Myelin Whitepaper Series

VIDEO ENCODING

Codecs

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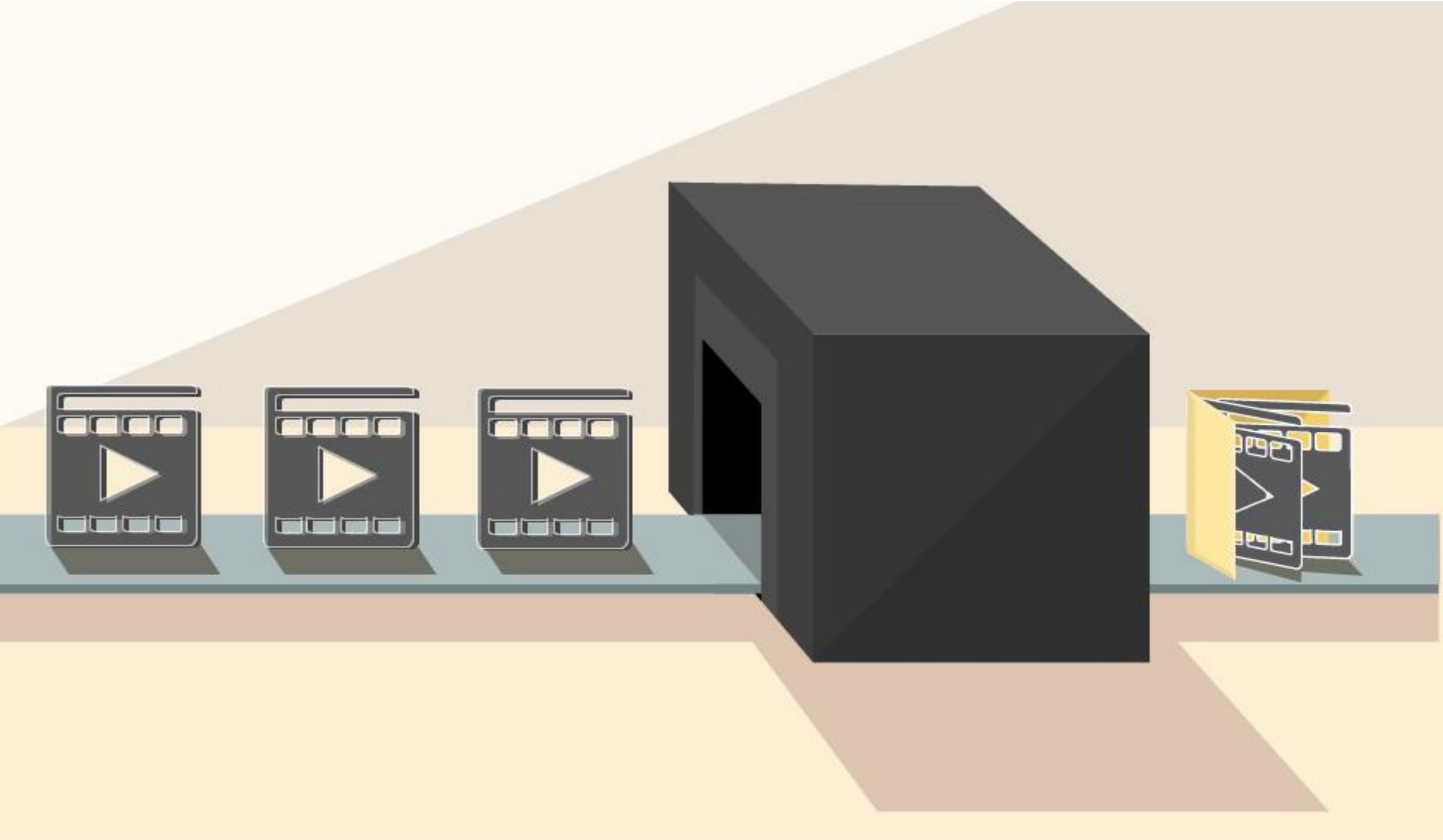


WHAT IS A CODEC?

