ENCODING LIVE AND VOD FOR HEVC/HLS

A Joint SLC/RealEyes Production

Agenda

- Our assumptions and goals
- Section I: Introduction to HEVC
- Section II: Introduction to HLS
- Section III: Specification overview: HEVC in HLS
- Section IV: Playback performance and ladder composition
- Section V: Producing HEVC/HLS
    - VOD
    - Live
    - Hardware encoding

Assumptions and Goals

- Assumptions
  - Have some knowledge of how to produce HLS presentations
- Goal: Teach you to *add* HEVC to HLS
  - Encode HEVC
  - Choose an HEVC encoding ladder
  - Integrate that into an HLS presentation
  - With FFmpeg, Bento4 and some third party tools
- Not a soup to nuts, here's how to do HLS session

Section I. Introduction to HEVC

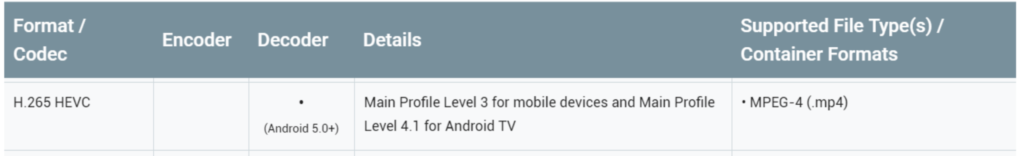
- About HEVC
- HEVC and royalties
- HEVC codecs
- HEVC encoding parameters
- Codec specific encoding profiles

What HEVC Is and Why It’s Important

- HEVC is a standards-based compression technology
- Jointly sponsored by MPEG and ISO standards bodies
  - That’s why it’s called both **HEVC** and **H.265**
- OS support
  - Supported in MacOS via HLS
  - Supported in Windows 10/Edge if hardware decode is available
- Mobile – Android and iOS
- Browser support
  - MacOS/Safari, Windows 8/Edge
  - Not supported in Chrome, Firefox, Opera, or Internet Explorer

Android Support of HEVC

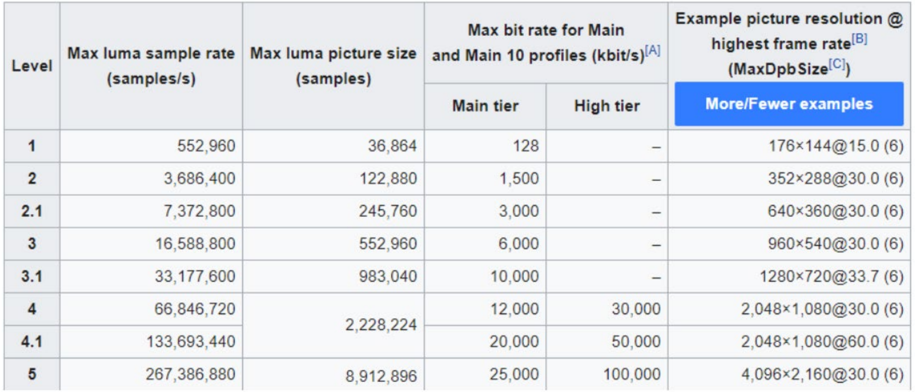
Android OS supports Main Profile Level 3 (Level 4.1 for Android TV)



Format / Codec	Encoder	Decoder	Details	Supported File Type(s) / Container Formats
H.265 HEVC		• (Android 5.0+)	Main Profile Level 3 for mobile devices and Main Profile Level 4.1 for Android TV	• MPEG-4 (.mp4)

Level 3=540p

Apple supports Level 5 (4K/30p)

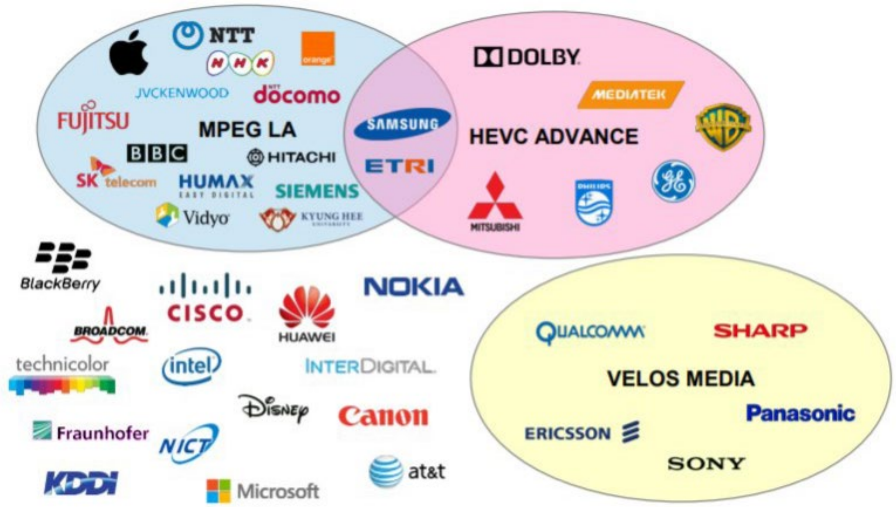


Level	Max luma sample rate (samples/s)	Max luma picture size (samples)	Max bit rate for Main and Main 10 profiles (kbit/s)[A]		Example picture resolution @ highest frame rate[B] (MaxDpbSize[C])
			Main tier	High tier	More/Fewer examples
1	552,960	36,864	128	–	176×144@15.0 (6)
2	3,686,400	122,880	1,500	–	352×288@30.0 (6)
2.1	7,372,800	245,760	3,000	–	640×360@30.0 (6)
3	16,588,800	552,960	6,000	–	960×540@30.0 (6)
3.1	33,177,600	983,040	10,000	–	1280×720@33.7 (6)
4	66,846,720	2,228,224	12,000	30,000	2,048×1,080@30.0 (6)
4.1	133,693,440		20,000	50,000	2,048×1,080@60.0 (6)
5	267,386,880	8,912,896	25,000	100,000	4,096×2,160@30.0 (6)

- Level of HEVC support in Android OS is relatively low
- Likely supported by hardware decode in many devices in US and Europe (but perhaps not in third world countries).

HEVC and Content Royalties

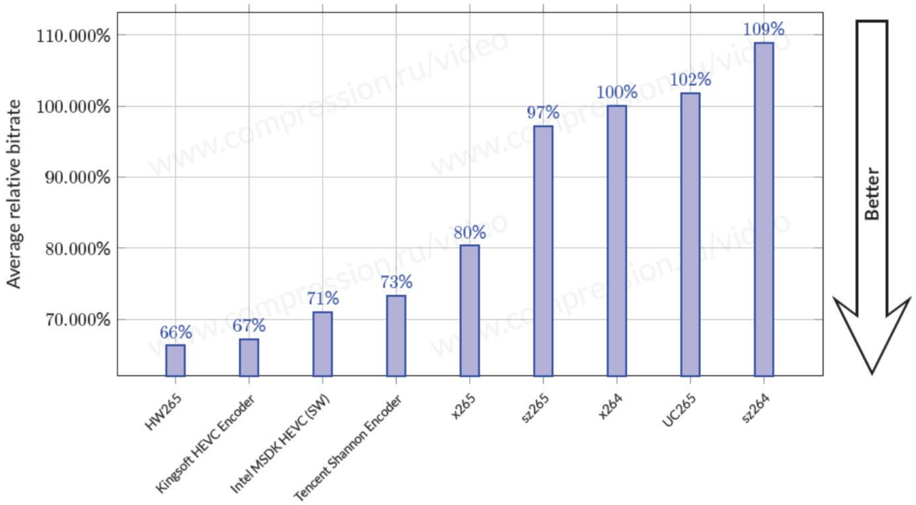
- Three royalty groups (MPEG-LA, HEVC Advance, and Velos)
  - MPEG-LA – no royalties on content
  - HEVC Advance – no royalties on content
  - Velos – may be content royalties
- Technicolor – also owns HEVC IP, but seems focused on larger entities
- Many others undeclared
- Content royalties seem unlikely, but are certainly possible



HEVC Codecs

- Because HEVC is a standard, there are many HEVC codecs
- x265 is the open-source HEVC encoder included with FFmpeg
  - Very accessible; may not be the highest quality
- Many others (Beamr, MainConcept) not included in Moscow State University Study

Moscow State University Codec Rankings



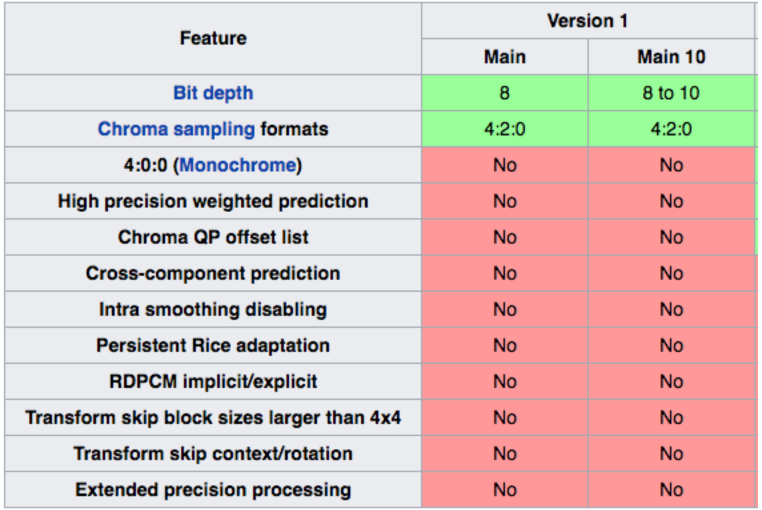
http://www.compression.ru/video/codec_comparison/hevc_2018/

Critical HEVC Encoding Parameters

- Some parameters apply to all H.265 codecs
    - Profiles
        - No matter which HEVC codec you work with, you'll have to set these
    - Levels - ditto
- Some are codec specific
    - Schema for balancing quality and encoding time

What Profiles are and Why They Exist

- Profiles enable different encoding techniques to balance decoding complexity
  - Version 2 codecs use more advanced features
- Apple supports both
  - HLS Authoring spec:
    - “1.6. Profile, Level, and Tier for HEVC MUST be less than or equal to Main10 Profile, Level 5.0, High.”

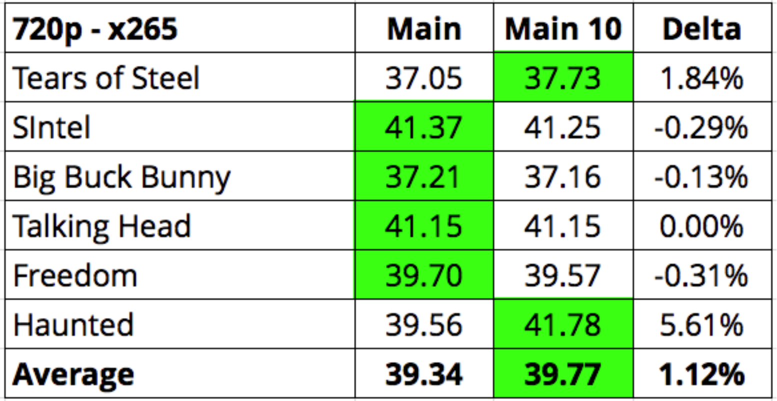


Feature	Version 1	
	Main	Main 10
Bit depth	8	8 to 10
Chroma sampling formats	4:2:0	4:2:0
4:0:0 (Monochrome)	No	No
High precision weighted prediction	No	No
Chroma QP offset list	No	No
Cross-component prediction	No	No
Intra smoothing disabling	No	No
Persistent Rice adaptation	No	No
RDPCM implicit/explicit	No	No
Transform skip block sizes larger than 4x4	No	No
Transform skip context/rotation	No	No
Extended precision processing	No	No

https://en.wikipedia.org/wiki/High_Efficiency_Video_Coding

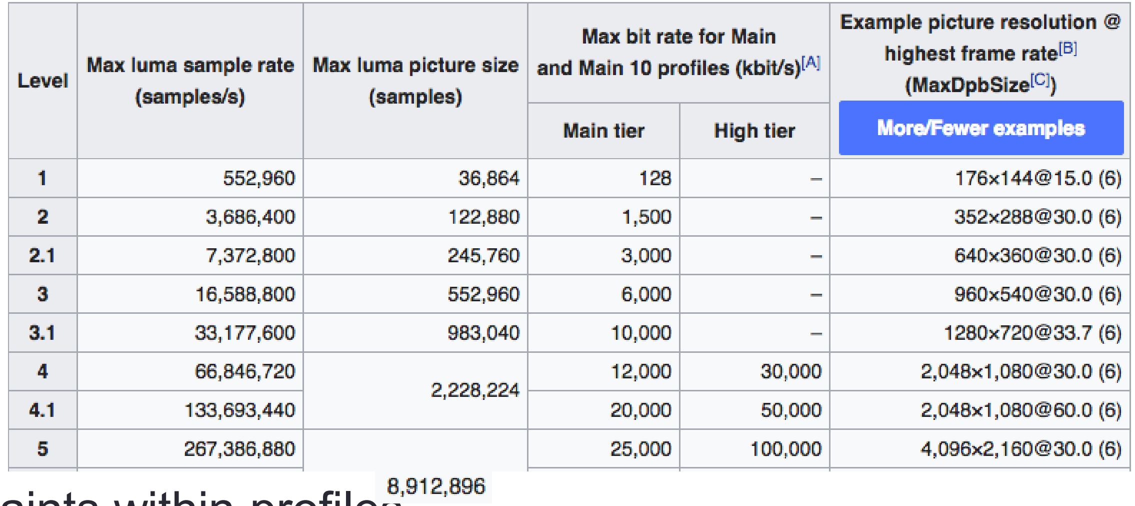
Main or Main10?

