PER-TITLE ENCODING – 2021
ENCODING IN 6.2 DIMENSIONS

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Lesson: Per-Title Encoding in 6.2 Dimensions

- ## What is per-title encoding?
  - Why is it important

- ## The evolution of per-title
  - Frame-by-Frame optimization
  - Per-title (rungs/resolution/data rate)
  - Shot-based encoding
  - Context-aware encoding
  - Expansion of controlled parameters (frame rate, dynamic range, color gamut)
  - Appendix – Product information from Ateme, AWS Elemental, Beamr, Bitmovin, Brightcove, Capella Systems

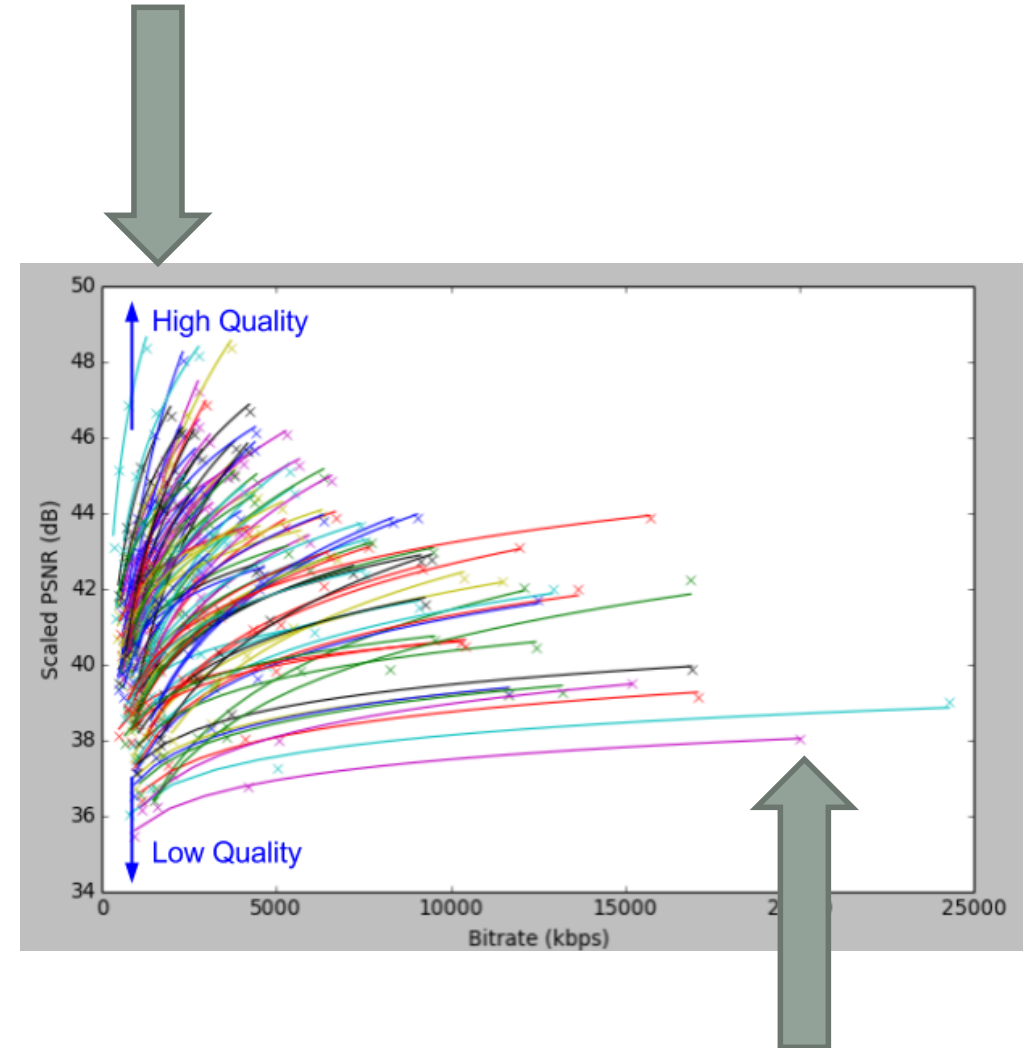# In the Beginning, Everyone Used TN2224 and it was Good

16:9 Aspect Ratio

	Dimensions	Frame Rate *	Total Bit Rate	Audio Bit Rate	Keyframe**
CELL	480x320	na	64	64	na
CELL	416x234	10 to 12	264	64	30 to 36
CELL	480x270	12 to 15	464	64	36 to 45
WIFI	640x360	29.97	664	64	90
WIFI	640x360	29.97	1264	64	90
WIFI	960x540	29.97	1864	64	90
WIFI	960x540	29.97	2564	64	90
WIFI	1280x720	29.97	4564	64	90
WIFI	1280x720	29.97	6564	64	90
WIFI	1920x1080	29.97	8564	64	90

https://blog.beamr.com/2016/03/17/tn2224-is-so-yesterday/

Then, Netflix Invented Per-Title Encoding

- Recognized that:
  - Some files encode to high quality at low bitrates
  - Some files don't achieve high quality even at very high bitrates
  - Makes no sense to use the same encoding ladder for both

Then, Netflix Invented Per-Title Encoding

- Recognized th
  - Some files en[c]
    low bitrates
  - Some files do[n]
    even at very h
  - Makes no sen[se]
    encoding lad[der]

Bitrate (kbps)

