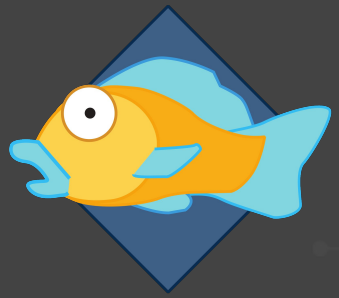
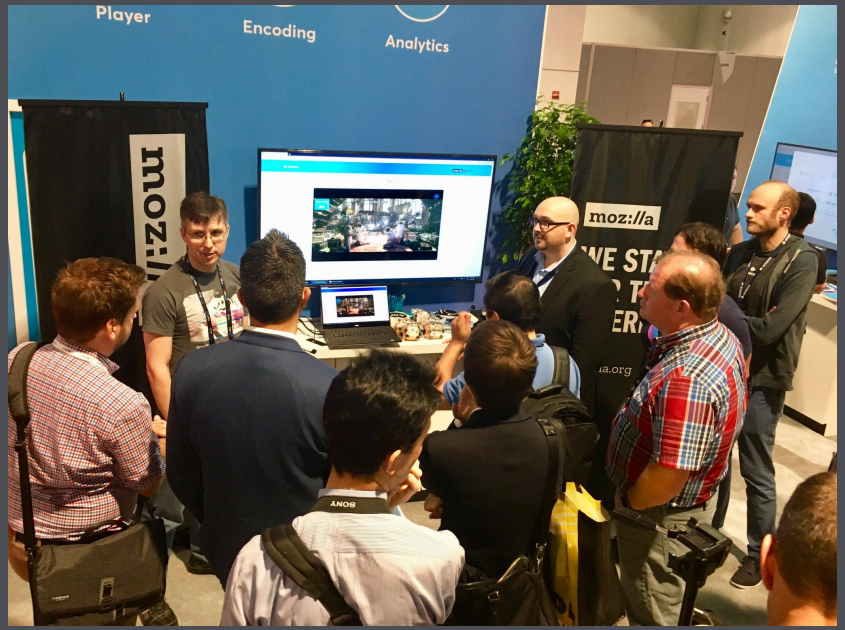


Presentation: Latest Technical and Business Progress with AV1

Nathan Egge <negge@mozilla.com>
NAB Streaming Summit - April 8, 2019
Slides: https://xiph.org/~negge/NAB2019.pdf

Mozilla at NAB 2018



Firefox Demo with Bitmovin [1]

Interview with Jan Ozer of Streaming Media [2]

[1] https://twitter.com/bitmovin/status/983810754003398656
[2] https://www.streamingmedia.com/Articles/ReadArticle.aspx?ArticleID=124396

Concerns We Heard at NAB 2018

- “The bitstream isn’t even frozen yet”
- “We need broad deployment of hardware decoders before adoption”
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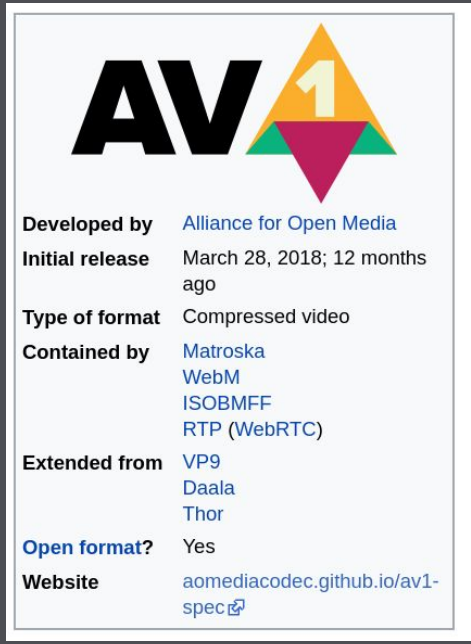
One Doesn’t Just Freeze the AV1 Bitstream

- Draft specification at NAB 2018 (`2018-Mar-28`)
  - Testing showed ~30% better than VP9
  - No new major coding tools added
- Engineering review period
  - Machine verification of spec document
  - Correct normative errors
- Tag release v1.0.0 (`2018-Jun-25`)



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  - No new major coding tools added
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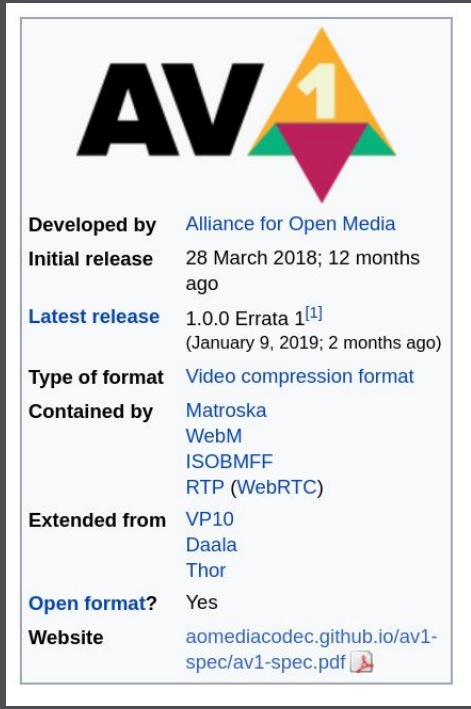
  - Correct normative errors
- Tag release v1.0.0 (`2018-Jun-25`)

- Issues found by implementers
  - Additional normative corrections
- Tag release v1.0.0-errata1 (`2019-Jan-08`)



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AV1 (libaom) decoding is slow (July 7, 2018)

moz://a

AV1 vs VP9 vs AVC (h.264) vs HEVC (h.265): Part IV - Decode

- July 07, 2018

Codec	Decode			
	real time	vs x264	CPU time	vs x264
x264	0.409s	1:1	1.059s	1:1
x265	0.980s	2.40:1	1.813s	1.71:1
VP9	0.761s	1.86:1	1.253s	1.18:1
AV1	4.178s	10.22:1	3.993s	3.77:1

Codec	Decode			
	real time	vs x264	CPU time	vs x264
x264	0.631s	1:1	1.856s	1:1
x265	1.190s	1.89:1	3.024s	1.63:1
VP9	0.780s	1.24:1	2.095s	1.13:1
AV1	11.750s	18.62:1	11.703s	6.31:1

"At of [sic] June 2018, the AV1 decoder can only decode in a **single thread**. Decoders for H.264, H265, and VP9 utilize multi-threads."

"To decode the files encoded with AV1, the CPU time was approximately **3.5-6x longer** than that to decode files encoded with x264. This means that it required **3.5-6x more CPU** power to decode files encoded with AV1."

[1] https://www.texpion.com/2018/07/av1-vs-vp9-vs-avc-h264-vs-hevc-h265-4-decode.html

Optimized Decoding

moz://a

- AV1 reference (libaom) is not designed for decoder performance
  - Large binary, too much memory, missing SIMD, research codebase

