

PER-TITLE ENCODING

Jan Ozer

www.streaminglearningcenter.com

[jozer@mindspring.com/](mailto:jozer@mindspring.com)

276-235-8542

@janozer

Agenda

- What is per-title encoding
 - Why is it important
 - Universe of features
- Our contestants
 - Capped Constant Rate Factor (CRF)
 - Capella Systems – Source Adaptive Bitrate Ladder (SABL)
 - Brightcove – Context Aware Encoding
 - FASTech – Intelligent Content Adaptive Video Compression
- Our tests
- Our results

What is Per-Title Encoding

- Customizing encoding for each file
- First implemented by Netflix and YouTube
- First encoder implementation – Capella Systems Cambria Encoder
- Can be implemented vis capped CRF

Why is Optimizing the Bitrate Critical?

Consumer Side

- Reduced bandwidth cost (consumer/corporate)
 - Home
 - Mobile
- More efficient on networks
- Better quality of experience
 - Higher rez stream to mobile

Producer Side

- Lower bandwidth costs
- Lower storage costs
- Lower encoding costs
- More video through fixed pipes
- Better reach to consumers on edge of networks
- More competitive because of consumer-side benefits
- More competitive because a feature in competitive products and services

Understanding Per-Title Techniques

Feature	Netflix	YouTube
Core	Brute force/CRF encodes/VMAF	Neural Network
Adjust data rate	Yes	Yes
Change number of files in ladder	Yes	Yes
Adjust resolution	Yes	Yes
Customizability	Presume yes	Presume yes
Bitrate control (CBR/VBR)	Presume yes	Presume yes
Post-encode quality check	Presume yes	Presume yes

- Universe of features

Our Contestants

- Capped CRF
 - Used by some OVPs (JW Player); available using FFmpeg and multiple encoders
- Capella Systems
 - Source Adaptive Bitrate Ladder (SABL)
 - Standard feature of Cambria FTC encoder
 - Review here http://bit.ly/cambria_pt
- Brightcove
 - Context Aware Encoding
 - Standard feature for end-to-end Brightcove OVP offering
 - Premium for Brightcove encoder-only customers (pricing not set)
- FASTech.io – Quick Preview
 - Intelligent Content Adaptive Video Compression (here at the show)

How We Tested

Title	Genre
Elektra (2 minutes)	Movie
El Ultimo (1 minutes)	Simple animated movie
Epiphan screencam (4:22)	Mixed screencam and real world video
Freedom (4:25)	Music video
Haunted (2 minutes)	Movie like video
Ironman preview (1:52)	Animated movie
New (92 seconds)	Test cliop
Screencam (2 minutes)	Screencam only
Sintel (2 minutes)	Animated movie
Sponge Bob preview (2:17)	Animated movie
Tears of Steel (2 minutes)	Movie with computer generated content
Test (8 minutes)	Mixed talking head and ballet
TalkingHead (2 minutes)	Simple talking head
Tutorial (2 minutes)	Mixed PowerPoint and small video
Zoolander (5 minutes)	Movie footage

- These videos
- To that ladder (as a baseline)
- Then encode using per-title technique

Width	Height	Profile	Preset	FPS	Data Rate
1920	1080	High	Medium	Native	4500
1280	720	High	Medium	Native	2700
960	540	High	Medium	Native	1900
852	480	High	Medium	Native	1350
640	360	High	Medium	Native	900
480	272	High	Medium	Native	500
320	180	High	Medium	Native	250

- Data rate can vary up to 150% upwards
- Parameters vary by encoder
 - Don't compare quality between encoders
 - Just before and after quality for each encoder

Interpreting VMAF Metrics

- CRF 22 @ 1080 - maps to 100
- CRF 28 @ 240 - maps to 20
 - Anything in between is mapped in the middle (for example, SD encode at 480 is typically mapped to 40 ~ 70)
- +/- 6 points ~ Just Noticeable Difference

Ranking the Contestants

- Very early days of per-title
- Highly programmable tools/complex test cases
- Wanted to create some scoring mechanisms to measure the contenders

Ranking the Contestants

- Very early days of per-title
- Highly programmable tools/complex test cases
- Wanted to create some scoring mechanisms to measure the contenders