10000   15000   25000
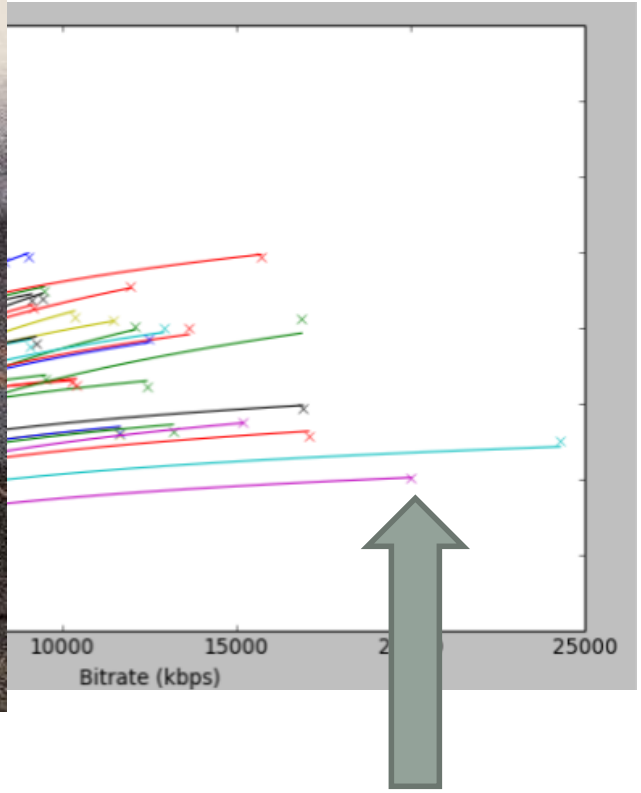
Evolution of Per-Title

When	Prior to 2015
What	Optimization
Who	Beamr/CRF
Operation	Frame by frame
Dimensions	1 (data rate)
VOD	Yes
Live	Yes

- Operation: Set quality target
  - CRF level
    - Encode each frame to specified quality level
  - Beamr – set target
    - Iteratively encodes each frame at more aggressive parameters until target met
- Key benefit: enables live
- Key weakness: data rate only
  - Doesn't impact resolution
  - Doesn't impact number of rungs

Why Adjusting the Number of Rungs is So Important

Fixed ladder

Width	Height	Data Rate	Jump	PSNR	SSIM	VMAF
1920	1080	4,129	1.68	54.71	0.998	97.48
1280	720	2,458	1.42	32.99	0.989	90.45
960	540	1,732	1.44	29.98	0.979	84.76
852	480	1,206	1.53	28.76	0.972	81.58
640	360	786	1.77	26.41	0.950	69.48
480	272	444	2.03	24.16	0.918	46.09
320	180	218		21.21	0.849	5.97

Per-title A

	Width	Height	Data Rate		PSRN	SSIM	VMAF
Tutorial_PT_1080p_840825.mp4	1920	1080	859.9	2.07	49.25	0.996	96.99
Tutorial_PT_1080p_449219.mp4	1920	1080	415.7	1.94	45.09	0.995	95.94
Tutorial_PT_900p_240000.mp4	1600	900	214.8		35.05	0.988	90.22
			1,490		43.13	0.993	94.39

> Three rungs; good data rate coverage; good quality

Per-title B

	Width	Height	Data Rate		VMAF
Tutorial_1080p_	1920	1080	375	1.93	95.68
Tutorial_720p_	1280	720	194	1.65	88.33
Tutorial_540p_	960	540	118	1.20	81.15
Tutorial_480p_	854	480	99	1.57	77.75
Tutorial_360p_	640	360	63	1.51	64.43
Tutorial_270p_	480	270	42	1.90	41.38
Tutorial_180p_	320	180	22		4.24
			912		64.71

> Maintains rungs - creates 5 rungs you'll never use, increasing encoding cost

Why Adjusting Resolution is So Important

Deploy higher rez files (with higher VMAF) scores lower in ladder

Per-title A

Fixed ladder

Fixed ladder table:

	Width	Height	Bitrate	PSNR	SSIM	VMAF
Elektra_1080p_CVBR	1920	1080	4,433	42.64	0.958	94.79
Elektra_720p_CVBR	1280	720	2,677	40.95	0.954	89.89
Elektra_540p_CVBR	960	540	1,895	39.83	0.950	85.72
Elektra_480p_CVBR	854	480	1,350	39.2	0.947	82.80
Elektra_360p_CVBR	640	360	897	37.97	0.939	74.18
Elektra_270p_CVBR	480	270	491	35.97	0.924	54.77
Elektra_180p_CVBR	320	180	232	32.95	0.898	20.49
			11,974	**38.50**	**0.938**	**71.81**

Per-title A table:

	Width	Height	Bitrate		PSNR	SSIM	VMAF
Elektra_PT_1080p_4051375	1920	1080	3975	1.97	42.47	0.957	94.66
Elektra_PT_1080p_2132303	1920	1080	2014	1.90	41.21	0.950	91.46
Elektra_PT_900p_1122265	1600	900	1061	1.91	39.63	0.941	85.35
Elektra_PT_576p_590666	1024	576	555.5	1.65	38.08	0.934	76.93
Elektra_PT_432p_367815	768	432	337.6	1.60	36.84	0.925	68.08
Elektra_PT_360p_240000	640	360	210.8		35.53	0.912	57.63
			8,154		**38.96**	**0.936**	**79.02**

Per-title B

Stuck at same resolutions

Per-title B table:

	Width	Height	Bitrate		PSNR	SSIM	VMAF
Elektra_1080p_CVBR_output	1920	1080	6,101	2.61	41.90	0.967	93.79
Elektra_720p_CVBR_output	1280	720	2,338	1.78	39.66	0.961	86.49
Elektra_540p_CVBR_output	960	540	1,312	1.27	38.35	0.956	79.95
Elektra_480p_CVBR_output	854	480	1,031	1.68	37.82	0.954	76.81
Elektra_360p_CVBR_output	640	360	613	1.59	36.44	0.946	65.77
Elektra_270p_CVBR_output	480	270	387	1.73	34.64	0.935	46.80
Elektra_180p_CVBR_output	320	180	224		32.01	0.918	15.95
			12,005		**37.26**	**0.9**	**66.51**