- AOMedia asked for proposals for an open-source optimized decoder

```
Requirements:
+ Open Source (MIT/BSD licensed, or similar)
+ Full SIMD for x86-32, x86-64, ARMv7, and ARMv8.
+ Multi-threaded
+ Bit-identical decoding of all features vs. libaom
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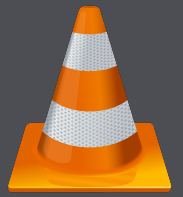
- French non-profit VideoLAN selected

- Dav1d is an AV1 Decoder (dav1d) project is born



dav1d Project

VideoLAN / FFmpeg / Two Orioles

Goals

- Small binary size
- Low CPU utilization
- Multi-threaded
- Cross-platform

Implementation

- C99 (no VLA, complex, GNU extensions)
- ASM (no intrinsics, ASM files like FFmpeg)

License

- BSD (like opus, libvorbis, etc.)

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`2018-Dec-27:` dav1d in vlc-3.0.5
`2019-Mar-13:` dav1d-0.2.1 Release

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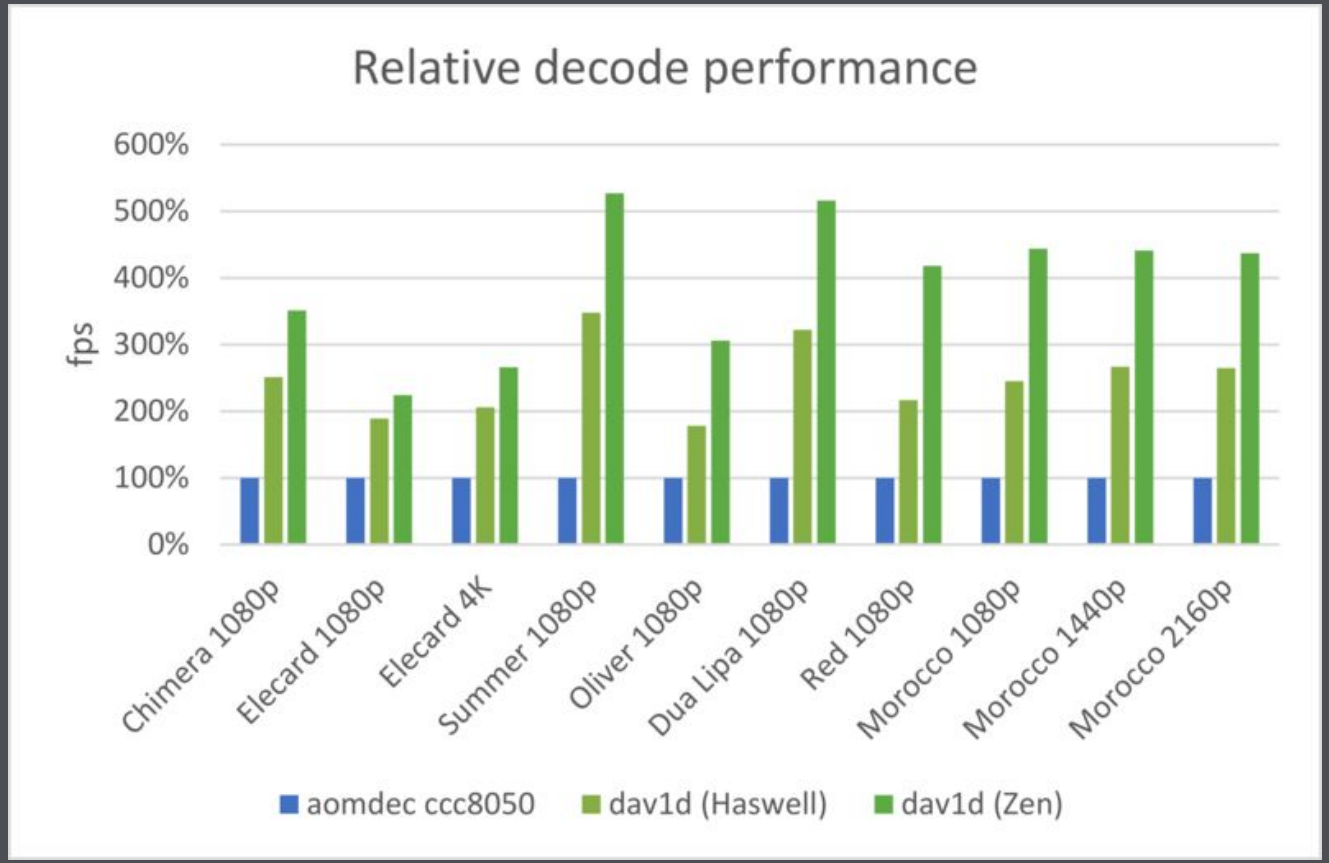
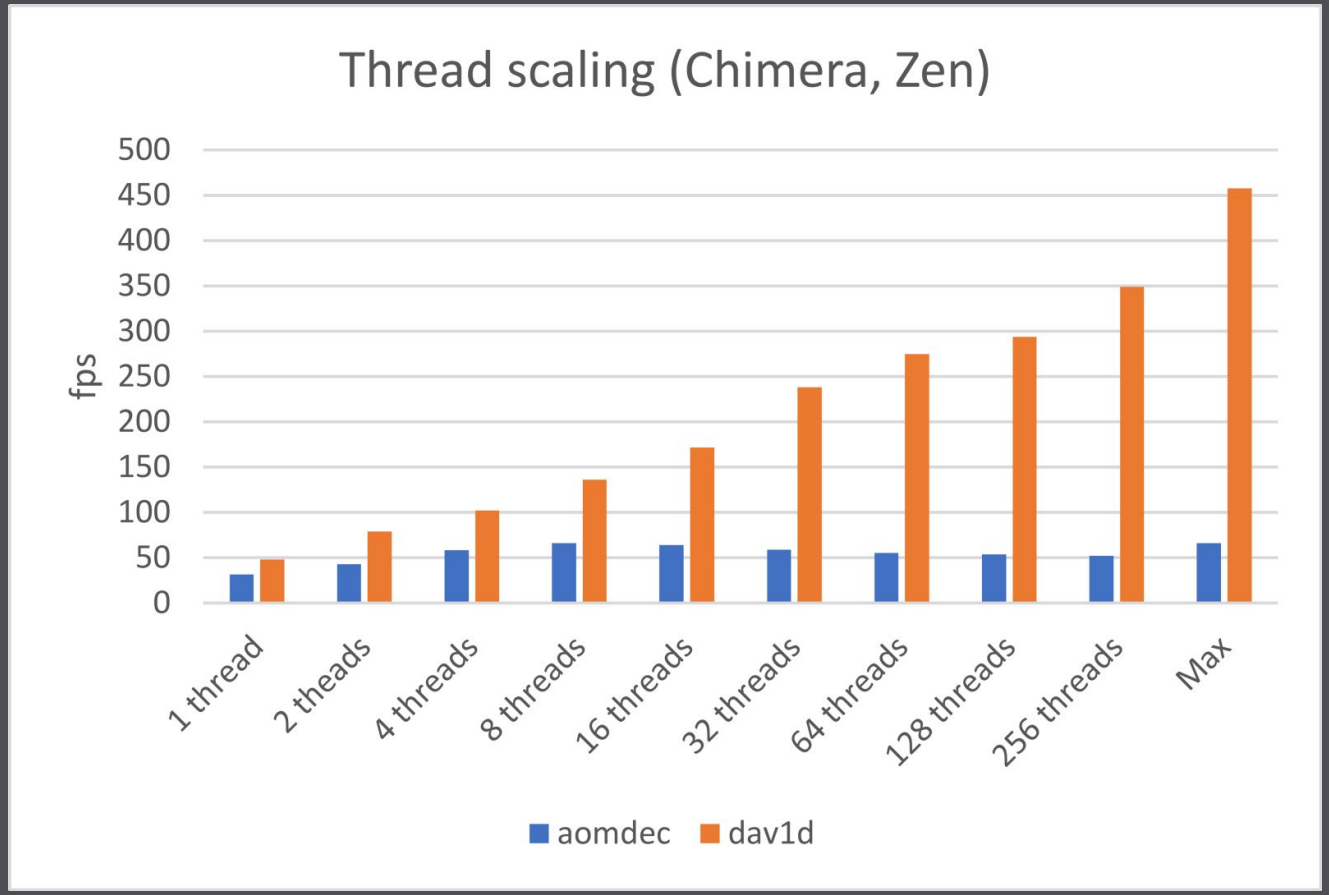
`2019-Mar-13:` dav1d-0.2.1 Release
`2019-Mar-29:` dav1d in Chrome Canary

dav1d-0.1.0 Release (December 11, 2018)

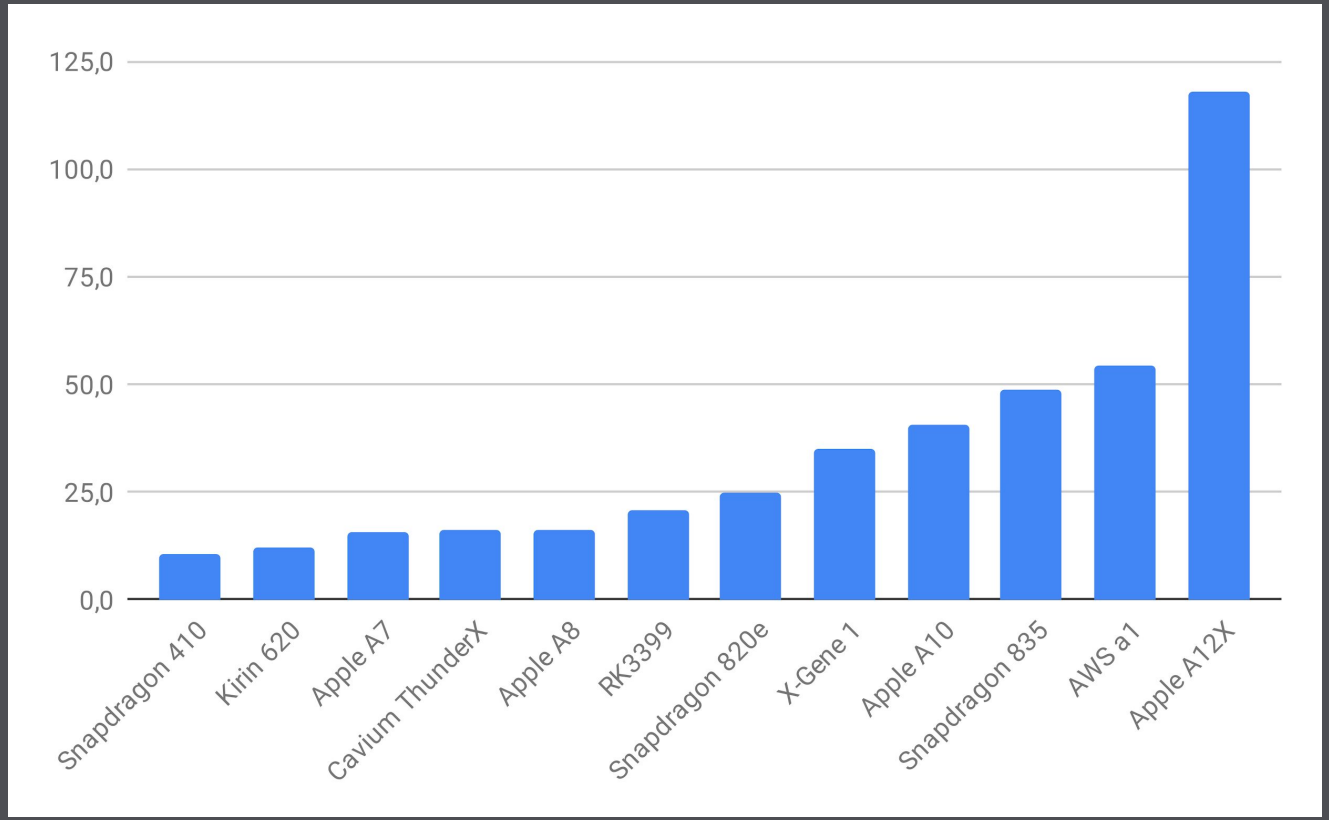


[1] http://www.jbkempf.com/blog/post/2018/First-release-of-dav1d

dav1d-0.2.1 Release (March 13, 2019)



dav1d Can Decode 4k on Mobile(*)



1080p decode speeds in FPS

(*) If you are Apple

dav1d is Awesome

- dav1d is very fast
  - 2x - 5x faster than libaom
  - “Instead of a C library with SIMD optimization, dav1d is an ASM library with C compatibility”
- dav1d is scalable
- dav1d is production ready
  - BSD-2 License means you can fork for commercial purposes
- dav1d will soon be everywhere
  - Firefox 67 (`2019-May-07`)
  - Chromium 74 [1] (week of `2019-Apr-23`)
  - Android Q ???
- dav1d should run everywhere
  - Need support somewhere they can help
- dav1d is open source and community driven

[1] https://storage.googleapis.com/chromium-find-releases-static/ede.html#ede43457