Grading - Absolute

Width	Height	Data Rate	Jump	PSNR	VMAF
1920	1080	4,503	1.67	40.91	93.39
1280	720	2,697	1.42	38.86	87.87
960	540	1,893	1.41	37.37	82.02
852	480	1,340	1.51	36.17	76.45
640	360	889	1.83	34.13	65.04
480	272	485	2.06	31.42	41.23
320	180	235		28.84	9.68
		12,041			

Width	Height	Data Rate	Jump	PSNR	VMAF
1920	1080	2,897	1.44	39.20	87.61
1600	900	2,009	1.91	38.14	83.99
1024	576	1,051	1.94	36.09	73.97
480	270	541	1.89	31.71	43.28
320	180	286		29.10	12.00
		6,784			

5257 - storage savings

- Fifteen test clips (most completed 14)
- Encode standard ladder

- Encode per-title
 - Fewer rungs
 - Different resolutions data rates

Grading - Experiential

Epiphan	Original						4500	Degraded					File	Data Rate	VMAF
	Width	Height	Data Rate	Jump	PSNR	VMAF		Width	Height	Data Rate	PSNR	VMAF			
	1920	1080	3,194	1.64	44.74	93.19		1920	1080	841	42.73	91.47	1080	-73.69%	-1.72
	1280	720	1,951	1.43	40.28	89.88	2700	1920	1080	841	42.73	91.47	720	-56.92%	1.60
	960	540	1,362	1.35	37.84	84.82	1900	1920	1080	841	42.73	91.47	540	-38.29%	6.65
	852	480	1,007	1.50	36.88	81.82	1350	1920	1080	841	42.73	91.47	480	-16.53%	9.66
	640	360	672	1.74	34.67	70.99	900	1920	1080	841	42.73	91.47	360	25.17%	20.49
	480	272	387	2.01	32.50	54.54	500	1280	720	443	38.95	85.62	272	14.47%	31.08
	320	180	192		29.85	23.57	250	852	480	229	35.76	75.48	180	19.21%	51.91
														-18.08%	17.09

- Which per-title clip would viewer watch at bandwidth target of original ladder
 - Highest quality per-title clip under the bandwidth of the original source

- How does the VMAF rating of per-title clip compare to original?
 - Here, lower by 9.84
 - This would be a loss because per-title degraded experience

Wins/Losses/Hits

Wins/Losses

- **Win**
 - Experiential VMAF > -2.99
 - With bandwidth reduction
- **Loss**
 - Experiential VMAF < 2.99 or lower

Hits

- **Home run** – experiential VMAF positive
- **Triple** – Win with 20%+ bitrate saving
- **Double** – Win with 10-20% bitrate saving
- **Single** – Win with less than 10% saving

Other Scores

Errors

- Didn't meet lowest data rate target
 - Cellular viewers get no stream

	Width	Height	Data Rate	PSNR	VMAF
4500	1920	1080	4,477	41.05	86.27
2700	1280	720	2,416	39.32	80.70
1900	960	540	1,562	38.35	77.20
1350	852	480	1,313	37.88	75.49
900	640	360	852	36.40	68.58
500	480	272	555	34.43	58.06
250	320	180	300	31.82	34.67

Other Scores

Errors

- Jump between streams greater than 2x or less than 1x
 - Could degrade operation of ABR mechanism

Width	Height	Data Rate	Jump	PSNR	VMAF
1920	1080	4,411	1.66	43.01	93.69
1280	720	2,656	1.42	41.54	88.84
960	540	1,867	1.42	40.26	84.75
852	480	1,318	1.50	39.69	82.36
640	360	882	1.84	38.27	74.54
480	272	480	2.06	36.26	57.78
320	180	233		33.36	24.04

Save (encoding costs)

- Reduced the number of rungs in the ladder
 - One save for each eliminated rung
 - Without violating any other rule
- Eliminate encoding pass

Epiphan	Width	Height	Data Rate	Jump	PSNR	VMAF	Width	Height	Data Rate	Jump	PSNR	VMAF
	1920	1080	4,483	1.67	49.68	96.66	1920	1080	2,261	1.75	49.60	95.38
	1280	720	2,686	1.43	42.01	93.90	1280	720	1,289	1.75	41.43	92.54
	960	540	1,884	1.41	39.10	89.50	1024	576	736	1.78	38.84	88.63
	852	480	1,332	1.51	37.92	86.72	768	432	413	1.78	36.40	80.99
	640	360	883	1.84	35.20	76.48	576	324	232		33.97	68.18
	480	272	480	2.05	32.73	60.39						
	320	180	235		30.09	29.89						