Much lower quality after top rung

This Takes us to Netflix
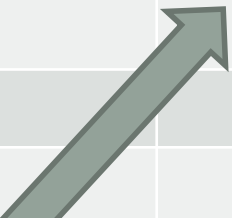
When	Prior to 2015	Late 2015
What	Optimization	Per-title
Who	Beamr/CRF/ QVBR (later)	Netflix
Operation	Frame by frame	Set quality target: brute force to find convex hull
Dimensions	1 (data rate)	3 (add resolution/# rungs)
VOD	Yes	Yes
Live	Yes	No

- Ope
  - O
  - Br
    ra

H.264	1080p	720p	540p	432p	360p	270p	234p
5000	96.22						
4800	96.01						
4600	95.80	95.27					
4400	95.55	95.10					
4200	95.30	94.96					
4000	94.96	94.73					
3800	94.60	94.53					
3600	94.14	94.30					
3400	93.70	93.99					
3200	93.11	93.64					
3000	92.48	93.24					
2800	91.70	92.78					
2600	90.75	92.25					
2400	89.70	91.59	90.39				
2200	88.37	90.80	89.76				
2000	86.72	89.85	88.95	86.93			
1800	84.68	88.66	88.00	86.10			
1600	82.13	87.13	86.77	85.02	81.58		
1400	78.65	85.19	85.16	83.67	80.28		
1200	73.91	82.56	83.01	81.84	78.57		
1000	67.39	78.86	80.02	79.24	76.19		
900	63.18	76.39	77.98	77.47	74.60	66.66	60.58
800	57.93	73.25	75.51	75.34	72.68	65.11	59.23
700	51.47	69.42	72.34	72.59	70.23	63.14	57.49
600	43.12	64.52	68.37	69.11	67.12	60.70	55.33
500	33.31	58.05	63.13	64.66	63.04	57.52	52.46
400	20.82	49.48	56.00	58.46	57.48	53.13	48.59
300	9.74	37.56	45.95	49.62	49.60	46.80	42.96
200	3.73	20.40	30.87	36.12	37.48	36.88	34.03
100		2.75	8.08	14.45	17.50	19.85	18.66

This Takes us to Netflix
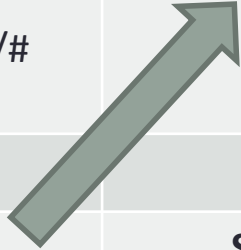
When	Prior to 2015	Late 2015
What	Optimization	Per-title
Who	Beamr/CRF/ QVBR (later)	Netflix
Operation	Frame by frame	Set quality target: brute force to find convex hull
Dimensions	1 (data rate)	3 (add resolution/# rungs)
VOD	Yes	Yes
Live	Yes	No

- Operation: Set quality target
  - Originally PSNR, now VMAF
  - Brute force computation at multiple data rates and resolutions to find "convex hull"
    - Highest quality resolution for each data rate
- Key benefit: No guesswork; best quality throughout
- Key weakness: cost
  - More than offset for Netflix with high viewer count for each video

Evolution of Per-Title/Optimization

When	Prior to 2015	Late 2015	2016 -
What	Optimization	Per-title	**Commercial Per-Title**
Who	Beamr/CRF/ QVBR (later)	Netflix	**Bitmovin, Brightcove, Capella (many others)**
Operation	Frame by frame	Set quality target: brute force to find convex hull	**Gauge complexity (CRF/AI), create unique encoding ladder**
Dimensions	1 (data rate)	3 (add resolution/# rungs)	**3**
VOD	Yes	Yes	**Yes**
Live	Yes	No	**Some**

- Operation:
  - Estimate encoding complexity using typically proprietary measure (ML/AI driven)
  - Encode to specified target quality level
- Key benefit: Much more efficient than Netflix approach
  - Encode once for each rung in ladder
- Key weakness: Effectiveness depends upon metric, complexity gauge, and implementation details