- Apple supports both
- Required for HDR
- With 8-bit input, Main 10 has a very slight quality advantage
  - Encode with Main10 when encoding for HLS
  - Standard FFmpeg build may not support Main10
    - My have to compile your own
    - http://www.gregwessels.com/dev/2017/10/27/ffmpeg-x265.html



720p - x265	**Main**	**Main 10**	**Delta**
Tears of Steel	37.05	37.73	1.84%
SIntel	41.37	41.25	-0.29%
Big Buck Bunny	37.21	37.16	-0.13%
Talking Head	41.15	41.15	0.00%
Freedom	39.70	39.57	-0.31%
Haunted	39.56	41.78	5.61%
Average	**39.34**	**39.77**	**1.12%**

HEVC Levels



Level	Max luma sample rate (samples/s)	Max luma picture size (samples)	Max bit rate for Main and Main 10 profiles (kbit/s)[A]		Example picture resolution @ highest frame rate[B] (MaxDpbSize[C])
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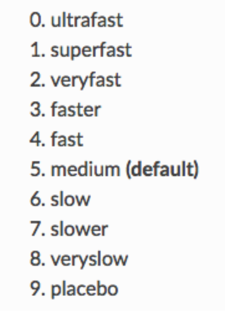
- Set constraints within profiles
- Enable compatibility with lower power devices
- Apple spec:
  - No higher than Main10 Profile, Level 5.0, High Tier (which seems limited to 4K30p
  - Encoding ladder (as you'll see) says same as source for HEVC (HDR is 30p limit)
  - Unresolved issue at this point

Codec Quality/Encoding Time Presets

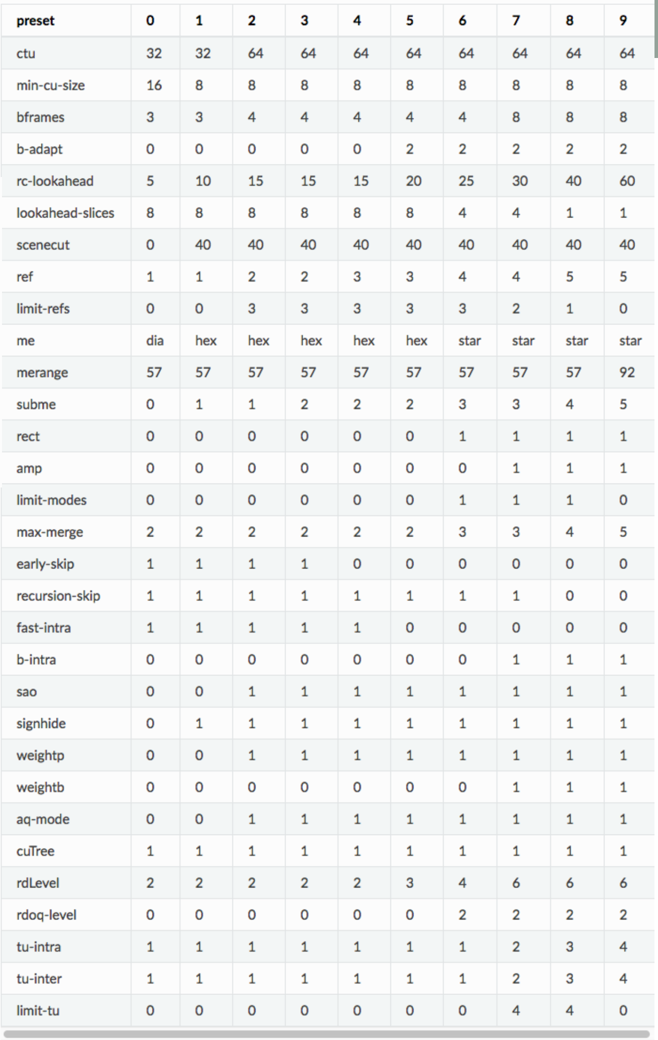
- Different HEVC codecs use different schemas to simplify quality/encoding time tradeoffs
  - x265 uses presets – ultra fast to placebo
  - MainConcept uses a number from 1-28
- What's important is understanding how the mechanism trades off encoding time and quality

x265 Presets

- Same name as x264; different parameters



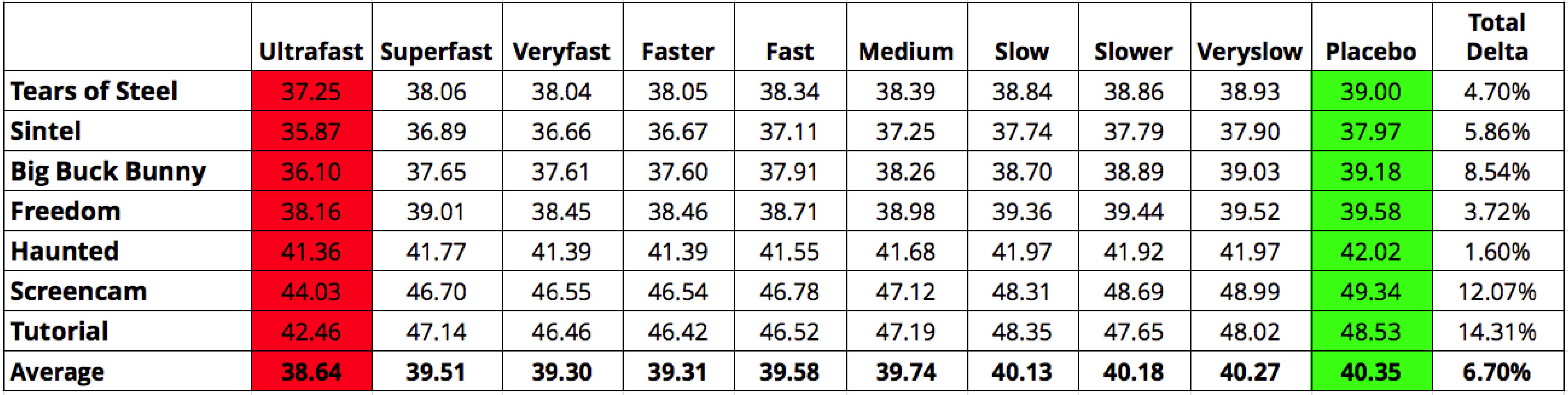
0. ultrafast
1. superfast
2. veryfast
3. faster
4. fast
5. medium **(default)**
6. slow
7. slower
8. veryslow
9. placebo



preset	0	1	2	3	4	5	6	7	8	9
ctu	32	32	64	64	64	64	64	64	64	64
min-cu-size	16	8	8	8	8	8	8	8	8	8
bframes	3	3	4	4	4	4	4	8	8	8
b-adapt	0	0	0	0	0	2	2	2	2	2
rc-lookahead	5	10	15	15	15	20	25	30	40	60
lookahead-slices	8	8	8	8	8	8	4	4	1	1
scenecut	0	40	40	40	40	40	40	40	40	40
ref	1	1	2	2	3	3	4	4	5	5
limit-refs	0	0	3	3	3	3	3	2	1	0
me	dia	hex	hex	hex	hex	hex	star	star	star	star
merange	57	57	57	57	57	57	57	57	57	92
subme	0	1	1	2	2	2	3	3	4	5
rect	0	0	0	0	0	0	1	1	1	1
amp	0	0	0	0	0	0	0	1	1	1
limit-modes	0	0	0	0	0	0	1	1	1	0
max-merge	2	2	2	2	2	2	3	3	4	5
early-skip	1	1	1	1	0	0	0	0	0	0
recursion-skip	1	1	1	1	1	1	1	1	0	0
fast-intra	1	1	1	1	1	0	0	0	0	0
b-intra	0	0	0	0	0	0	0	1	1	1
sao	0	0	1	1	1	1	1	1	1	1
signhide	0	1	1	1	1	1	1	1	1	1
weightp	0	0	1	1	1	1	1	1	1	1
weightb	0	0	0	0	0	0	0	1	1	1
aq-mode	0	0	1	1	1	1	1	1	1	1
cuTree	1	1	1	1	1	1	1	1	1	1
rdLevel	2	2	2	2	2	3	4	6	6	6
rdoq-level	0	0	0	0	0	0	2	2	2	2
tu-intra	1	1	1	1	1	1	1	2	3	4
tu-inter	1	1	1	1	1	1	1	2	3	4
limit-tu	0	0	0	0	0	0	0	4	4	0

http://x265.readthedocs.io/en/default/presets.html

x265 Presets

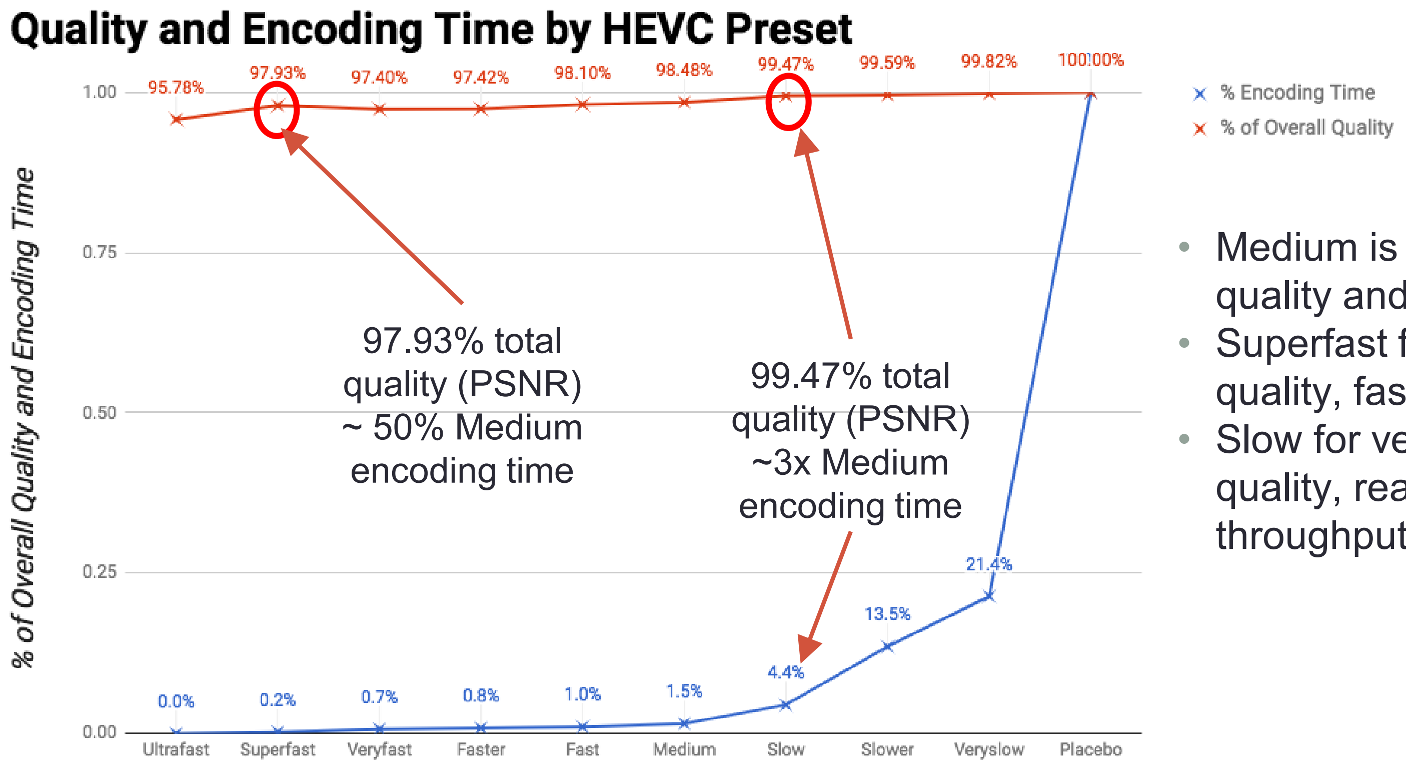


	Ultrafast	Superfast	Veryfast	Faster	Fast	Medium	Slow	Slower	Veryslow	Placebo	Total Delta
Tears of Steel	37.25	38.06	38.04	38.05	38.34	38.39	38.84	38.86	38.93	39.00	4.70%
Sintel	35.87	36.89	36.66	36.67	37.11	37.25	37.74	37.79	37.90	37.97	5.86%
Big Buck Bunny	36.10	37.65	37.61	37.60	37.91	38.26	38.70	38.89	39.03	39.18	8.54%
Freedom	38.16	39.01	38.45	38.46	38.71	38.98	39.36	39.44	39.52	39.58	3.72%
Haunted	41.36	41.77	41.39	41.39	41.55	41.68	41.97	41.92	41.97	42.02	1.60%
Screencam	44.03	46.70	46.55	46.54	46.78	47.12	48.31	48.69	48.99	49.34	12.07%
Tutorial	42.46	47.14	46.46	46.42	46.52	47.19	48.35	47.65	48.02	48.53	14.31%
Average	**38.64**	**39.51**	**39.30**	**39.31**	**39.58**	**39.74**	**40.13**	**40.18**	**40.27**	**40.35**	**6.70%**

- Ultrafast is always the worst
  - Typically only use when necessary for live encoding

- Superfast is higher quality than Veryfast and Faster
- Starts increasingly steadily after Fast, with Placebo the best

Presets, Quality and Encoding Time



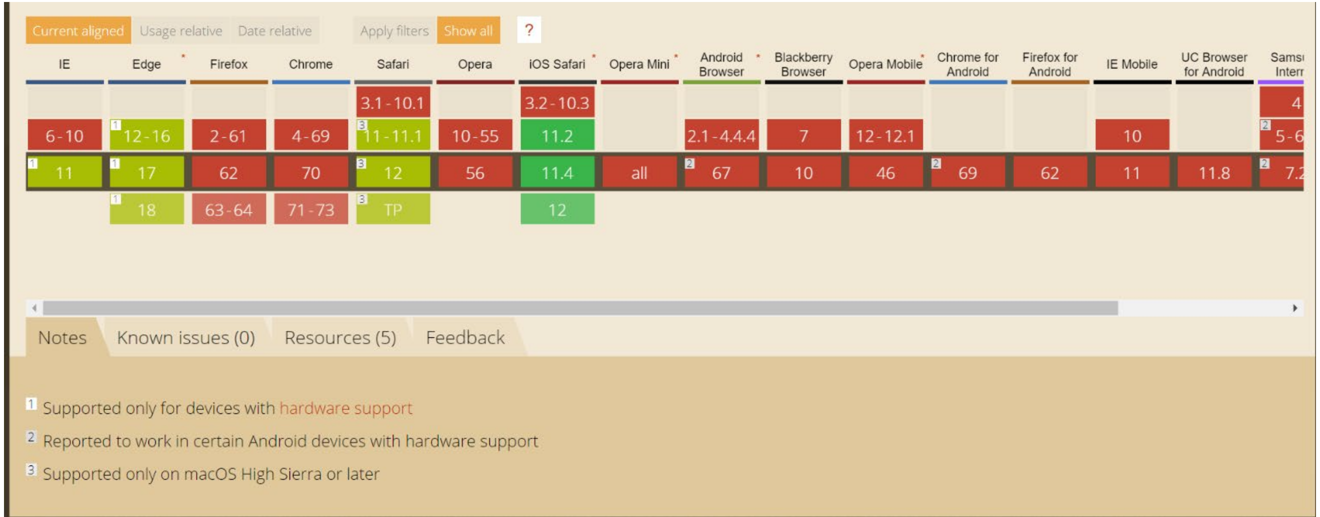
97.93% total quality (PSNR) ~ 50% Medium encoding time

99.47% total quality (PSNR) ~3x Medium encoding time

- Medium is reasonable for quality and throughput
- Superfast for good quality, fast throughput
- Slow for very good quality, reasonable throughput

Section II: Playback Performance

- How HEVC compares to H.264
  - The assumption:
    - HEVC will work better on newer hardware that supports HW acceleration
    - HEVC will have good quality with lower CPU consumption when HW acceleration is used
  - The caveat:
    - Many platforms still don't support HEVC: http://caniuse.com/#search=h.265



IE	Edge *	Firefox	Chrome	Safari	Opera	iOS Safari *	Opera Mini *	Android Browser *	Blackberry Browser	Opera Mobile *	Chrome for Android	Firefox for Android	IE Mobile	UC Browser for Android	Samsı Interr
				3.1 - 10.1		3.2 - 10.3									4
6 - 10	[1] 12 - 16	2 - 61	4 - 69	[3] 11 - 11.1	10 - 55	11.2		2.1 - 4.4.4	7	12 - 12.1			10		[2] 5 - 6
[1] 11	[1] 17	62	70	[3] 12	56	11.4	all	[2] 67	10	46	[2] 69	62	11	11.8	[2] 7.2
	[1] 18	63 - 64	71 - 73	[3] TP		12									