Capped CRF

- Encoding mode available in x264, x265, VP8/9
- Encodes to a specific quality level, not a data rate
- Can "cap" to meet data rate targets
- Procedure
 - Choose quality level (CRF 23)
 - Choose maximum bitrate
- One pass encode, so saves time

```
ffmpeg -i input -crf 23 -maxrate 6750k -bufsize 4500k output
```

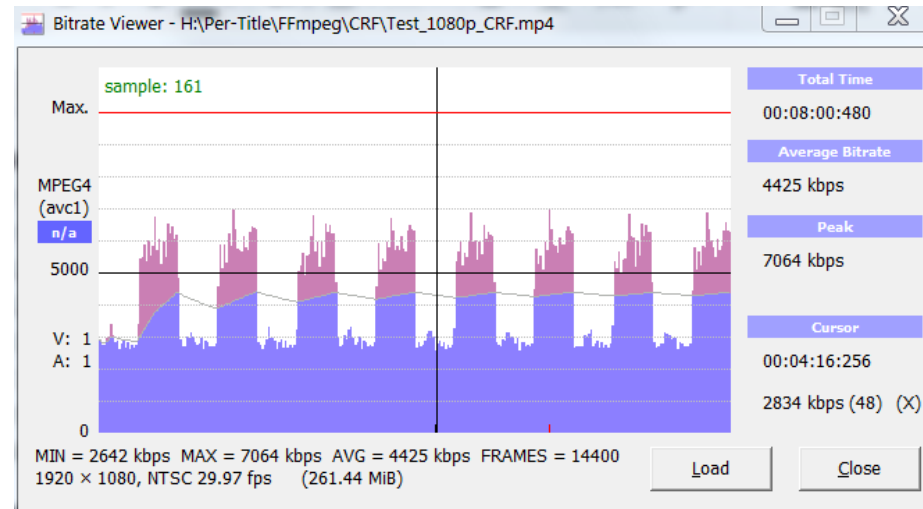
High Level View

Feature	Capped CRF
Core schema	CRF encode
Adjust data rate	Yes
Change number of files in ladder	No
Adjust resolution	No
Customizability	CRF/max rate
Bitrate control (CBR/VBR)	No
Post-encode quality check	No

- Works with existing ladder
 - Can't change number of files
 - Can't adjust resolution
 - Limited customizability

- No data rate control
 - Adjusts data rate for specified quality (CRF 23)
 - Caps at specified level
 - Data rate can swing wildly
- No post-encode quality check

No Data Rate Control



- My big concern with capped CRF is potential impact on QoE
 - Big data rate swings in test file reduced QoE substantially (see article at http://bit.ly/BRC_QOE)
 - **Counterpoint:** used by JWPlayer, presumably with good results
- Gives Capped CRF advantage over other technologies, particularly Capella and FASTTech (who used 110% constrained VBR)

Capped CRF Box Score

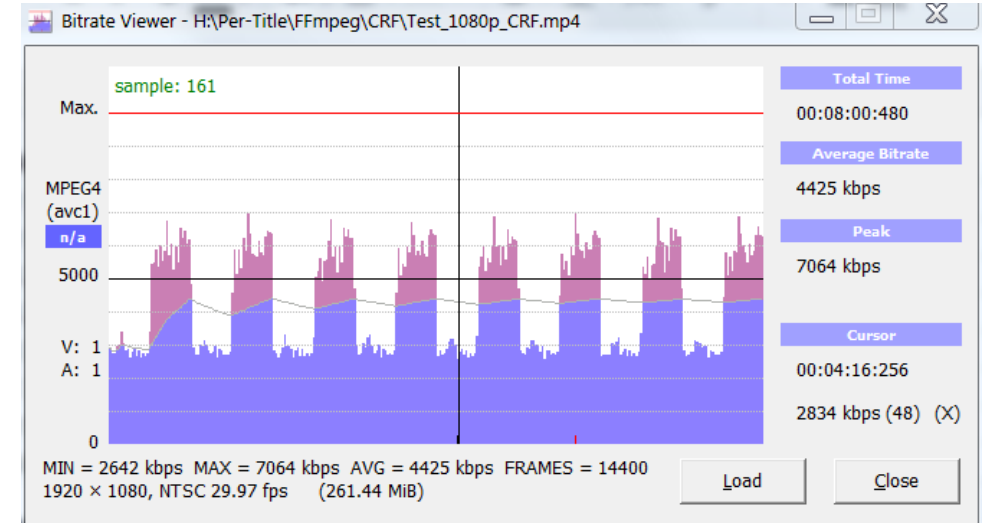
	Capped CRF
Wins	15
Losses	0
Storage saved	39,876
Streaming saved	-208%
Net impact on VMAF	65.47
Saves	98
Singles	1
Doubles	4
Triples	1
Home runs	10
Errors	6

