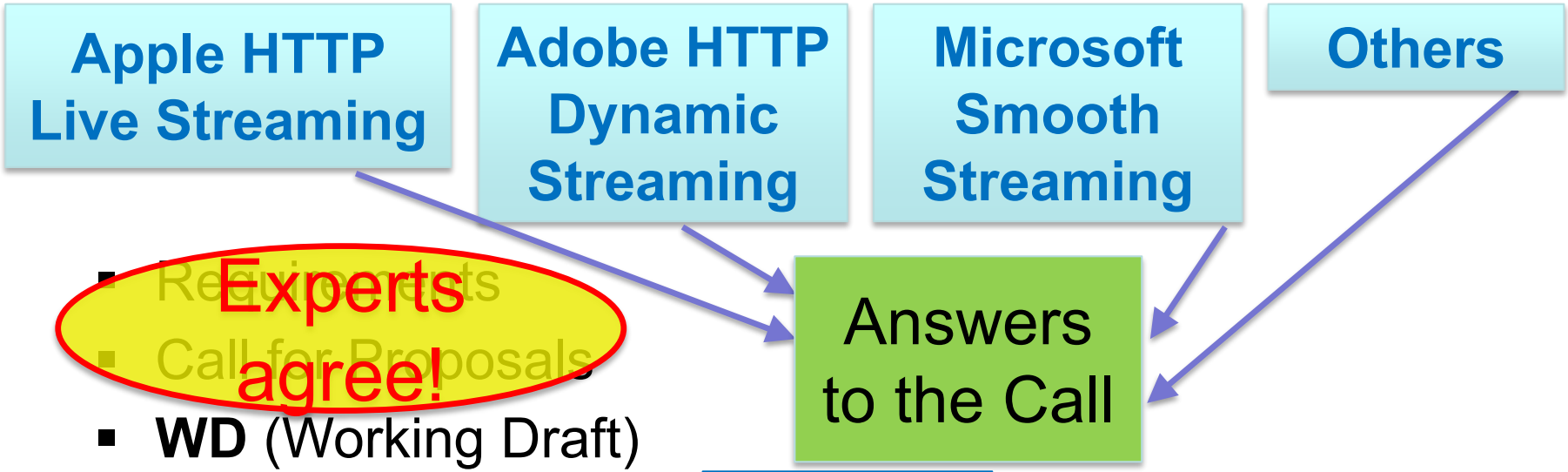
Standardization – DASH example



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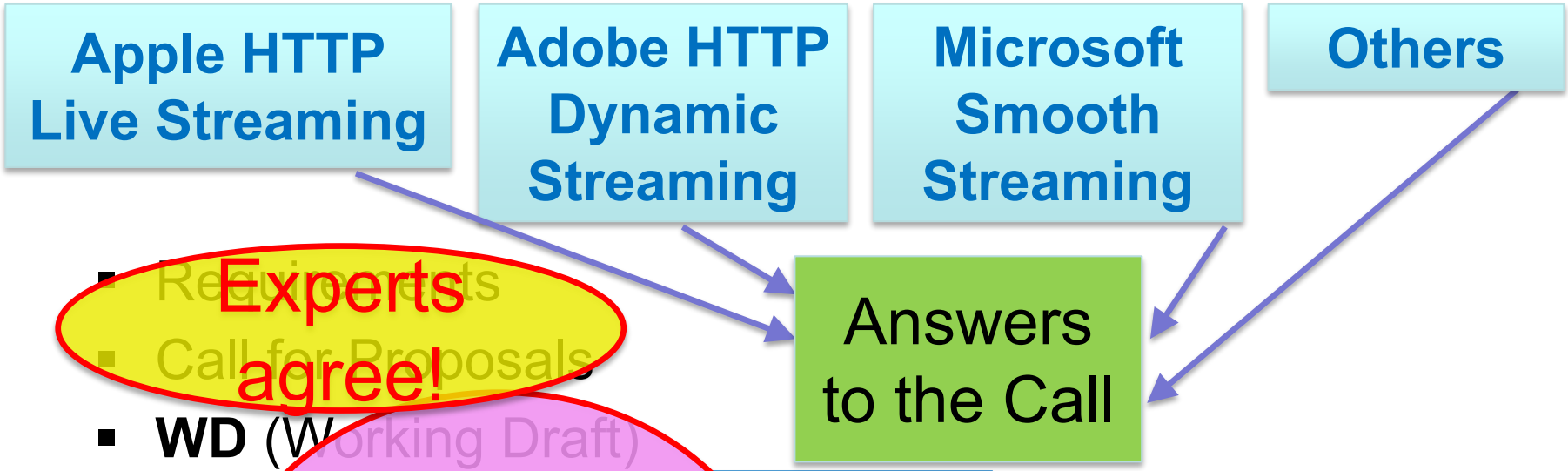
Standardization – DASH example



- Requirements
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- **WD** (Working Draft)
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- **DIS** (Draft International Standard)
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- **IS (International Standard)**

Experts agree!

Several times!

consultation

ballot

ballot

- *Corrigenda and amendments*

DASH Standardization

- ISO/IEC 23009 (Dynamic Adaptive Streaming over HTTP)
- Part 1: Media presentation description and segment formats
- Part 2: Reference software and conformance
- Part 3 (TR): Implementation guidelines
- Part 4: Format Independent Segment encryption and authentication
- Part 5: Server and network assisted DASH (SAND)
- Part 6: DASH with Server Push and WebSockets
- Part 7 (TR): Delivery of CMAF content with DASH
- Part 8: Session based DASH operations
- Part 9: Redundant encoding and packaging for segmented live media (REAP)

DASH Standardization

- Part 1:
  1st edition 2012, 2nd edition 2014, 3rd edition 2019
  4th edition Dec. 2019 ! Several AMDs!
  5th edition 2021 (FDIS May 21) !!! Several AMDs!
  → 6th Edition FDIS Jan 2025
- Part 2: 3rd edition 2020
- Part 3 (TR): 2nd edition 2015. 3rd edition WD 2018
- Part 4: 2nd edition 2018
- Part 5: 2017. AMD in 2020
- Part 6: 2017
- Part 7 (TR): WD 2018 → 2025
- Part 8: 2021; 2nd edition 2022
- Part 9: FDIS Nov 2024