Evolution of Per-Title/Optimization

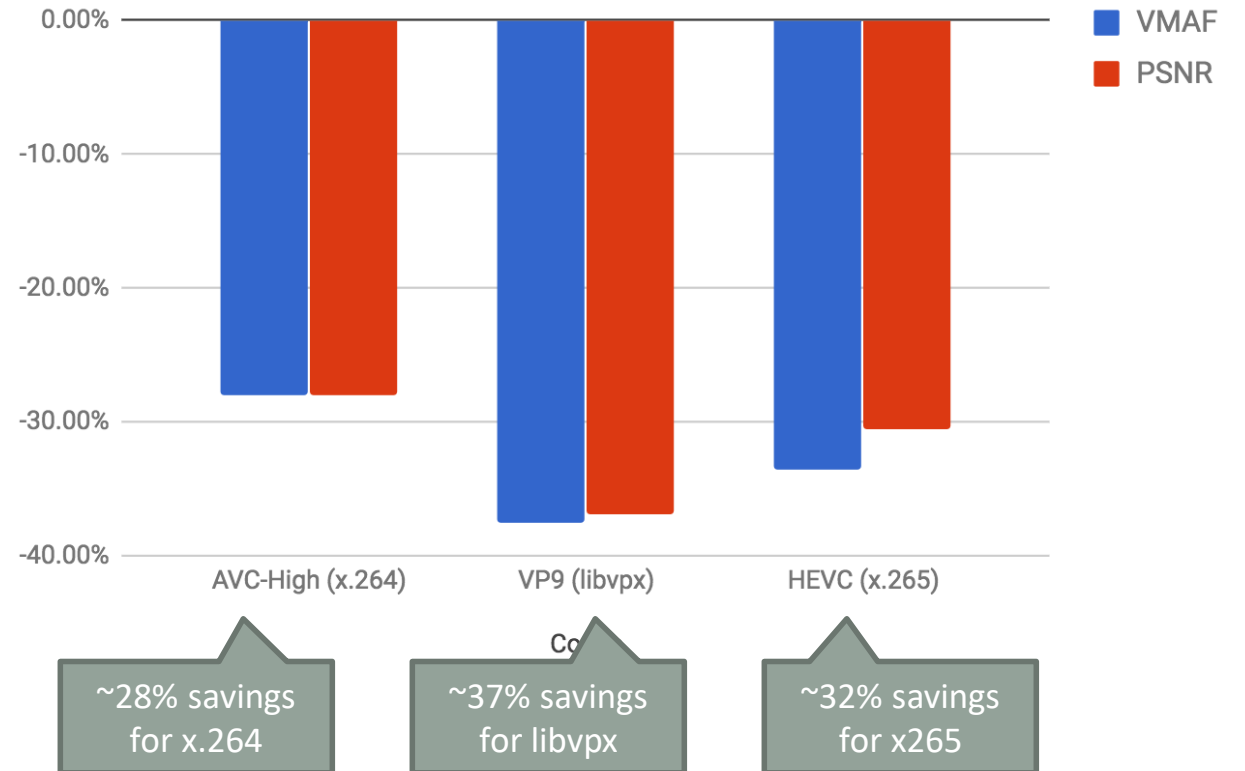| When	Prior to 2015	Late 2015	2016 -	2018
What	Optimization	Per-title	Commercial Per-Title	**Shot-based encoding**
Who	Beamr/CRF/ QVBR (later)	Netflix	Bitmovin, Brightcove, Capella (many others)	**Netflix**
Operation	Frame by frame	Set quality target: brute force to find convex hull	Gauge complexity (CRF/AI), create unique encoding ladder	**Divide each video into shots; encode each separately**
Dimensions	1 (data rate)	3 (add resolution/# rungs)	3	**3**
VOD	Yes	Yes	Yes	**Yes**
Live	Yes	No	No	**No**

Shot-Based Encoding

- What it is:
  - Parse video
  - Split at scene changes
  - Encode each scene separately
- Why beneficial?
  - Most logical level for applying compression parameters (why use arbitrary key frame or segment duration?)
  - Encoding changes applied at scene changes so less noticeable
- Key frames at scene changes preserve ABR switching integrity

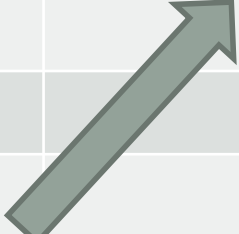http://bit.ly/nf_shot
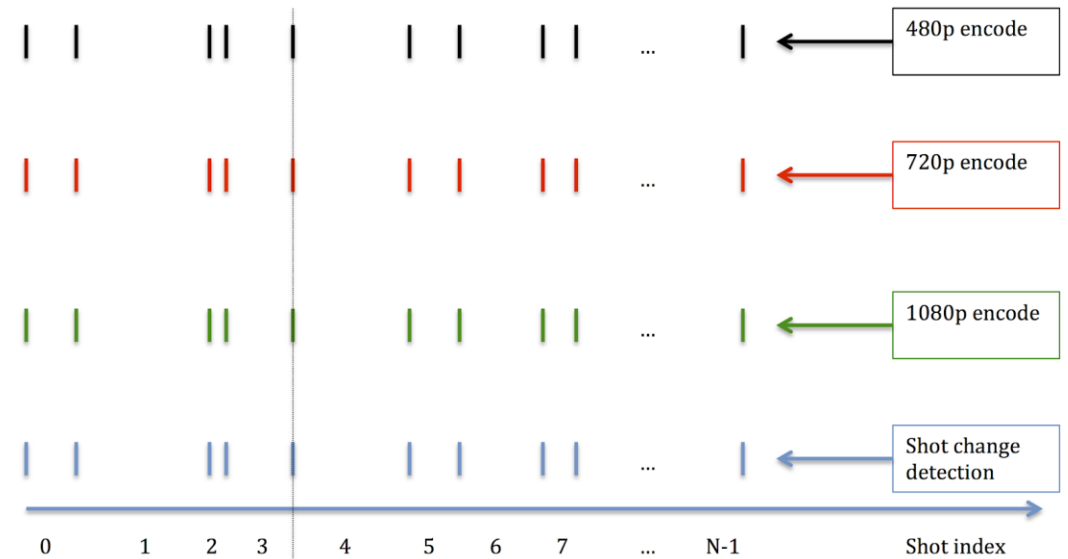
Why Shot-Based Encoding Make Sense

- Benefits are very significant

- Not codec-dependent

- Key benefits: more efficient encoding

- Key weakness:
  - You can't have it (no commercial implementations that I'm aware of)
  - Complexity – different GOP and segment sizes

VMAF

PSNR

AVC-High (x.264) · VP9 (libvpx) · HEVC (x.265)

~28% savings for x.264

~37% savings for libvpx

~32% savings for x265

http://bit.ly/nf_shot

Evolution of Per-Title/Optimization

When	Prior to 2015	Late 2015	2016 -	2018
What	Optimization	Per-title	Commercial Per-Title	**Shot-based encoding**
Who	Beamr/CRF/ QVBR (later)	Netflix	Bitmovin, Brightcove, Capella (many others)	**Netflix**
Operation	Frame by frame	Set quality target: brute force to find convex hull	Gauge complexity (CRF/AI), create unique encoding ladder	**Divide each video into shots; encode each separately**
Dimensions	1 (data rate)	3 (add resolution/# rungs)	3	**3**
VOD	Yes	Yes	Yes	**Yes**
Live	Yes	No	No	**No**