Width	Height	Data Rate	Jump	PSNR	VMAF
1920	1080	5,840	2.56	42.66	91.81
1280	720	2,282	1.73	40.14	86.06
960	540	1,317	1.28	38.83	81.17
852	480	1,030	1.66	38.20	78.57
640	360	619	1.22	36.51	70.24
480	272	509	1.81	34.34	57.69
320	180	282		31.73	33.64

- All wins, no losses
- Multiple errors where highest rung was too far from 720p
 - May strand viewers at 720p rung
 - Try lower quality – CRF 24/25 - for top rung?
- Lots of saves due to single pass encoding
- Big overall savings

Highlights and Bloopers

	Width	Height	Data Rate	PSNR	VMAF	File	Data Rate	VMAF
4500	1920	1080	1,804	46.38	95.82	1080	-44.36%	-0.11
2700	1920	1080	1,804	46.38	95.82	720	-25.64%	13.25
1900	1920	1080	1,804	46.38	95.82	540	10.13%	22.04
1350	1280	720	878	28.11	81.32	480	-27.76%	10.52
900	1280	720	878	28.11	81.32	360	10.50%	22.62
500	852	480	433	26.07	69.03	272	-4.82%	27.59
250	480	272	176	24.08	39.99	180	-19.46%	29.22
			7,778				-14.49%	17.88



- Screencam
 - Low data rate of high rez clips pushed overall VMAF average up 17.88

- Biggest issue for me is potential QoE issues

Capella Systems – Source Adaptive Bitrate Ladder

- Feature of Cambria FTC encoder
- Technical description
 - Use CRF encode to measure complexity of encoded footage
 - Adjust encoding ladder up or down based up results
 - If 7000 or higher, adjust data rate upwards by 1.5
 - If lower than 2000, adjust downwards by 50%
- Implemented as a JSON script
 - Pretty simple to make simple adjustments (no programming required)

```
# Function to get Multiplier value
sub getMultiplierValue
{
  my $complexityValue = $_[0];
  if ($complexityValue <= 0) { return 1.0; }
  if ($complexityValue >= 7000) { return 1.5; }
  if ($complexityValue >= 5000) { return 1.25; }
  if ($complexityValue >= 4000) { return 1.0; }
  if ($complexityValue >= 3500) { return 0.9; }
  if ($complexityValue >= 3000) { return 0.8; }
  if ($complexityValue >= 2500) { return 0.7; }
  if ($complexityValue >= 2000) { return 0.6; }
  return 0.5;
}
```

Cambria Adjustments

Width	Height	Data Rate	Jump	PSNR	VMAF		Width	Height	Data Rate	Jump	PSNR	VMAF
1920	1080	4448	1.66	55.22	97.49		1920	1080	901	1.67	47.07	96.49
1280	720	2686	1.42	33.06	88.66		1600	900	538	1.41	35.67	91.10
960	540	1885	1.42	30.36	83.96		1200	674	382	2.12	31.86	85.56
852	480	1327	1.52	28.23	74.44		800	450	180		27.71	67.36
640	360	871	1.80	26.23	62.33							
480	272	485	2.05	24.07	39.83							
320	180	236		21.11	4.75							