HETEROGENEOUS DEVICES

Desktop/Laptop

Mobile

Living Room

Web-based video

- User Frustration in Web-based Video

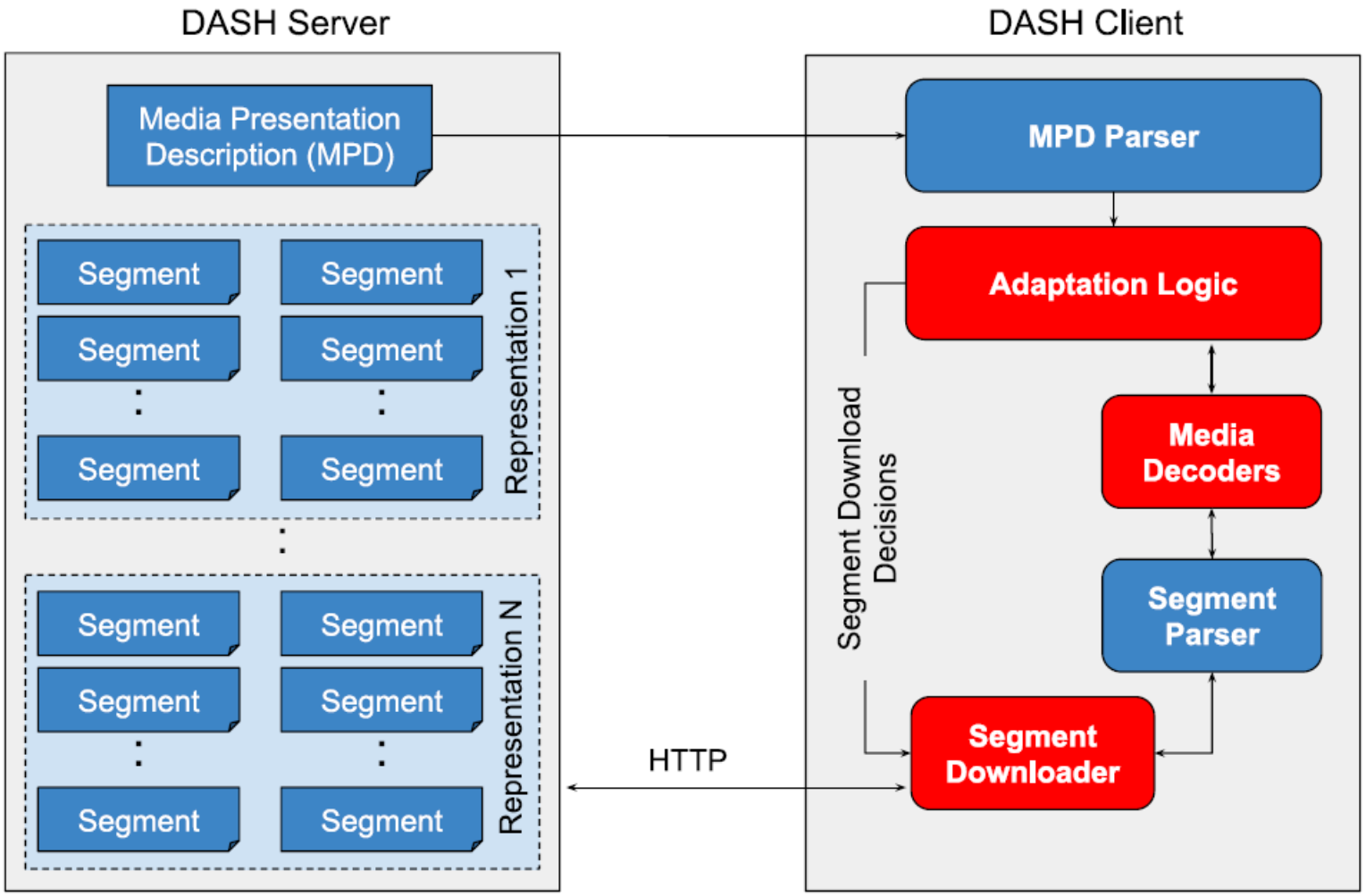
• Video not accessible – Behind a firewall – Plugin not available – Bandwidth not sufficient – Wrong/non-trusted device – Wrong format • Fragmentation – Devices – Content Formats – DRMs	• Low quality of experience – Long start-up delay – Frequent re-buffering – Low playback quality – No lip-sync – No DVD quality (language, subtitle) • Expensive – Eats my bandwidth – Needs a dedicated device – etc.

- SOLUTION → Standard:
  Dynamic Adaptive Streaming over HTTP (DASH)

DASH

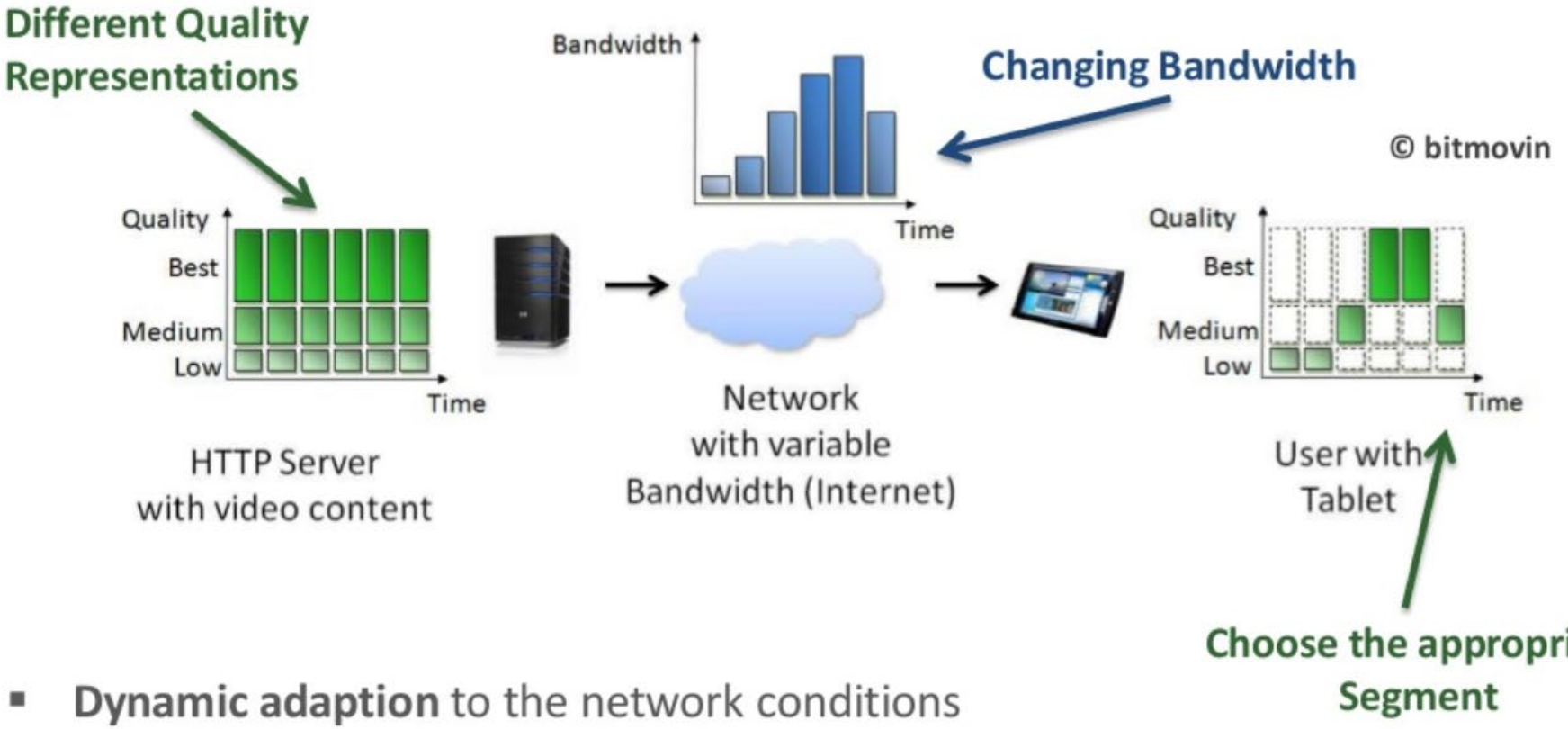
- Architecture
  - "Classic" web server
  - Client downloads 2 kinds of files:
    - **MPD: Media Presentation Description**
    - Files with the content described in the MPD:
      - Different qualities (bit rates)
      - Several languages
  - Client manages all content download process, continuously calculating the bandwidth
- Standard still being extended (6th edition)