[1] Supported only for devices with hardware support

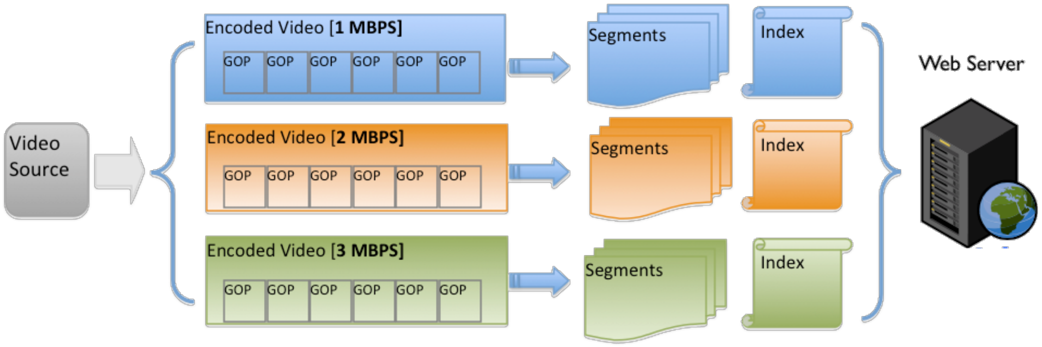
[2] Reported to work in certain Android devices with hardware support

[3] Supported only on macOS High Sierra or later

Section II: A Brief Introduction to HLS

- How HLS works – encoder side
- How HLS works – player side
- HLS content
- HLS manifest files

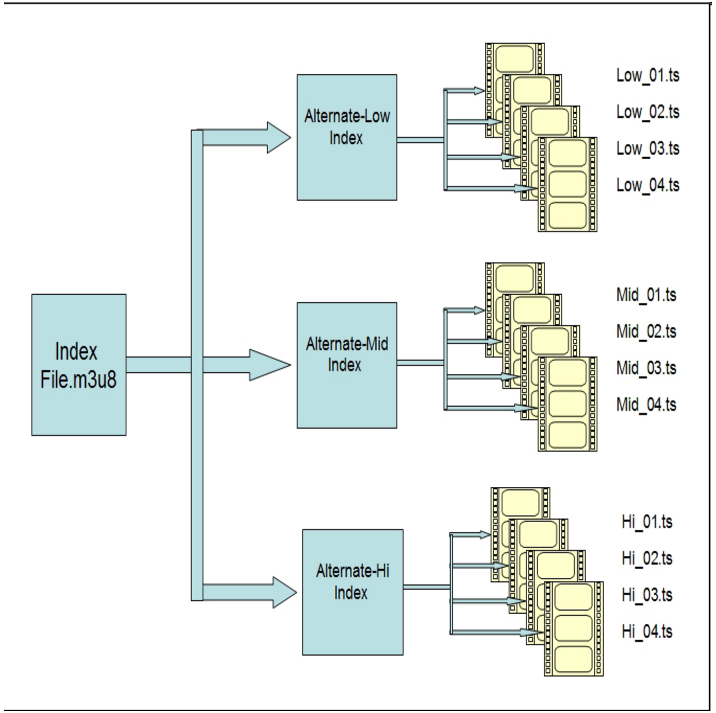
How HLS Works – Encode Side



- Encoder creates:
  - Multiple sets of segmented video files
  - Index files (M3U8) with file descriptions (rez/data rate/profile) and chunk URLs

- Uploads to HTTP web server

How HLS Works - Player SIde



- Retrieves master index, retrieves segment from first variant listed in master index
- Monitors the buffer status
- Changes streams as needed using index files to find location
  - If heuristics are good, moves to higher quality stream
  - If heuristics are poor, moves to lower quality stream

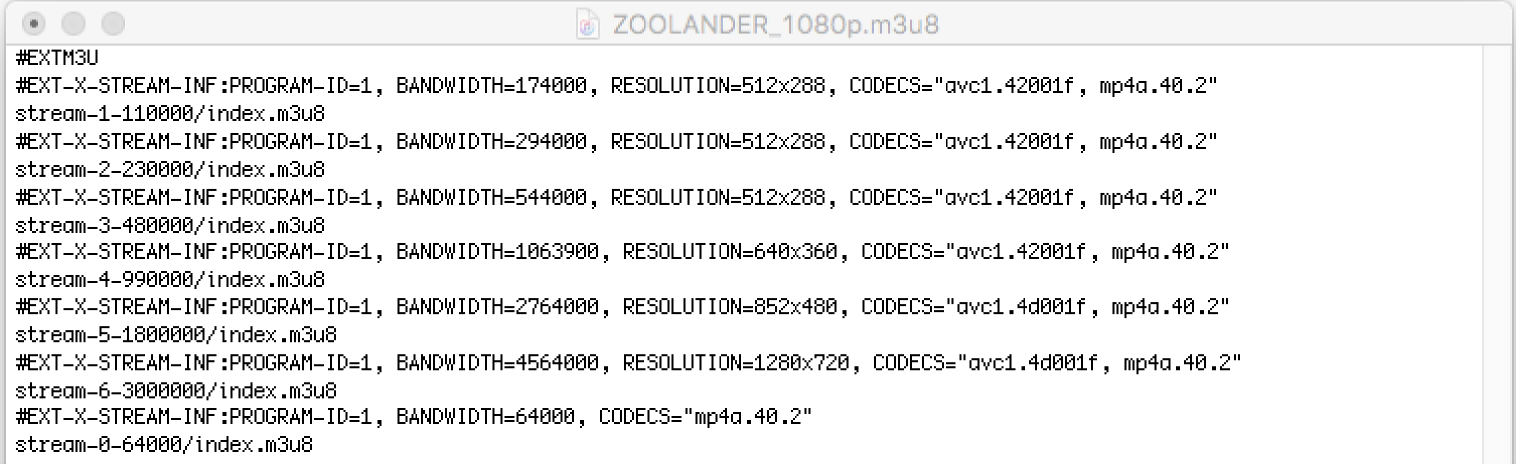
HLS Content

- Initially, used the MPEG-2 transport stream (.ts files)
    - Started with separate files (many, many .ts files)
    - Later enabled byte range requests (more later), enabling player to retrieve segments from a single file
        - Much easier to administrate
- Later, adopted fragmented mp4 files (fMP4)
- HEVC must use fMP4

Manifest or Playlist Files

- Master
  - Points to other playlists
- Variant
  - One for each piece of content (audio, video, subtitle, caption) in the HLS presentation
  - Points to actual location of content on the server
- I-frame
  - Enables trick play, or fast scrubbing backwards and forwards through the file

Master Manifest Files

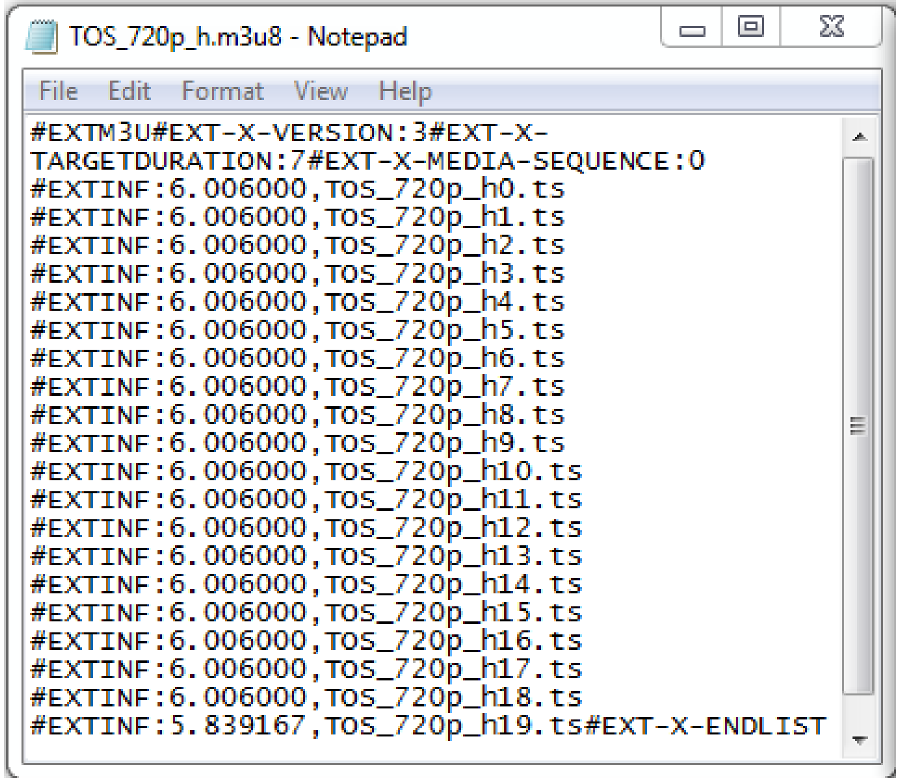


```
#EXTM3U
#EXT-X-STREAM-INF:PROGRAM-ID=1, BANDWIDTH=174000, RESOLUTION=512x288, CODECS="avc1.42001f, mp4a.40.2"
stream-1-110000/index.m3u8
#EXT-X-STREAM-INF:PROGRAM-ID=1, BANDWIDTH=294000, RESOLUTION=512x288, CODECS="avc1.42001f, mp4a.40.2"
stream-2-230000/index.m3u8
#EXT-X-STREAM-INF:PROGRAM-ID=1, BANDWIDTH=544000, RESOLUTION=512x288, CODECS="avc1.42001f, mp4a.40.2"
stream-3-480000/index.m3u8
#EXT-X-STREAM-INF:PROGRAM-ID=1, BANDWIDTH=1063900, RESOLUTION=640x360, CODECS="avc1.42001f, mp4a.40.2"
stream-4-990000/index.m3u8
#EXT-X-STREAM-INF:PROGRAM-ID=1, BANDWIDTH=2764000, RESOLUTION=852x480, CODECS="avc1.4d001f, mp4a.40.2"
stream-5-1800000/index.m3u8
#EXT-X-STREAM-INF:PROGRAM-ID=1, BANDWIDTH=4564000, RESOLUTION=1280x720, CODECS="avc1.4d001f, mp4a.40.2"
stream-6-3000000/index.m3u8
#EXT-X-STREAM-INF:PROGRAM-ID=1, BANDWIDTH=64000, CODECS="mp4a.40.2"
stream-0-64000/index.m3u8
```

- This is the file you link to on your website – first file retrieved
- Contains links to ”variant” playlists that identify location of media files
  - Contains enough data to allow player to choose correct streams
  - Codec/profile, resolution, bandwidth

Traditional Variant Playlist

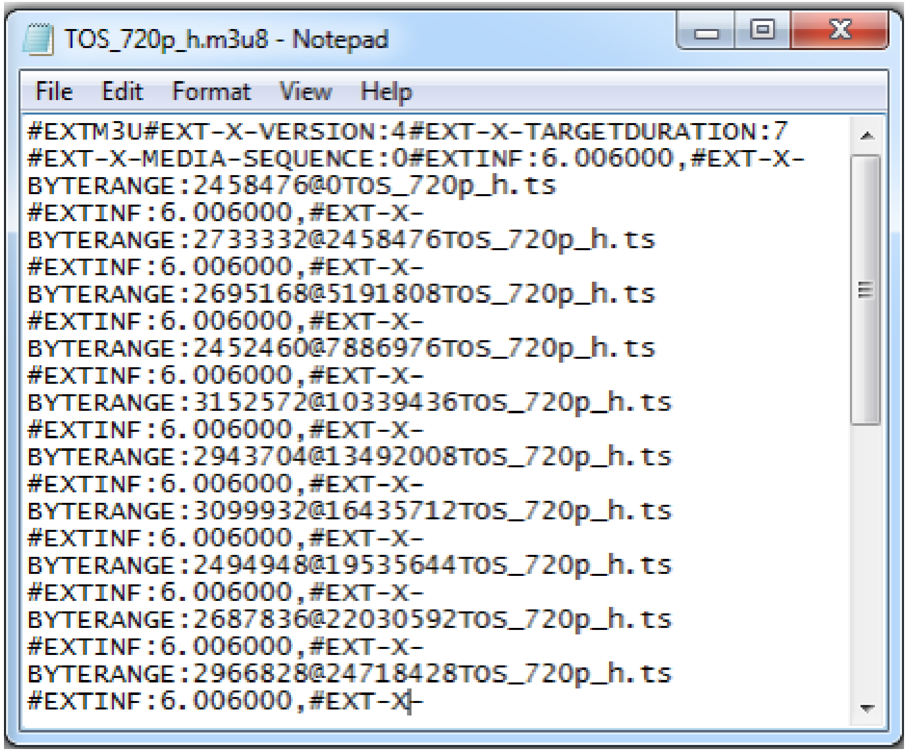
- Name, location, and duration of all individual files
  - .ts files are MPEG-2 transport streams



```
#EXTM3U#EXT-X-VERSION:3#EXT-X-
TARGETDURATION:7#EXT-X-MEDIA-SEQUENCE:0
#EXTINF:6.006000,TOS_720p_h0.ts
#EXTINF:6.006000,TOS_720p_h1.ts
#EXTINF:6.006000,TOS_720p_h2.ts
#EXTINF:6.006000,TOS_720p_h3.ts
#EXTINF:6.006000,TOS_720p_h4.ts
#EXTINF:6.006000,TOS_720p_h5.ts
#EXTINF:6.006000,TOS_720p_h6.ts
#EXTINF:6.006000,TOS_720p_h7.ts
#EXTINF:6.006000,TOS_720p_h8.ts
#EXTINF:6.006000,TOS_720p_h9.ts
#EXTINF:6.006000,TOS_720p_h10.ts
#EXTINF:6.006000,TOS_720p_h11.ts
#EXTINF:6.006000,TOS_720p_h12.ts
#EXTINF:6.006000,TOS_720p_h13.ts
#EXTINF:6.006000,TOS_720p_h14.ts
#EXTINF:6.006000,TOS_720p_h15.ts
#EXTINF:6.006000,TOS_720p_h16.ts
#EXTINF:6.006000,TOS_720p_h17.ts
#EXTINF:6.006000,TOS_720p_h18.ts
#EXTINF:5.839167,TOS_720p_h19.ts#EXT-X-ENDLIST
```

