Whitepaper

VisualOn Optimizer

Harnessing the Power of Content-Adaptive Encoding

Tel: +1(408) 645-6618
E-mail: sales@visualon.com
www.visualon.com

VisualOn

Content

As digital content consumption reaches unprecedented levels, the demand for efficient video streaming and storage solutions is more critical than ever. Enter content-adaptive encoding (CAE), a cutting-edge technology poised to transform the way the video streaming industry and other business segments deliver and store video content. By dynamically adjusting encoding parameters based on the unique characteristics of each video, CAE offers substantial improvements in video quality, bandwidth usage, and storage efficiency without disrupting the existing production flow. This white paper delves into the benefits and applications of CAE, highlighting why it is a game-changer for content creators, streaming platforms, and consumers alike. In addition, the paper explores VisualOn's award-winning Optimizer, the industry's first AI-enhanced universal CAE solution.

What is Content-Adaptive Encoding?

Netflix first introduced per-title encoding in 2015 [1], followed by per-chunk encoding in 2016 [2] and finally per-shot encoding in 2018 [3] and demonstrated that it can reduce video bitrate by over 30% on average without degrading visual quality as measured by VMAF score [4]. Building on the strides made by Netflix in encoding strategies, CAE takes video compression a step further by adapting the encoding process to the specific content of each video segment. Unlike traditional encoding methods that apply uniform settings across an entire video, CAE analyzes factors such as motion, texture, and complexity within the video to optimize encoding settings dynamically. This results in more efficient compression that preserves quality while reducing file size and bandwidth requirements, benefits that are otherwise only achievable through the introduction of new, more complex compression standards that will entail high cost, long time to market and compatibility issues within the whole ecosystem.

Key Benefits of Content-Adaptive Encoding

Content-adaptive encoding offers several unique benefits for video streaming, which are detailed below.

1. Enhanced Video Quality: CAE ensures that high-motion and complex scenes receive the necessary bitrate to maintain visual fidelity, while simpler scenes are encoded with lower bitrates without compromising quality. This intelligent allocation of resources leads to consistently high-quality playback. As a consequence, more HD or UHD profiles are selected vs. without CAE.
2. Better User Experience: With CAE, viewers can experience higher-quality streams with fewer interruptions or quality drops, resulting in better overall satisfaction and engagement.
3. Bandwidth Efficiency: By reducing the bitrate for less complex segments, CAE significantly lowers the overall bandwidth required for streaming. This is particularly beneficial for users with limited internet speeds or data caps, as it enables smoother streaming experiences with fewer interruptions.
4. Cost Savings: For streaming platforms and content delivery networks (CDNs), reducing bandwidth usage translates directly into cost savings. Lower data transfer requirements mean reduced expenses for both the provider and the end user.
5. Storage Optimization: Content creators and archiving services can benefit from CAE by minimizing storage requirements. Efficient encoding results in smaller file sizes, allowing for more content to be stored within the same physical space or cloud storage allocation.
6. Scalability: As the demand for high-resolution content such as 4K and 8K grows, CAE provides a scalable solution to manage the increased data. By optimizing encoding for each piece of content, platforms can deliver high-resolution streams without exponentially increasing bandwidth or storage needs.
7. Address 100% of installed base: as opposed to adoption of new codecs that requires new players, CAE does not require any changes to the application on the client devices of deployed installed base.

Applications of Content-Adaptive Encoding

Beyond video streaming, content-adaptive encoding brings value to a variety of applications.

1. Video Streaming Services: Leading streaming platforms can leverage CAE to enhance user experience by delivering high-quality videos with minimal buffering. Services like Netflix, YouTube, and Amazon Prime Video can implement CAE to optimize their vast libraries, ensuring smooth playback for millions of users worldwide.
2. Social Media Platforms: With the surge in user-generated content, social media platforms such as Facebook, Instagram, and TikTok can utilize CAE to handle the diverse range of video uploads. This ensures that videos are displayed at the best possible quality without overburdening the platform's infrastructure.
3. Broadcast and Media Companies: Traditional broadcasters and media companies transitioning to digital platforms can use CAE to optimize their content delivery. This assures that live broadcasts and on-demand content are delivered with the best possible quality and efficiency.

Introducing VisualOn Optimizer

VisualOn officially introduced its Optimizer suite of AI-enhanced universal CAE products at the International Broadcasting Convention (IBC) in 2023 and subsequently won the Product of the Year award at the National Association of Broadcasters (NAB) Show in 2024. Optimizer is an efficient single-pass transcoding technology that continuously analyzes the content on the frame level and dynamically configures the encoder to achieve target quality using a minimal number of bits. It's compression standard agnostic solution that currently supports H.264, HEVC, and AV1, and can be readily integrated with any encoders, whether they are CPU, GPU or ASIC based. Optimizer's efficient implementation means it can be adopted without requiring additional hardware, in most cases.

Optimizer transforms media streaming by utilizing dynamic advanced coding technology that combines parameter matching, scene recognition, and image quality enhancement. This allows for reduced bitrates while maintaining or enhancing video quality, as measured by VMAF scores. A novel machine learning-based one-pass encoder parameter prediction framework determines reconfigurable settings such as CRF, bitrate and other similar or equivalent parameters. This framework segments videos, extracts spatial and temporal features, and predicts new parameters using a pre-trained classifier. The encoder then compresses each segment efficiently based on these parameters. The methodology includes a training phase, where encoder parameters are optimized using a particle swarm optimization algorithm, and a testing phase, where the classifier determines encoding parameters for each segment based on texture features and target quality metrics.