A Codec(encoder-decoder) is a device/software that encodes/decodes a signal or data-stream[2]. Particularly for video streaming, there are several codecs available that compress the video for transmission, which is then decompressed on the edge device where the video is to be played. Encoding is usually a more computationally complex process and thus is usually cloud-based, whereas decoding is a relatively simple process carried out by edge-device hardware. With newer codecs being released every few years, the compression efficiency for video transmission has gone up significantly. This allows for video transmission for streaming at the same visual quality but at lower bitrates, thus saving streaming cost and bandwidth. The following is an in-depth study all available codecs comparing them against various performance parameters along with recommendations and best practices for codec selection.

TYPES OF CODECS

Most codecs use the guiding principle of frequency transforms to bring about efficient compression, with every new codec offering incremental improvements over the older ones. The codecs for this study were chosen after consideration of several factors including industry adoption rate, popularity and device compatibility. Four codecs were selected for this study:

- **Advanced Video Encoding (AVC/ H.264/MPEG-4 Part 10)**: Part of the MPEG family of codecs developed by the Joint Video Team (JVT), which consists of members of both MPEG and the ITU-T Video Coding Experts Group, it's a video compression standard that's based on motion-compensated Discrete Cosine Transforms (DCTs) for efficient artifact removal. It is the most widely used codec across industries. It was released in 2003.

- **Highly Efficient Video Encoding (HEVC/H.265/MPEG-H Part 2)**: Part of the MPEG family of codecs developed by the Joint Collaborative Team on Video Coding (JCT-VC), which is a collaboration between ITU-T Video Coding Experts Group (VCEG) and ISO/IEC Moving Picture Experts Group (MPEG), it's a video compression standard aiming to provide better compression efficiency over AVC. It uses Discrete Cosine Transforms and Discrete Sine Transforms (DCTs and DSTs) with variations in block sizes. It is the second most widely used codec across industries. It was released in 2013.

- **VP9**: A competitor for HEVC, developed by Google. It is a block-based transform coding format that uses larger DCTs and Asymmetric Discrete Sine Transforms (ADSTs). Its features include, improved entropy encoding and improved motion compensation. It was released in 2013.

- **AOMedia Video 1 (AV1)**: It was developed as a successor to VP9 by the Alliance for Open Media (AOMedia), a consortium founded in 2015. AV1 is a traditional block-based frequency transform format featuring new techniques. Based on Google's VP9, AV1 incorporates additional techniques that mainly give encoders more coding options to enable better adaptation to different types of input. It uses larger superblocks for compression and has improved quantization and entropy encoding over VP9. It was released in 2018.