Variant Manifest - Byte Range Request

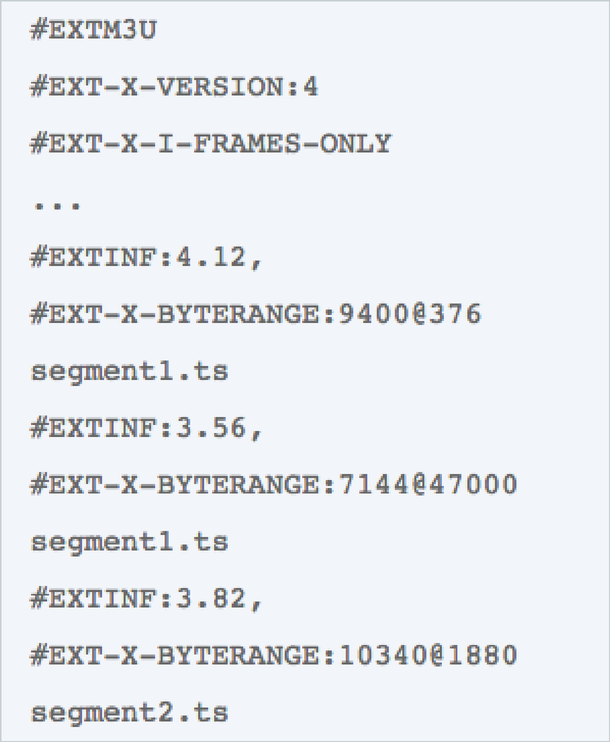
- Single content file
  - Easier to administrate
- Playlist points to byte ranges within the file
- Need HLS version 5 compatible player



```
#EXTM3U#EXT-X-VERSION:4#EXT-X-TARGETDURATION:7
#EXT-X-MEDIA-SEQUENCE:0#EXTINF:6.006000,#EXT-X-
BYTERANGE:2458476@0TOS_720p_h.ts
#EXTINF:6.006000,#EXT-X-
BYTERANGE:2733332@2458476TOS_720p_h.ts
#EXTINF:6.006000,#EXT-X-
BYTERANGE:2695168@5191808TOS_720p_h.ts
#EXTINF:6.006000,#EXT-X-
BYTERANGE:2452460@7886976TOS_720p_h.ts
#EXTINF:6.006000,#EXT-X-
BYTERANGE:3152572@10339436TOS_720p_h.ts
#EXTINF:6.006000,#EXT-X-
BYTERANGE:2943704@13492008TOS_720p_h.ts
#EXTINF:6.006000,#EXT-X-
BYTERANGE:3099932@16435712TOS_720p_h.ts
#EXTINF:6.006000,#EXT-X-
BYTERANGE:2494948@19535644TOS_720p_h.ts
#EXTINF:6.006000,#EXT-X-
BYTERANGE:2687836@22030592TOS_720p_h.ts
#EXTINF:6.006000,#EXT-X-
BYTERANGE:2966828@24718428TOS_720p_h.ts
#EXTINF:6.006000,#EXT-X-
```

I-Frame Manifest

- Separate .m3u8 file
- Can point to existing media files, or be a video file with I-frames
  - Either way, the player scans the I-frame at the start of each segment
- Requires HLS version 5 player



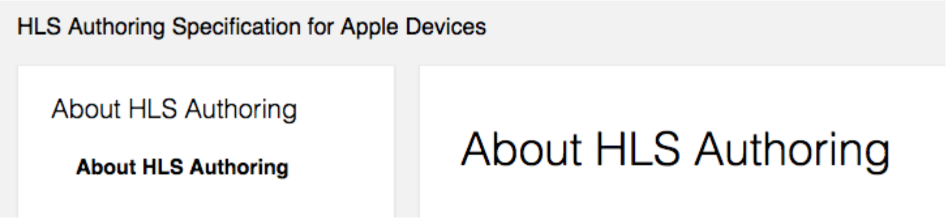
```
#EXTM3U
#EXT-X-VERSION:4
#EXT-X-I-FRAMES-ONLY
...
#EXTINF:4.12,
#EXT-X-BYTERANGE:9400@376
segment1.ts
#EXTINF:3.56,
#EXT-X-BYTERANGE:7144@47000
segment1.ts
#EXTINF:3.82,
#EXT-X-BYTERANGE:10340@1880
segment2.ts
```

Section III: Specification Overview

- Controlling and sample documents
- Producing HLS streams
  - H264 only
  - H264/HEVC
  - H264/HEVC/HDR

Apple Resources

- HLS Authoring Spec provides
  - Sample encoding ladders
  - Details regarding all aspects of HLS production



HLS Authoring Specification for Apple Devices

About HLS Authoring

About HLS Authoring

About HLS Authoring

http://bit.ly/hls_spec_2017

- HTTP Live Streaming Examples
  - Provides sample streams and manifest files

HTTP Live Streaming Examples

http://bit.ly/hls_samps

- We will reference both during presentation

H.264 Only

Video Streams

- H.264 streams

Trick Play Streams

- i-Frame streams (I-frame playlists (EXT-X-I-FRAME-STREAM-INF) **MUST** be provided to support scrubbing and scanning UI
- SHOULD create one fps “dense” dedicated I-frame renditions
- MAY use I-frames from normal content, but trick play performance is improved with a higher density of I-frames

Configuration (h.264)

- Profile and Level MUST be less than or equal to High Profile, Level 4.2.
- SHOULD use High Profile in preference to Main or Baseline Profile

H264 Encoding Ladder - Content

Data Rate	Rez	Frame rate	Profile	Level *	Key Frame	Segment
145	416 x 234	≤ 30 fps	High	4.2	2	6
365	480 x 270	≤ 30 fps	High	4.2	2	6
730	640 x 360	≤ 30 fps	High	4.2	2	6
1100	768 x 432	≤ 30 fps	High	4.2	2	6
2000	960 x 540	source	High	4.2	2	6
3000	1280 x 720	source	High	4.2	2	6
4500	1280 x 720	source	High	4.2	2	6
6000	1920 x 1080	source	High	4.2	2	6
7800	1920 x 1080	source	High	4.2	2	6

* Level: Should not use a higher level than required for content resolution and frame rate

H264 Encoding Ladder – I-Frame/Trick Play

Data Rate	Rez	Frame rate	Profile	Key Frame	Profile	Segment
45	480 x 270	1 fps	High	1	High	1
90	640 x 360	1 fps	High	1	High	1
250	960 x 540	1 fps	High	1	High	1
375	1280 x 720	1 fps	High	1	High	1
600	1920 x 1080	1 fps	High	1	High	1

HEVC/H.264

Video Streams

- H.265
- H.264 streams (For backward compatibility some video content **SHOULD** be encoded with H.264)

Trick Play Streams

- H.264
- H.265 (not specified, but Apple has for both)
- Dedicated encodes are preferred, but can use existing file

Configuration (HEVC)

- Main 10, Level 5, High
  - Level 5 peaks at 30 fps
  - Apple HLS sample stream @ 60 fps (but peak at 1080p)
  - Encoding ladder says 30 fps
- Must be fragmented MP4

HEVC Encoding Ladder - Content

Data Rate	Rez	Frame rate	Profile	Level *	Key Frame	Segment
145	416 x 234	≤ 30 fps	Main 10	5.0	2	6
300	480 x 270	≤ 30 fps	Main 10	5.0	2	6
660	640 x 360	≤ 30 fps	Main 10	5.0	2	6
990	768 x 432	≤ 30 fps	Main 10	5.0	2	6
1700	960 x 540	30	Main 10	5.0	2	6
2400	1280 x 720	30	Main 10	5.0	2	6
3200	1280 x 720	30	Main 10	5.0	2	6
4500	1920 x 1080	30	Main 10	5.0	2	6
5800	1920 x 1080	30	Main 10	5.0	2	6
8100	2566x1440	30	Main 10	5.0	2	6
11600	3840x2160	30	Main 10	5.0	2	6
16800	3840x2160	30	Main 10	5.0	2	6

* Level: Should not use a higher level than required for content resolution and frame rate

HEVC Encoding Ladder – I-Frame/Trick Play

Data Rate	Rez	Frame rate	Profile	Key Frame	Profile	Segment
40	480 x 270	1 fps	High	1	High	1
80	640 x 360	1 fps	High	1	High	1
210	960 x 540	1 fps	High	1	High	1
300	1280 x 720	1 fps	High	1	High	1
525	1920 x 1080	1 fps	High	1	High	1

Note: 6.1 – I-frame playlists MUST be provided to support scrubbing and scanning UI.
No requirement for HEVC

HDR/HEVC/H264

Video Streams

- HDR
- H.265 (SDR streams must be provided – not specified if H.264 content suffices)
- H.264 streams (For backward compatibility some video content **SHOULD** be encoded with H.264)

Trick Play Streams

- H.264
- H.265 (SDR must be provided; not clear if H.264 suffices)
- If HDR provided, should provide at all resolutions

Configuration (HDR)

- MUST be HDR10 or Dolby Vision
  - Dolby Vision – profile 5 (10-bit single layer), level 7
- If HDR provided, SHOULD be provided at all resolutions
- 30 fps or less
- Must be fMP4

HDR Encoding Ladder - Content

Data Rate	Rez	Frame rate	Profile	Level *	Key Frame	Segment
160	416 x 234	≤ 30 fps	Main 10	5.0	2	6
360	480 x 270	≤ 30 fps	Main 10	5.0	2	6
800	640 x 360	≤ 30 fps	Main 10	5.0	2	6
1200	768 x 432	≤ 30 fps	Main 10	5.0	2	6
2050	960 x 540	30	Main 10	5.0	2	6
2900	1280 x 720	30	Main 10	5.0	2	6
3850	1280 x 720	30	Main 10	5.0	2	6
5400	1920 x 1080	30	Main 10	5.0	2	6
7000	1920 x 1080	30	Main 10	5.0	2	6
9700	2566x1440	30	Main 10	5.0	2	6
13900	3840x2160	30	Main 10	5.0	2	6
20000	3840x2160	30	Main 10	5.0	2	6

* Level: Should not use a higher level than required for content resolution and frame rate

HDR Encoding Ladder – I-Frame/Trick Play

Data Rate	Rez	Frame rate	Profile	Key Frame	Profile	Segment
55	480 x 270	1 fps	High	1	High	1
100	640 x 360	1 fps	High	1	High	1
250	960 x 540	1 fps	High	1	High	1
360	1280 x 720	1 fps	High	1	High	1
650	1920 x 1080	1 fps	High	1	High	1

Note: 6.1 – I-frame playlists MUST be provided to support scrubbing and scanning UI.
No requirement for HEVC

All Frame Rate/Bitrate Control

- Frame rates above 60 fps **SHALL NOT** be used.

VOD:

- If progressive use that rate
- You **SHOULD** de-interlace 30i content to 60p instead of 30p (streams above 2 Mbps)

Live:

- Live/linear video from NSTC or ATSC source SHOULD be 60 or 59.94 fps (PAL=50 fps)
- HEVC/HDR – max 30 fps

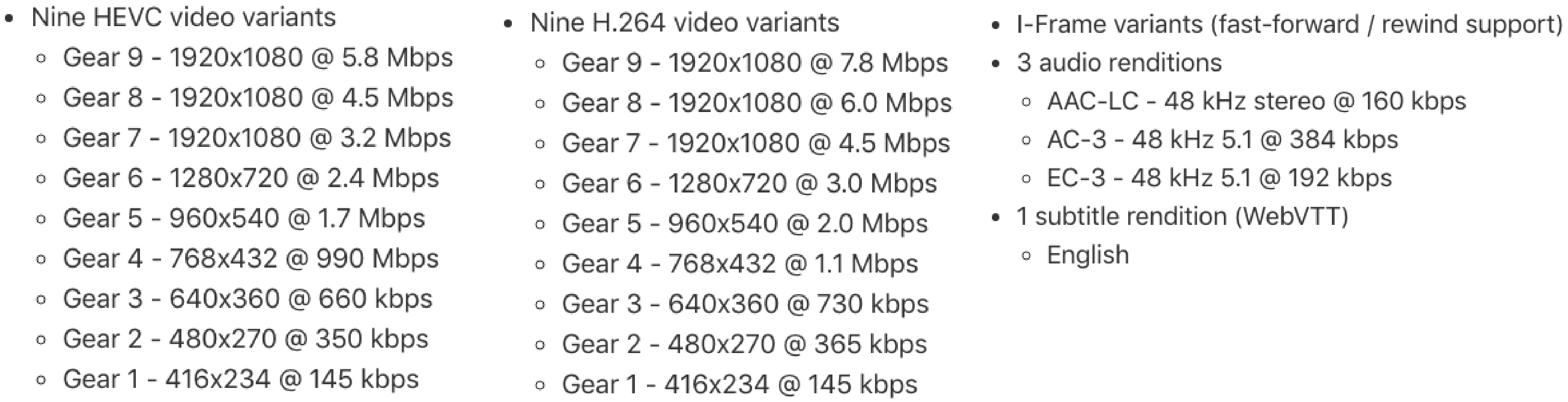
VOD:

- Average segment bit rate MUST be within 10% of the AVERAGE-BANDWIDTH attribute
- Measured peak bit rate MUST be within 10% of the BANDWIDTH attribute.
- Peak bit rate SHOULD be no more than 200% of the average bit rate.

Live:

- Average segment bit rate over a long (~1 hour) MUST be less than 110% of the AVERAGE-BANDWIDTH attribute
- Measured peak bit rate MUST be less than 125% of the BANDWIDTH attribute.

Apple’s HEVC/H264 Encoding Ladder



- Nine HEVC video variants
  - Gear 9 - 1920x1080 @ 5.8 Mbps
  - Gear 8 - 1920x1080 @ 4.5 Mbps
  - Gear 7 - 1920x1080 @ 3.2 Mbps
  - Gear 6 - 1280x720 @ 2.4 Mbps
  - Gear 5 - 960x540 @ 1.7 Mbps
  - Gear 4 - 768x432 @ 990 Mbps
  - Gear 3 - 640x360 @ 660 kbps
  - Gear 2 - 480x270 @ 350 kbps
  - Gear 1 - 416x234 @ 145 kbps

- Nine H.264 video variants
  - Gear 9 - 1920x1080 @ 7.8 Mbps
  - Gear 8 - 1920x1080 @ 6.0 Mbps
  - Gear 7 - 1920x1080 @ 4.5 Mbps
  - Gear 6 - 1280x720 @ 3.0 Mbps
  - Gear 5 - 960x540 @ 2.0 Mbps
  - Gear 4 - 768x432 @ 1.1 Mbps
  - Gear 3 - 640x360 @ 730 kbps
  - Gear 2 - 480x270 @ 365 kbps
  - Gear 1 - 416x234 @ 145 kbps

- I-Frame variants (fast-forward / rewind support)
- 3 audio renditions
  - AAC-LC - 48 kHz stereo @ 160 kbps
  - AC-3 - 48 kHz 5.1 @ 384 kbps
  - EC-3 - 48 kHz 5.1 @ 192 kbps
- 1 subtitle rendition (WebVTT)
  - English