Concerns We Heard at NAB 2018

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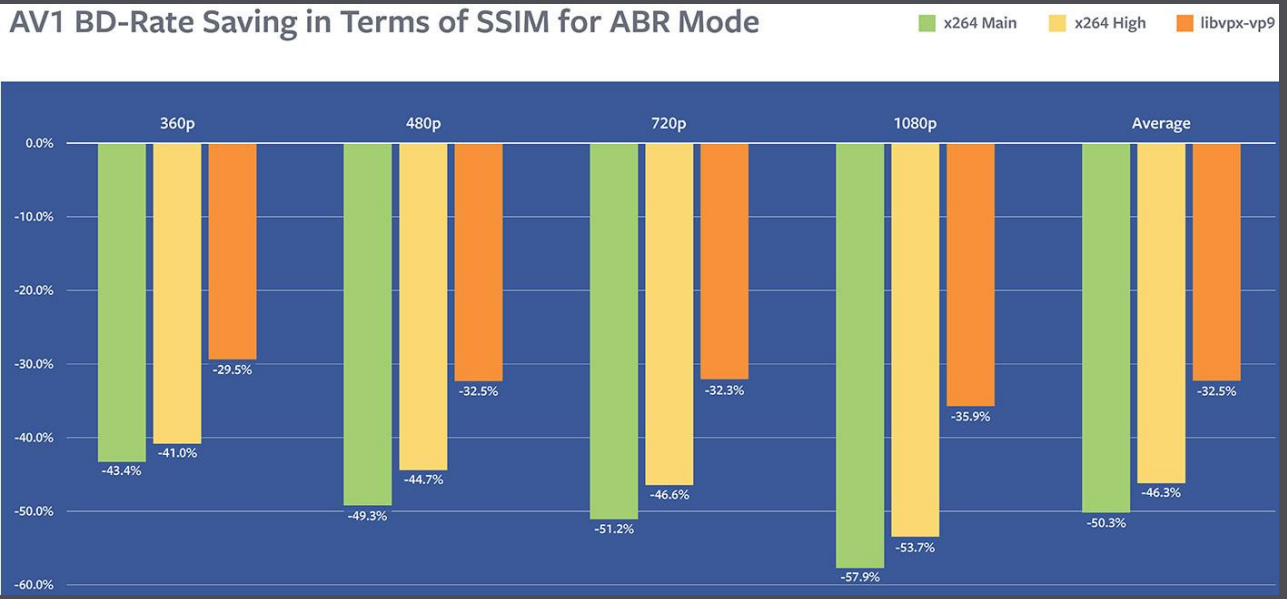
Jan Ozer on AV1 Encoding (January 30, 2018)

January 30, 2018
By Jan Ozer Contributing Editor
Online Video News

AV1 Beats VP9 and HEVC on Quality, if You've Got Time, says Moscow State

[1] https://www.streamingmedia.com/Articles/ReadArticle.aspx?ArticleID=122945

Facebook Study (April 2018)



"Our testing shows AV1 surpasses its stated goal of 30% better compression than VP9, and achieves gains of **50.3%**, **46.2%** and **34.0%**, compared to x264 main profile, x264 high profile and libvpx-vp9, respectively."

"However, AV1 saw increases in encoding computational complexity compared with x264 main, x264 high and libvpx-vp9 for ABR mode. Encoding run time was **9226.4x**, **8139.2x** and **667.1x** greater, respectively"

[1] https://code.fb.com/video-engineering/av1-beats-x264-and-libvpx-vp9-in-practical-use-case/

Jan Ozer on AV1 Encoding (August 31, 2018)

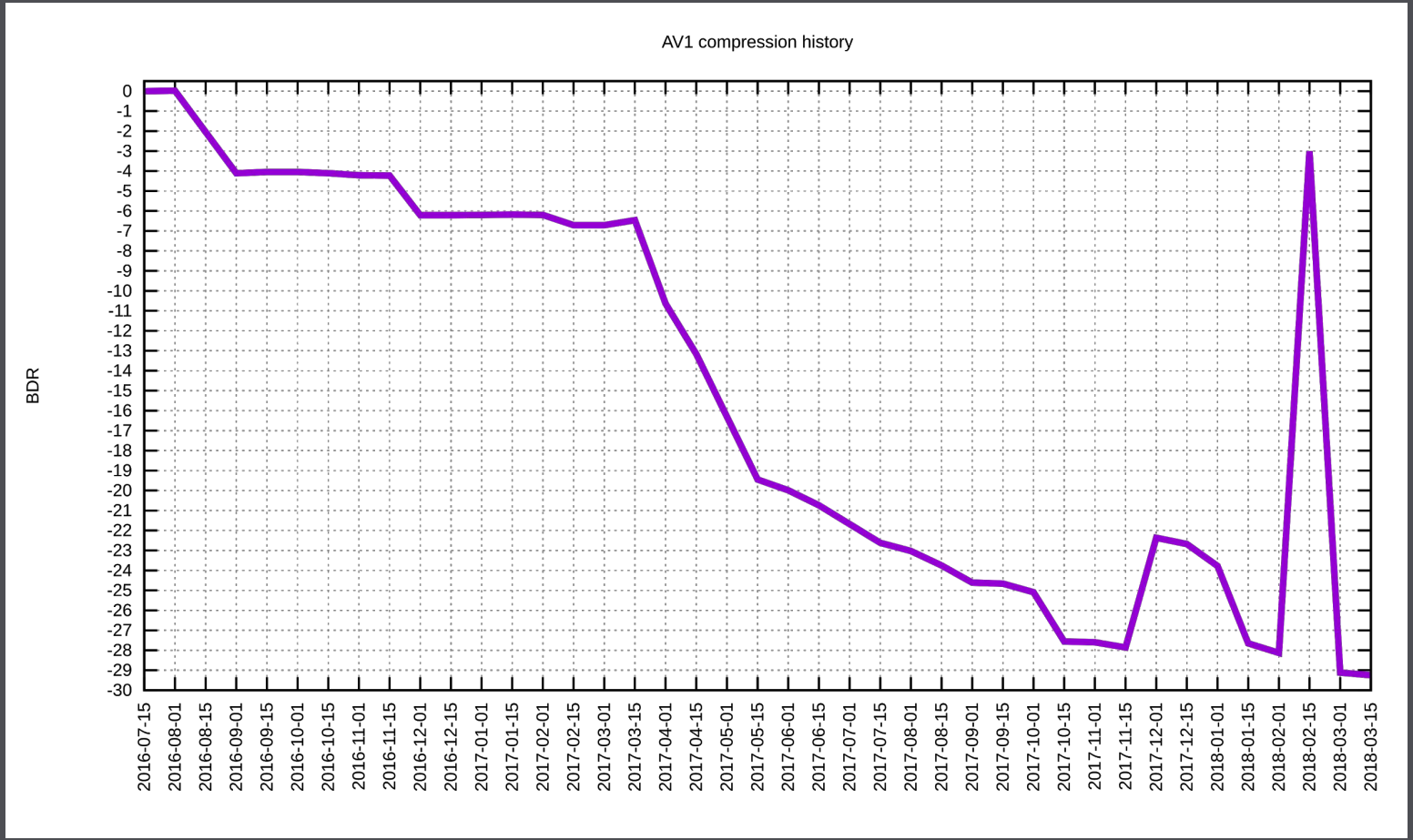
August 31, 2018
By Jan Ozer Contributing Editor
Featured Articles

AV1: A First Look

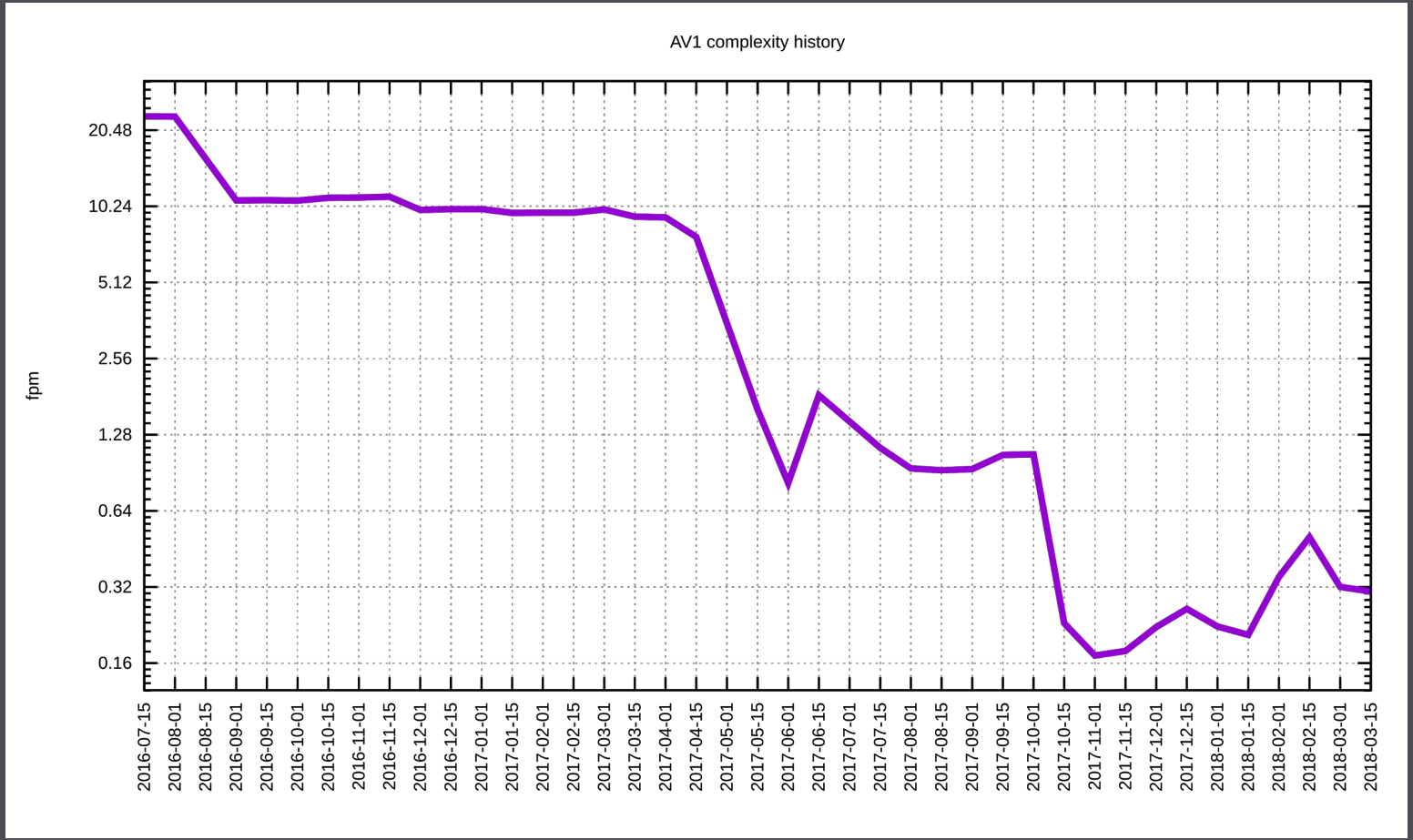
	Encoding Time (seconds)	Times Real Time
AV1	226,080	45,216
x265	289	58
LibVPx	226	45
x264	18	4

[1] https://www.streamingmedia.com/Articles/Editorial/Featured-Articles/AV1-A-First-Look-127133.aspx

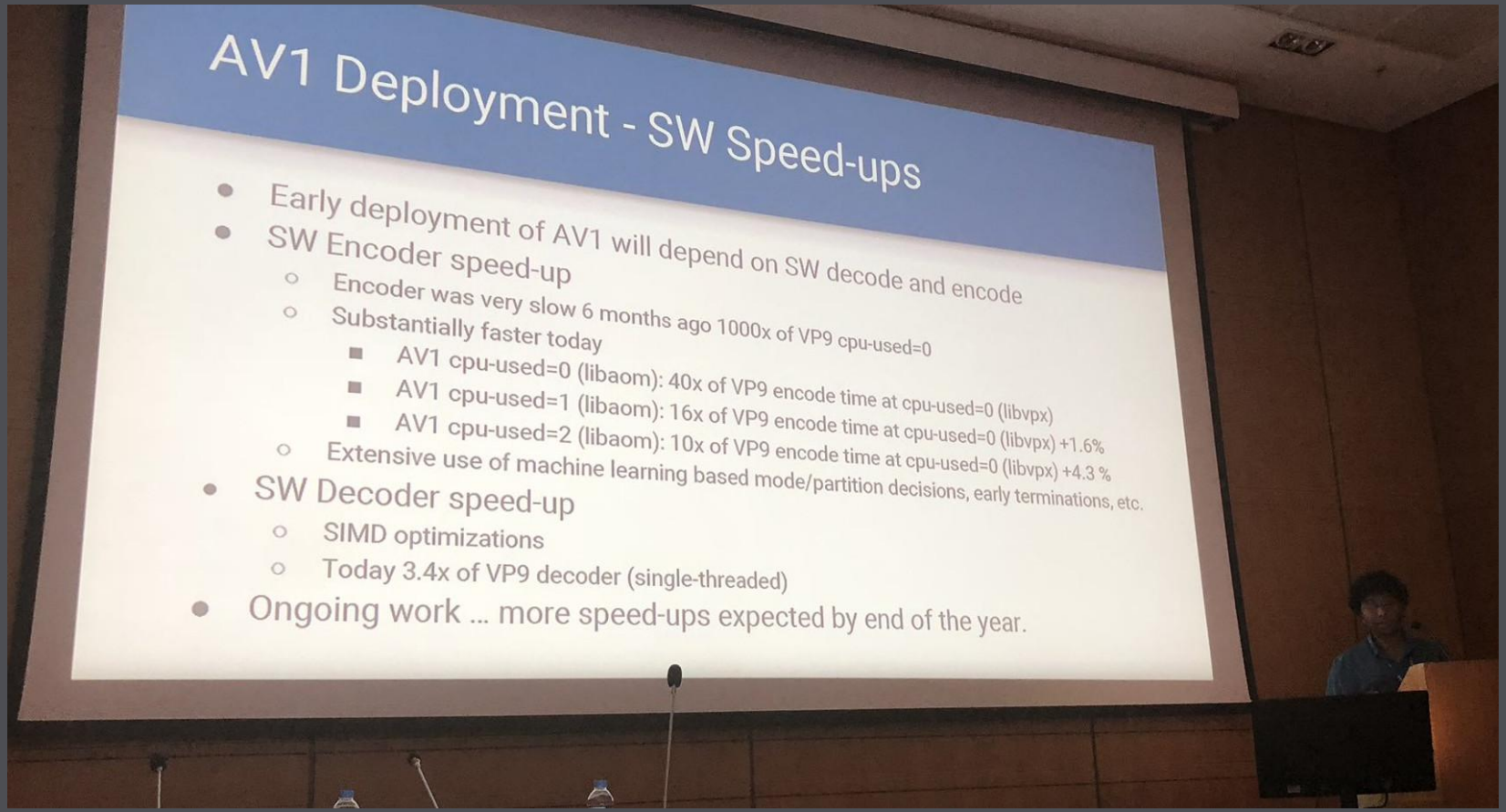
AV1 (libaom) Compression History



AV1 (libaom) Complexity History



Debargha at ICIP 2018 (October 9, 2018)



[1] https://twitter.com/timse7/status/1049607841072459776

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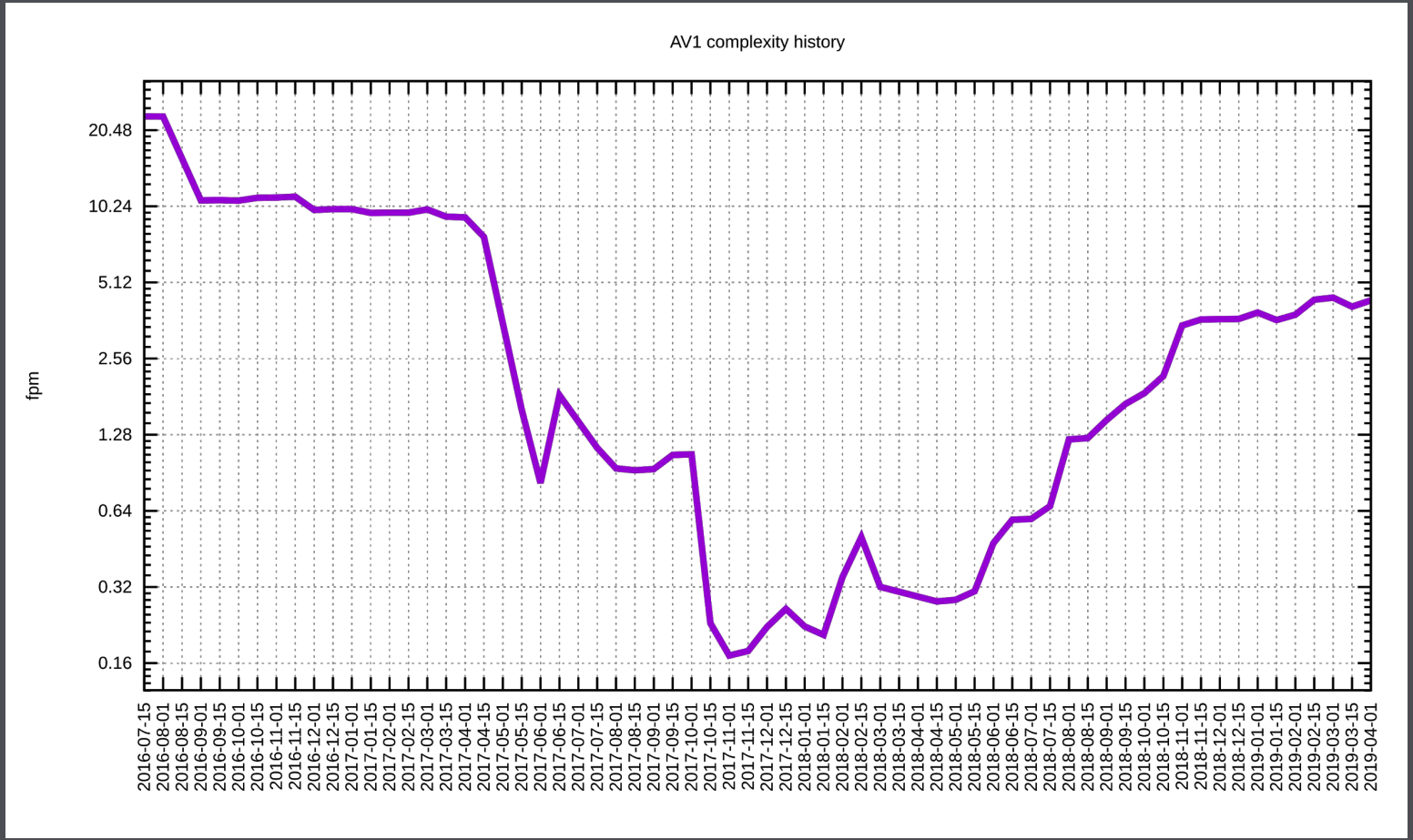

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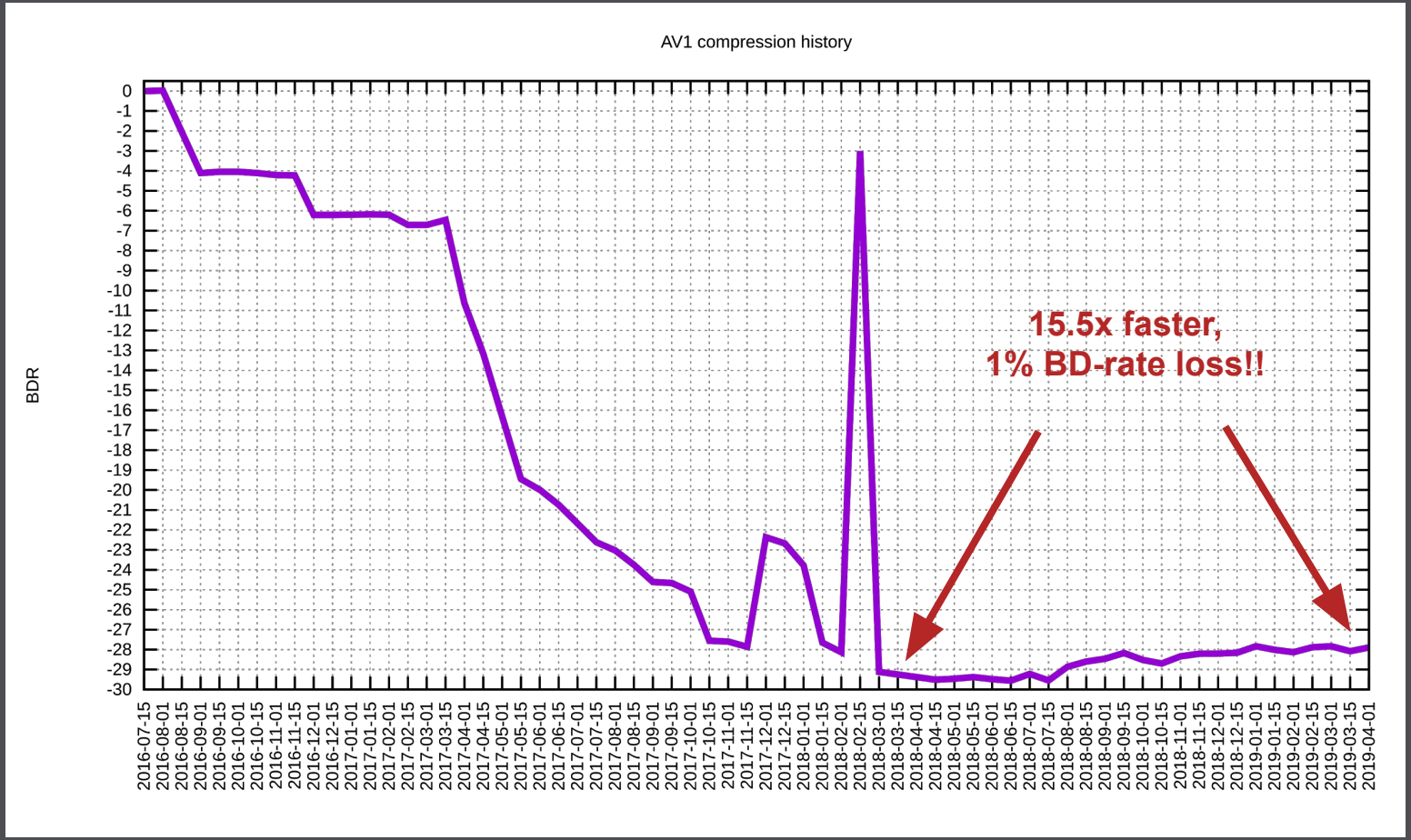
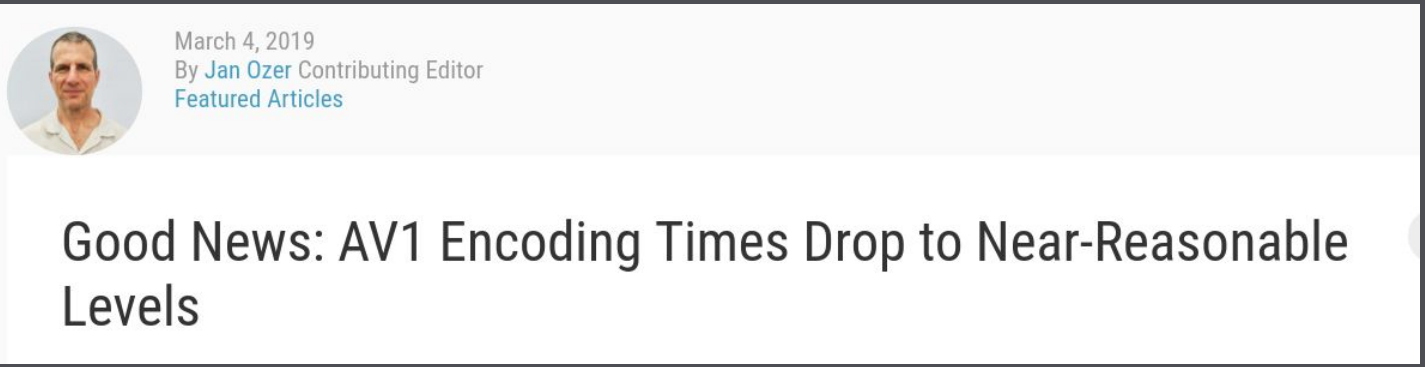


Jan Ozer on AV1 Encoding (March 3, 2019)



March 4, 2019
By Jan Ozer Contributing Editor
Featured Articles