To further enhance performance, the Optimizer incorporates a real-time feedback mechanism that dynamically adjusts encoder parameters based on scene analysis and video quality evaluations (such as PSNR, SSIM, and VMAF scores). This ensures high video quality while minimizing bitrate. Optional preprocessing steps, such as sharpening, anti-interlacing, and noise reduction, are applied based on user preferences. Live streaming tests integrated into an FFmpeg-based service confirm the method's efficiency, stability, and suitability for industrial production.

As can be seen from Figure 1 below, Optimizer readily fits into any streaming workflow through a simple API call before or in parallel with the encoder, without disrupting the other modules.

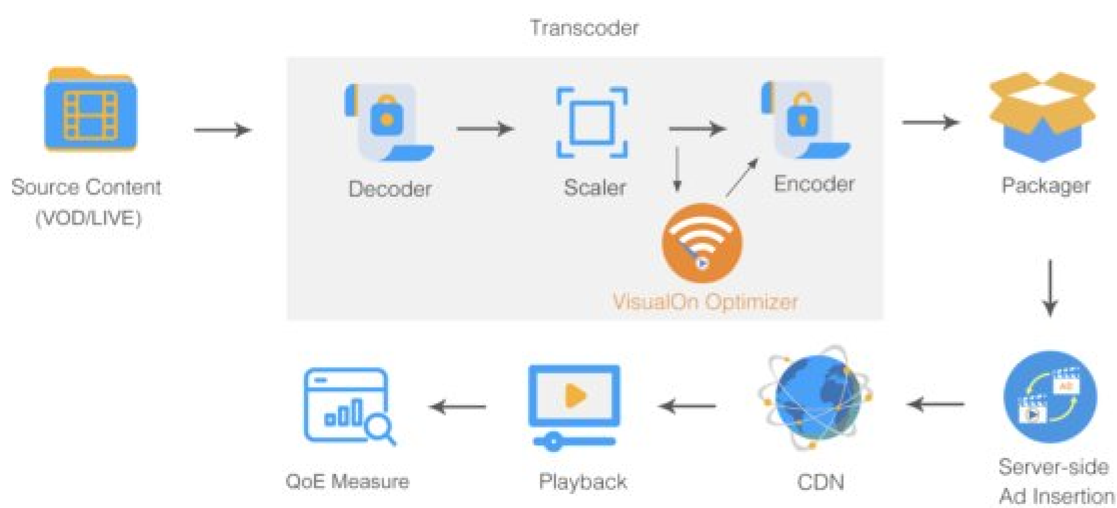

Figure1. Optimizer Workflow Illustration

Optimizer is embedded within the FFmpeg ecosystem and can be readily integrated with video encoders through a patch to FFmpeg using FFmpeg's APIs. It is available in different variants to best suit a wide range of different use cases:

1. Optimizer Live: Designed for streaming workflows with real-time transcoding, Optimizer Live features an efficient implementation that allows it to achieve zero additional latency while reducing both average and peak bitrates without compromising visual quality, which is important to improve the scalability of large events. It has optimization presets that can be used to achieve the best trade-off between computing resources and bitrate reduction without increasing hardware resources.
2. Optimizer VOD: Built for VOD workflows, Optimizer VOD supports FFmpeg's filter-complex feature for simultaneously transcoding the entire ABR ladder in a single command, without repeating the same calculation for different rungs of the ABR ladder.
3. Optimizer Fidelity: Enabling visually lossless file-to-file video transcoding, Optimizer Fidelity reduces the storage requirements of massive mezzanine video files.
4. Optimizer: Optimizer is also available for general purpose file-to-file transcoding to reduce the size of video files.

Key Benefits of Optimizer Include:

1. Universal solution: Optimizer is a universal solution not bound by any encoder implementation, making it suitable for wide adoption for different use cases, workflows, and more.
2. Significant bitrate reduction: As demonstrated by extensive benchmark results as well as actual production deployments, Optimizer significantly reduces the average video bitrate while maintaining or improving video quality, as demonstrated in Figure 2 below. This results in improved operational efficiency through reduced bandwidth and storage costs, enhanced user experience with better visual quality and improved KPIs (startup time, buffering ratio, etc.) and energy consumption (due to less video data needing to be transmitted and stored as well as more efficient playback of lower bitrate content at client devices).
3. Enhanced video quality: It drastically improves visual quality without increasing video bitrate, as illustrated in Figure 3 below.
4. Easy to deploy: Optimizer is easy to adopt without disrupting existing operations. It can readily be integrated within any streaming workflow without changing any other modules, including the encoder itself. In most cases, no additional hardware is required. It took our customer EiTV a matter of days to integrate Optimizer VOD into their production workflow.