DASH architecture components



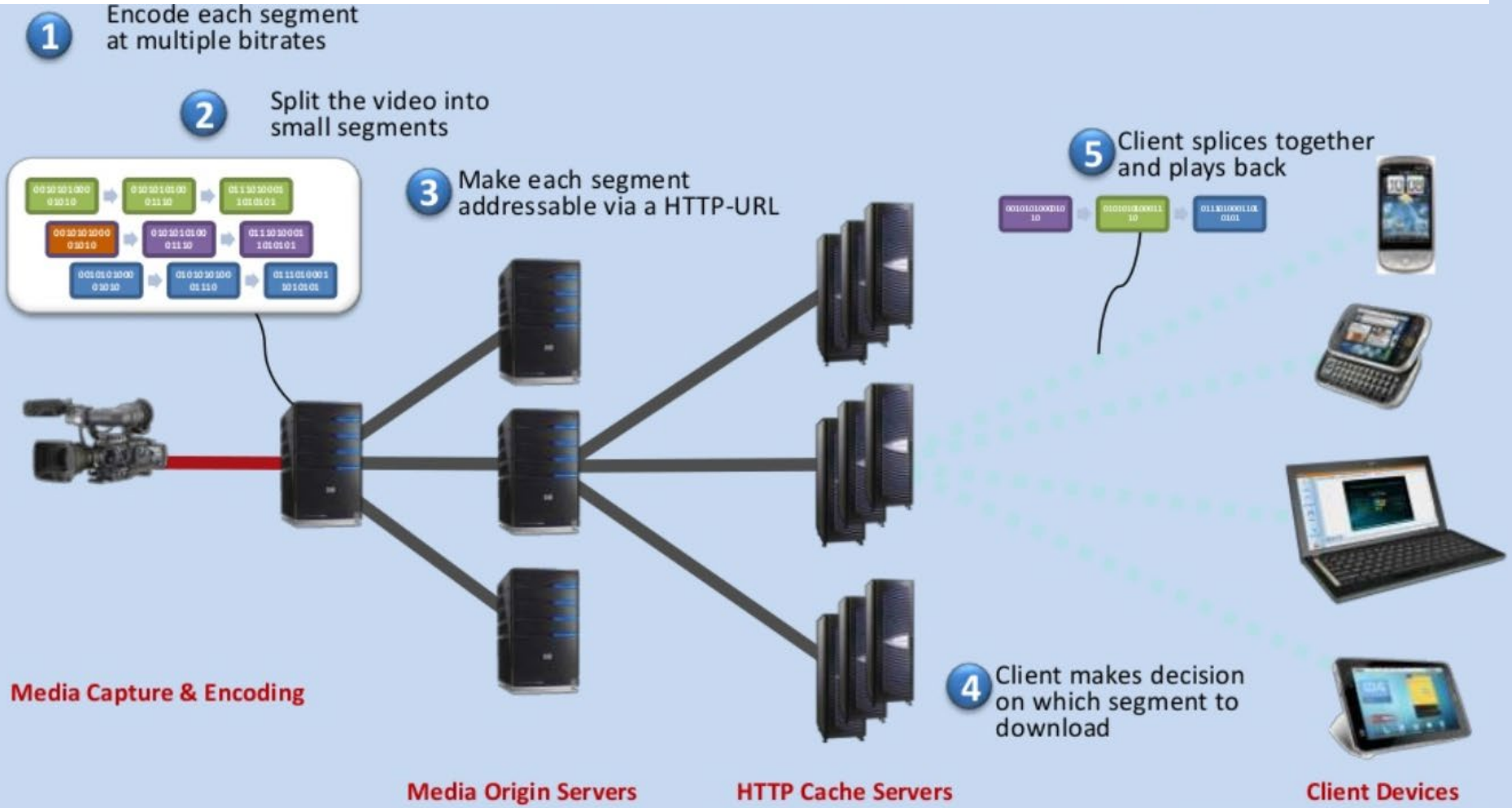
From IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 21, NO. 1, FIRST QUARTER 2019

DYNAMIC ADAPTIVE STREAMING OVER HTTP



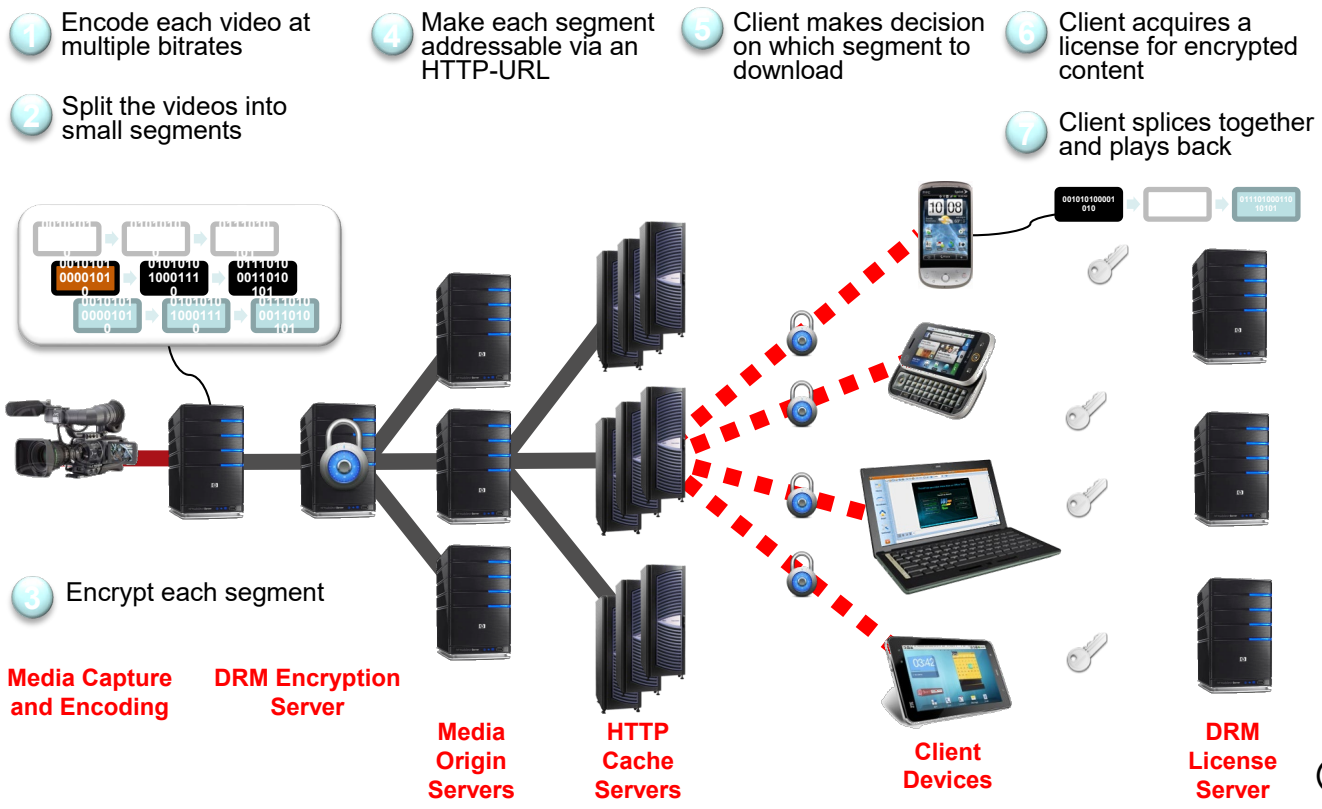
- **Dynamic adaption** to the network conditions
- Usage of existing and cheap **Internet (HTTP) Infrastructure**
- Streaming-Logic is located at the **Client**
- **Flexible** and **scalable**