Good News: AV1 Encoding Times Drop to Near-Reasonable Levels

Then	Encoding Time (seconds)	Times Real Time
AV1	226,080	45,216
x265	289	58
LibVPx	226	45
x264	18	4

	Encoding Time (seconds)	Times Real Time
AV1	736	147
x265	289	58
LibVPx	226	45
x264	18	4

[1] https://www.streamingmedia.com/Articles/ReadArticle.aspx?ArticleID=130284

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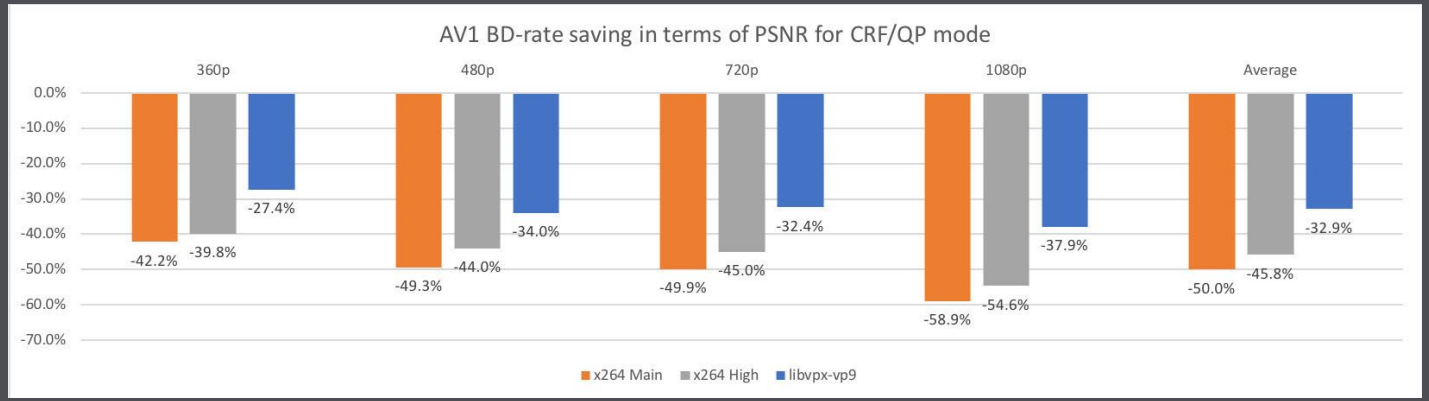
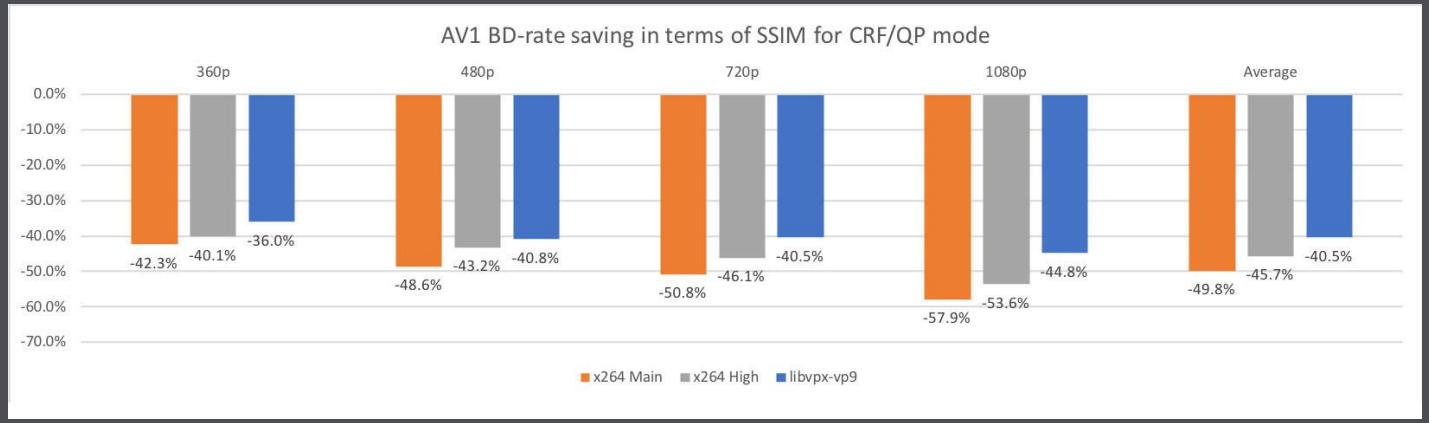


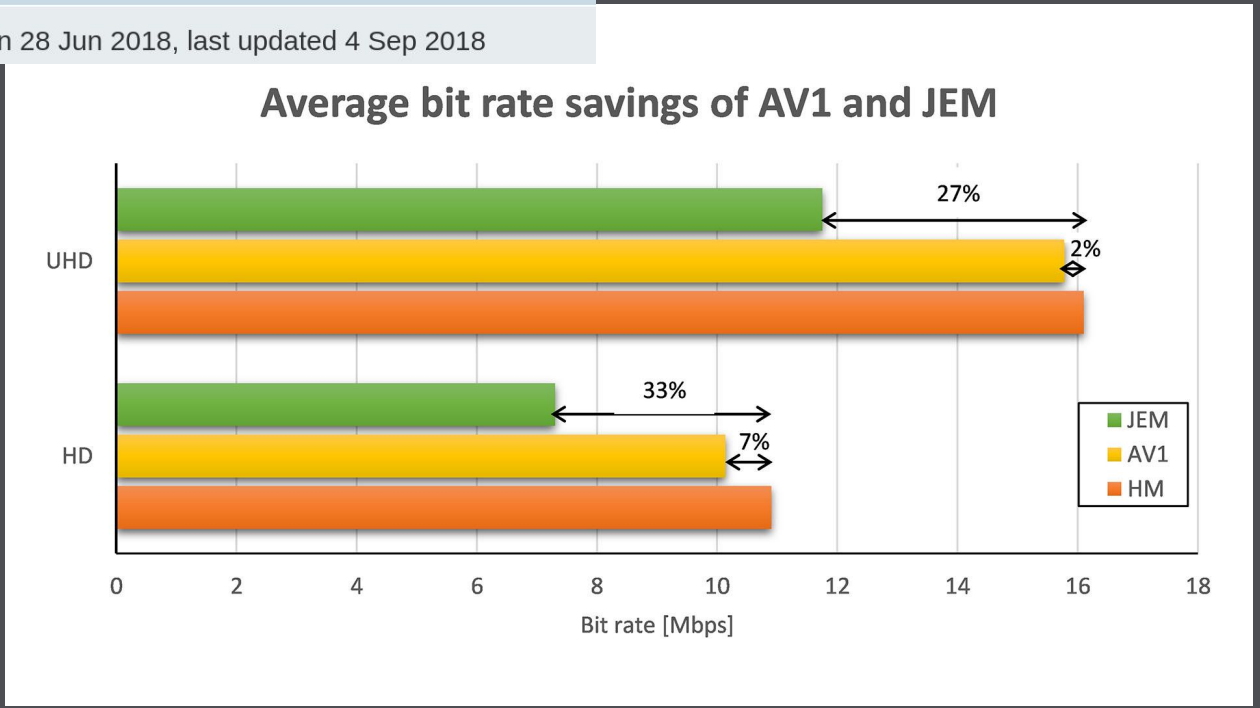


[1] https://www.texpion.com/2018/07/av1-vs-vp9-vs-avc-h264-vs-hevc-h265-2-psnr.html

BBC R&D Study (June 28, 2018)

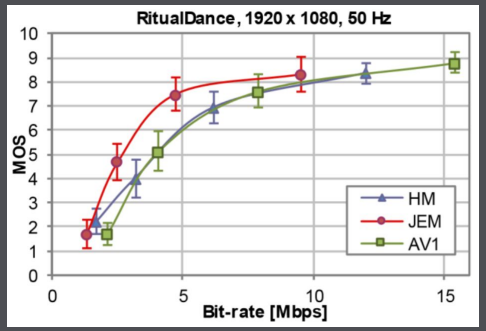
Comparison of recent video coding technologies in MPEG and AOMedia

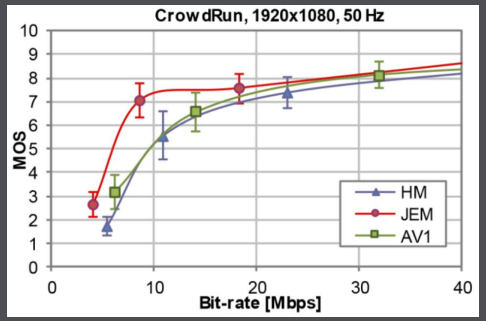
Posted by **Marta Mrak**, **Andre Seixas Dias** on 28 Jun 2018, last updated 4 Sep 2018



[1] https://www.bbc.co.uk/rd/blog/2018-06-comparison-of-recent-video-coding-technologies-in-mpeg-and-aomedia

BBC Subjective Evaluation at IBC 2018 (Sept 2018)



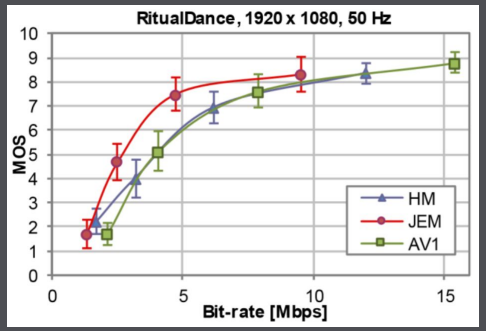


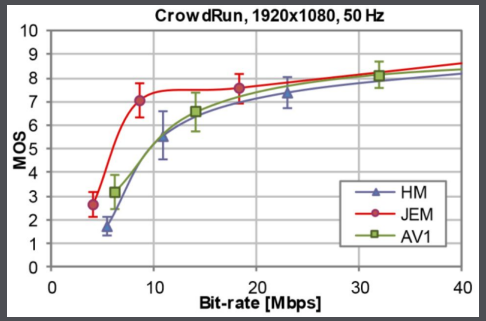
	AV1 vs HM				JEM vs HM			
Sequence	PSNR BD-rate Y	PSNR BD-rate Cb	PSNR BD-rate Cr	MOS BD-rate	PSNR BD-rate Y	PSNR BD-rate Cb	PSNR BD-rate Cr	MOS BD-rate
Book	2%	-15%	-22%	1%	-44%	-61%	-66%	-41%
Manege	0%	-10%	-8%	-9%	-36%	-44%	-41%	-37%
ParkDancers	-1%	-24%	-52%	-5%	-28%	-53%	-52%	-23%
Voiles	29%	-17%	-14%	14%	-39%	-63%	-56%	-19%
YoungDancers2	-6%	-11%	-23%	-34%	-38%	-65%	-63%	-45%
CrowdRun	2%	7%	11%	-9%	-25%	-30%	-26%	-42%
OldTownCross	15%	-37%	-30%	22%	-30%	-60%	-46%	-11%
ParkJoy	8%	22%	-17%	-19%	-19%	-20%	-17%	-32%
PedestrianArea	-1%	-4%	0%	-8%	-29%	-38%	-36%	-18%
RitualDance	-1%	-7%	-9%	3%	-29%	-34%	-38%	-32%
Average	**5%**	**-10%**	**-16%**	**-4%**	**-32%**	**-47%**	**-44%**	**-30%**
Encoding time	**~106x**				**~5x**			
Decoding time	**~4x**				**~5x**			

- Low-latency subjective evaluation: `--passes=1 --lag-in-frames=0`