Evolution of Per-Title/Optimization

When	Prior to 2015	Late 2015	2016 -	2018	2019
What	Optimization	Per-title	Commercial Per-Title	Shot-based encoding	**Context-aware encoding**
Who	Beamr/CRF/ QVBR (later)	Netflix	Bitmovin, Brightcove, Capella (many others)	Netflix	**Brightcove, Epic Labs (Haivision)**
Operation	Frame by frame	Set quality target: brute force to find convex hull	Gauge complexity (CRF/AI), create unique encoding ladder	Divide each video into shots; encode each separately	**Incorporates bandwidth, rung consumption and device data into encoding ladder**
Dimensions	1 (data rate)	3 (add resolution/# rungs)	3	3	**3.2**
VOD	Yes	Yes	Yes	Yes	**Yes**
Live	Yes	No	No	No	**No**

Context Aware Encoding

- Operation
  - Feed playback and quality of experience data into encoding ladder creation

Context-Aware Encoding

Usage Pattern

Device type	Usage [%]	Average bandwidth [M...
PC	0.004	7.5654
Mobile	94.321	3.2916
Tablet	5.514	3.8922
TV	0.161	5.4374
All devices	**100**	**3.3283**

TABLE 2: USAGE AND AVERAGE BANDWIDTH STATISTICS FOR OPER...

Mostly mobile with low bandwidth

Device type	Usage [%]	Average bandwidth [Mbps...
PC	63.49	14.720
Mobile	6.186	10.609
Tablet	9.165	12.055
TV	21.15	24.986
All devices	100	16.393

TABLE 3: USAGE AND AVERAGE BANDWIDTH STATISTICS FOR OPERATOR 2

Mostly PC & TV at high bitrates

Device type	Usage [%]	Average bandwidth [Mbps]
PC	0.0	N/A
Mobile	0.0	N/A
Tablet	0.0	N/A
TV	100	35.7736
All devices	100	35.7736

TABLE 4: USAGE AND AVERAGE BANDWIDTH STATISTICS FOR OPERATOR 3.

All TV at very high bitrates

Encoding Ladder

Rendition	Profile	Resolution	Framerate	Bitrate	SSIM
1	Baseline	320x180	30	125	0.93369
2	Baseline	480x270	30	223.08	0.93793
3	Main	640x360	30	398.11	0.94636
4	Main	960x540	30	774.78	0.94953
5	Main	1280x720	30	1549.5	0.95637
6	High	1600x900	30	2765.3	0.96105
7	High	1920x1080	30	4935.1	0.96576
Storage				10771	

TABLE 9: CAE-GENERATED ENCODING LADDER FOR OPERATOR 1.

- 4 rungs under 800 kbps

Rendition	Profile	Resolution	Framerate	Bitrate	SSIM
1	Baseline	320x180	30	125	0.93338
2	Baseline	480x270	30	239.71	0.94122
3	Main	640x360	30	469.54	0.95202
4	Main	1024x576	30	939.08	0.95221
5	Main	1280x720	30	1568.8	0.95658
6	High	1600x900	30	2765.3	0.96105
7	High	1920x1080	30	4935.1	0.96576
Storage				11026	

TABLE 10: CAE-GENERATED ENCODING LADDER FOR OPERATOR 2.

- Higher bitrate in mid-rungs

Rendition	Profile	Resolution	Framerate	Bitrate	SSIM
1	Baseline	320x180	30	125	0.93447
2	Baseline	512x288	30	307.42	0.94855
3	Main	960x540	30	803.59	0.95050
4	Main	1280x720	30	1727.8	0.95864
5	High	1920x1080	30	5050.7	0.96599
Storage				8014.6	

TABLE 11: CAE-GENERATED ENCODING LADDER FOR OPERATOR 3.

- Fewer rungs
- Lower bitrate below top
- Highest quality top bitrate
- Lowest storage and encoding

bit.ly/bc_contextaware

Context Aware Encoding

- Operation
  - Feed playback and quality of experience data into encoding ladder creation
- Key benefit
  - Adding contextual data optimizes encoding costs, storage, and QoE *for actual viewers*
- Key challenges:
  - No standards (AFAIK) for data exchange from QoS/QoE vendors and encoding vendors
  - May be locked into comprehensive solution (like Brightcove) to access this function

What's Next: Expanding Definition of Quality and Quality Metric

Where to make this switch

	Width	Height	Frame Rate	Data Rate
hi250	240	192	15	250
hi500	480	540	15	500
hi1400	960	540	30	1400
hi3500	1280	720	30	3500
hp3500	1920	1080	60	5000
hp7000	1920	1080	60	7000

And this switch

For football

NASCAR

Other content

Same Issue for Dynamic Range and Color Gamut

- We know that frame rate, dynamic range (HDR/SDR), and color gamut impact perceived quality

- We know that they should be adjusted in encoding ladder to meet target bitrates

- How do you do this with PSNR?
  - You don't
  - We're gonna need a better metric

Evolution of Quality Metrics

What	PSNR/SSIM
Who	Various
What	Static algorithm
Measures what?	• Spatial (rez/data rate)
Dimensions	2

Evolution of Quality Metrics

What	PSNR/SSIM	VMAF	PW-SSIM	SSIMPLUS	Quality Vector
Who	Various	Netflix	Brightcove	SSIMWAVE	Ateme
What	Static algorithm	Algorithms + Machine Learning	"perceptually-weighted SSIM"	Algorithm + Machine Learning	Algorithm + AI
Measures what?	• Spatial (rez/data rate)	• Visual Information Fidelity • Detail Loss Metric (DLM) • Mean Co-Located Pixel Difference (MCPD) • Anti-noise signal-to-noise ratio (AN-SNR)	• Spatial sampling • Temporal sampling (framerate) • Spatial reproduction accuracy • Viewer device and setup information	• Spatial • Temporal • Device • HDR • Wide color gamut • Playback quality assessment • Degraded reference	• Encoded quality (bitrate) • Spatial (rez) • Temporal (frame rate) • Dynamic range index • Color Gamut index
Dimensions	2	2.5	5+	7+	5

Temporal differences

Can't compare files with different frame rates

Ateme Quality Vector Driven Content Adoptive Encoding Process

8 50fps HDR PQ Input

Codec	Resolution	Fps	Dynamic range	Bitrate (kbps)
HEVC	7680x4320	50	HDR	17606
HEVC	3840x2160	50	HDR	6924
HEVC	2560x1440	50	HDR	3095
HEVC	1920x1080	50	HDR	1755
HEVC	1280x720	50	HDR	1054
HEVC		50	HDR	642
HEVC	640x360	25	HDR	383
HEVC	480x270	25	HDR	224

TABLE 3: CONTENT ADAPTED SET OF PROFILES FOR SEQUENCE POLYNÉSIE.