- I-frame variants in HEVC/H264 formats
- Dolby obviously not required

https://developer.apple.com/streaming/examples/

H.264 Adaptive Group (from Master)

```
#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=2190673,BANDWIDTH=2523597,CODECS="avc1.640020,mp4a.40.2",
RESOLUTION=960x540,FRAME-RATE=60.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v5/prog_index.m3u8

#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=8052613,BANDWIDTH=9873268,CODECS="avc1.64002a,mp4a.40.2",
RESOLUTION=1920x1080,FRAME-RATE=60.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v9/prog_index.m3u8

#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=6133114,BANDWIDTH=7318337,CODECS="avc1.64002a,mp4a.40.2",
RESOLUTION=1920x1080,FRAME-RATE=60.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v8/prog_index.m3u8

#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=4681537,BANDWIDTH=5421720,CODECS="avc1.64002a,mp4a.40.2",
RESOLUTION=1920x1080,FRAME-RATE=60.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v7/prog_index.m3u8

#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=3183969,BANDWIDTH=3611257,CODECS="avc1.640020,mp4a.40.2",
RESOLUTION=1280x720,FRAME-RATE=60.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v6/prog_index.m3u8

#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=1277747,BANDWIDTH=1475903,CODECS="avc1.64001f,mp4a.40.2",
RESOLUTION=768x432,FRAME-RATE=30.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v4/prog_index.m3u8

#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=890848,BANDWIDTH=1017705,CODECS="avc1.64001f,mp4a.40.2",
RESOLUTION=640x360,FRAME-RATE=30.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v3/prog_index.m3u8

#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=533420,BANDWIDTH=582820,CODECS="avc1.64001f,mp4a.40.2",
RESOLUTION=480x270,FRAME-RATE=30.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v2/prog_index.m3u8

#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=303898,BANDWIDTH=339404,CODECS="avc1.64001f,mp4a.40.2",
RESOLUTION=416x234,FRAME-RATE=30.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v1/prog_index.m3u8
```

H.264 I-Frame Group

```
#EXT-X-I-FRAME-STREAM-INF:AVERAGE-BANDWIDTH=928091,BANDWIDTH=1015727,CODECS="avc1.640028",
RESOLUTION=1920x1080,URI="tp5/iframe_index.m3u8”

#EXT-X-I-FRAME-STREAM-INF:AVERAGE-BANDWIDTH=731514,BANDWIDTH=760174,CODECS="avc1.64001f",
RESOLUTION=1280x720,URI="tp4/iframe_index.m3u8”

#EXT-X-I-FRAME-STREAM-INF:AVERAGE-BANDWIDTH=509153,BANDWIDTH=520162,CODECS="avc1.64001f",
RESOLUTION=960x540,URI="tp3/iframe_index.m3u8”

#EXT-X-I-FRAME-STREAM-INF:AVERAGE-BANDWIDTH=176942,BANDWIDTH=186651,CODECS="avc1.64001f",
RESOLUTION=640x360,URI="tp2/iframe_index.m3u8”

#EXT-X-I-FRAME-STREAM-INF:AVERAGE-BANDWIDTH=90796,BANDWIDTH=95410,CODECS="avc1.64001f",
RESOLUTION=480x270,URI="tp1/iframe_index.m3u8"
```

H.265 Adaptive Group (from Master)

```
#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=1966314,BANDWIDTH=2164328,CODECS="hvc1.2.4.L123.B0,mp4a.40.2",
RESOLUTION=960x540,FRAME-RATE=60.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v14/prog_index.m3u8

#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=6105163,BANDWIDTH=6664228,CODECS="hvc1.2.4.L123.B0,mp4a.40.2",
RESOLUTION=1920x1080,FRAME-RATE=60.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v18/prog_index.m3u8

#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=4801073,BANDWIDTH=5427899,CODECS="hvc1.2.4.L123.B0,mp4a.40.2",
RESOLUTION=1920x1080,FRAME-RATE=60.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v17/prog_index.m3u8

#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=3441312,BANDWIDTH=4079770,CODECS="hvc1.2.4.L123.B0,mp4a.40.2",
RESOLUTION=1920x1080,FRAME-RATE=60.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v16/prog_index.m3u8

#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=2635933,BANDWIDTH=2764701,CODECS="hvc1.2.4.L123.B0,mp4a.40.2",
RESOLUTION=1280x720,FRAME-RATE=60.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v15/prog_index.m3u8

#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=1138612,BANDWIDTH=1226255,CODECS="hvc1.2.4.L123.B0,mp4a.40.2",
RESOLUTION=768x432,FRAME-RATE=30.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v13/prog_index.m3u8

#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=829339,BANDWIDTH=901770,CODECS="hvc1.2.4.L123.B0,mp4a.40.2",
RESOLUTION=640x360,FRAME-RATE=30.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v12/prog_index.m3u8

#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=522229,BANDWIDTH=548927,CODECS="hvc1.2.4.L123.B0,mp4a.40.2",
RESOLUTION=480x270,FRAME-RATE=30.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v11/prog_index.m3u8

#EXT-X-STREAM-INF:AVERAGE-BANDWIDTH=314941,BANDWIDTH=340713,CODECS="hvc1.2.4.L123.B0,mp4a.40.2”
,RESOLUTION=416x234,FRAME-RATE=30.000,CLOSED-CAPTIONS="cc",AUDIO="a1",SUBTITLES="sub1"v10/prog_index.m3u8
```

HEVC I-Frame Group

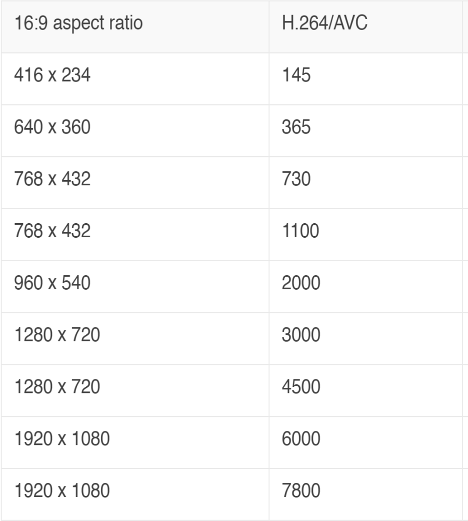
```
#EXT-X-I-FRAME-STREAM-INF:AVERAGE-BANDWIDTH=287207,BANDWIDTH=328352,CODECS="hvc1.2.4.L123.B0",
RESOLUTION=1920x1080,URI="tp10/iframe_index.m3u8”

#EXT-X-I-FRAME-STREAM-INF:AVERAGE-BANDWIDTH=216605,BANDWIDTH=226274,CODECS="hvc1.2.4.L123.B0",
RESOLUTION=1280x720,URI="tp9/iframe_index.m3u8”

#EXT-X-I-FRAME-STREAM-INF:AVERAGE-BANDWIDTH=154000,BANDWIDTH=159037,CODECS="hvc1.2.4.L123.B0",
RESOLUTION=960x540,URI="tp8/iframe_index.m3u8”

#EXT-X-I-FRAME-STREAM-INF:AVERAGE-BANDWIDTH=90882,BANDWIDTH=92800,CODECS="hvc1.2.4.L123.B0",
RESOLUTION=640x360,URI="tp7/iframe_index.m3u8”

#EXT-X-I-FRAME-STREAM-INF:AVERAGE-BANDWIDTH=50569,BANDWIDTH=51760,CODECS="hvc1.2.4.L123.B0",
RESOLUTION=480x270,URI="tp6/iframe_index.m3u8"
```

IV: Playback Performance and Ladder Creation

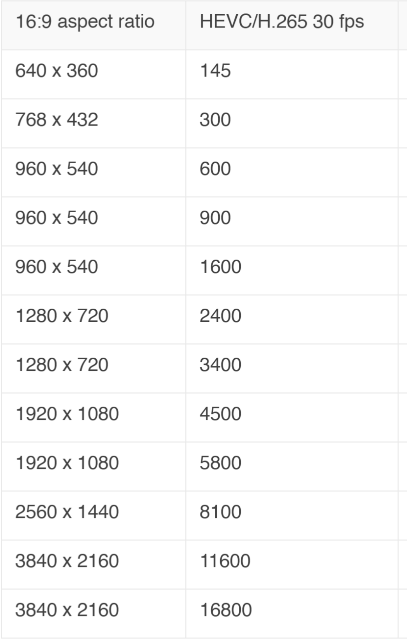
- Hybrid and low hybrid
- Tests and results
- Conclusions

Created Two Encoding Ladders for Testing

- "Hybrid"
  - Contained all rungs of recommended H.264 and HEVC ladders



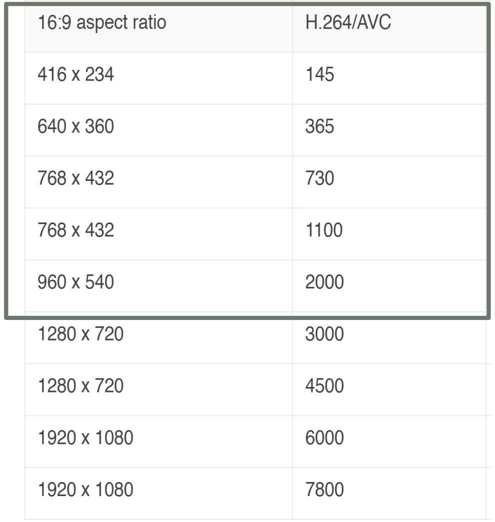
16:9 aspect ratio	H.264/AVC
416 x 234	145
640 x 360	365
768 x 432	730
768 x 432	1100
960 x 540	2000
1280 x 720	3000
1280 x 720	4500
1920 x 1080	6000
1920 x 1080	7800



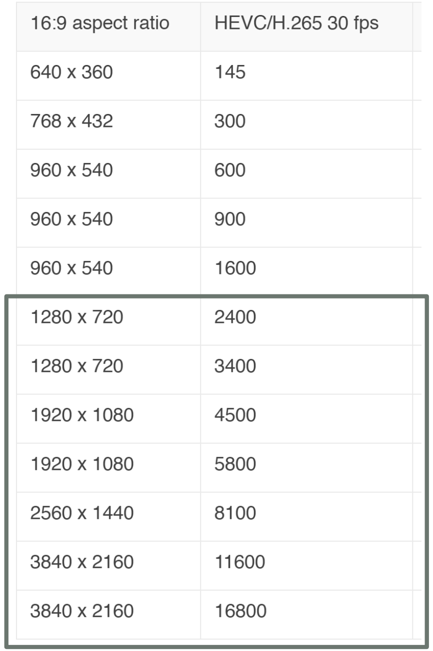
16:9 aspect ratio	HEVC/H.265 30 fps
640 x 360	145
768 x 432	300
960 x 540	600
960 x 540	900
960 x 540	1600
1280 x 720	2400
1280 x 720	3400
1920 x 1080	4500
1920 x 1080	5800
2560 x 1440	8100
3840 x 2160	11600
3840 x 2160	16800

Created Two Encoding Ladders for Testing

- "Hybrid"
  - Contained all rungs of recommended H.264 and HEVC ladders
- "Low-Hybrid"
  - Sub 720p rungs in H.264
  - 720p and higher rungs in HEVC

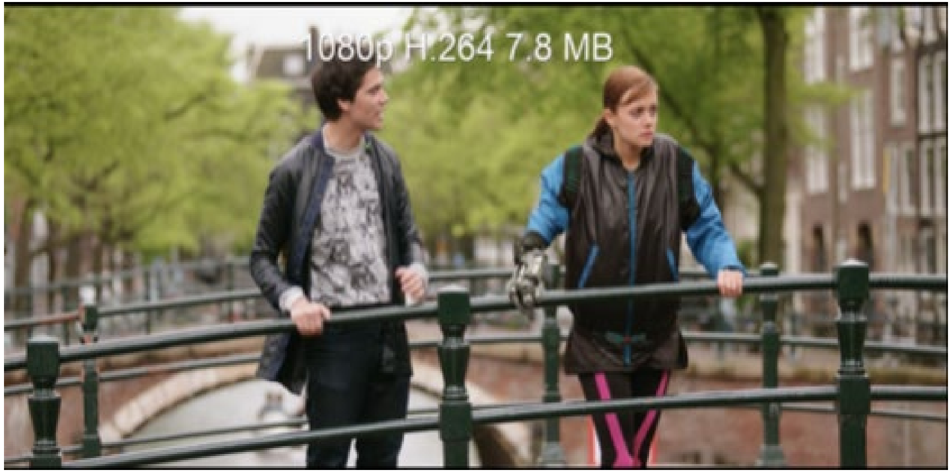


16:9 aspect ratio	H.264/AVC
416 x 234	145
640 x 360	365
768 x 432	730
768 x 432	1100
960 x 540	2000
1280 x 720	3000
1280 x 720	4500
1920 x 1080	6000
1920 x 1080	7800



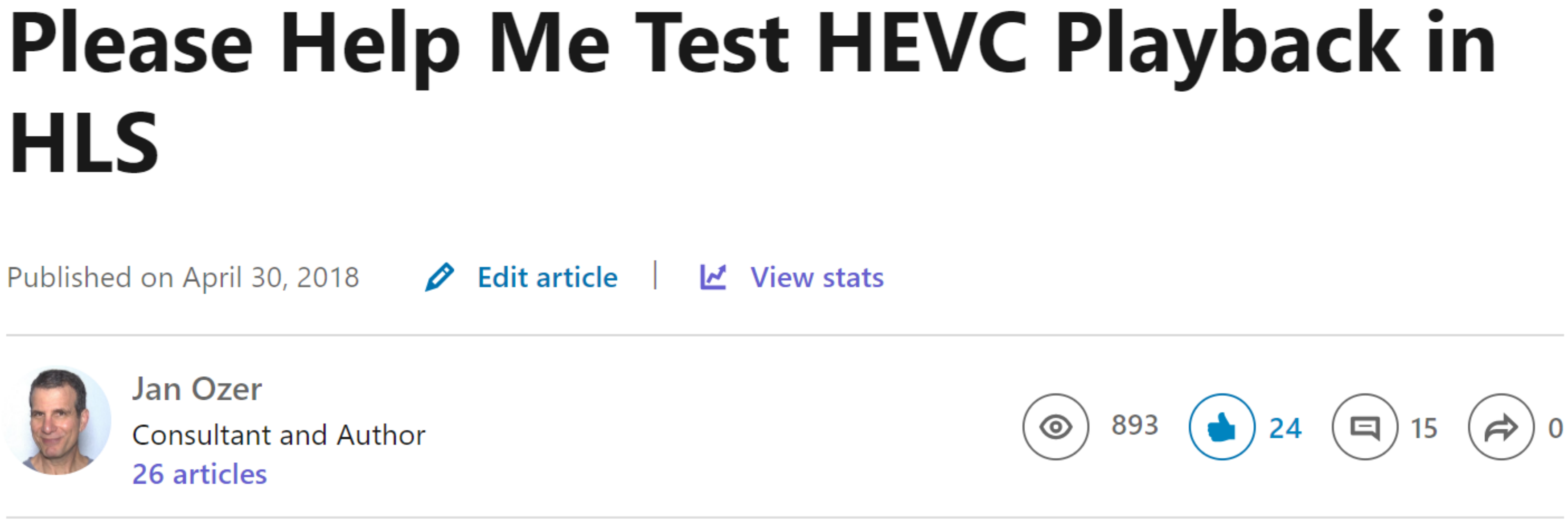
16:9 aspect ratio	HEVC/H.265 30 fps
640 x 360	145
768 x 432	300
960 x 540	600
960 x 540	900
960 x 540	1600
1280 x 720	2400
1280 x 720	3400
1920 x 1080	4500
1920 x 1080	5800
2560 x 1440	8100
3840 x 2160	11600
3840 x 2160	16800

Burned File Configuration into Files



- Used FFmpeg text filter to burn rez/codec/data rate info into file

Asked for Volunteer Testers on LinkedIn



Please Help Me Test HEVC Playback in HLS

Published on April 30, 2018

Jan Ozer

Consultant and Author

26 articles

Results

- 43 desktop
- 19 mobile

What Did We Learn

- Generally good performance and compatibility
  - H.264 streams played on older devices without problem
  - Very few quality issues
  - No disruption when switching between H.264 and HEVC

What Did We Learn

- Playback
  - Apple typically won’t retrieve higher resolution file than display resolution
    - One instance where MacBookPro with 1800 vertical rez retrieved 4K file
    - Otherwise, followed this rule
  - 4K doesn’t get retrieved all that often
    - Average bandwidth when retrieving 4K was 580 Mbps
    - Lowest was 64 Mbps for 16.8 Mbps stream
    - Many devices with very high bandwidth and necessary resolution could not play
    - Apple looking into this as potential “bug”

Does Ladder Composition Make a Difference?