- May not reflect current quality, evaluated on libaom-5f4f738e (`2018-Jan-09`)

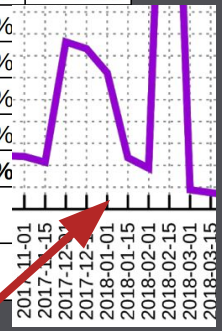
[1] https://show.ibc.org/sites/default/files/An%20Overview%20of%20Recent%20Video%20Coding%20Developments%20in%20MPEG%20and%20AOMEDIA%20-%20Andre%20Dias.pdf

BBC Subjective Evaluation at IBC 2018 (Sept 2018)





	AV1 vs HM				JEM vs HM			
Sequence	PSNR BD-rate Y	PSNR BD-rate Cb	PSNR BD-rate Cr	MOS BD-rate	PSNR BD-rate Y	PSNR BD-rate Cb	PSNR BD-rate Cr	MOS BD-rate
Book	2%	-15%	-22%	1%	-44%	-61%	-66%	-41%
Manege	0%	-10%	-8%	-9%	-36%	-44%	-41%	-37%
ParkDancers	-1%	-24%	-52%	-5%	-28%	-53%	-52%	-23%
Voiles	29%	-17%	-14%	14%	-39%	-63%	-56%	-19%
YoungDancers2	-6%	-11%	-23%	-34%	-38%	-65%	-63%	-45%
CrowdRun	2%	7%	11%	-9%	-25%	-30%	-26%	-42%
OldTownCross	15%	-37%	-30%	22%	-30%	-60%	-46%	
ParkJoy	8%	22%	-17%	-19%	-19%	-20%	-17%	
PedestrianArea	-1%	-4%	0%	-8%	-29%	-38%	-36%	
RitualDance	-1%	-7%	-9%	3%	-29%	-34%	-38%	
Average	**5%**	**-10%**	**-16%**	**-4%**	**-32%**	**-47%**	**-44%**	
Encoding time	**~106x**				**~5x**			
Decoding time	**~4x**				**~5x**			

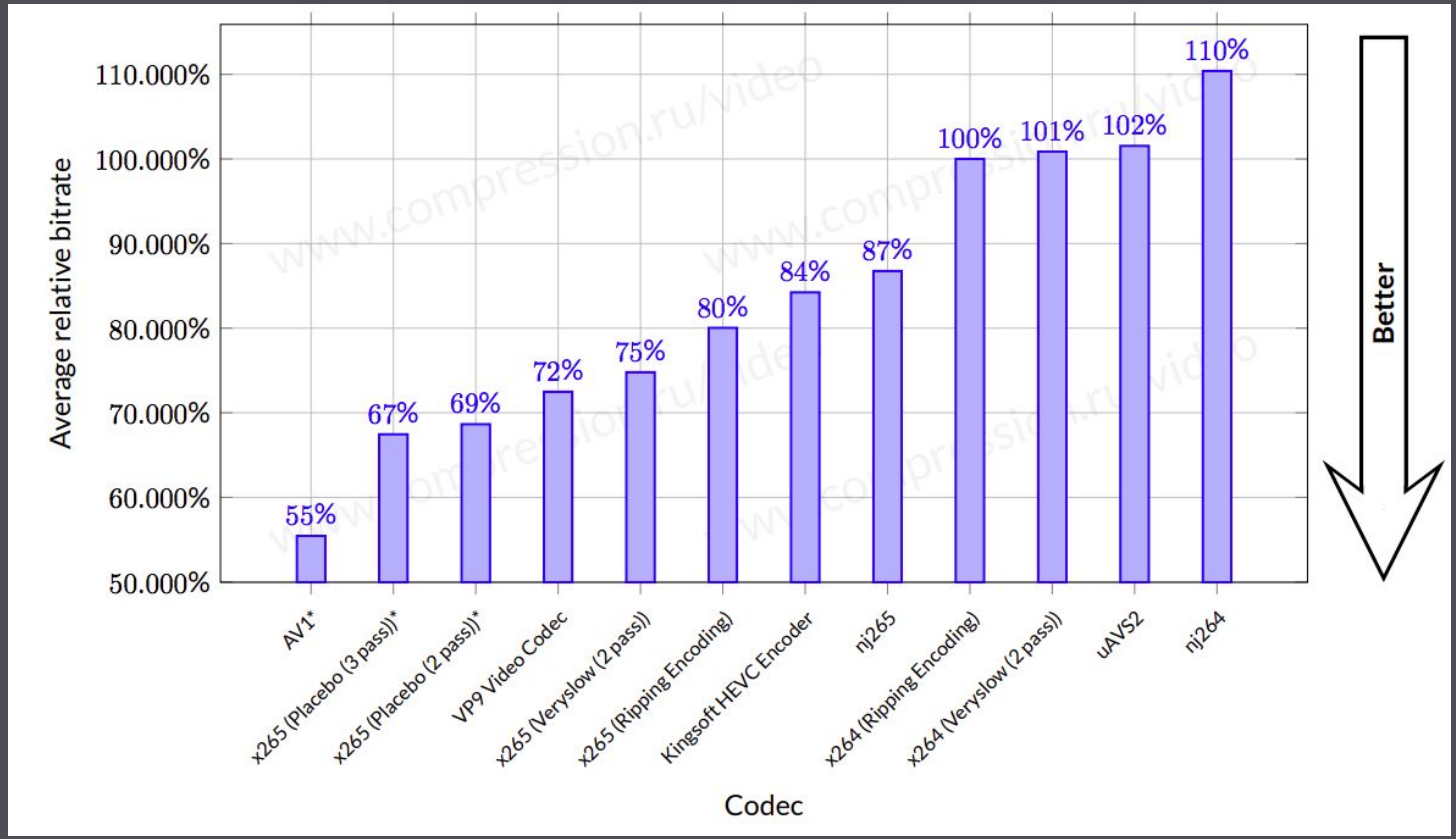


Old version, likely broken

- Low-latency subjective evaluation: `--passes=1 --lag-in-frames=0`
- May not reflect current quality, evaluated on libaom-5f4f738e (`2018-Jan-09`)

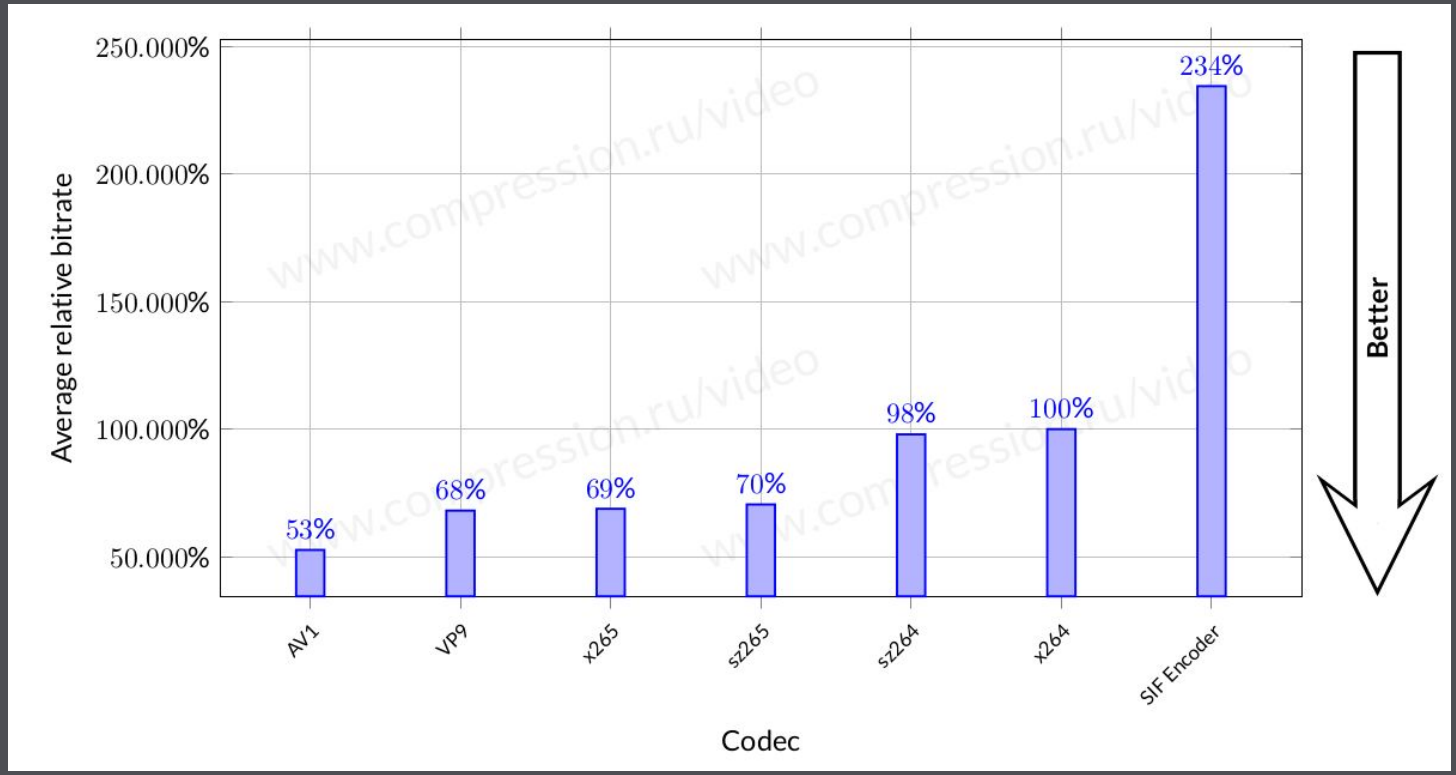
[1] https://show.ibc.org/sites/default/files/An%20Overview%20of%20Recent%20Video%20Coding%20Developments%20in%20MPEG%20and%20AOMEDIA%20-%20Andre%20Dias.pdf

Moscow State University (SSIM - January 2018)



[1] http://www.compression.ru/video/codec_comparison/hevc_2017/MSU_HEVC_comparison_2017_P5_HQ_encoders.pdf

Moscow State University (SSIM - April 2019)



[1] http://www.compression.ru/video/codec_comparison/hevc_2018/pdf/MSU_HEVC_AV1_comparison_2018_P4_HQ_encoders.pdf

Moscow State University (SSIM - April 2019)