Figure 2. Bitrate Comparison for VisualOn Optimizer

Figure 3.1. The quality improvement – left x264, right x264 with Optimizer

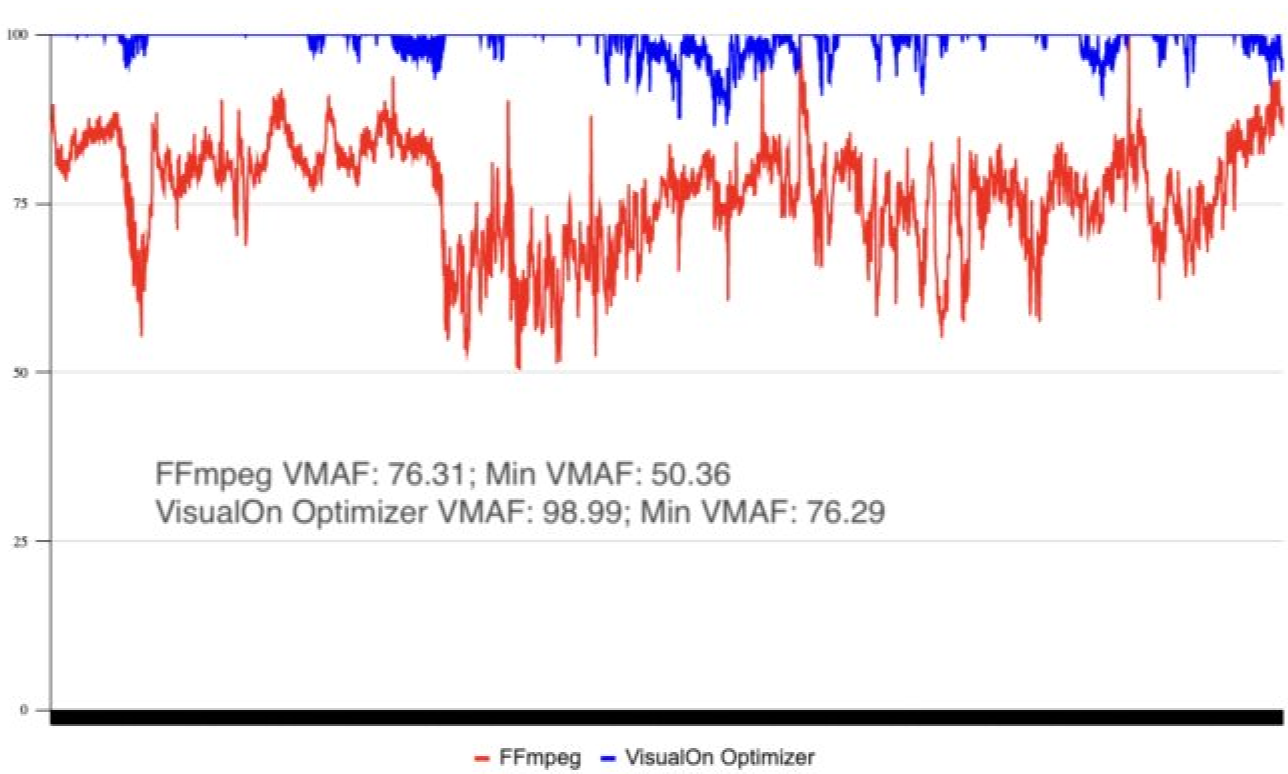

Figure 3.2. VMAF score comparison per frame

The following sessions show some benchmark results with Optimizer in action.

Production Results:
VisualOn Optimizer is a production proven solution that has been successfully deployed by multiple customers with dramatically improved results, not just in terms of bandwidth and storage reductions, but also in improved user experience KPIs, such as startup time and buffering ratio. Table 1 below shows the comparison of Intigral's operation results before and after adopting Optimizer [7].

	Before Optimizer	After Optimizer	Improvement
Average bitrate	3.0 Mbps	1.36 Mbps	54.67%
Startup Time	1.84s	1.51s	17.93%
Buffering Ratio	0.195%	0.185%	5.13%

Table 1. x264 vs. Optimizer with x264

EiTV in Brazil was able to successfully integrate Optimizer within its production workflow on their own within one week, and achieved over 40% average bitrate reduction [8].

Optimizing Open-Source Encoders

The benchmark is run on the same test suite as in [5], consists of 21 clips of different categories of content – Animation, Movie-ish, Synthetic, Other Business and Sports, for a total of over 50 minutes of video clips. The comparisons are between results of various encoders by themselves and with VisualOn Optimizer integrated, with the same ABR ladder as in [5]. The benchmark is run within the FFmpeg framework and Optimizer is integrated with the encoders through simple FFmpeg APIs. The target VMAF score for Optimizer is set to 96 by default and the maxrate is set to the corresponding encoder's target bitrate in kbps.