- Duration measured by CRF encode
 - Uses data rate from hardest to encode 30 second segment
 - Extend this for more aggressive view
 - Shorten it for more conservative
- Adjustments to ladder – Very flexible
 - Increase resolution for simple videos
 - Decrease number of rungs for lower bitrates
 - Add bitrates to ensure minimum target met

High Level View

- Cambria is CRF with
 - **Better bitrate control**
 - More control over CRF computation
 - Better control over adjustment to bitrate ladder
- Very simple, mechanical system that works very well
 - Only commercial encoder with per-title encoding options

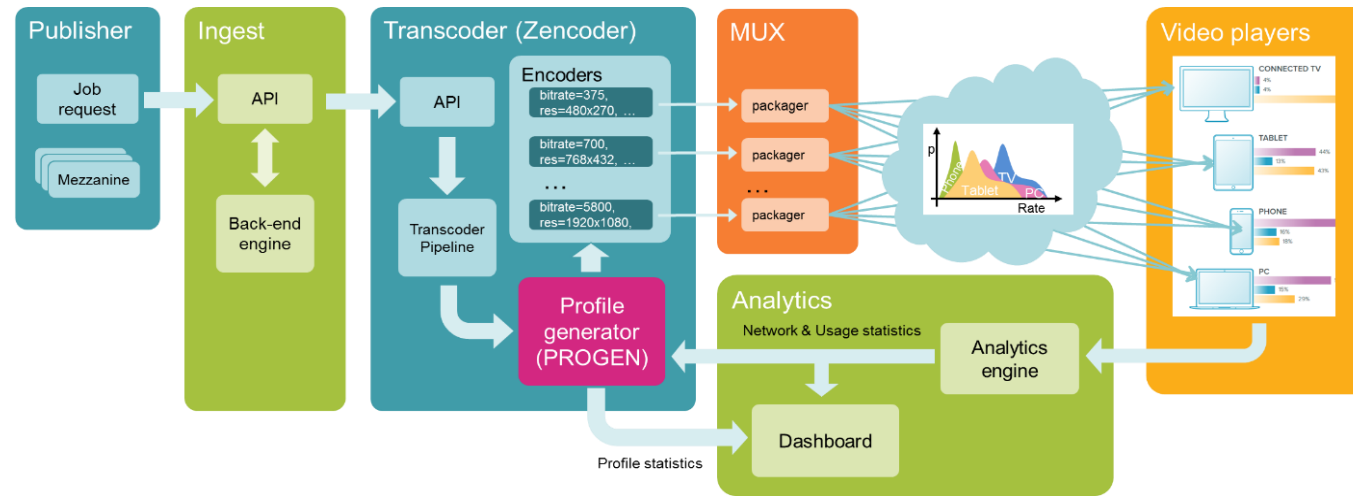
	Capped CRF	Capella Systems
Wins	15	14
Losses	0	0
Storage saved	39,876	41,807
Streaming saved	-208%	-193%
Net impact on VMAF	65.47	65.94
Saves	98	7
Singles	1	4
Doubles	4	5
Triples	1	1
Home runs	10	4
Errors	6	0

Highlights

Talking Head	Width	Height	Data Rate	Jump	VMAF		Width	Height	Data Rate	VMAF		File	Data Rate	VMAF
	1920	1080	4473	1.66	96.07	4500	1920	1080	2,241	94.49		1080	-49.90%	-1.58
	1280	720	2691	1.42	91.65	2700	1920	1080	2,241	94.49		720	-16.72%	2.84
	960	540	1895	1.41	87.10	1900	1600	900	1,342	91.49		540	-29.18%	4.39
	852	480	1343	1.51	83.58	1350	1600	900	1,342	91.49		480	-0.07%	7.91
	640	360	891	1.84	72.56	900	1064	600	673	84.98		360	-24.47%	12.43
	480	272	485	2.05	55.51	500	800	450	449	73.06		272	-7.44%	17.55
	320	180	237		23.95	250	600	336	249	57.99		180	5.29%	34.05
			12,015						8,537				-17.50%	11.08

- Reduce top data rate by 49%
- Average bitrate by 17.5%
- Increased VMAF experiential by 11.08 average

Brightcove Context Aware Encoding



- Feature of Brightcove OVP and encoding service
 - Not Zencoder
- Free with OVP; pricing not set for service
- In beta now (free), scheduled for release in Q4

- Black Box, considers
 1. Properties of the content
 2. Distribution of user devices (connected TVs, PCs, smartphones, tablets, etc.)
 3. Properties of user devices and networks
 4. Constraints specific to video codecs, profiles, etc.