HTTP Adaptive Streaming

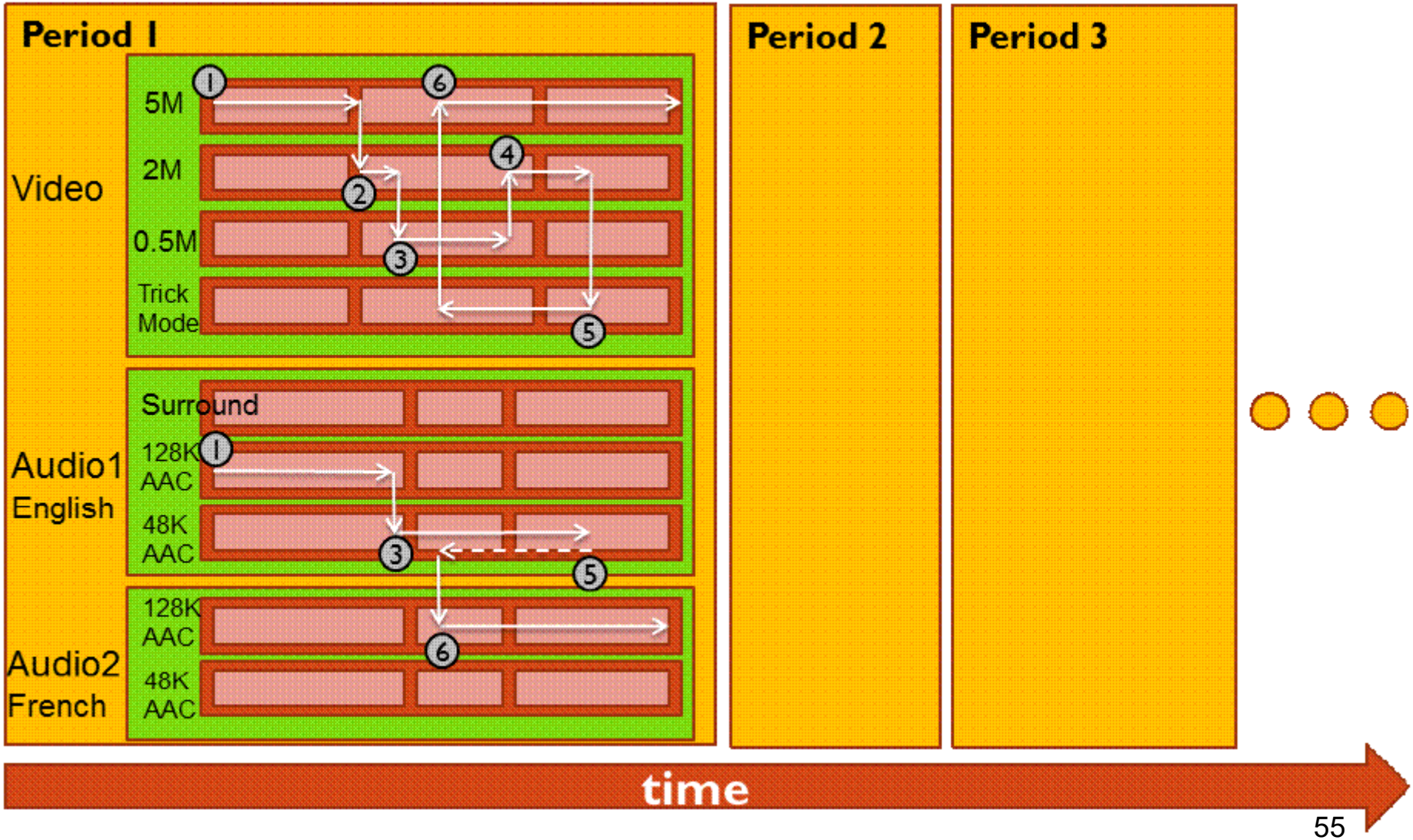


digital primates

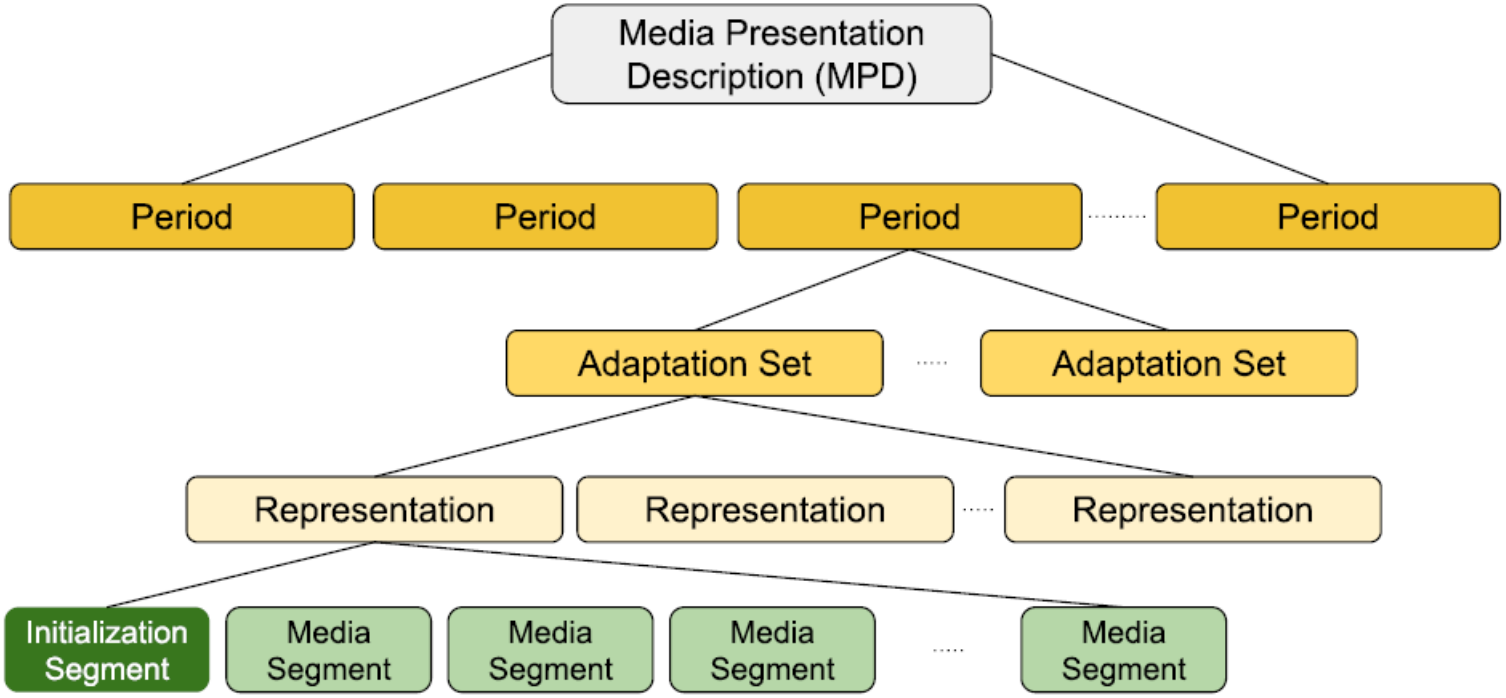
Adaptive Streaming - Protection



DASH

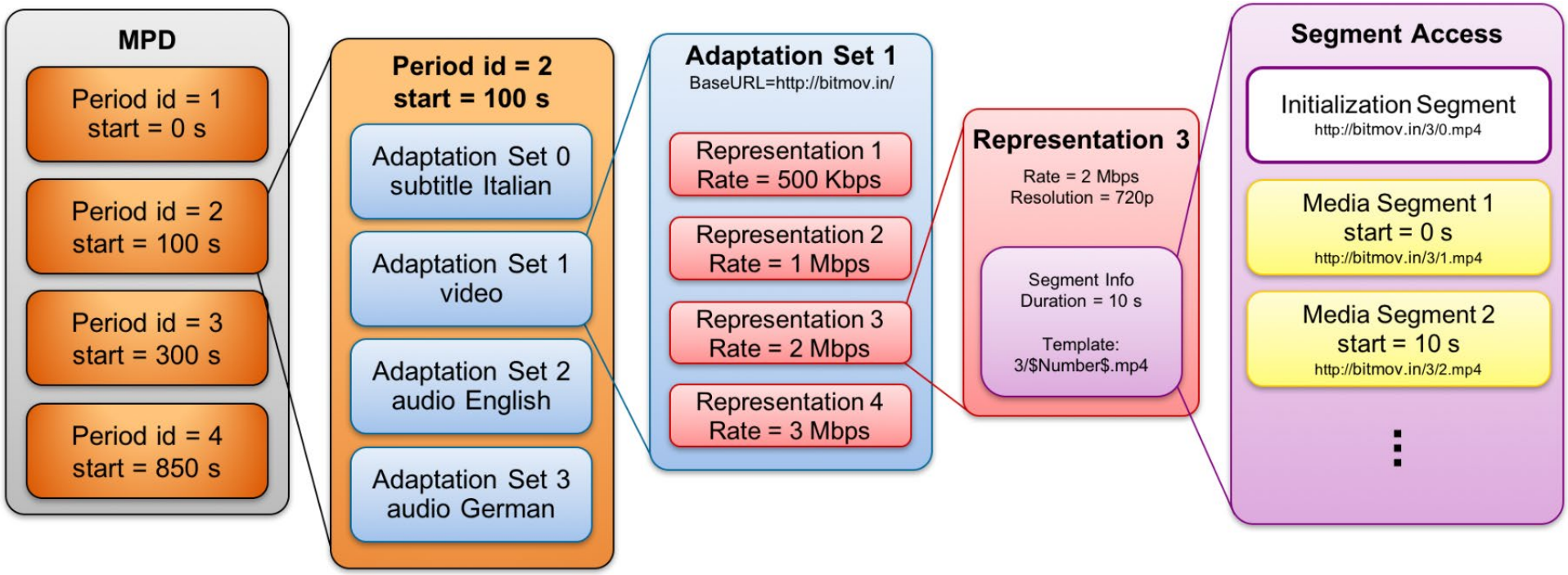

Period 1
Period 2
Period 3
Video
5M
2M
0.5M
Trick Mode
Audio1
English
Surround
128K AAC
48K AAC
Audio2
French
128K AAC
48K AAC
1
2
3
4
5
6
time

DASH - MPD Structure



From IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 21, NO. 1, FIRST QUARTER 2019

DASH - MPD Structure



From bitmovin.com

DASH

- Media Presentation Description (**MPD**)
  - XML file
  - Hierarchical model
  - 1st level: **Period**, part of a programme
  - 2nd level: **Adaptation Set**, versions of one or more multimedia components
  - 3rd level: **Representation**, different representations of the same component
  - 4th level: **Segment**, media chunk streams following a temporal sequence
- Kinds of Streams supported
  - ISO base media file format
  - MPEG-2 TS

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- Media Presentation Description (**MPD**)
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- Kinds of Streams supported
  - ISO base media file format
  - MPEG-2 TS

Containers / File formats

DASH MPD Schema (1/6)

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema targetNamespace="urn:mpeg:DASH:schema:MPD:2011"
  attributeFormDefault="unqualified"
  elementFormDefault="qualified"
  xmlns:xs="http://www.w3.org/2001/XMLSchema"
  xmlns:xlink="http://www.w3.org/1999/xlink"
  xmlns="urn:mpeg:DASH:schema:MPD:2011">

  <xs:import namespace="http://www.w3.org/1999/xlink" schemaLocation="xlink.xsd"/>

  <xs:annotation>
    <xs:appinfo>Media Presentation Description</xs:appinfo>
    <xs:documentation xml:lang="en">
      This Schema defines the Media Presentation Description for MPEG-DASH.
    </xs:documentation>
  </xs:annotation>

  <!-- MPD: main element -->
  <xs:element name="MPD" type="MPDtype"/>

  <!-- MPD Type -->
```

DASH MPD Schema (2/6)

```
  <!-- MPD Type -->
  <xs:complexType name="MPDtype">
    <xs:sequence>
      <xs:element name="ProgramInformation" type="ProgramInformationType" minOccurs="0"
maxOccurs="unbounded"/>
      <xs:element name="BaseURL" type="BaseURLType" minOccurs="0" maxOccurs="unbounded"/>
      <xs:element name="Location" type="xs:anyURI" minOccurs="0" maxOccurs="unbounded"/>
      <xs:element name="Period" type="PeriodType" maxOccurs="unbounded"/>
      <xs:element name="Metrics" type="MetricsType" minOccurs="0" maxOccurs="unbounded"/>
      <xs:element name="EssentialProperty" type="DescriptorType" minOccurs="0"
maxOccurs="unbounded"/>
      <xs:element name="SupplementalProperty" type="DescriptorType" minOccurs="0"
maxOccurs="unbounded"/>
      <xs:element name="UTCTiming" type="DescriptorType" minOccurs="0"
maxOccurs="unbounded"/>
       <xs:any namespace="##other" processContents="lax" minOccurs="0"
maxOccurs="unbounded"/>
    </xs:sequence>
    <xs:attribute name="id" type="xs:string"/>