The benchmark is on an Intel Xeon Scalable 8480+ (56 cores per socket), 192 GB system memory (16x32GB DDR5 4800), 500GB and 750 GB SSDs (Intel SSDSC2KB48 and Intel SSDSC2BB80), CPU microcode ver. 0x2b0005c0, Intel Turbo Boost Enabled (up to 3.80 GHz.), Hyperthreading enabled, Ubuntu ver. 22.04.1 LTS with 5.17.0-107-generic kernel patches (Intel SDP Server)

Table 2 shows the results for H.264, for the whole test suite overall, each content category and each rung of the ABR ladder (over all test clips), respectively. The command line for x264 without Optimizer, with target bitrate set to the same as in [5] is:

```
ffmpeg -i input.mp4 -vcodec libx264 -b:v 4500k -maxrate 9000k -bufsize 9000k -g 60/50/48 -keyint_min 60/50/48 -sc_threshold 0 -vf scale=1920:1080 -vsync 0 out.mp4
```

The corresponding command line for x264 with Optimizer with patch to FFmpeg that supports the -eagle_ parameters:

ffmpeg -eagle -i input.mp4 -vcodec libx264 -eagle_vmaf 96 -maxrate 4500k -bufsize 9000k -g 60/50/48 -keyint_min 60/50/48 -sc_threshold 0 -vf scale=1920:1080 -vsync 0 out.mp4

		FFmpeg x264			FFmpeg x264 with VisualOn Optimizer					
	Resolution	**Bitrate**	**VMAF**	**utime**	**Bitrate**	**Delta**	**VMAF**	**Delta**	**utime**	**Delta**
Overall		1,713	68.19	46,958.29	989	-42.29%	76.61	8.41	39,727.12	-15.40%
Animation		1,698	69.67	4,320.85	895	-47.32%	77.69	8.02	3,644.29	-15.66%
Movie-ish		1,721	68.53	20,108.18	1,097	-36.27%	77	8.47	17,471.92	-13.11%
Synthetic		1,622	62.55	1,295.62	474	-70.78%	70.27	7.72	1,247.87	-3.68%
Other Business		1,726	71.41	12,806.38	512	-70.33%	80.14	8.73	9,264.23	-27.66%
Sports		1,738	66.52	8,427.27	1,481	-14.78%	75.12	8.6	8,098.80	-3.90%
Top Rung	1080p	4,438	94.97	16,212.07	2,596	-41.50%	97.02	2.05	13,467.13	-16.93%
2nd Rung	720p	2,670	89.39	9,272.00	1,384	-48.16%	92.97	3.58	7,091.27	-23.52%
3rd Rung	540p	1,884	83.11	6,399.29	994	-47.22%	87.39	4.28	5,192.64	-18.86%
4th Rung	480p	1,345	78.35	5,254.62	822	-38.90%	84.61	6.25	4,580.12	-12.84%
5th Rung	360p	899	66.64	4,005.89	575	-36.09%	75.17	8.53	3,654.89	-8.76%
6th Rung	270p	504	47.12	3,140.88	360	-28.51%	61.54	14.41	3,071.61	-2.21%
7th Rung	180p	253	17.77	2,673.53	189	-25.17%	37.56	19.79	2,669.45	-0.15%

Table 2. x264 vs. Optimizer with x264

From Table 2 we can see:

1. Optimizer consistently reduces video bitrate for the test suite overall (by over 42%), for each category of contents (by from almost 15% to over 70%), and for each rung of the ABR ladder over all contents (by from over 25% to over 48%).
2. It is able to do so while simultaneously improving VMAF scores significantly (by around 8 overall and for each content categories, and by over 2 to close to 20 for each rung of the ABR ladder).
3. It requires less computing power because the encoder runs more efficiently due to lower bitrates.

Table 3 shows the results for HEVC. The command line for x265 without Optimizer, with target bitrate set to 70% of that for H.264 is:

ffmpeg -i input.mp4 -vcodec hevc_nvenc -rc cbr -b:v 3150k -maxrate 6300k -bufsize 6300k -g 48 -keyint_min 48 -sc_threshold 0 -vf scale=1920:1080 -fps_mode:v passthrough output.mp4

The corresponding command line for x265 with Optimizer is:

ffmpeg -eagle -i input.mp4 -eagle_vmaf 96 -vcodec hevc_nvenc -rc cbr -b:v 3150k -maxrate 3150k -bufsize 6300k -g 48 -keyint_min 48 -sc_threshold 0 -vf scale=1920:1080 -fps_mode:v passthrough output.mp4

		FFmpeg x265			FFmpeg x265 with VisualOn Optimizer					
	Resolution	**Bitrate**	**VMAF**	**utime**	**Bitrate**	**Delta**	**VMAF**	**Delta**	**utime**	**Delta**
Overall		1,214.83	66.43	68,233.89	749.2	-38.33%	75.65	9.22	69,488.45	1.84%
Animation		1,199.05	67.74	6,034.42	696.24	-41.93%	77.23	9.49	6,276.47	4.01%
Movie-ish		1,220.33	66.75	29,977.08	847.63	-30.54%	76.12	9.38	30,137.58	0.54%
Synthetic		1,223.86	62.54	2,657.65	362.29	-70.40%	69.73	7.2	3,053.67	14.90%
Other Business		1,183.82	70.45	17,147.74	403.57	-65.91%	79.67	9.22	16,095.11	-6.14%
Sports		1,237.80	63.55	12,417.01	1,074.43	-13.20%	73.18	9.63	13,925.61	12.15%
Top Rung	1080p	3,153	95.11	28,956.23	1,866	-40.81%	96.86	1.75	29,092.36	0.47%
2nd Rung	720p	1,895	88.65	13,246.56	1,072	-43.41%	92.53	3.88	13,265.29	0.14%
3rd Rung	540p	1,337	81.72	8,256.70	784	-41.40%	86.67	4.95	8,370.83	1.38%
4th Rung	480p	952	76.53	6,749.59	640	-32.79%	83.79	7.25	7,103.73	5.25%
5th Rung	360p	636	64.04	4,660.42	457	-28.16%	74.26	10.23	4,955.18	6.32%
6th Rung	270p	354	43.7	3,530.24	280	-20.69%	59.8	16.1	3,750.50	6.24%
7th Rung	180p	177	15.26	2,834.14	145	-18.02%	35.63	20.37	2,950.57	4.11%