Highly Customizable (JSON)

- Can choose
 - Min/max renditions
 - Min/max resolution
 - Max frame rate
 - Key frame rate
 - Min/max bitrate
 - Max first rendition bitrate
 - Min/max ssim (as quality check)
 - Select baseline config
- Plus all normal configuration options
 - Resolution
 - Aspect ratio
 - Frame rate
 - Codec/profile/level
 - Reference frames
 - Bframes

JSON used On Our Encodes

- "input":
"s3://zencodertesting/DynamicProfiles/SourceMedia/JanOzer/Freedom_1080p.mp4",
- "generate_dynamic_profile": true,
- "dynamic_profile_options":
 - {
 - "min_renditions": 2,
 - "max_renditions": 10,
 - "max_resolution": {"width": 1920,"height":1080},
 - "min_resolution": {"width": 320, "height":180},
 - "max_bitrate": 4500,
 - "max_first_rendition_bitrate": 250,
 - "max_frame_rate": 30,
 - "keyframe_rate": 0.5,
 - "max_granularity": 75,
- "video_configurations": [
 - {"width": 320, "height": 180, "video_codec_profile": "high"},
 - {"width": 384, "height": 216, "video_codec_profile": "high"},
 - {"width": 416, "height": 234, "video_codec_profile": "high"},
 - {"width": 480, "height": 270, "video_codec_profile": "high"},
 - {"width": 512, "height": 288, "video_codec_profile": "high"},
 - {"width": 576, "height": 324, "video_codec_profile": "high"},
 - {"width": 640, "height": 360, "video_codec_profile": "high"},
 - {"width": 768, "height": 432, "video_codec_profile": "high"},
 - {"width": 800, "height": 450, "video_codec_profile": "high"},
 - {"width": 960, "height": 540, "video_codec_profile": "high"},
 - {"width": 1024, "height": 576, "video_codec_profile": "high"},
 - {"width": 1152, "height": 648, "video_codec_profile": "high"},
 - {"width": 1280, "height": 720, "video_codec_profile": "high"},
 - {"width": 1440, "height": 810, "video_codec_profile": "high"},
 - {"width": 1536, "height": 864, "video_codec_profile": "high"},
 - {"width": 1600, "height": 900, "video_codec_profile": "high"},
 - {"width": 1920, "height":1080, "video_codec_profile": "high"}] },
 - "outputs": [

High Level View

Feature	Capped CRF	Capella Systems	Brightcove
Core schema	CRF encode	CRF encode	Probe encodes
Adjust data rate	Yes	Yes	Yes
Change number of files in ladder	No	Yes	Yes
Adjust resolution	No	Yes	Yes
Customizability	CRF/max rate	Some	Extensive
Bitrate control (CBR/VBR)	No	Yes	Yes
Post-encode quality check	No	No	Yes - SSIM

- Highly functional
 - Change numbers of files
 - Change resolution
 - Post-encode quality check
- Still work in progress with lots of moving parts
- Getting close to finding one-size-fits-all configuration that meets 99% of needs

Brightcove Box Score

- 13-1
- Best storage and streaming savings
- Highest impact on VMAF
- Most home runs

	Capped CRF	Capella Systems	Brightcove
Wins	15	14	13
Losses	0	0	1
Storage saved	39,876	41,807	53,171
Streaming saved	-208%	-193%	-234%
Net impact on VMAF	65.47	65.94	82.97
Saves	98	7	19
Singles	1	4	1
Doubles	4	4	2
Triples	1	1	0
Home runs	10	5	10
Errors	6	0	5