    <xs:attribute name="profiles" type="xs:string" use="required"/>
    <xs:attribute name="type" type="PresentationType" default="static"/>
    <xs:attribute name="availabilityStartTime" type="xs:dateTime"/>
    <xs:attribute name="availabilityEndTime" type="xs:dateTime"/>
    <xs:attribute name="publishTime" type="xs:dateTime"/>
    <xs:attribute name="mediaPresentationDuration" type="xs:duration"/>
    <xs:attribute name="minimumUpdatePeriod" type="xs:duration"/>
    <xs:attribute name="minBufferTime" type="xs:duration" use="required"/>
    <xs:attribute name="timeShiftBufferDepth" type="xs:duration"/>
    <xs:attribute name="suggestedPresentationDelay" type="xs:duration"/>
    <xs:attribute name="maxSegmentDuration" type="xs:duration"/>
    <xs:attribute name="maxSubsegmentDuration" type="xs:duration"/>
    <xs:anyAttribute namespace="##other" processContents="lax"/>
  </xs:complexType>
```

DASH MPD Schema (3/6)

```
  <!-- Period -->
  <xs:complexType name="PeriodType">
    <xs:sequence>
      <xs:element name="BaseURL" type="BaseURLType" minOccurs="0"
maxOccurs="unbounded"/>
      <xs:element name="SegmentBase" type="SegmentBaseType" minOccurs="0"/>
      <xs:element name="SegmentList" type="SegmentListType" minOccurs="0"/>
      <xs:element name="SegmentTemplate" type="SegmentTemplateType" minOccurs="0"/>
      <xs:element name="AssetIdentifier" type="DescriptorType" minOccurs="0"/>
      <xs:element name="EventStream" type="EventStreamType" minOccurs="0"
maxOccurs="unbounded"/>
      <xs:element name="AdaptationSet" type="AdaptationSetType" minOccurs="0"
maxOccurs="unbounded"/>
      <xs:element name="Subset" type="SubsetType" minOccurs="0" maxOccurs="unbounded"/>
      <xs:element name="SupplementalProperty" type="DescriptorType" minOccurs="0"
maxOccurs="unbounded"/>
      <xs:any namespace="##other" processContents="lax" minOccurs="0"
maxOccurs="unbounded"/>
    </xs:sequence>
    <xs:attribute ref="xlink:href"/>
    <xs:attribute ref="xlink:actuate" default="onRequest"/>
    <xs:attribute name="id" type="xs:string" />
    <xs:attribute name="start" type="xs:duration"/>
    <xs:attribute name="duration" type="xs:duration"/>
    <xs:attribute name="bitstreamSwitching" type="xs:boolean" default="false"/>
    <xs:anyAttribute namespace="##other" processContents="lax"/>
  </xs:complexType>

  <!-- Adaptation Set -->
```

DASH MPD Schema (4/6)

```
  <!-- Event Stream -->
  <xs:complexType name="EventStreamType">
    <xs:sequence>
      <xs:element name="Event" type="EventType" minOccurs="0" maxOccurs="unbounded"/>
      <xs:any namespace="##other" processContents="lax" minOccurs="0"
maxOccurs="unbounded"/>
    </xs:sequence>
    <xs:attribute ref="xlink:href"/>
    <xs:attribute ref="xlink:actuate" default="onRequest"/>
    <xs:attribute name="schemeIdUri" type="xs:anyURI" use="required"/>
    <xs:attribute name="value" type="xs:string"/>
    <xs:attribute name="timescale" type="xs:unsignedInt"/>
  </xs:complexType>