Table 3. x265 vs. Optimizer with x265

As can be seen from Table 3, Optimizer consistently reduces video bitrate for the test suite overall (by over 38%), for each category of contents (by from over 13% to over 70%), and for each rung of the ABR ladder over all contents (by from over 18% to over 43%). And it is able to do so while simultaneously improving VMAF scores significantly (by around 9 overall and for each content categories, and by almost 2 to over 20 for each rung of the ABR ladder). It requires only less than 2% more computing power overall.

Table 4 shows the results for AV1. The command line for SVT-AV1 without Optimizer, with target bitrate set to 50% of that of H.264:

ffmpeg -i input.mp4 -vcodec libsvtav1 -b:v 2250k -maxrate 4500k -bufsize 4500k -svtav1-params tune=0 -preset 6 -g 48 -keyint_min 48 -sc_threshold 0 -fps_mode:v passthrough output.mp4

The corresponding command line for SVT-AV1 with Optimizer is:

ffmpeg -eagle -i input.mp4 -vcodec libsvtav1 -eagle_vmaf 96 -maxrate 2250k -bufsize 4500k -svtav1-params tune=0 -preset 6 -g 48 -keyint_min 48 -sc_threshold 0 -fps_mode:v passthrough output.mp4

		FFmpeg SVT-AV1			FFmpeg SVT-AV1 with VisualOn Optimizer					
	Resolution	**Bitrate**	**VMAF**	**utime**	**Bitrate**	**Delta**	**VMAF**	**Delta**	**utime**	**Delta**
Overall		773.83	65.8	144,880.62	643.69	-16.82%	74.55	8.75	161,829.11	11.70%
Animation		762.64	65.17	11,404.21	752.5	-1.33%	74.32	9.15	13,132.53	15.16%
Movie-ish		757.65	66.51	60,098.17	686.06	-9.45%	75.57	9.05	69,779.34	16.11%
Synthetic		776.36	62.46	7,870.22	484.64	-37.57%	71.14	10.85	6,835.46	-13.15%
Other Business		759.5	70.61	36,755.62	415.79	-45.26%	81.47	10.85	38,084.23	3.61%
Sports		811.4	62.55	28,752.40	786.77	-3.04%	69.05	6.51	33,997.55	18.24%
Top Rung	1080p	2,004.25	94.43	61,667.71	1,615.85	-19.38%	95.89	1.46	63,110.78	2.34%
2nd Rung	720p	1,201.65	87.49	27,579.29	972.35	-19.08%	92.02	4.53	31,959.50	15.88%
3rd Rung	540p	845.65	80.65	19,283.45	704.8	-16.66%	86.68	6.03	22,295.68	15.62%
4th Rung	480p	608.45	75.44	15,352.63	536.9	-11.76%	82.25	6.81	18,624.19	21.31%
5th Rung	360p	409.75	63.39	9,994.72	361.2	-11.85%	72.76	9.37	12,593.00	26.00%
6th Rung	270p	231.7	43.61	6,389.55	208.25	-10.12%	57.5	13.9	7,829.96	22.54%
7th Rung	180p	115.35	15.61	4,613.28	106.45	-7.72%	34.75	19.13	5,416.02	17.40%

Table 4. SVT-AV1 vs. Optimizer with SVT-AV1

As can be seen from Table 4, Optimizer consistently reduces video bitrate for the test suite overall (by almost 17%), for each category of contents (by from over 1% to over 45%), and for each rung of the ABR ladder over all contents (by from almost 8% to over 19%). And it is able to do so while simultaneously improving VMAF scores significantly (by almost 9 overall and for each content categories, and by over 1 to almost 20 for each rung of the ABR ladder). It requires about 12% more computing power overall.

A comparison of x264 with Optimizer's results for the top ABR rungs (1080p) to the per-title encoder results presented in [6] is shown below in Table 5. It can be seen that Optimizer reduces the average video bitrate by over 36% on average (by from almost 17% to over 42%) while improving the VMAF score by 1.64 on average (ranging from 0.79 to 3.62)

	Average Bitrate	Delta	Average VMAF	Delta
Bitmovin	3,947	-35.09%	95.35	1.52
AWS Elemental	4,275	-40.07%	93.24	3.63
Brightcove	4,155	-38.34%	95.93	0.94
Azure	4,330	-40.83%	96.08	0.79
Tencent	3,084	-16.93%	95.28	1.59
x264 Medium ABR	4,432	-42.19%	94.95	1.92
x264 with Optimizer	2,562		96.87	
Average		-36.08%		1.64

Table 5. Top Rung Results vs. Different H.264 Per-Title Encoders

Optimizing Nvidia NVENC Encoders

This session presents benchmark results with NVENC encoders on the same test suite, running on an AMD Ryzen Threadripper 2970WX with 24 cores, 48 threads and 64GB of RAM, running 20.04.1-Ubuntu, with NVIDIA GeForce RTX 4060 8G GPU (driver version: 550.54.14), CUDA Version 12.4.