Highlights

El Ultimo	Width	Height	Data Rate	Jump	PSNR	VMAF		Width	Height	Data Rate	PSNR	VMAF	File	Data Rate	VMAF
	1920	1080	4,326	1.64	45.94	97.25	4500	1920	1080	1,927	45.21	95.64	1080	-55.46%	-1.62
	1280	720	2,630	1.40	42.90	93.94	2700	1920	1080	1,927	45.21	95.64	720	-26.73%	1.70
	960	540	1,879	1.40	40.32	90.10	1900	1600	900	1,165	43.27	92.60	540	-38.00%	2.50
	852	480	1,340	1.50	39.23	87.79	1350	1600	900	1,165	43.27	92.60	480	-13.06%	4.81
	640	360	896	1.79	37.20	80.20	900	1280	720	712	41.45	88.97	360	-20.56%	8.76
	480	272	501	2.06	35.23	64.08	500	960	540	426	38.94	82.06	272	-14.99%	17.98
	320	180	243		32.35	27.24	250	640	360	237	36.20	69.83	180	-2.71%	42.59
			11,816							7,559				-24.50%	10.96

- Animated clip
 - Added higher resolution rungs (900p)
 - Cut data rate significantly
- Cut 1080p data rate by 55%
- Average data rate down 24.5%
- VMAF up average 10.96%

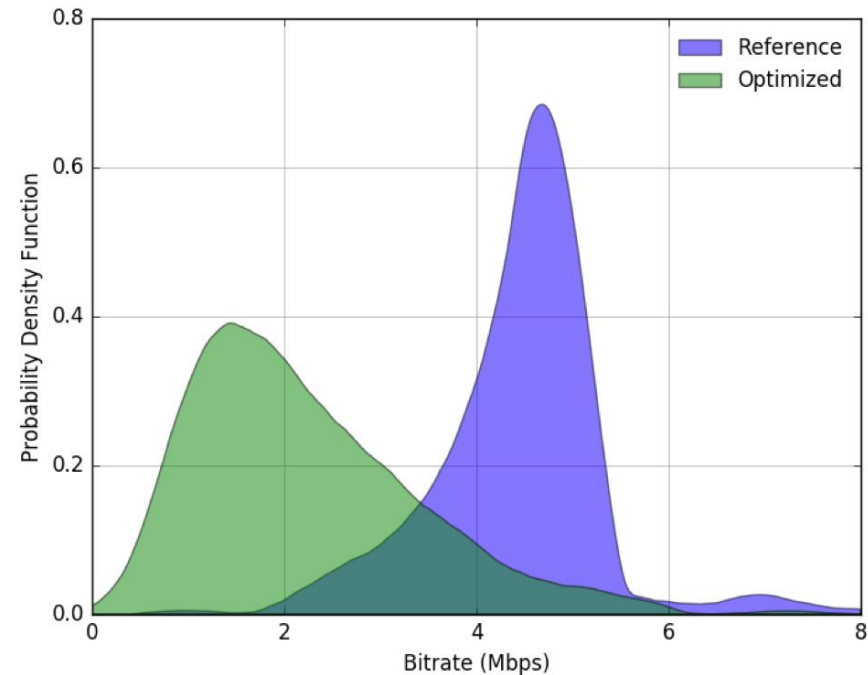
Bloopers

Sponge Bob	Width	Height	Data Rate	Jump	PSNR	VMAF	Width	Height	Data Rate	Jump	PSNR	VMAF
	1920	1080	4,724	1.68	40.97	95.12	1920	1080	4,593	1.77	41.41	95.13
	1280	720	2,818	1.43	39.00	91.50	1152	648	2,593	1.77	38.89	91.39
	960	540	1,977	1.41	37.38	87.19	800	450	1,465	1.80	36.22	83.03
	852	480	1,398	1.51	36.19	82.45	576	324	812	1.80	33.16	66.21
	640	360	925	1.84	33.91	70.76	416	234	451	1.74	30.47	42.34
	480	272	503	2.06	31.11	46.99	320	180	259		28.66	17.76
	320	180	244		28.42	14.90						

- Sponge Bob (only loss)
- Reduced resolution (never a good idea with animations) without dramatic data rate reduction
- Fourth rung comparison lost 16 VMAF points

FASTech.io - Intelligent Content Adaptive Video Compression

- Startup hosted at the Qualcomm Institute Innovation and at StartR, an accelerator at the Rady School of Management, University of California, San Diego
- Black Box technology based upon predictive models
- Cloud only (so far)
- Some commercial users
- Pricing
 - Based upon bandwidth savings or,
 - Fixed license