4k 00fps HDR HLG input

Codec	Resolution	Fps	Dynamic range	Bitrate (kbps)
HEVC	3840 x 2160	100 fps	HDR	20477
HEVC	2560 x 1440	100 fps	HDR	9697
HEVC	1920 x 1080	100 fps	SDR	5859
HEVC	1	100 fps	SDR	3649
HEVC	1280 x 720	50 fps	SDR	2381
HEVC	960 x 540	50 fps	SDR	1564
HEVC	960 x 540	50 fps	SDR	1042

TABLE 4: CONTENT ADAPTED SET OF PROFILES FOR SEQUENCE TOUR DE FRANCE.

http://bit.ly/ateme_wp

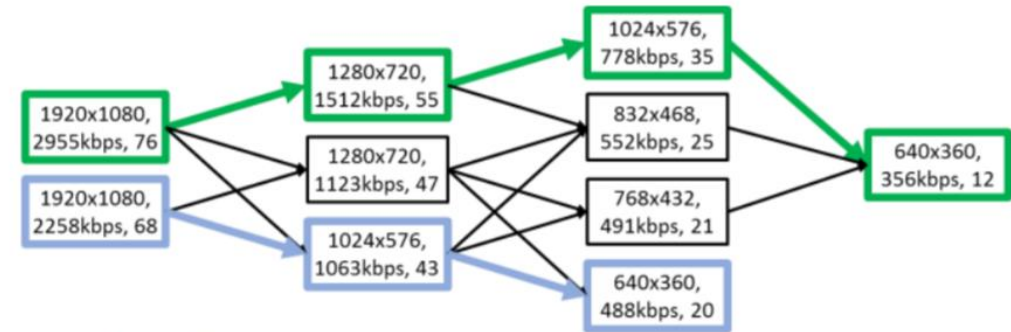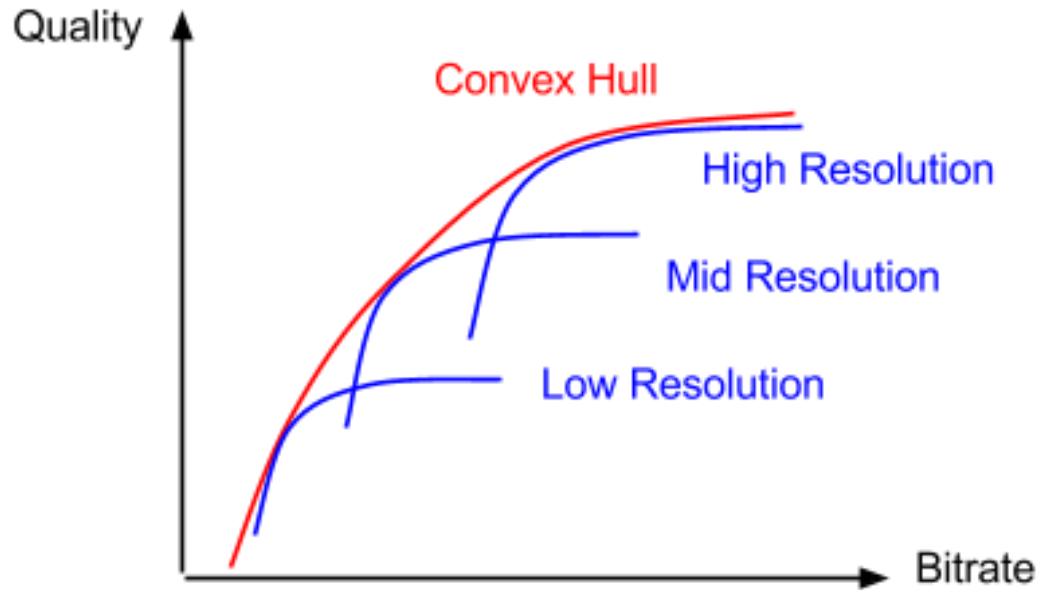# Moving from Convex Hull to 6.2 Dimension Per-Title

FIGURE 7: CONTENT ADAPTIVE TRELLIS OPTIMIZATION EXAMPLE.

- 2-dimensional convex hull

- Six adjustment dimensions
- Two additional input dimensions

What the Heck is 6.2 Dimension Per-Title Encoding?

- Ability to adjust (6):
  - Number of rungs
  - Resolution
  - Data rate
  - Frame rate
  - Dynamic range
  - Color gamut

- Ability to incorporate other relevant data points (2)
  - Actual viewer data (bitrate, ladder rung)
  - Device and viewing data

When Considering Per-Title Technologies

- Ask/Determine
  - What kind (optimization, per-title, per-shot?)
  - Can it incorporate real world and device playback data?
    - Where can it get that data?
  - Live/VOD or both?
  - What's the quality metric?
  - Does it reduce the number of rungs?
  - Can it adjust rung resolutions?
  - Can it adjust the frame rate?
  - Can it adjust the dynamic range?
  - Can it adjust the color gamut?
  - How does it impact encoding cost?
  - Can you specify lowest bitrate file and the maximum bitrate?