As can be seen from tables 6 to 8 below, Optimizer similarly consistently achieves significant bitrate reduction while improving VMAF scores with each of the NVENC encoders for H.264, HEVC and AV1.

		FFmpeg NVENC_H.264		FFmpeg NVENC_H.264 with Optimizer			
	Resolution	**Bitrate**	**VMAF**	**Bitrate**	**Delta**	**VMAF**	**Delta**
Overall		1,680	67.04	1,370	-18.49%	73.9	6.86
Animation		1,758	67.23	1,495	-14.95%	74.02	6.79
Movie-ish		1,672	67.25	1,500	-10.30%	74.64	7.39
Synthetic		1,249	62.29	717	-42.60%	67.36	5.07
Other Business		1,742	70.83	945	-45.77%	77.09	6.26
Sports		1,793	64.06	1,729	-3.58%	71.31	7.25
Top Rung	1080p	4,233	92.4	3,650	-13.79%	95.71	3.32
2nd Rung	720p	2,540	87.08	1,958	-22.89%	92.41	5.34
3rd Rung	540p	1,790	80.99	1,363	-23.83%	87.13	6.13
4th Rung	480p	1,261	75.7	1,048	-16.91%	83.74	8.04
5th Rung	360p	878	64.53	650	-25.93%	70.6	6.07
6th Rung	270p	528	45.34	432	-18.26%	54	8.66
7th Rung	180p	241	16.98	197	-18.22%	28.07	11.09

Table 6. H.264 NVENC vs. Optimizer with H.264 NVENC

		FFmpeg NVENC_HEVC		FFmpeg NVENC_HEVC with Optimizer			
	Resolution	**Bitrate**	**VMAF**	**Bitrate**	**Delta**	**VMAF**	**Delta**
Overall		1,217	65.49	968	-20.46%	72.41	6.92
Animation		1,254	64.76	1,097	-12.57%	72.12	7.36
Movie-ish		1,251	65.99	1,051	-15.97%	73.51	7.52
Synthetic		874	62.08	501	-42.67%	67.11	5.03
Other Business		1,243	69.84	713	-42.64%	77.17	7.33
Sports		1,276	61.35	1,200	-5.94%	67.76	6.42
Top Rung	1080p	3,098	93.06	2,559	-17.41%	95.75	2.7
2nd Rung	720p	1,861	86.65	1,422	-23.56%	91.82	5.17
3rd Rung	540p	1,321	80.16	995	-24.71%	86.2	6.03
4th Rung	480p	943	74.89	767	-18.65%	82.67	7.78
5th Rung	360p	659	62.79	497	-24.63%	69.39	6.59
6th Rung	270p	397	43.28	334	-15.87%	52.65	9.37
7th Rung	180p	179	15.03	148	-17.40%	26	10.96

Table 7. HEVC NVENC vs. Optimizer with HEVC NVENC

		FFmpeg NVENC-AV1			FFmpeg NVENC-AV1 with VisualOn Optimizer					
	Resolution	Bitrate	VMAF	utime	Bitrate	Delta	VMAF	Delta	utime	Delta
Overall		773.83	65.8	144,880.62	643.69	-16.82%	74.55	8.75	161,829.11	11.70%
Animation		762.64	65.17	11,404.21	752.5	-1.33%	74.32	9.15	13,132.53	15.16%
Movie-ish		757.65	66.51	60,098.17	686.06	-9.45%	75.57	9.05	69,779.34	16.11%
Synthetic		776.36	62.46	7,870.22	484.64	-37.57%	71.14	10.85	6,835.46	-13.15%
Other Business		759.5	70.61	36,755.62	415.79	-45.26%	81.47	10.85	38,084.23	3.61%
Sports		811.4	62.55	28,752.40	786.77	-3.04%	69.05	6.51	33,997.55	18.24%
Top Rung	1080p	2,004.25	94.43	61,667.71	1,615.85	-19.38%	95.89	1.46	63,110.78	2.34%
2nd Rung	720p	1,201.65	87.49	27,579.29	972.35	-19.08%	92.02	4.53	31,959.50	15.88%
3rd Rung	540p	845.65	80.65	19,283.45	704.8	-16.66%	86.68	6.03	22,295.68	15.62%
4th Rung	480p	608.45	75.44	15,352.63	536.9	-11.76%	82.25	6.81	18,624.19	21.31%
5th Rung	360p	409.75	63.39	9,994.72	361.2	-11.85%	72.76	9.37	12,593.00	26.00%
6th Rung	270p	231.7	43.61	6,389.55	208.25	-10.12%	57.5	13.9	7,829.96	22.54%
7th Rung	180p	115.35	15.61	4,613.28	106.45	-7.72%	34.75	19.13	5,416.02	17.40%

Table 8. AV1 NVENC vs. Optimizer with AV1 NVENC

Optimizer on Intel Xeon Scalable Processors and Intel Data Center GPU Flex Series with Intel Quick Sync Video (QSV)

This session presents benchmark results with Intel's QSV encoders running on the Intel SDP Server. The input test suite is the same as in [5].

As can be seen from tables 9 to 10 below, Optimizer similarly consistently achieves significant bitrate reduction while improving VMAF scores with each of Intel's Quick Sync Video encoders for H.264, HEVC and AV1.