Script-Based Technology

- Set VMAF target
- Figures data rate necessary to achieve that target at 1080p resolution
- Uses that to determine encode params for lower rungs
- Can limit by data rate top and bottom
- Excellent bitrate control (used 110% CVBR for our tests)

High Level View

Feature	Capped CRF	Capella Systems	Brightcove	FASTech.io
Core schema	CRF encode	CRF encode	Probe encodes	Proprietary predictive models
Adjust data rate	Yes	Yes	Yes	Yes
Change number of files in ladder	No	Yes	Yes	Not currently
Adjust resolution	No	Yes	Yes	Not currently
Customizability	CRF/max rate	Some	Extensive	Yes
Bitrate control (CBR/VBR)	No	Yes	Yes	Yes
Post-encode quality check	No	No	Yes - SSIM	Yes

- Currently can't change resolution or number of ladders
 - Ladder capabilities relatively new, could change

- Has multiple quality levels
- Has post-encode quality check

What I Learned

- Multiple rungs of utility
 - Good – CRF with no data rate control
 - Better – CRF with quality checks and bitrate control
 - Best – adjust number of ladders and resolution, plus bitrates
- Evaluating per-title is complex
- Per category encoding should work for:
 - Very low motion videos (talking heads)
 - All synthetic videos (Camtasia, PPT, etc, slide shows)
 - Custom ladder (emphasis on high-resolution)
 - 1080p, 900p, 720p, 540p
 - Very low data rates

FastTech Scoring

- Only “rookie” in analysis
 - Capella/Brightcove worked with in webinar had refinements
- Tended to “overcook” some encodes producing very good storage savings but some low scores
- Errors due to missed data rate at lowest two rungs
- Overall, very promising but needs resolution adjustments to compet

	Capped CRF	Capella Systems	Brightcove	FAST Tech
Wins	15	14	13	12
Losses	0	0	1	2
Storage saved	39,876	41,807	53,171	47,224
Streaming saved	-208%	-193%	-234%	-172%
Net impact on VMAF	65.47	65.94	82.97	42.04
Saves	98	7	19	0
Singles	1	4	1	5
Doubles	4	4	2	1
Triples	1	1	0	1
Home runs	10	5	10	5
Errors	6	0	5	9

Bloopers

Sintel	Width	Height	Data Rate	Jump	PSNR	VMAF	4500	Width	Height	Data Rate	PSNR	VMAF	File	Data Rate	VMAF
	1920	1080	4,278	1.66	39.54	91.95		1920	1080	3,817	39.64	92.29		1080	-10.78%
	1280	720	2,581	1.42	36.96	86.47	2700	1280	720	2,070	35.88	79.69	720	-19.80%	-6.79
	960	540	1,821	1.41	35.41	80.76	1900	960	540	1,346	34.46	72.80	540	-26.08%	-7.96
	852	480	1,296	1.50	34.52	75.25	1350	960	540	1,346	34.46	72.80	480	3.86%	-2.45
	640	360	863	1.82	33.05	65.15	900	640	360	736	32.57	59.44	360	-14.68%	-5.71
	480	272	474	2.04	31.34	49.34	500	480	272	476	31.19	47.30	272	0.49%	-2.04
	320	180	233		29.14	23.30	250	320	180	255	29.13	23.37	180	9.63%	0.07
			11,546							10,047				-8.20%	-3.50

- Data rate reductions that were too aggressive; reducing VMAF
- Couldn't counterbalance with higher resolutions like Brightcove and Capella

Conclusions

- Seeing some significant bandwidth savings and improvements in experiential VMAF
 - Per-title is the clear future
- Multiple options
 - On-premise – Capella/Capped CRF
 - Cloud – Brightcove/Bitmovin (at show)
 - Licensable – FASTTech (at show)
 -

	Capped CRF	Capella Systems	Brightcove	FAST Tech
Wins	15	14	13	12
Losses	0	0	1	2
Storage saved	39,876	41,807	53,171	47,224
Streaming saved	-208%	-193%	-234%	-172%
Net impact on VMAF	65.47	65.94	82.97	42.04
Saves	98	7	19	0
Singles	1	4	1	5
Doubles	4	4	2	1
Triples	1	1	0	1
Home runs	10	5	10	5
Errors	6	0	5	10