- Maybe
- There were several instances where the result between hybrid and low hybrid differed
  - In all but one instance, the low-hybrid experience was worse
    - Either H.264 instead of HEVC
    - Lower data rate/resolution
- Safest approach appears to be two complete ladders
  - Obviously, also the most expensive

What Know About Switching?

- Ask Apple – two streams in ladder; which does player select?

1080p – HEVC – 2 Mbps
720p – H.264 – 2.5 Mbps

- Their switching logic is in transition but it "knows" that H.265 should be higher quality than H.264 at similar data rates
    - So don't need to game the system (create artificially high data rate for H.265 streams so
- Typically won't switch between H.264 and H.265 when both available
- Apple recommends full H.264/H.265 ladders in all cases

Section V. Producing HEVC/HLS

- DIY – VOD
  - FFmpeg – create the A/V files
  - Bento4 – package and manifest files
- Third-party alternatives
  - Live
  - VOD

Creating HEVC Files in FFmpeg

- Use the x265 codec
  - Need to compile Main10-specific version
- All scaling and other syntaxes apply
- Need to choose profile and preset (unless defaults OK)
- Must use –x265-params command for some parameters

Encoding x265 in FFmpeg

```
ffmpeg -y -i TOS_1080p.mov -c:v libx265 -preset slow -x265-params profile=main:keyint=48:
min-keyint=48:scenecut=0:ref=5:bframes=3:b-adapt=2:bitrate=4000:vbv-maxrate=4400:vbv-
bufsize=4000:pass=1 -an -f mp4 NUL && \

ffmpeg -i TOS_1080p.mov -c:v libx265 -preset slow  -x265-params profile=main:keyint=48:
min-keyint=48:scenecut=0:ref=5:bframes=3:b-adapt=2:bitrate=4000:vbv-maxrate=4400:vbv-
bufsize=4000:pass=2 -an TOS_1080p_h.mp4

ffmpeg -i TOS_1080p.mov -c:v libx265 -s 1280x720 -preset slow  -x265-params profile=main:
keyint=48:min-keyint=48:scenecut=0:ref=5:bframes=3:b-adapt=2:bitrate=1000:vbv-maxrate=1100:
vbv-bufsize=1000:pass=2 -an TOS_720p_l.mp4
```

- Integrate x265 commands into FFmpeg

`-x265-params` – start of x265 commands, in x265 syntax

  - http://x265.readthedocs.io/en/default/
- One string of commands, separated by colon, no spaces until finished
- Note “pass” configuration - not like H.264

- Preset, an (audio no), format, and Null outside of this structure
- Scaling commands outside of – x265-params structure

FFmpeg Learning Resources

- Includes H.264/H.265
  - Full documentation of Bento4
  - No cloud stuff
- T103. HOW-TO: Building A More Robust Cloud Encoder With FFMPEG & More
  - Tuesday, November 13: 1:45 p.m. - 2:30 p.m.

http://bit.ly/ffmpeg_30

HARDWARE ACCELERATION FOR HEVC/FFMPEG

Creating HEVC in FFmpeg w/ HW Acceleration

- Use the -hwaccel codecs
- HW Decoders have traditionally been okay but SW as good
- HW Encoders have always gotten less quality at higher BR
- NVIDIA NVENC changes this

Previous Issues in HW Encoding

- HW Decoders great
- HW Encoders not so great
- HW Decoders couldn’t easily pass data to SW Encoders
- Reduced general usefulness of HW decoding at all
- Industry needed a full HW decode and encode solution

What’s The Beef?

- NVENC + NVDEC first true HW pipeline solution for all
- HW decode to HW memory surface
- FFmpeg video filters using HW memory surface benefits
- HW encode from HW memory surface
- Multi-fold reduction in stream copying in FFmpeg

What’s The Beef?

- Allows for more real-time video manipulation
- GPU powered real-time augmented, interactive VR
- FFmpeg control for ease of development
- Only true, easy to access HW pipeline solution
- Encoding structure benefits live use case

How to Use HW Accel

- Need an ND-series Azure VM using Pascal V4 (P40)
- Windows 2012 R2 / 2016 or Ubuntu 16.04, RHEL 7.3, 7.4
- Nvidia GPU Driver Extension
- A Pay-As-You-Go or high Azure Subscription

How to Use HW Accel

- FFmpeg today comes w/ hwaccel enabled
- On Linux use nvidia-smi to check GPU Driver install
- Nvidia GPU Driver Extension
- A Pay-As-You-Go or high Azure Subscription

Benefits of Azure w/ Nvidia NVDEC/NVENC

- Same level as todays SW solutions but at higher scale
- Low latency decoding/encoding and videograph filters
- Unique live, low-latency HEVC/H265 solutions
- Share hardware surface memory of GPUs between VMs

PACKAGERS: BENTO4

Introduction to Bento4

- What it is: A fast, modern, open source C++ toolkit for all your MP4, HLS, and MPEG DASH media format needs
  - https://www.bento4.com/
  - Documentation for HLS - https://www.bento4.com/developers/hls/
- What you can do with Bento4
- Bento 4 vs. FFmpeg
- HLS options and Bento4 syntax

What can I do with Bento4?

- HLS generation, including master manifests, stream level manifests, mpeg-2 ts files, and fMP4 (fragmented MP4)
- MP4 to fMP4 conversion
- DASH generation
- Parsing and multiplexing of H.264 and AAC streams
- Support for DRM (Marlin, PlayReady, Widevine and FairPlay).
- Support for H.264, H.265, AAC, AC3, eAC3, DTS, ALAC, and other codec types.
- Dual generation of HLS and DASH from fragmented MP4
- Atom/box editing, and stream/codec information
- A lot more… https://www.bento4.com/

Bento4 vs FFMPEG

- Bento4 focuses on MP4 based content: Packaging & Transmuxing

- FFMPEG is a broad spectrum tool for media conversion, encoding & packaging

HLS options

- Master playlists
- Single file output with byte range requests
- I-Frame only playlists
- AES encryption
- DRM
- Audio stream sidecar
- Subtitle sidecar
- fMP4

Create Multiple Bitrate Assets

```
mp4hls --hls-version 4 input_7000kb.mp4 input_5000kb.mp4 input_3500kb.mp4
```

- Outputs:
- Master.m3u8
- Stream.m3u8 for each bitrate
- Iframe.m3u8 for each bitrate
- ts fragments for each bitrate

Multiple Audio Streams

`mp4hls video.mp4 spanish_audio.m4a` (different audio file)
`mp4hls video.mp4 [+language=es]audio.m4a` (multiplexed audio file, getting the spanish stream)

Outputs:

- Master.m3u8
- Stream.m3u8 for video and audio
- Iframe.m3u8 for video and audio
- ts fragments
- Audio.m3u8 and aac fragments

WebVTT Subtitles

```
mp4hls video.mp4 [+format=webvtt,+language=en]english.vtt
```

Outputs

- Master.m3u8
- Stream.m3u8
- Webvtt manifest and .vtt file

Encryption and Single Segment

```
mp4hls --hls-version 4 --output-single-file --segment-duration 6 --encryption-mode AES-128
  --encryption-key abaa09cd8c75abba54ac12dbcc65acd7 --encryption-url
  http://getmyKey?token=token video.mp4
```

Outputs

- All HLS assets (master, stream with byterange requests, iframe, single ts file)
- Assets are encrypted with AES-128, and encryption URL is added to the stream manifests
- Segment duration will be set to 6 seconds, but will only segment at the closest i-frame

Dual HLS and DASH From fMP4

`mp4fragment input.mp4 output.mp4` (converts mp4 to fmp4)

```
mp4dash --force --hls --no-split --use-segment-timeline output.mp4
```

(without --no-split it will output .m4s segments)

Outputs

- Master.m3u8
- Audio.m3u8
- Video.m3u8
- Stream.mpd (DASH manifest)

Dual HLS and DASH From fMP4

DEMO

Let’s see this happen

Example Master Playlist for Single Bitrate

```
#EXTM3U
#EXT-X-VERSION:6
# Media Playlists
# Audio
#EXT-X-MEDIA:TYPE=AUDIO,GROUP-
   ID="audio/mp4a",LANGUAGE="en",NAME="English",AUTOSELECT=YES,DEFAULT=YES,URI="audio-en-mp4a.m3u8"
# Video
#EXT-X-STREAM-INF:AUDIO="audio/mp4a",AVERAGE-
   BANDWIDTH=3454711,BANDWIDTH=4209761,CODECS="avc1.640020,mp4a.40.2",RESOLUTION=1280x720 video-
   avc1.m3u8
```

Other Info

- Bento will only segment at an i-frame
- Creates HLS assets faster than ffmpeg or shaka packager
- Gathers its metadata while segmenting, so codecs, average bandwidth, bandwidth, and resolution are automatically added to the manifests
- A full set of DASH and metadata options

List of all Bento4 binaries: https://www.bento4.com/

PACKAGERS: SHAKA

Introduction to Shaka

- Shaka has made many performance improvements over the past year.
- Makes it simple to demux audio and captions
- Simple DRM integration
- The only known open source packager to have Ad CUE capabilities

Introduction to Shaka

-
  ```
  packager 'in=/media/input.mp4,stream=audio,segment_template=audio/$Number$.ts,playlist_name=audio/stream.m3u8,hls_group_id=audio,hls_name=ENGLISH' 'in=/media/input.mp4,stream=video,segment_template=video/$Number$.ts,playlist_name=video/stream.m3u8,iframe_playlist_name=video/iframe.m3u8' --enable_widevine_encryption --key_server_url https://license.uat.widevine.com/cenc/getcontentkey/widevine_test --content_id 7465737420636f6e74656e74206964 --signer widevine_test --aes_signing_key 1ae8ccd0e7985cc0b6203a55855a1034afc252980e970ca90e5202689f947ab9 --aes_signing_iv d58ce954203b7c9a9a9d467f59839249 --hls_master_playlist_output master.m3u8
  ```

BUILDING A FULL SOLUTION: CLOUD/ON-PREM

VOD: Server-based HEVC/HLS Asset Generation

- Overview
- Sizing your server
- Our experience
- Hardware starting point
- GPU pipeline
- Getting the software

Implementing Steps

- VOD: Server-based HEVC/HLS asset generation
- Cloud workflow
- Scaling
- Cloud encoding (the server)

OVERVIEW

- Choose your Cloud:
  - AWS
  - Azure
  - RackSpace
  - IBM SoftLayer
- Or don’t (On-prem)
- Or a hybrid (e.g. - On-prem and S3)

SIZING YOUR SERVER

- General
  - What general bitrates are you dealing with?
- Live
  - How many concurrent live streams?
  - Are you also transcoding optional renditions for ABR?
- VOD
  - How many concurrent videos being processed?
  - Is it transcoding or just transmuxing?
  - Do you need to create sidecar assets?

OUR EXPERIENCE

- In AWS we've found m3.large to be a pretty cost effective, decently performant and reliable instance size
- We made our decision in Azure based on AWS and went with as similar a match we could find, DS2_V2
- We use Linux as our base since it's friendlier with our software stack. Mostly RHEL.

STARTING POINT

- Get started with ec2 instances: http://docs.aws.amazon.com/AWSEC2/latest/UserGuide/EC2_GetStarted.html
- Get started with Azure VMs: https://azure.microsoft.com/en-us/documentation/articles/virtual-machines-linux-quick-create-portal/

GPU PIPELINE

- Offload processing from CPU to dedicated hardware
- FFmpeg has some support for GPU Acceleration
- You need to have specific supported hardware
  - Example: AWS EC2 g2.2xlarge + CUDA + FFmpeg with -hwaccel option specified

GETTING THE SOFTWARE

- You’ll need to download and install software
- Our preferred toolset:
  - Bento4/FFmpeg (Video processing and Static Builds are easy install)
  - ImageMagick (spritesheets, thumbnails and image manipulation)
  - Node.js (You need an application server wrapper)
  - MongoDB (You need some data persistence)
  - Cloud Provider SDK (e.g. AWS SDK for JavaScript in Node.js)

Cloud Workflow: Making it Happen

- Designing a workflow API
- Workflow: file transfer
- Workflow: queue
- Open source libraries
- Sample code

DESIGNING A WORKFLOW - API

- You need a good workflow architecture
- Similar to AWS Simple Workflow Service for logical and atomic chunks:
  - Workflow (End to End Execution)
  - Steps (Ingestion, Processing, Transfer)
  - Tasks (Create alternate bitrate rendition, Thumbnails)
  - Adapters (We added this to be agnostic.
    E.g. AWS S3 vs. Azure Blob vs. On-prem)

WORKFLOW: FILE TRANSFER

- Try to leverage any performance enhancements available

- Day to Day Ingestion
  - AWS Multipart Upload
  - Azure Streaming Put a BlockBlob

- Initial Content Migration
  - AWS Import/Export Snowball
  - Azure Import/Export Service

WORKFLOW: QUEUE

- Gracefully handle all your users
- Processing takes time. You need to line up requests.
- Queuing w/persistence also lets you keep track of job status and what’s pending in case of restart.

OPEN SOURCE LIBRARIES

- When there’s a vibrant community you never have to reinvent the wheel

- We use Node.js which has node modules.
  - aws-sdk: AWS JavaScript Library for Node.js
  - fluent-ffmpeg: A node wrapper for the FFmpeg command line tool

SAMPLE CODE

- Check out the demo: https://github.com/realeyes-media/demo-encoder
- Here’s a snippet

```
input.inputOptions = options.inputOptions;
output.outputOptions = ["-hls_time 8", "-hls_list_size 0", "-bsf:v h264_mp4toannexb", "-threads
0"];
input.inputURI = path.join(__dirname, '../../' + options.inputURI);
output.outputURI = `${directory}/${options.fileName +
options.timestamp}_${bitrate}.${options.outputType}`;
options.outputURI = output.outputURI;
output.outputOptions.push(`-b:v ${bitrate}k, `-r ${options.fps}`);

// Use options to call ffmpeg executions in parallel
executeFfmpeg(input, output)
```

Scaling

- Scaling and concurrency
- Scaling – multiple instances
- Multi-instance balancing
- Auto-scaling
- Container swarms

SCALING & CONCURRENCY

- How high can we go?
  FFmpeg will not error when the CPU is busy, just takes longer to process.

- First - Determine the Scenario:
  - The volume of files you need to simultaneously process
  - The average size of the files you need to process
  - The processing time that's acceptable for you org
  - The kinds of operations that need to occur (e.g. Just transmux? Transcode to 4 renditions?)