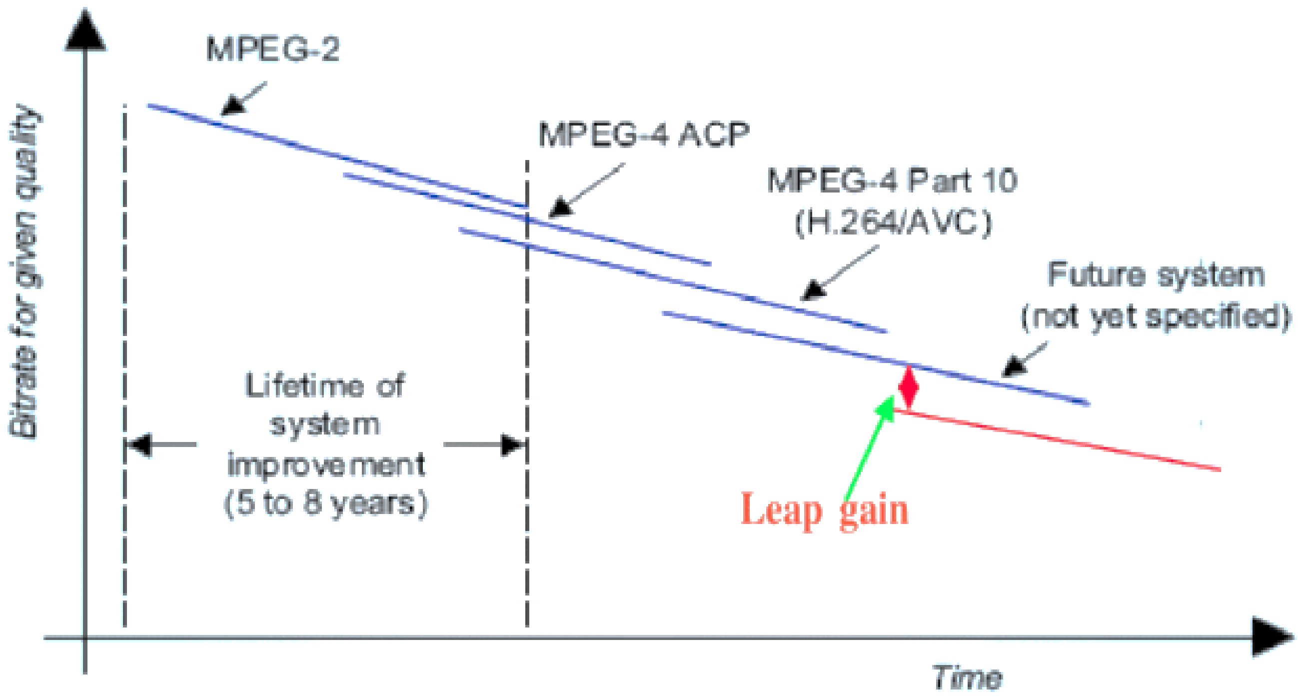


Figure 1[1]

CODEC COMPARISON

In this section, several pros and cons of the codecs have been discussed. According to the merits and demerits of each codec, we will be making recommendations regarding the specific use cases where a particular codec will give improved performance over the others.

Criterion	AVC	HEVC	VP9	AV1
License	Paid ●	Paid ●	Open Source ▲	Open Source ▲
Compression Efficiency & Bandwidth savings	Lowest ●	Higher than VP9 and AVC ▲	Higher than AVC, Lower than HEVC ▲	Highest ▲
Device Compatibility	Most widely compatible with all applications and device hardware ▲	Less compatible with lower device support and adoption rate than AVC and VP9 ●	More compatible than HEVC, less compatible than AVC. ■	Least compatible among all codecs ●
Encoding speed	Highest (lowest latency) ▲	Slower than AVC by 10X-20X. Comparable to VP9 ■	Slower than AVC by 10X-20X Comparable to HEVC ■	Slowest (20X-25X of VP9/HEVC) ●
CPU usage	Least ▲	Less than VP9. Higher than AVC ■	Higher than HEVC and AVC. ●	Highest ●
Video Output Perceptual Quality	Poorest with possible ringing artifacts ●	Better than AVC. More than VP9 at higher resolutions ▲	Better than AVC. Less than HEVC at higher resolutions ■	Best with barely any compression artifacts ▲

Recommendations

Based on the features listed above, we recommend using codecs depending on the content type as follows:

- **AVC**: for live streaming, where high speed & low latency matters more than content quality - such as for news and sports

- **HEVC**: for a subtle trade-off between encoding speed & perceptual content quality for high resolutions – such as for high-res VOD (Video On-Demand) streaming.

- **VP9**: for a subtle trade-off between encoding speed & perceptual content quality, specifically for low resolutions - such as for low-res VOD (Video On-Demand) streaming

- **AV1**: for cases where best perceptual quality is of prime importance and latency isn't a factor for consideration – such as for high-res VOD streaming.

COMPRESSION EFFICIENCY ACROSS CODECS

The two fundamental factors affecting video quality are:

- **Resolution**
- **Bitrate**

The video quality in this study is represented in terms of VMAF (Video Multimethod Assessment Fusion), a perceptual video quality metric (scored out of 100) developed by Netflix. Higher the VMAF score, better the perceptual quality of the video.[3]

The bitrate-resolution pairs chosen for video streaming are collectively referred to an adaptive bitrate (ABR) ladder, such that it can stream different qualities of a specific video based on the bandwidth available at that instant. The relation between VMAF of a video and its corresponding bitrate and resolution can be seen in the graph below in Figure 2. In order to construct this graph, a source video was selected and transcoded to different bitrates and resolutions using **AVC** codec. The resolutions and bitrates were chosen in accordance with industry standards.