  <!-- Event  -->
  <xs:complexType name="EventType">
    <xs:sequence>
      <xs:any namespace="##other" processContents="lax" minOccurs="0"
maxOccurs="unbounded"/>
    </xs:sequence>
      <xs:attribute name="presentationTime" type="xs:unsignedLong" default="0"/>
      <xs:attribute name="duration" type="xs:unsignedLong"/>
      <xs:attribute name="id" type="xs:unsignedInt"/>
      <xs:attribute name="messageData" type="xs:string"/>
    <xs:anyAttribute namespace="##other" processContents="lax"/>
  </xs:complexType>

  <!-- Adaptation Set -->
```

DASH MPD Schema (5/6)

```
 <!-- Adaptation Set -->
<xs:complexType name="AdaptationSetType">
  <xs:complexContent>
    <xs:extension base="RepresentationBaseType">
      <xs:sequence>
        <xs:element name="Accessibility" type="DescriptorType" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="Role" type="DescriptorType" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="Rating" type="DescriptorType" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="Viewpoint" type="DescriptorType" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="ContentComponent" type="ContentComponentType" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="BaseURL" type="BaseURLType" minOccurs="0" maxOccurs="unbounded"/>
        <xs:element name="SegmentBase" type="SegmentBaseType" minOccurs="0"/>
        <xs:element name="SegmentList" type="SegmentListType" minOccurs="0"/>
        <xs:element name="SegmentTemplate" type="SegmentTemplateType" minOccurs="0"/>
        <xs:element name="Representation" type="RepresentationType" minOccurs="0" maxOccurs="unbounded"/>
      </xs:sequence>
      <xs:attribute ref="xlink:href"/>
      <xs:attribute ref="xlink:actuate" default="onRequest"/>
      <xs:attribute name="id" type="xs:unsignedInt"/>
      <xs:attribute name="group" type="xs:unsignedInt"/>
      <xs:attribute name="lang" type="xs:language"/>
      <xs:attribute name="contentType" type="xs:string"/>
      <xs:attribute name="par" type="RatioType"/>
      <xs:attribute name="minBandwidth" type="xs:unsignedInt"/>
      <xs:attribute name="maxBandwidth" type="xs:unsignedInt"/>
      <xs:attribute name="minWidth" type="xs:unsignedInt"/>
      <xs:attribute name="maxWidth" type="xs:unsignedInt"/>
      <xs:attribute name="minHeight" type="xs:unsignedInt"/>
      <xs:attribute name="maxHeight" type="xs:unsignedInt"/>
      <xs:attribute name="minFrameRate" type="FrameRateType"/>
      <xs:attribute name="maxFrameRate" type="FrameRateType"/>
      <xs:attribute name="segmentAlignment" type="ConditionalUintType" default="false"/>
      <xs:attribute name="subsegmentAlignment" type="ConditionalUintType" default="false"/>
      <xs:attribute name="subsegmentStartsWithSAP" type="SAPType" default="0"/>
      <xs:attribute name="bitstreamSwitching" type="xs:boolean"/>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>
...
 <!-- Representation -->
```

DASH MPD Schema (6/6)

```
  <!-- Representation -->
  <xs:complexType name="RepresentationType">
    <xs:complexContent>
      <xs:extension base="RepresentationBaseType">
        <xs:sequence>
          <xs:element name="BaseURL" type="BaseURLType" minOccurs="0"
maxOccurs="unbounded"/>
          <xs:element name="SubRepresentation" type="SubRepresentationType" minOccurs="0"
maxOccurs="unbounded"/>
          <xs:element name="SegmentBase" type="SegmentBaseType" minOccurs="0"/>
          <xs:element name="SegmentList" type="SegmentListType" minOccurs="0"/>
          <xs:element name="SegmentTemplate" type="SegmentTemplateType" minOccurs="0"/>
        </xs:sequence>
        <xs:attribute name="id" type="StringNoWhitespaceType" use="required"/>
        <xs:attribute name="bandwidth" type="xs:unsignedInt" use="required"/>
        <xs:attribute name="qualityRanking" type="xs:unsignedInt"/>
        <xs:attribute name="dependencyId" type="StringVectorType"/>
        <xs:attribute name="mediaStreamStructureId" type="StringVectorType"/>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>

...

</xs:schema>
```

DASH MPD example

```
<?xml version="1.0" encoding="utf-8"?>
<MPD xmlns="urn:mpeg:dash:schema:mpd:2011" minBufferTime="PT1.500000S" type="static“
mediaPresentationDuration="PT0H10M54.00S" profiles="urn:mpeg:dash:profile:isoff-live:2011,http://dashif.org/guidelines/dash264">
  <ProgramInformation moreInformationURL="http://gpac.sourceforge.net">
    <Title>/home/elkhatib/Documents/dash264/TestCasesHD/2b/qualcomm/ED_2Sec_MultiRes_HighProf/MultiResMPEG2.mpd generated by GPAC</Title>
  </ProgramInformation>
  <Period id="" duration="PT0H10M54.00S">
    <AdaptationSet segmentAlignment="true" maxWidth="1920" maxHeight="1080" maxFrameRate="24" par="16:9">
      <Representation id="1" mimeType="video/mp4" codecs="avc1.640028" width="512" height="288" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="1196512">
        <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_512_640K_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_512_640K_MPEG2_video_init.mp4" />
      </Representation>
      <Representation id="2" mimeType="video/mp4" codecs="avc1.640028" width="768" height="432" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="1951761">
        <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_768_1440K_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_768_1440K_MPEG2_video_init.mp4" />
      </Representation>
      <Representation id="3" mimeType="video/mp4" codecs="avc1.640028" width="1280" height="720" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="4118235">
        <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_1280_4M_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_1280_4M_MPEG2_video_init.mp4" />
      </Representation>
      <Representation id="4" mimeType="video/mp4" codecs="avc1.640028" width="1920" height="1080" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="7953041">
        <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_1920_8M_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_1920_8M_MPEG2_video_init.mp4" />
      </Representation>
    </AdaptationSet>
    <AdaptationSet segmentAlignment="true">
      <Representation id="5" mimeType="audio/mp4" codecs="mp4a.40.29" audioSamplingRate="48000" startWithSAP="1" bandwidth="33432">
        <AudioChannelConfiguration schemeIdUri="urn:mpeg:dash:23003:3:audio_channel_configuration:2011" value="2" />
        <SegmentTemplate timescale="48000" duration="94175" media="ED_MPEG2_32k_$Number$.mp4" startNumber="1"
initialization="ED_MPEG2_32k_init.mp4" />
      </Representation>
    </AdaptationSet>
  </Period>
</MPD>
```

DASH MPD example