		FFmpeg H.264_QSV		FFmpeg H.264_QSV with Optimizer			
	Resolution	Bitrate	VMAF	Bitrate	Delta	VMAF	Delta
Overall		1,651	67.43	1,169	-29.21%	73.53	6.1
Animation		1,710	68.9	1,114	-34.83%	74.95	6.05
Movie-ish		1,723	68.05	1,184	-31.27%	73.43	5.38
Synthetic		1,286	62.33	1,141	-11.29%	70.53	8.2
Other Business		1,551	70.59	791	-49.02%	77.78	7.19
Sports		1,742	65.17	1,495	-14.21%	70.6	5.43
Top Rung	1080p	4,349	95.08	3,023	-30.49%	96.31	1.22
2nd Rung	720p	2,560	89.05	1,733	-32.30%	92.83	3.78
3rd Rung	540p	1,782	82.42	1,283	-27.99%	87.67	5.25
4th Rung	480p	1,285	77.42	973	-24.26%	83.94	6.51
5th Rung	360p	855	65.38	607	-29.04%	71.26	5.89
6th Rung	270p	483	45.66	370	-23.39%	54.65	8.99
7th Rung	180p	244	16.95	193	-20.75%	28.04	11.08

Table 9. Intel QSV H.264 Encoder

		FFmpeg HEVC_QSV		FFmpeg HEVC_QSV with Optimizer			
	Resolution	**Bitrate**	**VMAF**	**Bitrate**	**Delta**	**VMAF**	**Delta**
Overall		1,171	65.84	712	-39.18%	70.18	4.34
Animation		1,191	66.81	691	-42.02%	70.49	3.68
Movie-ish		1,196	66.28	747	-37.56%	70.49	4.21
Synthetic		1,085	62.24	620	-42.86%	68.83	6.59
Other Business		1,112	69.84	479	-56.94%	75.33	5.49
Sports		1,205	62.89	900	-25.31%	65.96	3.07
Top Rung	1080p	3,051	94.95	1,782	-41.58%	94.79	-0.16
2nd Rung	720p	1,825	88.26	1,091	-40.21%	90.8	2.54
3rd Rung	540p	1,282	81.19	784	-38.79%	84.76	3.56
4th Rung	480p	916	75.77	593	-35.26%	80.49	4.71
5th Rung	360p	610	63.2	378	-38.05%	66.7	3.49
6th Rung	270p	341	42.93	230	-32.58%	49.75	6.82
7th Rung	180p	171	14.57	126	-26.47%	23.95	9.38

Table 10. Intel QSV HEVC Encoder

		FFmpeg SVT-AV1_QSV		FFmpeg SVT-AV1_QSV with Optimizer			
	Resolution	**Bitrate**	**VMAF**	**Bitrate**	**Delta**	**VMAF**	**Delta**
Overall		863	62.93	704	-18.44%	70.49	7.55
Animation		859	64.15	698	-18.70%	71.63	7.48
Movie-ish		898	63.13	801	-10.86%	71.11	7.99
Synthetic		724	61.83	457	-36.98%	69.36	7.54
Other Business		788	67.77	465	-41.03%	76.1	8.33
Sports		933	58.52	863	-7.50%	64.88	6.37
Top Rung	1080p	2,320	93.28	1,842	-20.58%	95.75	2.47
2nd Rung	720p	1,372	86.04	1,087	-20.73%	91.65	5.62
3rd Rung	540p	817	76.68	688	-15.73%	84.07	7.39
4th Rung	480p	690	72.76	595	-13.86%	81.4	8.64
5th Rung	360p	458	59.81	375	-18.02%	67.32	7.51
6th Rung	270p	257	39.76	224	-13.02%	49.97	10.21
7th Rung	180p	130	12.21	118	-9.67%	23.24	11.03

Table 11. Intel QSV AV1 Encoder

Optimizing Qualcomm Encoders on ARM

Optimizer has been integrated with Qualcomm's H.264 and HEVC encoders on a Samsung Galaxy S22 phone. Table 12 below shows the average bitrate and VMAF scores for the top rungs (1080p) of the source clips in the test suite. Optimizer was running on the ARM process and its target VMAF score was set to 98. Again, Optimizer achieves bitrate reduction of over 23% while improving VMAF scores.

	Qualcomm Encoder		Qualcomm Encoder with Optimizer			
Codec	**Bitrate**	**VMAF**	**Bitrate**	**Delta**	**VMAF**	**Delta**
H.264	5,988	94.01	4,505	-24.77%	94.61	0.6
HEVC	4,199	93.38	3,222	-23.27%	94.23	0.85

Table 12. H.264 and HEVC results with Qualcomm Encoders

Optimizing ASIC HW Encoders

Optimizer has also been integrated with NETINT's ASIC HW hardware encoders through their FFmpeg APIs. The results on different input source clips are shown below in Table 13. An average bitrate reduction of over 35% for H.264 and over 45% for HEVC were achieved with visual quality improvements of close to 2 VMAF score.