The colored solid curves represent the video encodings across a range of bitrates at a specific resolution. The black dashed line represents the optimized ABR ladder for the set of resolutions considered, since the VMAF shows only negligible improvement when a higher bitrate than the one represented by the ladder is assigned to the video at that resolution. Thus, the ABR ladder indicates that the optimized streaming bitrate for a particular resolution is a magnitude roughly halfway between the two extreme ends of the bitrate range used for the study.

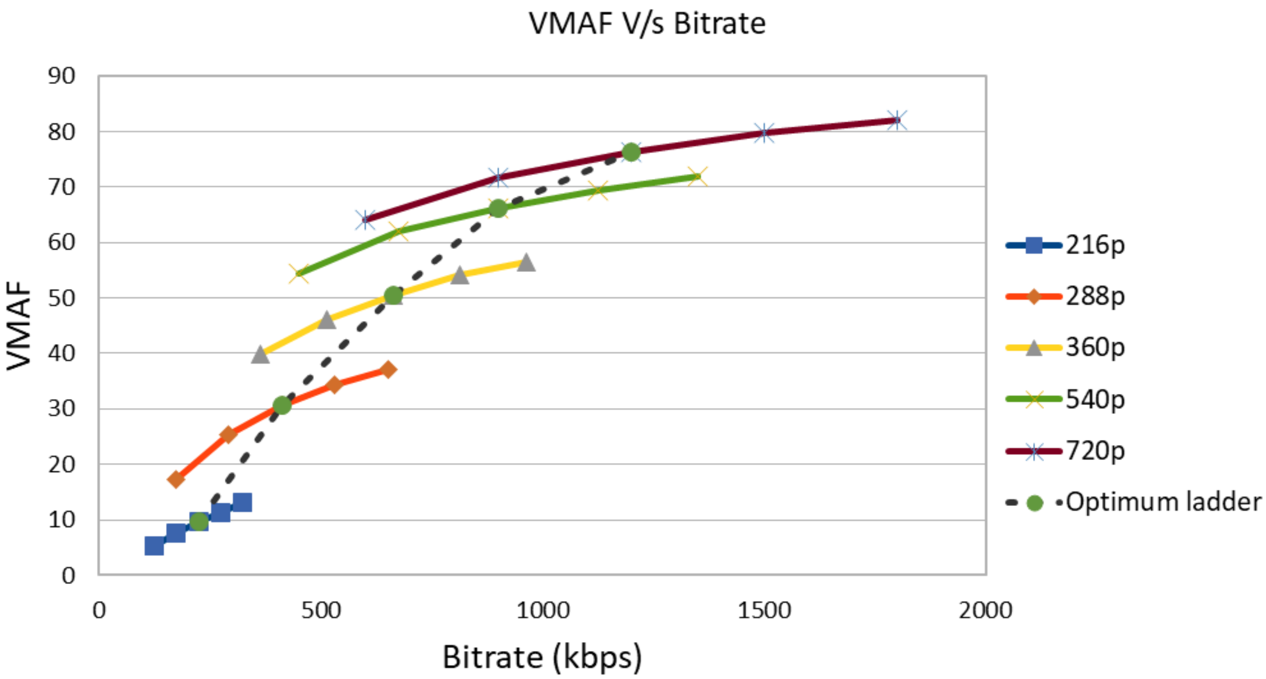


Figure 2

QUALITY V/S BITRATE FOR DIFFERENT CODECS

We made an attempt to infer an ABR ladder for HEVC, VP9 and AV1 based on the AVC ladder. In order to do this effectively, the process followed to create Figure 2 was replicated for the other three codecs. The idea for ladder inference is that, for the same quality (VMAF value) of the AVC bitrate ladder (black dashed line), the equivalent bitrates for another codec can be extrapolated from its individual resolution curves. The extrapolation is done by extending an imaginary line from each point on the AVC ladder and noting the corresponding bitrate(x-axis) value at the exact point it hits the individual resolution curve for the new codec. Figure 3 shows the inferred bitrate ladders for each new codec, and the horizontal gap (indicated by the maroon dotted line) between the AVC ladder and the ladders of other codecs indicates the bandwidth saved.