```
<?xml version="1.0" encoding="utf-8"?>
<MPD xmlns="urn:mpeg:dash:schema:mpd:2011" minBufferTime="PT1.500000S" type="static"
mediaPresentationDuration="PT0H10M54.00S" profiles="urn:mpeg:dash:profile:isoff-live:2011,http://dashif.org/guidelines/dash264">
  <ProgramInformation moreInformationURL="http://gpac.sourceforge.net">
    <Title>/home/elkhatib/Documents/dash264/TestCasesHD/2b/qualcomm/ED_2Sec_MultiRes_HighProf/MultiResMPEG2.mpd generated by GPAC</Title>
  </ProgramInformation>
  <Period id="" duration="PT0H10M54.00S">
    <AdaptationSet segmentAlignment="true" maxWidth="1920" maxHeight="1080" maxFrameRate="24" par="16:9">
      <Representation id="1" mimeType="video/mp4" codecs="avc1.640028" width="512" height="288" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="1196512">
        <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_512_640K_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_512_640K_MPEG2_video_init.mp4" />
      </Representation>
      <Representation id="2" mimeType="video/mp4" codecs="avc1.640028" width="768" height="432" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="1951761">
        <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_768_1440K_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_768_1440K_MPEG2_video_init.mp4" />
      </Representation>
      <Representation id="3" mimeType="video/mp4" codecs="avc1.640028" width="1280" height="720" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="4118235">
        <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_1280_4M_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_1280_4M_MPEG2_video_init.mp4" />
      </Representation>
      <Representation id="4" mimeType="video/mp4" codecs="avc1.640028" width="1920" height="1080" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="7953041">
        <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_1920_8M_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_1920_8M_MPEG2_video_init.mp4" />
      </Representation>
    </AdaptationSet>
    <AdaptationSet segmentAlignment="true">
      <Representation id="5" mimeType="audio/mp4" codecs="mp4a.40.29" audioSamplingRate="48000" startWithSAP="1" bandwidth="33432">
        <AudioChannelConfiguration schemeIdUri="urn:mpeg:dash:23003:3:audio_channel_configuration:2011" value="2" />
        <SegmentTemplate timescale="48000" duration="94175" media="ED_MPEG2_32k_$Number$.mp4" startNumber="1"
initialization="ED_MPEG2_32k_init.mp4" />
      </Representation>
    </AdaptationSet>
  </Period>
</MPD>
```

Adaptation Set

Adaptation Set

DASH MPD example

```
<?xml version="1.0" encoding="utf-8"?>
<MPD xmlns="urn:mpeg:dash:schema:mpd:2011" minBufferTime="PT1.500000S" type="static"
mediaPresentationDuration="PT0H10M54.00S" profiles="urn:mpeg:dash:profile:isoff-live:2011,http://dashif.org/guidelines/dash264">
 <ProgramInformation moreInformationURL="http://gpac.sourceforge.net">
  <Title>/home/elkhatib/Documents/dash264/TestCasesHD/2b/qualcomm/ED_2Sec_MultiRes_HighProf/MultiResMPEG2.mpd generated by GPAC</Title>
 </ProgramInformation>
 <Period id="" duration="PT0H10M54.00S">
  <AdaptationSet segmentAlignment="true" maxWidth="1920" maxHeight="1080" maxFrameRate="24" par="16:9">
   <Representation id="1" mimeType="video/mp4" codecs="avc1.640028" width="512" height="288" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="1196512">
    <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_512_640K_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_512_640K_MPEG2_video_init.mp4" />
   </Representation>
   <Representation id="2" mimeType="video/mp4" codecs="avc1.640028" width="768" height="432" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="1951761">
    <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_768_1440K_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_768_1440K_MPEG2_video_init.mp4" />
   </Representation>
   <Representation id="3" mimeType="video/mp4" codecs="avc1.640028" width="1280" height="720" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="4118235">
    <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_1280_4M_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_1280_4M_MPEG2_video_init.mp4" />
   </Representation>
   <Representation id="4" mimeType="video/mp4" codecs="avc1.640028" width="1920" height="1080" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="7953041">
    <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_1920_8M_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_1920_8M_MPEG2_video_init.mp4" />
   </Representation>
  </AdaptationSet>
  <AdaptationSet segmentAlignment="true">
   <Representation id="5" mimeType="audio/mp4" codecs="mp4a.40.29" audioSamplingRate="48000" startWithSAP="1" bandwidth="33432">
    <AudioChannelConfiguration schemeIdUri="urn:mpeg:dash:23003:3:audio_channel_configuration:2011" value="2" />
    <SegmentTemplate timescale="48000" duration="94175" media="ED_MPEG2_32k_$Number$.mp4" startNumber="1"
initialization="ED_MPEG2_32k_init.mp4" />
   </Representation>
  </AdaptationSet>
 </Period>
</MPD>
```

DASH MPD example

```
<?xml version="1.0" encoding="utf-8"?>
<MPD xmlns="urn:mpeg:dash:schema:mpd:2011" minBufferTime="PT1.500000S" type="static"
mediaPresentationDuration="PT0H10M54.00S" profiles="urn:mpeg:dash:profile:isoff-live:2011,http://dashif.org/guidelines/dash264">
 <ProgramInformation moreInformationURL="http://gpac.sourceforge.net">
  <Title>/home/elkhatib/Documents/dash264/TestCasesHD/2b/qualcomm/ED_2Sec_MultiRes_HighProf/MultiResMPEG2.mpd generated by GPAC</Title>
 </ProgramInformation>
 <Period id="" duration="PT0H10M54.00S">
  <AdaptationSet segmentAlignment="true" maxWidth="1920" maxHeight="1080" maxFrameRate="24" par="16:9">
   <Representation id="1" mimeType="video/mp4" codecs="avc1.640028" width="512" height="288" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="1196512">
    <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_512_640K_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_512_640K_MPEG2_video_init.mp4" />
   </Representation>
   <Representation id="2" mimeType="video/mp4" codecs="avc1.640028" width="768" height="432" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="1951761">
    <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_768_1440K_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_768_1440K_MPEG2_video_init.mp4" />
   </Representation>
   <Representation id="3" mimeType="video/mp4" codecs="avc1.640028" width="1280" height="720" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="4118235">
    <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_1280_4M_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_1280_4M_MPEG2_video_init.mp4" />
   </Representation>
   <Representation id="4" mimeType="video/mp4" codecs="avc1.640028" width="1920" height="1080" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="7953041">
    <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_1920_8M_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_1920_8M_MPEG2_video_init.mp4" />
   </Representation>
  </AdaptationSet>
  <AdaptationSet segmentAlignment="true">
   <Representation id="5" mimeType="audio/mp4" codecs="mp4a.40.29" audioSamplingRate="48000" startWithSAP="1" bandwidth="33432">
    <AudioChannelConfiguration schemeIdUri="urn:mpeg:dash:23003:3:audio_channel_configuration:2011" value="2" />
    <SegmentTemplate timescale="48000" duration="94175" media="ED_MPEG2_32k_$Number$.mp4" startNumber="1"
initialization="ED_MPEG2_32k_init.mp4" />
   </Representation>
  </AdaptationSet>
 </Period>
</MPD>
```

Segment Indexing

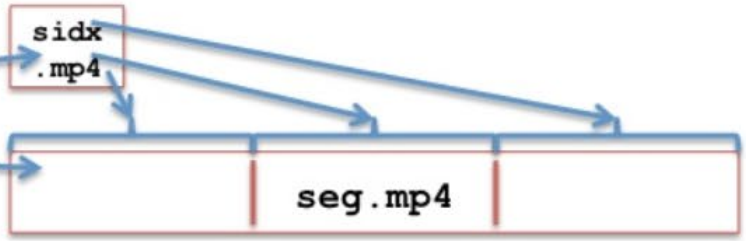
Segment Index in MPD only