This ranks are based on quality results ONLY (not considering encoding speed). If we will perform complex analysis – the results will be the next:

- **AV1** ha extremely high encoding quality in approachable to other encoders and very low encoding speed due to lack of speed optimization.
- **VP9** and **x265** encoder have very close results (in speed and quality) and have a very good quality/speed balance for high-quality encoding
- **sz265** has good quality results with comparative low encoding speed

The plot below shows overall quality scores for the encoders in our comparison (see Section D for a description of the integral-score computation method). First place in the quality competition goes to **AV1**, second place goes to **VP9**, **x265**, and **sz265**, and third place to **sz264** and **x264**.

[1] http://www.compression.ru/video/codec_comparison/hevc_2018/pdf/MSU_HEVC_AV1_comparison_2018_P4_HQ_encoders.pdf

AV1 Encoder Ecosystem

- Open Source Encoders:
  - Google - libaom [1]
  - Intel & Netflix - SVT-AV1 [2]
  - Mozilla & Xiph - rav1e [3]

- Closed Source Encoders:
  - Two Orioles - EVE for AV1
  - Socionext (FPGA offload)
  - NGCodec (FPGA intra only)
  - ATEME
  - Harmonic
  - Bitmovin (cloud encoder)
  - Visionular - Aurora
  - Every hardware vendor in AOM
  - Probably more I don't know of

[1] https://aomedia.googlesource.com/aom/
[2] https://github.com/OpenVisualCloud/SVT-AV1
[3] https://github.com/xiph/rav1e

Concerns We Heard at NAB 2018

- ~~“The bitstream isn’t even frozen yet”~~
- ~~“We need broad deployment of hardware decoders before adoption”~~
- ~~“The reference encoder is too slow to be usable”~~
- ~~“AV1 is not much better than HEVC”~~
- “There is no support for AV1 in XXX”
- “The broadcast space is slow to adopt new things”

AV1 is Everywhere

- ISO-BMFF [1]
- MP4 / MKV [2]
- TS [3]
- HEIF (aka AVIF) [4]
- RTP [5]
- FFmpeg [6]

[1] https://aomediacodec.github.io/av1-isobmff/