- Second - Run Performance Tests

SCALING - MULTIPLE INSTANCES

- Bigger instance or more instances?

- Bigger Instance
  - PRO: Handles more concurrency
  - CONS: Can be more costly
- More Instances
  - PRO: Cheaper - Can be scaled up and down to only pay when needed
  - CONS: More complicated to manage

MULTI INSTANCE BALANCING

- Scale Horizontally Transparently
  Clients hit a load balancer
- You can add more instances as needs grow in a transparent and simple way
- If your architecture is sound there's no need for session stickiness between the clients and the transcoding system
- AWS Elastic Load Balancer: https://aws.amazon.com/elasticloadbalancing/
- Azure Load Balancing: https://azure.microsoft.com/en-us/documentation/articles/virtual-machines-linux-load-balance/

AUTO-SCALING

- Leverage Auto Scaling Features
- Automate the spin up/down of instances based on a number of criteria:
  - Instance Load
  - Periodic Need for Faster Processing
  - Time of Day
  - Specific Events
- AWS Auto Scaling: https://aws.amazon.com/autoscaling
- Azure Auto Scale: https://azure.microsoft.com/en-us/documentation/articles/cloud-services-how-to-scale-portal/

CONTAINER SWARMS

- Docker is all the rage. Swarms and Service Discovery
- Create a swarm of Docker containers for a highly repeatable processing server snapshot that utilizes system resources efficiently
- Further increase automation through service discovery
- Implement “auto scaling” on steroids

Cloud Encoding (The Server)

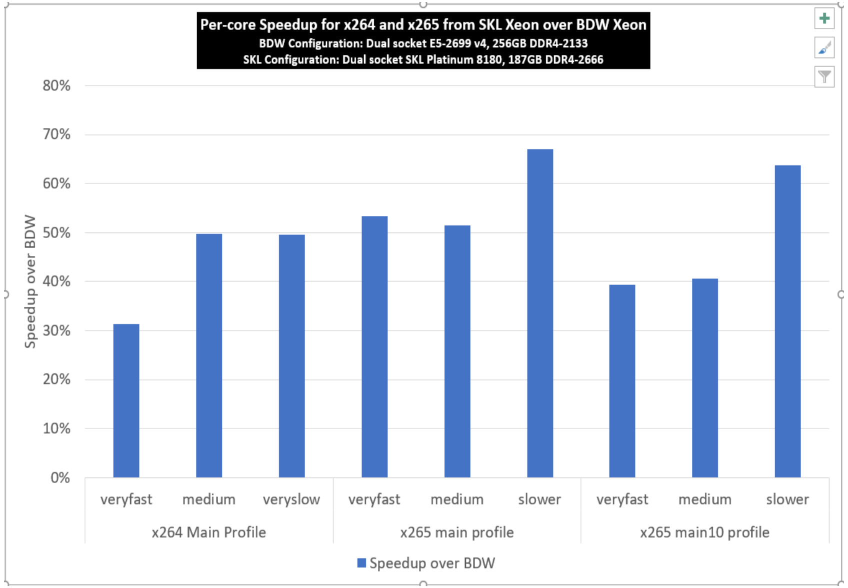
- >>> DEMO <<<

LIVE: Streaming with HEVC/HLS

- x265 Boost from Intel Xeon Scalable processor family
- Wowza
- Encoding – basically it comes down to hardware or cloud

HEVC Live – Intel Scalable Processor Family

- x265 Boost from Intel Xeon Scalable Processor Family
- x265 show a 67% average per-core gain
  for encoding using HEVC Main profile
- 50% average gain with Main10 profile across different presets



HEVC Live

- Wowza: https://www.wowza.com/docs/how-to-stream-using-hevc-h-265-transcoding

HEVC Live

- Live 4K HEVC/H.265 Software Encoding

- Haivision demoed live 4Kp60 HEVC software-only (x265) performance video streaming w/off the shelf hardware

- In the end it all comes down to hardware for live, at least for initial stream (contribution)

FFmpeg Live

```
ffmpeg -re -i  input \
-y -c:v libx265 -preset fast \
-x265-params profile=main:keyint=48:bitrate=4500:vbv-maxrate=4500:vbv-bufsize=9000 \
-c:a aac -b:a 128k -ac 2 -ar 48000 output_1080p.mp4 \
\
-y -c:v libx265 -s 1280x720 -preset fast \
-x265-params profile=main:keyint=48:bitrate=2500:vbv-maxrate=2500:vbv-bufsize=5000 \
-c:a aac -b:a 128k -ac 2 -ar 48000 output_720p.mp4 \
\
-y -c:v libx265 -s 640x360  -preset fast \
-x265-params profile=main:keyint=48:bitrate=1000:vbv-maxrate=1000:vbv-bufsize=2000 \
-c:a aac -b:a 128k -ac 2 -ar 48000 output_360p.mp4
```

- Input is typically from a capture device or incoming stream
- Outputs will be to server addresses
- Easiest if you can encode complete ladder on a single instance
  - Otherwise, split all rungs over multiple computers

More Demos

- Manifest Demo
- Playback demo and discussion (H.265 only)
- Playback demo and discussion (mixed H.264 and H.264)
- Playback demo and discussion (H.264 only)
- Additional resources

Manifest Demo: Walking through VOD and LIVE HEVC/HLS during playback (manifest viewer)

Manifest Demo: Walking through VOD and LIVE HEVC/HLS during playback (manifest viewer)

Playback Demo/Discussion: H.265 only

Playback Demo/Discussion: Mixed H.265 + H.264

Playback Demo/Discussion: H.264 only

Resources

- Slides: http://bit.ly/2gwIYs5

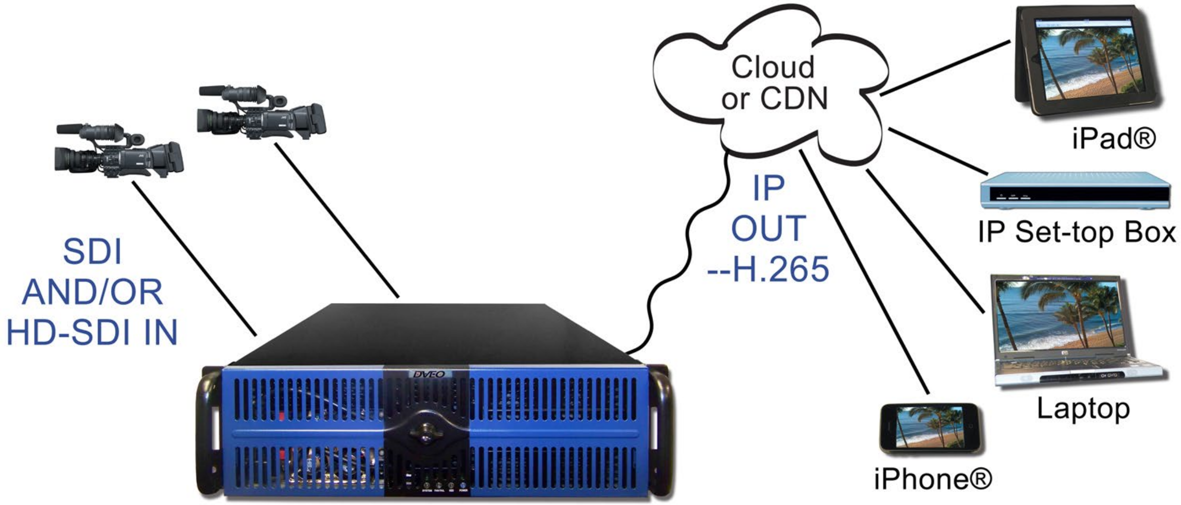
Third Party Alternatives

- Live
  - Full transcode and package
  - Contribution
  - Cloud transcode
- VOD
  - Appliance
  - Software
  - Cloud

Live: Full Transcode and Package

- DVEO Gearbox265
- Elemental Live
- Harmonic Electra XT
- Harmonic VOS Cloud Software
- Telestream Vantage Lightspeed

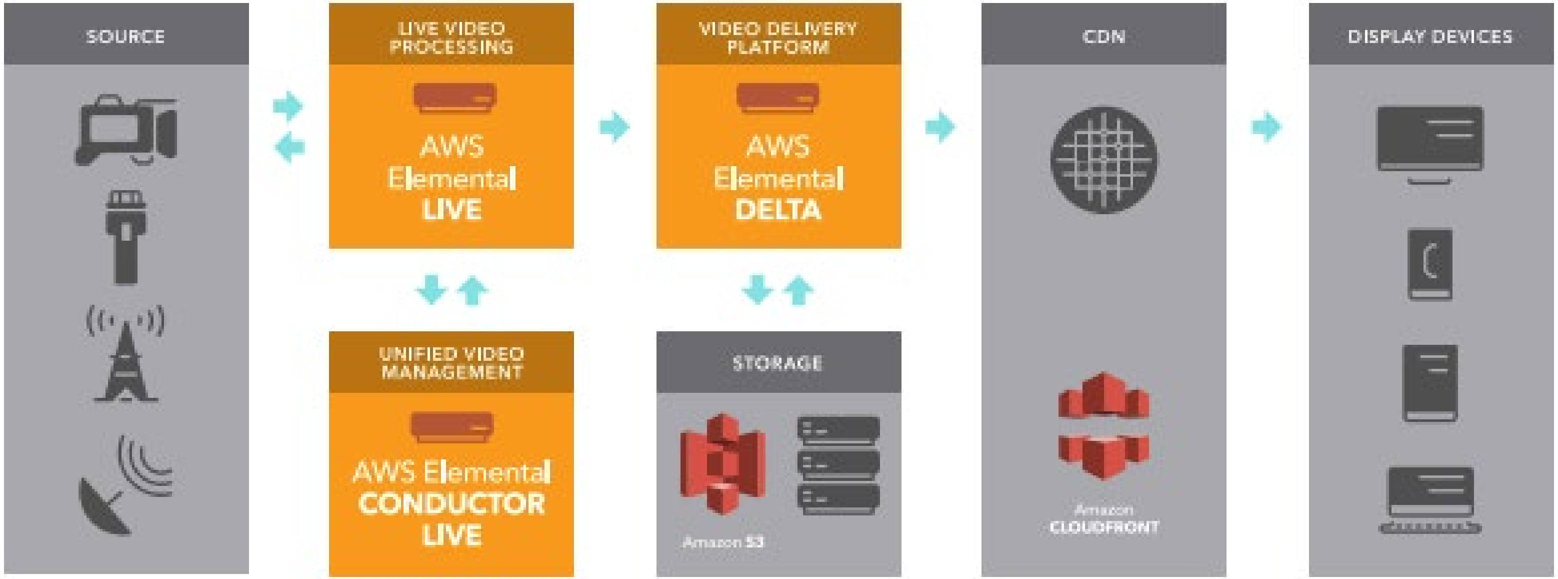
Full Transcode and Package: DVEO Gearbox265



- Hardware appliance

- No pricing info on website
- At Streaming Media West

Full Transcode and Package: Elemental Live



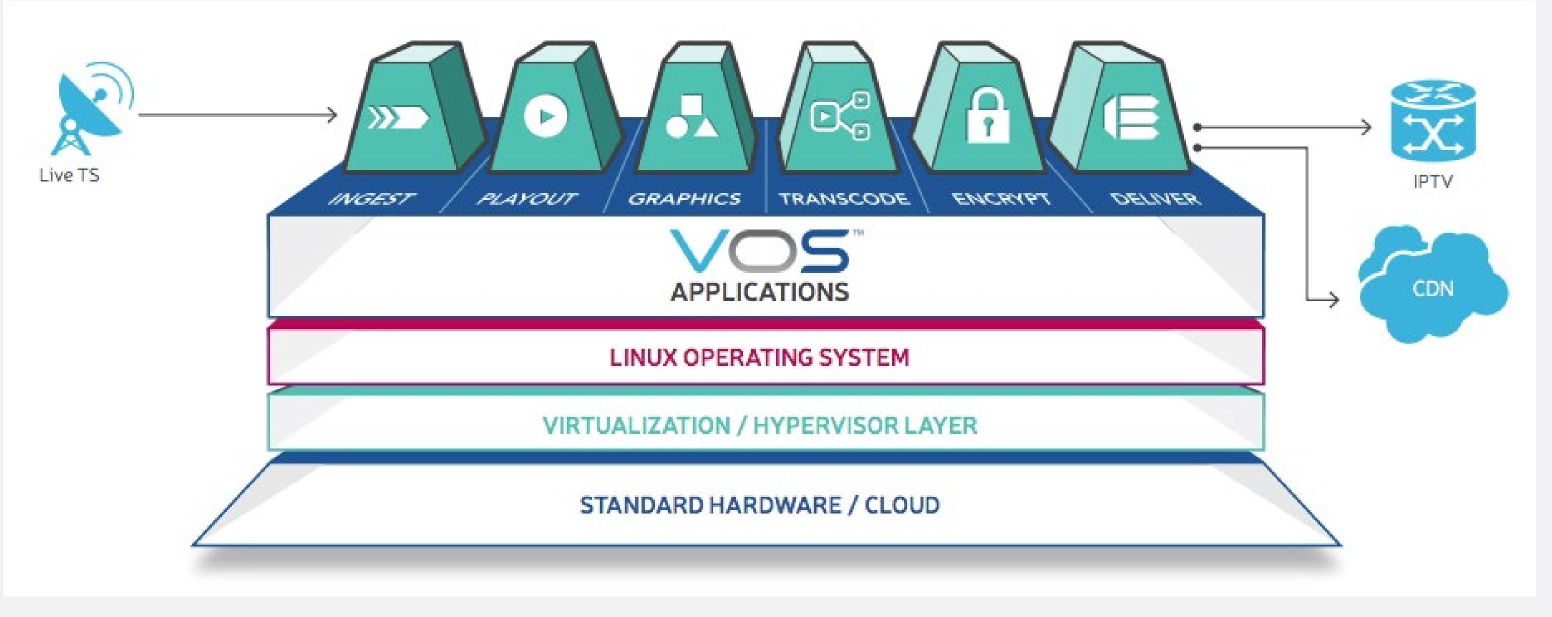
- Linux-based software; deploy anywhere
- No pricing info on website
- At Streaming Media West

Full Transcode and Package: Harmonic Electra XT, X2, X2S, VS

- Linux-based software; deploy anywhere

- No pricing info on website
- At Streaming Media West

Cloud Transcode: Harmonic VOS Cloud Software



- Licensed software
- Deploy in OpenStack or AWS

- No pricing info on website
- At Streaming Media West
- Live and VOD

Full Transcode and Package: Telestream Lightspeed Live Stream

- Linux-based software; deploy anywhere

- No pricing info on website
- At Streaming Media West

Live Contribution

- Harmonic
- LiveU
- Teradek

Cloud Transcode: Harmonic ViBE 4K

- Hardware/VOD
- Needs external packager for HLS

- No pricing info on website
- At Streaming Media Westn

Contribution: LiveU

HEVC Pro Card (for LU) 600
$2,790
(Ethernet)

Cube 755
$2,990
(Ethernet + Wi_Fi)

Slice 756
$3,990
(Ethernet + Wi_Fi)