Product Data

- Ateme
- AWS Elemental
- Beamr
- Bitmovin
- Brightcove
- Capella Systems

Ateme

Company	Ateme
Feature/product	Content Aware Encoding
Business model (SaaS? Licensed software? Hardware?)	Software
Pricing model/pricing?	Perpetual license or rental
Kind (optimization/per-title/per-scene)	Rely on the VBR/Constant quality principle. Adaptation is at the frame level. Automatic profile derivation has been demonstrated at the sequence level, but any granularity is achievable.
Core schema (CRF? AI?)	Combination of AI, especially for the predictive perceptual metric, and traditional optimization
Does the schema work with VOD video?	Yes
Does the schema work with live video?	Yes, with less features than file (obviously no full scan of the content prior to encoding)
Does the schema incorporate viewer playback data?	No
Can I specify a bitrate control technique? (CBR/VBR)	CBR has been studied and implemented for tests, but only VBR is advocated, as providing the best performance
Does the schema adjust the number of rungs?	Yes
Does the schema adjust the resolution of rungs?	Yes
Does the schema adjust the frame rate of rungs?	Yes
Does the schema adjust the dynamic range of rungs	Yes
Does the schema adjust the color gamut of rungs	Yes
Can I specify resolutions to include in output ladder?	Yes
Can I specify bitrate min?	Yes
Can I specify bitmate max?	Yes
Does the schema incorporate post-encode quality data?	No, it relies on the predictive step. That's why efficient modeling and AI is of paramount importance
What's the impact of per-title on encoding time?	Negligible. First pass is fast. Second pass is regular encoding. Second pass may have less profiles than your reference, hence computing reduction
What's the impact of per-title on encoding cost?	Negligible – and introduce significant savings on storage/delivery

AWS Elemental

Feature/product	AWS	AWS
Business model (SaaS? Licensed software? Hardware?	**Automated ABR Configuration**	**QVBR (Quality-Defined Variable Bitrate)**
Pricing model/pricing?	Pay-as-you-go managed service (AWS Elemental MediaConvert).	Media Services: Pay-as-you-go managed service. Appliances & Software: Software.
Kind (optimization/per-title/per-scene)	Pay-as-you-go, billed at Professional Tier, 2-pass, quality optimized rates in AWS Elemental MediaConvert	Pay-as-you-go, available in AWS Elemental MediaLive and MediaConvert Appliance and software in AWS Elemental Live and AWS Elemental Server
Core schema (CRF? AI?)	QVBR optimizations, plus per-title ladder optimization	Integrated optimizations at scene, frame, and macroblock level
Claimed bandwidth reduction	Custom AWS Elemental technology	Custom AWS Elemental technology
Does the schema work with VOD video?	QVBR savings on each bitstream plus up to 40% reduction in overall ABR package size.	10 - 50%, average 30%
Does the schema work with live video?	Yes	Yes
Does the schema adjust the dynamic range of rungs	Yes	No
Does the sdchema adjust the color gamut of rungs	AI-based HDR-->SDR tone mapping and standard HDR-->HDR conversions are user options	
Can I specify resolutions to include in output ladder?		

AWS Elemental

Feature/product	AWS Automated ABR Configuration	AWS QVBR (Quality-Defined Variable Bitrate)
Business model (SaaS? Licensed software? Hardware?		
Can I specify bitrate min?	No	Yes
Can I specify bitmate max?	Yes	No
Does the schema incorporate post-encode quality data?	Yes	Yes
What's the impact of per-title on encoding time?	Yes	No
What's the impact of per-title on encoding cost?	Increased encoding time can be offset with accelerated transcoding	Single pass or multi pass, no material change in encoding time vs. other rate control modes
	2-pass encoding pricing for final ABR outputs, no additional feature cost	No additional cost
	https://docs.aws.amazon.com/mediaconvert/latest/ug/auto-abr.html	https://docs.aws.amazon.com/mediaconvert/latest/ug/cbr-vbr-qvbr.html

Beamr Optimization (Page 1)

Company	Beamr
Feature/product	CABR - Content Adaptive BitRate rate control library, available as part of H.264 (Beamr 4x) and HEVC (Beamr 5x) video encoders or as a stand-alone library that can be integrated with any software or hardware video encoder
Business model (SaaS? Licensed software? Hardware?)	Licensed software or hardware (silicon IP)
Pricing model/pricing?	Flexible model - per usage, per channel or site license for SW, per unit for HW
Kind (optimization/per-title/per-scene)	Optimization (per-frame)
Core schema (CRF? AI?)	Per-frame compression adjustment guided by the Beamr Quality Measure (BQM)
Claimed bandwidth reduction	20-50%
Does the schema work with VOD video?	Yes
Does the schema work with live video?	Yes
Does the schema incorporate viewer playback data?	No
Can I specify a bitrate control technique? (CBR/VBR)	Yes, CABR can work over a reference VBR, CRF of fixed-QP encode.
Does the schema adjust the number of rungs?	No
Does the schema adjust the resolution of rungs?	No
Does the schema adjust the frame rate of rungs?	No
Does the schema adjust the dynamic range of rungs	No

Beamr Optimization (Page 2)

Company	Beamr
Feature/product	Content Adaptive BitRate (CABR) library
Does the schema adjust the color gamut of rungs	No
Can I specify resolutions to include in output ladder?	Yes
Can I specify bitrate min?	No
Can I specify bitmate max?	Yes
Does the schema incorporate post-encode quality data?	Yes
What's the impact of per-title on encoding time?	20-100% increase in encoding time
What's the impact of per-title on encoding cost?	depends on the implementation
Website	https://beamr.com/cabr_library