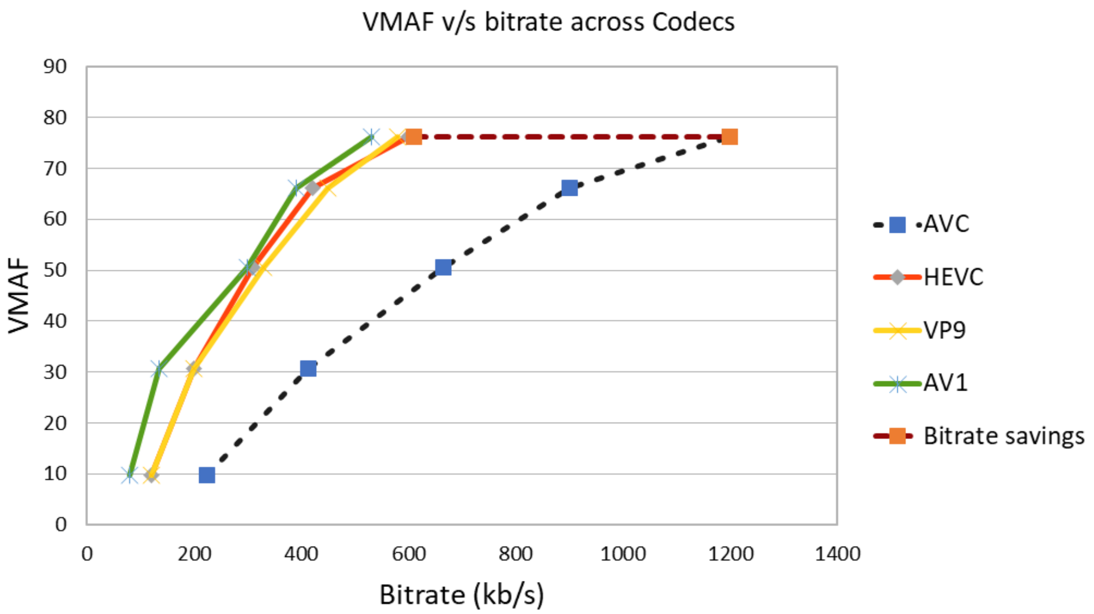
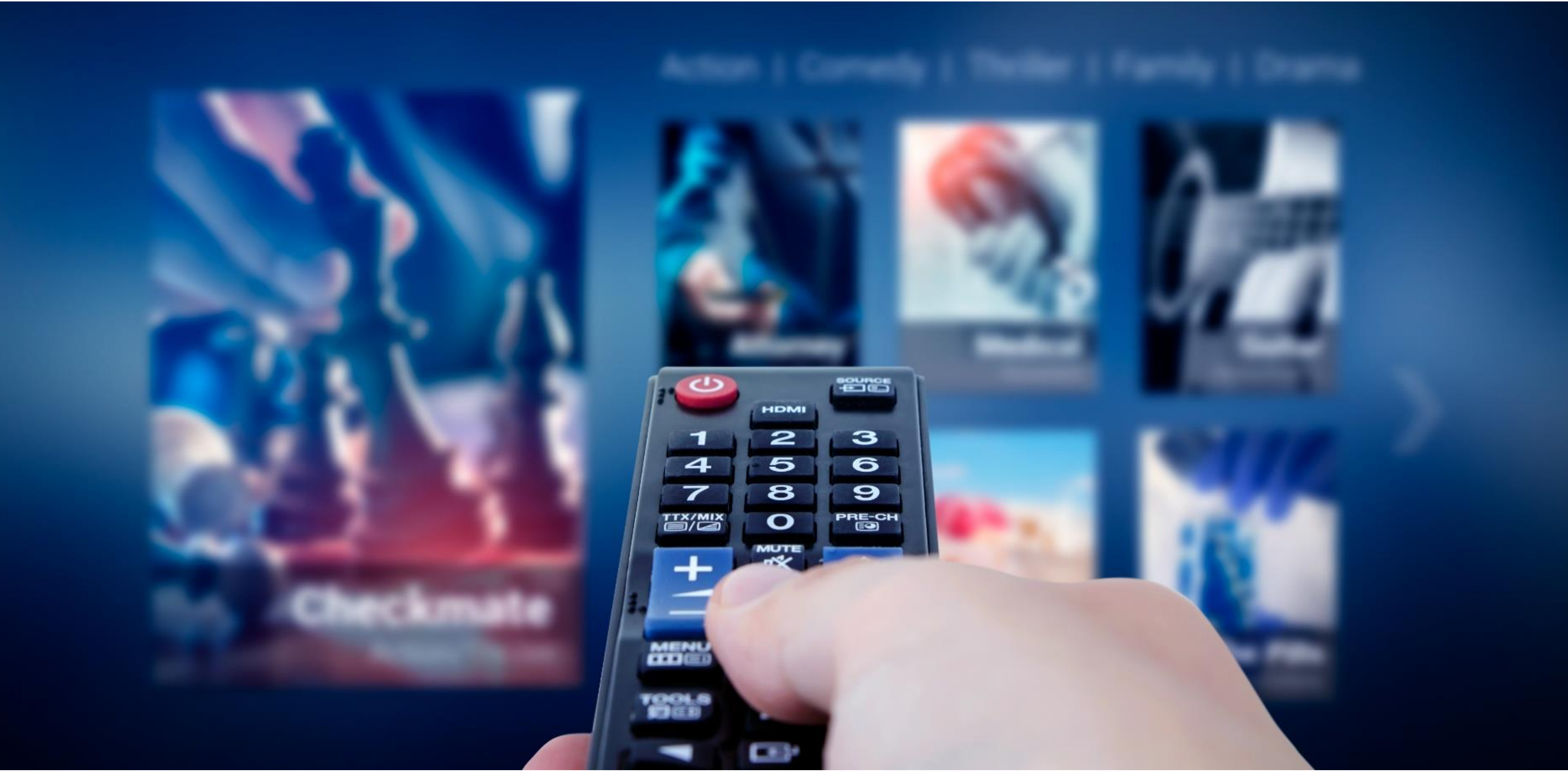