[2] https://github.com/Matroska-Org/matroska-specification/blob/master/codec/av1.md

[3] https://code.videolan.org/videolan/av1-mapping-specs/blob/master/ts-carriage.md

[4] https://aomediacodec.github.io/av1-avif/

[5] https://github.com/AOMediaCodec/av1-rtp-spec

[6] https://trac.ffmpeg.org/wiki/Encode/AV1

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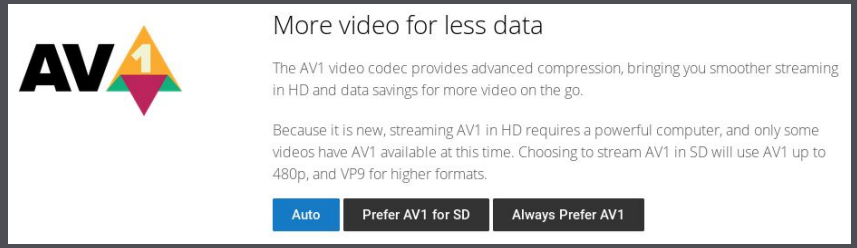
AV1 on YouTube at IBC 2018 (September 17, 2018)

moz://a

Youtube starts test with open royalty-free AV1 codec

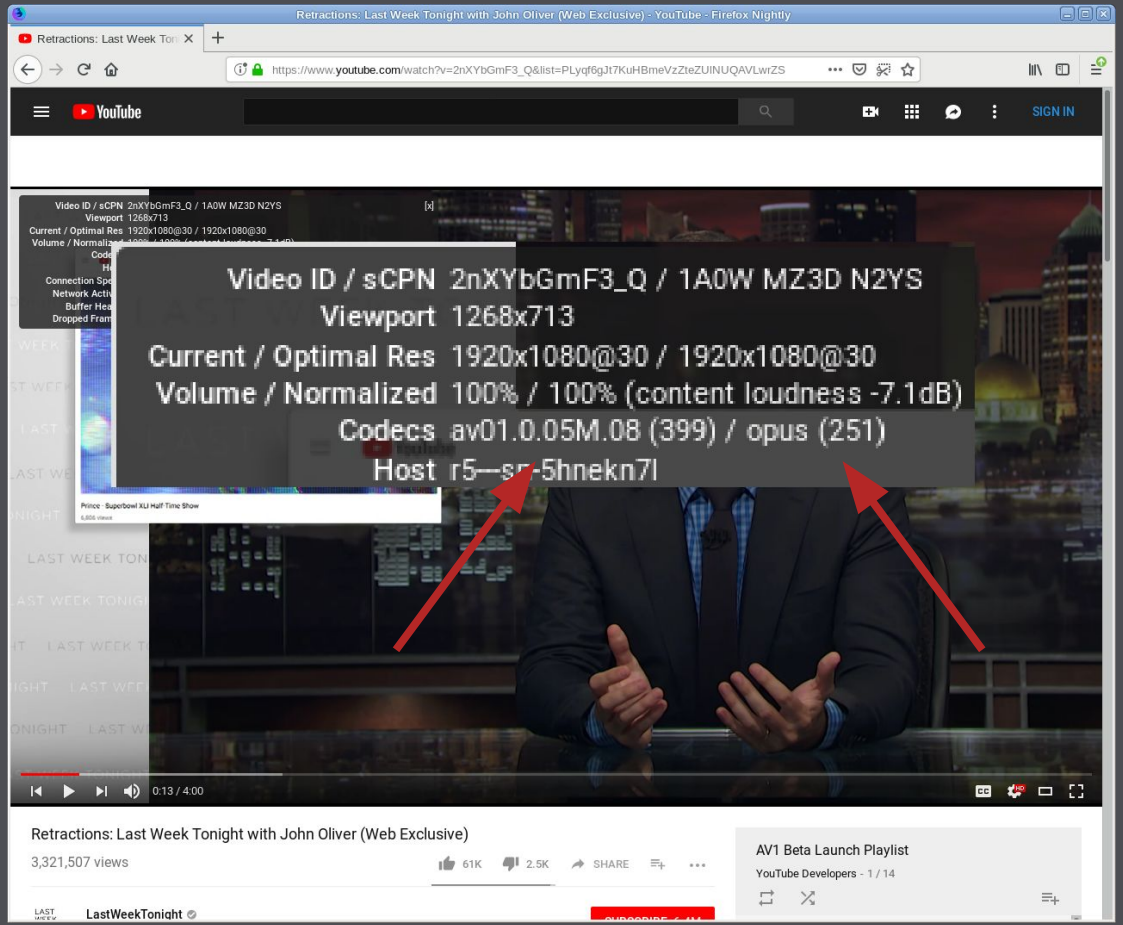
September 17, 2018 by Jan Willem Aldershoff

- Launched with just 14 videos [3]
- Most popular encoded as AV1 first



[1] https://www.myce.com/news/youtube-starts-test-with-open-royalty-free-av1-codec-85094/
[2] https://www.youtube.com/testtube
[3] https://www.youtube.com/playlist?list=PLyqf6gJt7KuHBmeVzZteZUlNUQAVLwrZS

AV1 + Opus Content on YouTube at IBC 2018



Firefox 65

- Non-Windows behind flag:
  `media.av1.enabled = true`

Chrome 70

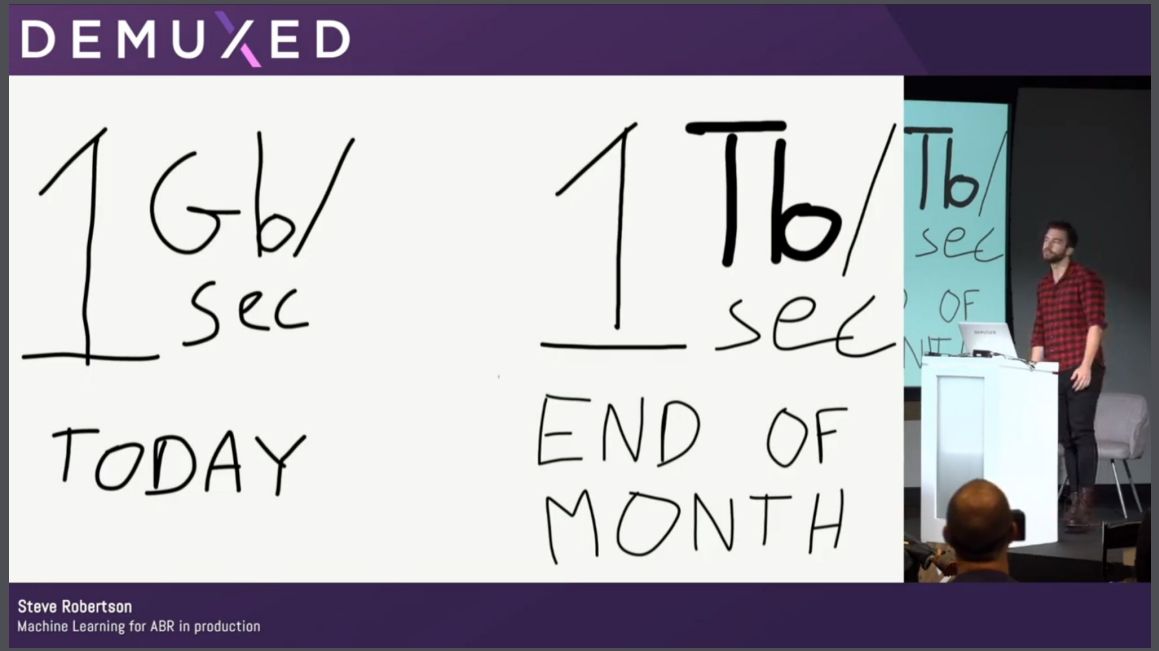
- Enabled by default on desktop platforms and Android

Edge 18

- Enabled with AV1 Video Extension from Microsoft Store

AV1 software decoders on billions of devices in October 2018!!!

AV1 Update - Demuxed (October 18, 2018)



Steve Robertson (Google / YouTube)

- "Project will be **streaming 1 Tb / sec** AV1 by the end of the month"
- "Small fraction of YouTube's egress, sign that **it is working for us in production**"
- "**Not a cost effective choice** at this time"
- "We are doing this to make sure people know we are **deadly serious about AV1** and are committed to its success"

[1] https://www.youtube.com/watch?v=iuaWhmETcRE&t=65

AOM Members - NAB 2018 (33)

AOM Members - Today (42)

Android Q with AV1 + Opus (March 13, 2019)

moz://a

Android Q Reaches Public Beta With Improved Privacy, Opus/AV1 Support, ANGLE On Vulkan

Written by Michael Larabel in Google on 13 March 2019 at 03:57 PM EDT. 46 Comments