Contribution: Teradek

Cube 705
$2,790
(Ethernet)

Cube 755
$2,990
(Ethernet + Wi_Fi)

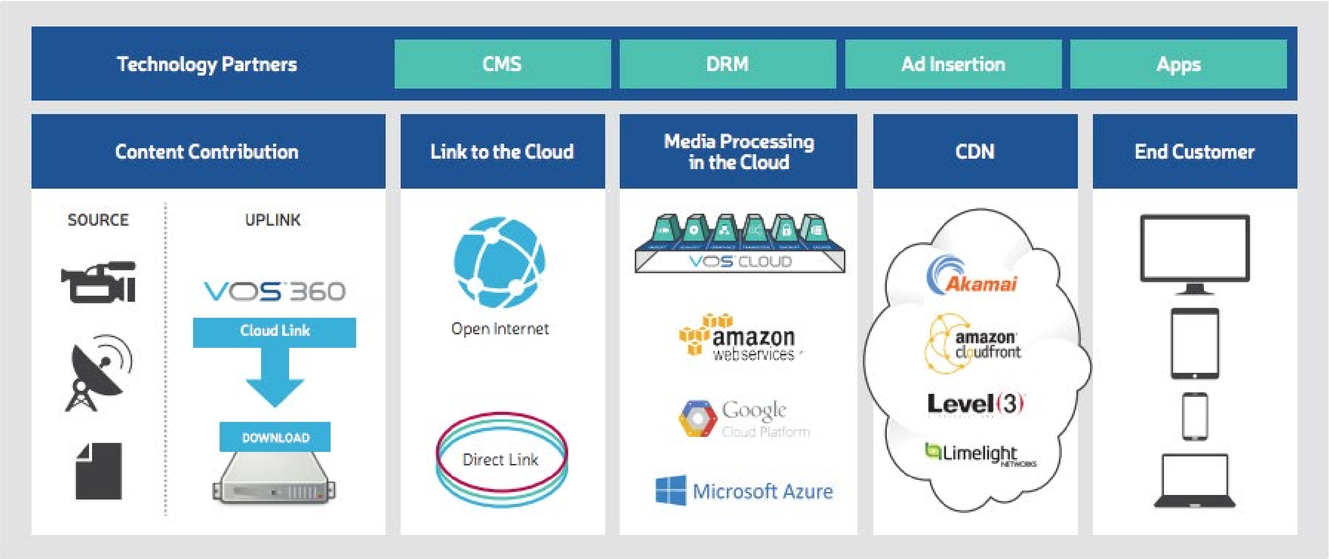
Slice 756
$3,990
(Ethernet + Wi_Fi)

Live Cloud Transcode

- Harmonic VOS 360 cloud service
- Wowza

Cloud Transcode: Harmonic VOS 360 Service

VOS 360 ECOSYSTEM



Technology Partners
CMS
DRM
Ad Insertion
Apps

Content Contribution
Link to the Cloud
Media Processing in the Cloud
CDN
End Customer

- Linux-based software; deploy anywhere

- No pricing info on website
- At Streaming Media West

Wowza

- Can transcode to HEVC/not yet compliant with HLS spec
  - No CMAF yet
  - Here at show; ask when they will have

HEVC, HLS, and Live Production: A Wowza Interview

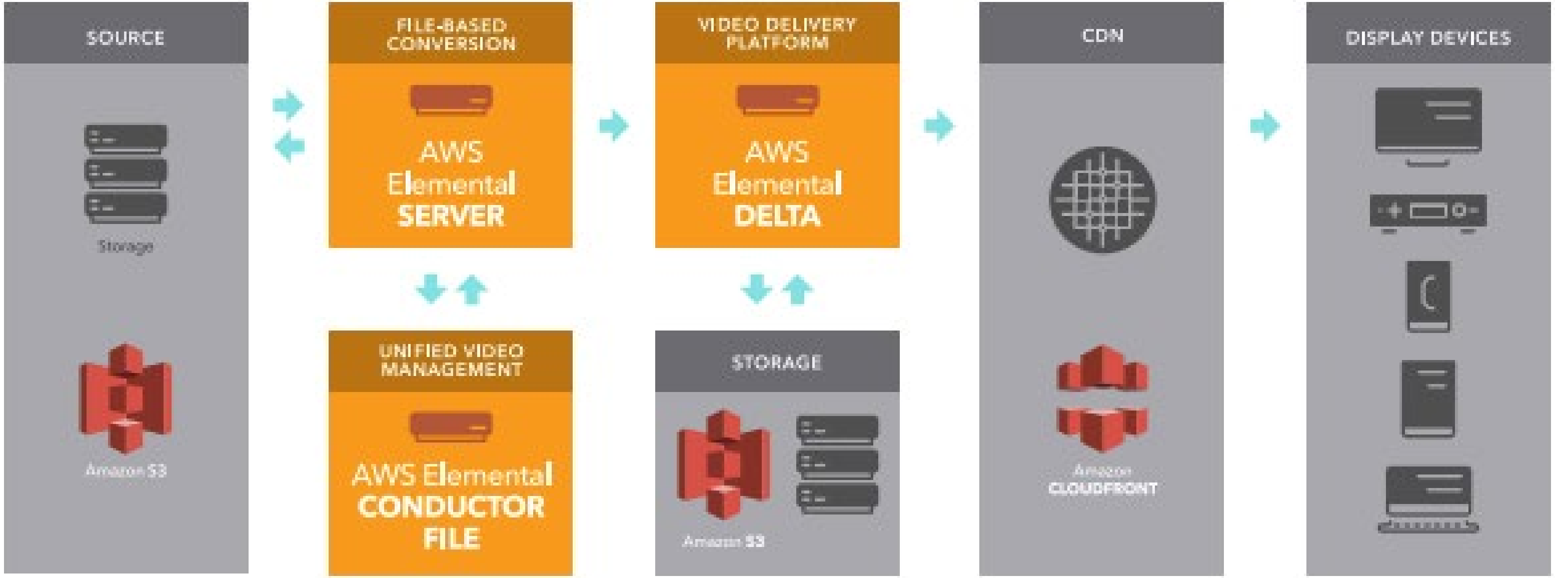
Wowza VP of Engineering Barry Owen

http://bit.ly/wz_hls

VOD

- Appliance
- Software
- Cloud

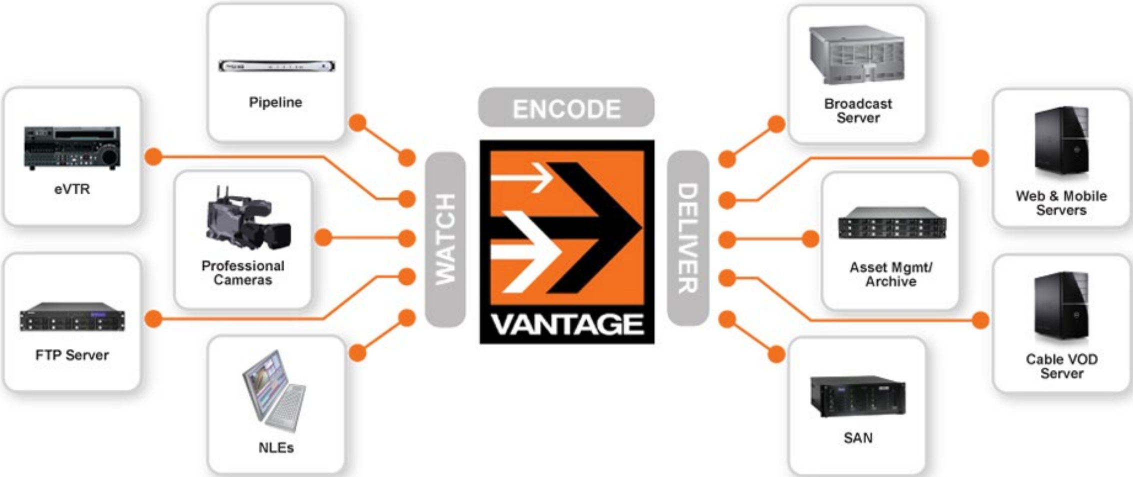
Appliance: AWS Elemental Server



- Linux-based software; deploy anywhere

- No pricing info on website
- At Streaming Media West

Software: Vantage Media Processing Platform



- Can run on servers or on public and private virtualized infrastructures
- At show

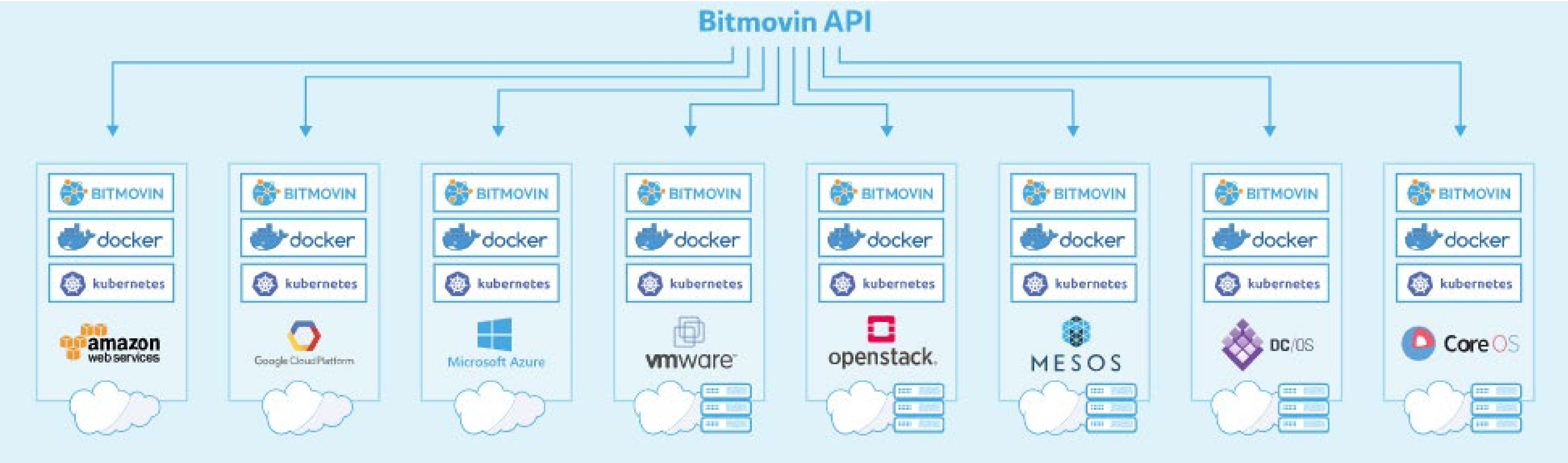
Cloud: AWS Elemental Cloud

The picture can't be displayed.

- True cloud-based product; extensible with other products

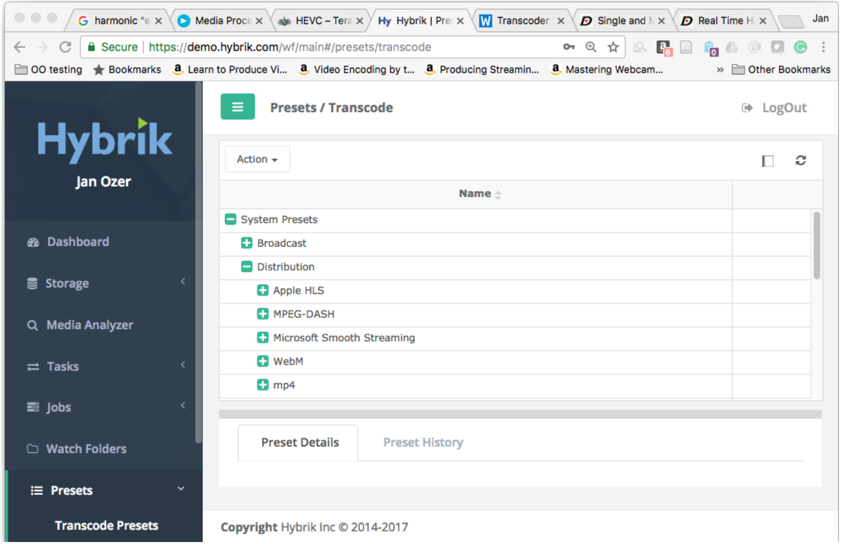
- No pricing info on website
- At Streaming Media West

Software/Cloud: Bitmovin Video Encoding



- Available as a SaaS offering or for internal deployment
- No pricing info on website
- At Streaming Media West

Cloud: Hybrik Cloud



harmonic "e | Media Proce | HEVC – Tera | Hy Hybrik | Pre | W Transcoder | D Single and | D Real Time H | Jan

Secure | https://demo.hybrik.com/wf/main#/presets/transcode

OO testing | Bookmarks | Learn to Produce Vi... | Video Encoding by t... | Producing Streamin... | Mastering Webcam... | » | Other Bookmarks

Hybrik

Jan Ozer

- Dashboard
- Storage
- Media Analyzer
- Tasks
- Jobs
- Watch Folders
- Presets
  - Transcode Presets

Presets / Transcode

LogOut

Action

Name
⊟ System Presets
⊞ Broadcast
⊟ Distribution
⊞ Apple HLS
⊞ MPEG-DASH
⊞ Microsoft Smooth Streaming
⊞ WebM
⊞ mp4

Preset Details | Preset History

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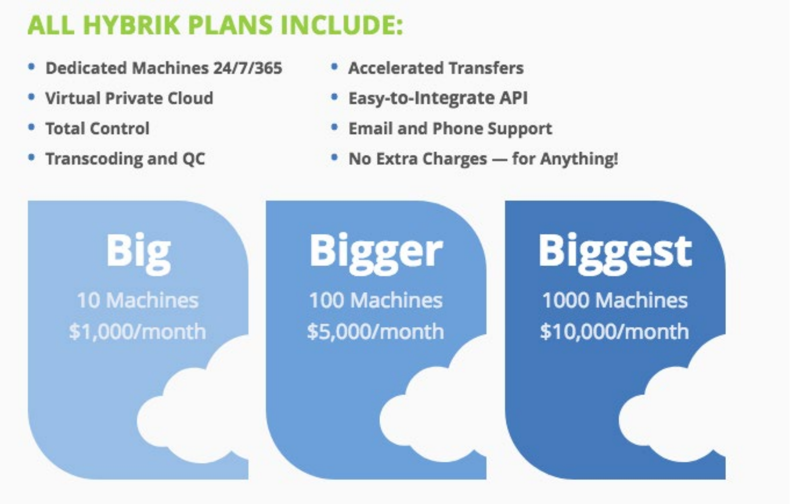

ALL HYBRIK PLANS INCLUDE:

- Dedicated Machines 24/7/365
- Virtual Private Cloud
- Total Control
- Transcoding and QC
- Accelerated Transfers
- Easy-to-Integrate API
- Email and Phone Support
- No Extra Charges — for Anything!

Big	Bigger	Biggest
10 Machines	100 Machines	1000 Machines
$1,000/month	$5,000/month	$10,000/month

- Currently VOD; moving to live
- At Streaming Media West

Other Vendors

- Live
  - Contribution
    - Vitec – multiple encoders

- VOD
  - SDKs
    - Beamr
    - MainConcept
    - Multicoreware