	NETINT_ABR_3M		NETINT_Optimizer_3M			
	Bitrate (kbps)	**VMAF**	**Bitrate**	**delta**	**VMAF**	**delta**
Basketball	00:02:01.29, yuv420p, 1920x1080 [SAR 1:1 DAR 16:9], 50313 kb/s, 23.98 fps					
H.264	2,973	90.59	2,993	0.67%	92.32	1.73
HEVC	2,990	97.48	2,695	-9.87%	98.34	0.86
modern-animation	00:05:07.92, yuv422p10le(bt709/unknown/unknown, top first), 1920x1080, SAR 1:1 DAR 16:9, 25 fps					
H.264	2,936	97.15	785	-73.26%	98.68	1.54
HEVC	2,938	97.3	558	-81.01%	99.37	2.07
modern-live-action	00:01:00.00, yuv422p10le(bt709/unknown/unknown, top first), 1920x1080, SAR 1:1 DAR 16:9, 25 fps					
H.264	3,087	92.96	2,675	-13.35%	96.64	3.69
HEVC	3,047	93.71	2,058	-32.46%	97.25	3.54
Movie_SAMPLE	00:04:00.00, yuv422p(tv, unknown/bt709/bt709, progressive), 1920x1080 [SAR 1:1 DAR 16:9], 50000 kb/s, 25 fps					
H.264	3,018	95.52	1,435	-52.45%	97.51	1.99
HEVC	3,017	95.73	1,001	-66.82%	97.25	1.51
news-clip	00:04:00.00, yuv422p10le(pc, bt709, top first), 1920x1080 [SAR 1:1 DAR 16:9], 25 fps					
H.264	2,999	93.62	2,443	-18.54%	97.49	3.87
HEVC	3,002	94.05	2,048	-31.78%	98.08	4.04
series-clip	00:04:00.00, yuv422p10le(pc, bt709, top first), 1920x1080 [SAR 1:1 DAR 16:9], 25 fps					
H.264	3,002	97.58	722	-75.95%	98.01	0.42
HEVC	2,999	97.61	408	-86.40%	97.92	0.31
Soccer	00:02:00.08, yuv420p, 1920x1080 [SAR 1:1 DAR 16:9], 49936 kb/s, 25 fps					
H.264	3,010	89.57	3,000	-0.33%	89.42	-0.16
HEVC	3,004	93.72	2,967	-1.23%	94.07	0.35
TalkingHead	00:02:00.17, yuv420p(tv, bt709), 1920x1080 [SAR 1:1 DAR 16:9], 50050 kb/s, 29.97 fps					
H.264	2,993	96.8	973	-67.49%	99.54	2.74
HEVC	2,996	96.8	665	-77.80%	99.46	2.67
talkshow-clip	00:04:00.00, yuv422p10le(pc, bt709, top first), 1920x1080 [SAR 1:1 DAR 16:9], 25 fps					
H.264	3,002	91.13	2,995	-0.23%	94.31	3.18
HEVC	3,003	92.75	2,959	-1.47%	97.05	4.31
v2_animation	00:03:59.56, yuv422p(tv, top first), 1920x1080 [SAR 1:1 DAR 16:9], 50000 kb/s, 25 fps					
H.264	2,992	97.85	1,040	-65.24%	97.35	-0.5
HEVC	2,995	98	703	-76.53%	97.46	-0.55
H.264 (Avg.)	3,001	94.28	1,906	-36.49%	96.13	1.85
HEVC(Avg.)	2,999	95.72	1,606	-46.44%	97.63	1.91

Table 13. NETINT H.264 and HEVC Encoders on Quadra T2A

Summary

VisualOn Optimizer is a production-proven, highly differentiating CAE solution backed by multiple granted and pending patents. As extensive benchmarking data above demonstrates:

1. It's a universal solution that has been integrated with many popular encoders for different compression formats;
2. It dramatically reduces video bitrates for different types of content, with different encoders while maintaining and in many cases improving visual quality. It typically reduces bitrate for H.264 by 30-40%, HEVC by 20-40% and AV1 by 15-30% or more. It outperforms leaving per-title cloud encoding solutions by an average of over 35%;
3. Its highly efficient implementation approach doesn't require much additional computing resources and in some cases can run even more efficiently without Optimizer. More performance benchmarking data will be shared in a future white paper;
4. Its results are context dependent based on the content, target quality, and type of encoder. It provides simple APIs for fine-tuning, allowing users to achieve their desired trade-offs;
5. It can be easily adopted for production workflows without disrupting operations or creating additional costs. Taking our customers days instead of months or years to adopt Optimizer for production without having to change their apps on their install base's client devices.

The Future of Video Encoding is CAE

Content-adaptive encoding represents a significant advancement in video compression technology, offering a myriad of benefits for both providers and consumers. It offers a practical, cost-effective solution that enhances both efficiency and quality without the need for drastic changes to existing systems. As video consumption continues to rise, the adoption of CAE will be crucial for staying competitive in a fast-evolving landscape. Embracing this technology ensures that high-quality video content can be delivered seamlessly to audiences around the world, setting a new standard for efficiency and performance in the digital age.

It's time to embrace the future of video encoding. Evaluating current encoding processes and exploring how CAE can be integrated into your workflow is critical. By partnering with technology providers like VisualOn that specialize in CAE, you can start reaping the benefits of smarter, more efficient video encoding today.

Visit VisualOn's website at www.visualon.com to download your evaluation copy of Optimizer today and see how you can dramatically improve your operations.

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