```
<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>
```

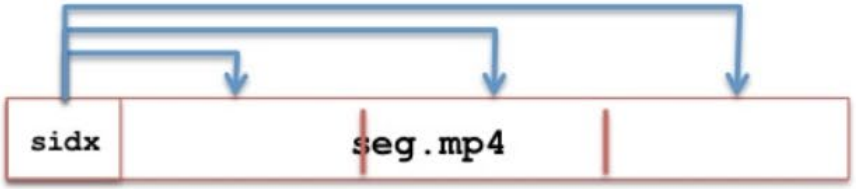
Segment Index in MPD + Segment

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



Segment Index in Segment only

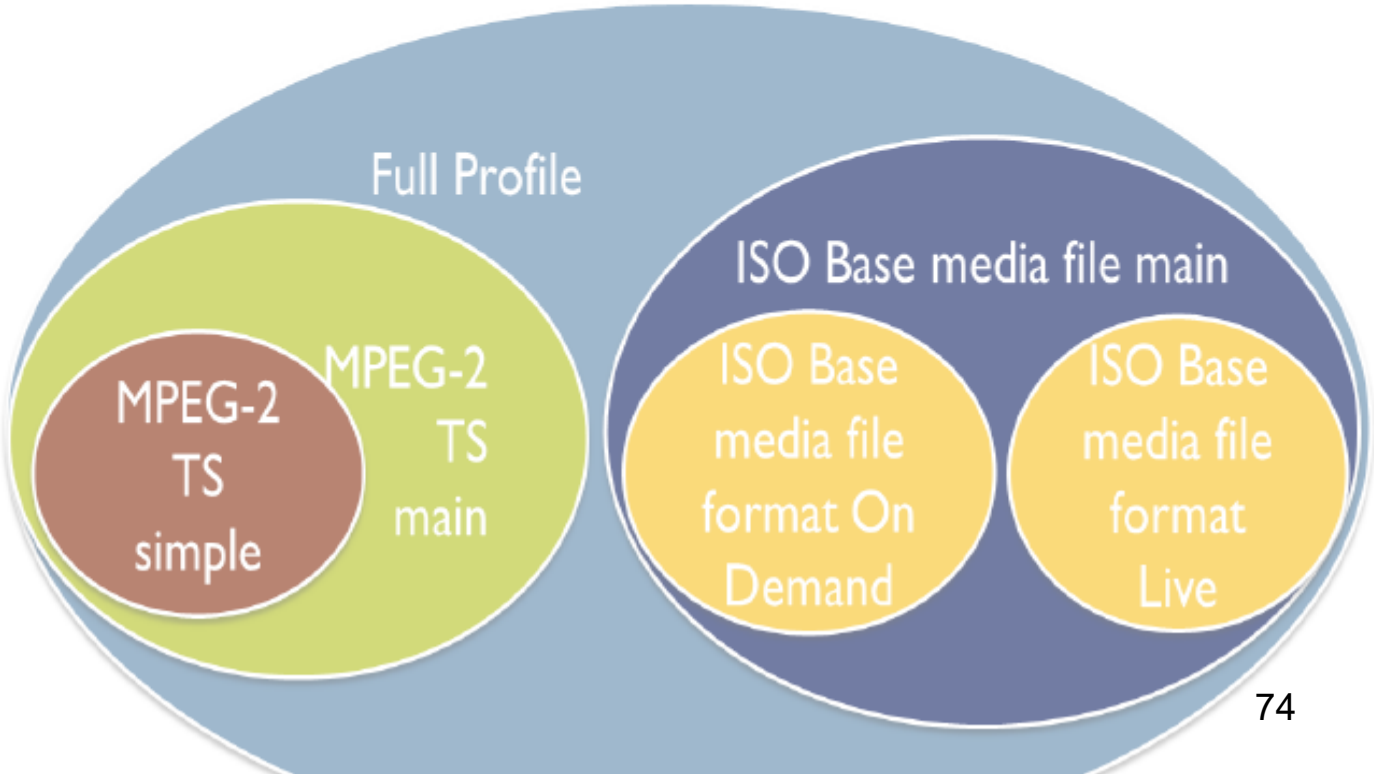
```
<MPD>
  ...
  <BaseURL>seg.mp4</BaseURL>
</MPD>
```



DASH

Profiles

- Set of restrictions on the Media Presentation (MPD & Segments)
- Permission for DASH clients that only implement the required features
- 6 Profiles defined in ISO/IEC 23009:



DASH MPD example

```
<?xml version="1.0" encoding="utf-8"?>
<MPD xmlns="urn:mpeg:dash:schema:mpd:2011" minBufferTime="PT1.500000S" type="static"
mediaPresentationDuration="PT0H10M54.00S" profiles="urn:mpeg:dash:profile:isoff-live:2011,http://dashif.org/guidelines/dash264">
  <ProgramInformation moreInformationURL="http://gpac.sourceforge.net">
    <Title>/home/elkhatib/Documents/dash264/TestCasesHD/2b/qualcomm/ED_2Sec_MultiRes_HighProf/MultiResMPEG2.mpd generated by GPAC</Title>
  </ProgramInformation>
  <Period id="" duration="PT0H10M54.00S">
    <AdaptationSet segmentAlignment="true" maxWidth="1920" maxHeight="1080" maxFrameRate="24" par="16:9">
      <Representation id="1" mimeType="video/mp4" codecs="avc1.640028" width="512" height="288" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="1196512">
        <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_512_640K_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_512_640K_MPEG2_video_init.mp4" />
      </Representation>
      <Representation id="2" mimeType="video/mp4" codecs="avc1.640028" width="768" height="432" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="1951761">
        <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_768_1440K_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_768_1440K_MPEG2_video_init.mp4" />
      </Representation>
      <Representation id="3" mimeType="video/mp4" codecs="avc1.640028" width="1280" height="720" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="4118235">
        <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_1280_4M_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_1280_4M_MPEG2_video_init.mp4" />
      </Representation>
      <Representation id="4" mimeType="video/mp4" codecs="avc1.640028" width="1920" height="1080" frameRate="24" sar="1:1"
startWithSAP="1" bandwidth="7953041">
        <SegmentTemplate timescale="12288" presentationTimeOffset="1024" duration="24576"
media="ED_1920_8M_MPEG2_video_$Number$.mp4" startNumber="1" initialization="ED_1920_8M_MPEG2_video_init.mp4" />
      </Representation>
    </AdaptationSet>
    <AdaptationSet segmentAlignment="true">
      <Representation id="5" mimeType="audio/mp4" codecs="mp4a.40.29" audioSamplingRate="48000" startWithSAP="1" bandwidth="33432">
        <AudioChannelConfiguration schemeIdUri="urn:mpeg:dash:23003:3:audio_channel_configuration:2011" value="2" />
        <SegmentTemplate timescale="48000" duration="94175" media="ED_MPEG2_32k_$Number$.mp4" startNumber="1"
initialization="ED_MPEG2_32k_init.mp4" />
      </Representation>
    </AdaptationSet>
  </Period>
</MPD>
```

DASH profiles

- Identified with a URN:
  - `urn:mpeg:dash:profile:full:2011`
  - `urn:mpeg:dash:profile:isoff-main:2011`
  - `urn:mpeg:dash:profile:isoff-on-demand:2011`
  - `urn:mpeg:dash:profile:isoff-live:2011`
  - `urn:mpeg:dash:profile:mp2t-main:2011`
  - `urn:mpeg:dash:profile:mp2t-simple:2011`

DASH profiles

- Profiles specified by other SDOs:
  - `urn:3GPP:PSS:profile:DASH11:FPS3D` (ETSI, 2013)
  - `urn:dvb:dash:profile:dvb-dash:2014`
  - `urn:hbbtv:dash:profile:isoff-live:2012`
  - …

Ha sido verificado con un test de software que el → subconjunto del standard funciona

- Interoperability points (DASH Industry Forum): (v4.3, 2018)
  - `https://dashif.org/guidelines/dash264`
  - `https://dashif.org/guidelines/dash264#hd`
  - `https://dashif.org/guidelines/dash-if-main`
  - …

DASH profiles

- Profiles specified by other SDOs:
  - `urn:3GPP:PSS:profile:DASH11:FPS3D` (ETSI, 2013)
  - `urn:dvb:dash:profile:dvb-dash:2014`
  - `urn:hbbtv:dash:profile:isoff-live:2012`
  - …
- Interoperability points (DASH Industry Forum): (v4.3, 2018)
  - `https://dashif.org/guidelines/dash264`
  - `https://dashif.org/guidelines/dash264#hd`
  - `https://dashif.org/guidelines/dash-if-main`
  - …

Just Identifiers!