Figure 3

Important observations:

- As is evident from the graph above, the bitrate-resolution ladder curve is similar in shape irrespective of the codec.
- The average percentages of bitrate savings for each codec as compared to AVC (indicative numbers which might differ slightly based on the video content used for this analysis)

Codec	Percentage Bitrate Savings
VP9	49.8 %
HEVC	50.9 %
AV1	60.3 %



CONCLUSION

From the above analysis it's clear that the selection of a codec for video encoding greatly impacts video quality and bitrate savings.

- Using **perceptual video quality** assessments through VMAF, for a given bitrate and resolution, the best order of video output perceptual quality would be **AV1 > VP9 > HEVC > AVC**

- Keeping the perceptual quality constant (in terms of **VMAF**), the order of compression efficiency and bitrate savings would be **AV1 > HEVC > VP9 > AVC**

- Conversely, there is a tradeoff to be considered in terms of **encoding time**, where a lower encoding speed causes lower latency while streaming. In order of encoding speed, the codecs are **AV1 > HEVC ~ VP9 > AVC**

The selection of a codec is highly dependent on numerous factors including perceptual quality, bandwidth savings, user QOE (Quality of Experience) and latency demands, infrastructure requirements for each specific codec, scale or extent of the customer base to which the content is being streamed, encoding cost, etcetera. Thus, the particulars of a use case are very important in codec selection.

The latest codec from ITU-T, Versatile Video Encoding (VVC/H.266, released in 2020) has very low compatibility with existing applications and edge devices. Nevertheless, it has been reported that this codec outperforms all its predecessors in terms of perceptual quality and compression efficiency. Thus, it will eventually become an important candidate for video codec selection, and we will publish a study on it in the future.

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