Google today rolled out their first public beta/development release of the upcoming Android Q that will be formally released in the second half of 2019.

Android Q is introducing new privacy protections, new foldable screen support given the recent wave of foldable devices, the ability to share shortcuts, improved peer-to-peer/internet connectivity, new WiFi performance and low latency modes, support for the AV1 video codec, support for audio encoding using Opus, a native MIDI API, and other enhancements.

[1] https://www.phoronix.com/scan.php?page=news_item&px=Android-Q-Beta-Released

AOM Members - Mobile OS

Samsung Joins AOMedia (April 3, 2019)

moz://a

Samsung Joins the Alliance for Open Media Board of Directors

on April 3, 2019

Audio  Share 

Samsung recently announced that it has joined the Alliance for Open Media (AOMedia), a nonprofit organization formed by leading internet and media technology companies which intends to define and develop open standards for media compression and delivery over the web.

[1] https://news.samsung.com/global/samsung-joins-the-alliance-for-open-media-board-of-directors

AOM Members - Mobile Devices

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Conclusion

- AV1 adoption is happening, and faster than we expected last year

Save the Date!

- Mozilla co-hosting Video Technology Conference
  - Where: New York City
  - When: Wednesday, June 26th 2019
  - Who: Video technology enthusiasts (no sales pitches)

- Will make a formal announcement immediately following NAB
  - Sponsor opportunities available
  - Contact Nathan Egge <negge@mozilla.com>

Questions?

Considering that video and images make up about 80% of all internet traffic, the impact of how things get encoded is pretty big. Even a modest 1% BDR gain tool translates into about 20 EB of traffic yearly currently, or 20,000,000,000 GB.

Steinar Midtskogen (Cisco)