Bitmovin

Company	Bitmovin
Feature/product	Per-title Encoding
Business model (SaaS? Licensed software? Hardware?	SaaS
Pricing model/pricing?	Encoding minute (1X factor)
Kind (optimization/per-title/per-scene)	Per-title
Core schema (CRF? AI?)	CRF encode (AI within 6 months)
Claimed bandwidth reduction	15% simple (cartoon style) content, 35% talking heads content, and 50% action content:
Does the schema work with VOD video?	Yes
Does the schema work with live video?	No
Does the schema incorporate viewer playback data?	No
Can I specify a bitrate control technique? (CBR/VBR)	CBR
Does the schema adjust the number of rungs?	Yes
Does the schema adjust the resolution of rungs?	Yes
Does the schema adjust the frame rate of rungs?	No
Does the schema adjust the dynamic range of rungs	No
Does the schema adjust the color gamut of rungs	No
Can I specify resolutions to include in output ladder?	Yes
Can I specify bitrate min?	Yes
Can I specify bitmate max?	Yes
Does the schema incorporate post-encode quality data?	Yes?
What's the impact of per-title on encoding time?	Three-pass but no impact due to scalability of cloud platform
What's the impact of per-title on encoding cost?	Pricing is volume based

Brightcove Context Aware Encoding (Page 1)

Company	Brightcove
Feature/product	Context Aware Encoding
Business model (SaaS? Licensed software? Hardware?)	SaaS
Pricing model/pricing?	?
Kind (optimization/per-title/per-scene)	Per-title
Core schema (CRF? AI?)	We use ML techniques for video content analysis and for analysis of playback statistics. The principal difference from classic per-title is that is not pure "encoding optimization", it is an "encoding + delivery" optimization. It is influenced by the properties of videos **and** the properties of networks, viewer devices, and viewers. This is why we call it Context-Aware Encoding.
Claimed bandwidth reduction	Reduce storage and delivery costs by up to 50%
Does the schema work with VOD video?	Yes
Does the schema work with live video?	Brightcove CAE is currently a VOD-only solution. Brightcove Live uses a completely different stack, running encoders in "capped VBR" mode.
Does the schema incorporate viewer playback data?	Yes
Can I specify a bitrate control technique? (CBR/VBR)	Yes. Moreover, we offer control over all essential VBV/HRD model parameters: decoder buffer size, initial fullness, maximum transmission rate, etc. These features are essential for enabling compatibility with settop boxes, game consoles, mobiles, and other devices with hardware decoders.
Does the schema adjust the number of rungs?	Yes
Does the schema adjust the resolution of rungs?	Yes
Does the schema adjust the frame rate of rungs?	Yes. Associated API control settings include "fixed_frame_rate", "max_frame_rate", and "frame_rate" that maybe explicitly set for each configuration.

Brightcove Context Aware Encoding (Page 2)

Company	Brightcove
Does the schema adjust the dynamic range of rungs?	Yes. We can generate SDR and HDR ladders separately as well as mixed ladders under an assumption that the user will direct appropriate subsets of them to different receivers. By default, all outputs are assumed to be SDR. By using "hdr_format" and associated options – all outputs or subsets of them can be designated as HDR outputs. We currently support all major SDR and HDR formats, including HDR10, PQ10, HLG10, DolbyVision 5, DolbyVision 8.1, etc.
Does the schema adjust the color gamut of rungs	Yes
Can I specify resolutions to include in output ladder?	Yes
Can I specify bitrate min?	Yes
Can I specify bitmate max?	Yes
Does the schema incorporate post-encode quality data?	?
What's the impact of per-title on encoding time?	We have 2 products with different behavior/impacts: VideoCloud: 0 impact. Video cloud has so-called "fast-publish" option, which enables customers to see a subset of renditions created at high speed, while final (usually 2-pass, and CAE-generated) renditions appear later and replacing those rapidly created outputs Zencoder: Depending on clip duration, CAE may increase overall processing time by about 10-30%. The longer the video the less impact can be expected.
What's the impact of per-title on encoding cost?	It depends on the product and volume of transcodes. For VideoCloud is a fixed per-year add-on. If a customer is processing a lot of videos, it probably will be in the noise. But for exact quotations and numbers, I must refer to our sales.

Capella Systems Cambria FTC (Page 1)

Company	Capella Systems Cambria FTC Encoder
Feature/product	Source Adaptive Bitrate Ladders feature
Business model (SaaS? Licensed software? Hardware?	License
Pricing model/pricing?	Standard feature
Kind (optimization/per-title/per-scene)	Per-Title
Core schema (CRF? AI?)	CRF encode to measure complexity; can calculate the reduction either on average difficulty of the footage, or on the peak difficultly over a period of time (like 20 seconds). Setting the reduction based on the peak difficulty avoids the common problem of 'most of the video looks good, but the action scenes have lots of artifacts'.
Claimed bandwidth reduction	Script dependent (you can specify bitrate reduction in script)
Does the schema work with VOD video?	Yes
Does the schema work with live video?	No
Does the schema incorporate viewer playback data?	No
Can I specify a bitrate control technique? (CBR/VBR)	Yes

Capella Systems Cambria FTC (Page 2)

Company	Capella Systems Cambria FTC Encoder
Feature/product	Source Adaptive Bitrate Ladders feature
Can I specify a bitrate control technique? (CBR/VBR)	Yes
Does the schema adjust the number of rungs?	Yes
Does the schema adjust the resolution of rungs?	Yes
Does the schema adjust the frame rate of rungs?	Yes
Does the schema adjust the dynamic range of rungs	No
Does the schema adjust the color gamut of rungs	No
Can I specify resolutions to include in output ladder?	Yes
Can I specify bitrate min?	Yes
Can I specify bitmate max?	Yes
Does the schema incorporate post-encode quality data?	Scriptable so yes
What's the impact of per-title on encoding time?	Adds another encoding pass
What's the impact of per-title on encoding cost?	Encoding time