LCEVC enhanced AV1 decoding on mobile devices
V-Nova 2021
LCEVC Enhanced AV1 Decoding on mobile devices

Introduction
The Alliance for Open Media’s AV1 codec is a modern video compression format, designed to be royalty free and based on testing conducted by Facebook that approximates real world conditions, the AV1 reference encoder achieved 30% better compression than HEVC or VP9. However, as of April 2021 it could be multiple years until a wide range of consumers can gracefully decode AV1 on their mobile devices. For example, Android support for software decoding of AV1 is present from version 10, but most devices lack the processing resources to decode most videos reliably. Also, as of early 2021 there are only a very limited set of devices with hardware accelerated decoding capabilities, with Qualcomm not supporting AV1 decode in their chipsets currently and declining to commit to a timeline. The problem is further exacerbated on iPhones, particularly for those applications relying on decoding on Safari browser.

This report aims to show that enhancing AV1 with the novel standard MPEG-5 Part 2 Low Complexity Enhancement Video Coding (LCEVC) could be the answer to unlocking reliable high-resolution AV1 decode in software for the wider mobile device user base.

We tested a representative set of Android devices and focused our analysis on assessing LCEVC’s impact on decoding efficiency, rather than visual quality. Having said that, while running the videos at same bitrates and at resolutions enabling a smooth payback for both native AV1 and LCEVC-enhanced AV1, we noticed a perceptible visual quality improvement, confirmed by both objective and subjective methodologies.

Decoding LCEVC on Android requires a build of ExoPlayer able to extract and display the enhancement data:

More can be read on LCEVC in V-Nova’s documentation in the links below:
https://docs.v-nova.com/v-nova/lcevc/sdk/dil
https://docs.v-nova.com/v-nova/lcevc/integrations/exoplayer-with-lcevc
Executive Summary

The tests on a wide range of Android devices outlined in this document found LCEVC-enhanced AV1 videos to exhibit visibly smoother playback than native AV1 at full resolution, produced by a measurable reduction of dropped frames, and reduce the device power consumption.

The performance benefits of LCEVC-enhanced AV1 over ‘native’ AV1 are documented across three sets of KPIs: percentage of dropped frames, power consumption and battery drain.

Across all the three measurements, the experiments demonstrate that the LCEVC enhancement can significantly improve AV1 playback on Android mobile devices, by enabling HD resolution (and even Full HD on relatively more powerful devices), which is otherwise unattainable for native AV1. In particular:

- **‘Native’ AV1 drops significantly more frames than LCEVC-enhanced AV1**, especially when the framerate is higher, or the complexity is increased. Across all tested devices and content, LCEVC allowed to smoothly playback at 1080p resolution with average dropped frames of 4% - barely noticeable, and only on most challenging content and less powerful devices – while native AV1 failed to reliably play back, with average dropped frames of 40%.

- **LCEVC-enhanced AV1 consumes less power**, with a benefit of up to 40-50% vs. native AV1 under similar circumstances (i.e., with comparable rendered frames).

- Consistently with the measures just mentioned, **AV1 drains battery of tested devices approximately 50% faster than when enhanced with LCEVC** when rendering a similar number of frames.

On top of the benefits above, LCEVC-enhanced AV1 also provides a material compression benefits with respect to native AV1.

Please contact us at info@v-nova.com, if you are interested to replicate these results using our test LCEVC-AV1 APK.
Content Selection

Short test content (typically 20 seconds), including various subject matter, frame rates and data rates, to compare LCEVC-enhanced AV1 to native AV1.

Meridian – Cinema – 1080p30 – 750kbps
Total frames: 601

Big Buck Bunny – Animation – 1080p30 – 750kbps
Total frames: 601

GTA V – eSports – 1080p30 – 3000kbps
Total frames: 601

Starcraft – eSports – 1080p30 – 1000kbps
Total frames: 1200

Driving – Dashcam – 1080p60- 1500kbps
Total frames: 600

Tested devices

Selection of six Android devices from multiple manufacturers from 2017 onwards, running Android 10 and Android 11 OS.

<table>
<thead>
<tr>
<th>#</th>
<th>Manufacturer</th>
<th>Model</th>
<th>Processor</th>
<th>Year</th>
<th>Firmware</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nokia</td>
<td>8.3G</td>
<td>Qualcomm Snapdragon 765G</td>
<td>2020</td>
<td>Android 11</td>
</tr>
<tr>
<td>2</td>
<td>Samsung</td>
<td>S20 Note</td>
<td>Samsung Exynos 990</td>
<td>2020</td>
<td>Android 11</td>
</tr>
<tr>
<td>3</td>
<td>Samsung</td>
<td>S10 5G</td>
<td>Samsung Exynos 9820</td>
<td>2019</td>
<td>Android 11</td>
</tr>
<tr>
<td>4</td>
<td>Google</td>
<td>Pixel3</td>
<td>Qualcomm Snapdragon 845</td>
<td>2018</td>
<td>Android 11</td>
</tr>
<tr>
<td>5</td>
<td>Huawei</td>
<td>Mate 20 Pro</td>
<td>Kirin 980</td>
<td>2018</td>
<td>Android 10</td>
</tr>
<tr>
<td>6</td>
<td>Google</td>
<td>Pixel2 XL</td>
<td>Qualcomm Snapdragon 835</td>
<td>2017</td>
<td></td>
</tr>
</tbody>
</table>
LCEVC AV1 player
Decoding LCEVC-enhanced AV1 on Android requires build of ExoPlayer with an Extension to extract and apply the LCEVC enhancement data to the decoded picture. For this test we used this build of ExoPlayer: Exo-DIL-r2.11.1-LCEVC-20210303-withExtensions-withPs-release.apk
Thanks to LCEVC hierarchical structure, the LCEVC-enabled ExoPlayer decodes the AV1 base layer at a quarter resolution (e.g., 540p for a Full HD stream) and leverage existing hardware blocks in the device, such as shaders and scalers, to efficiently decode the enhancement.

![Diagram of video stream and decoder process]

Testing Methodology
The performance benefits of LCEVC-enhanced AV1 against ‘native’ AV1 have been performed on mobile headsets with flight-mode turned on and screen luminosity set to half, and are documented across three sets of KPI, measured using the LCEVC-enabled ExoPlayer:

1. **Playback continuity: percentage of frames dropped.** Test performed on a series of 1080p contents of different complexity, across various data rates (between 750 kbps and 3.5 Mbps) and frame rates (between 25 fps and 60 fps);
2. **Power consumption.** Measurement of instantaneous power drain (mWatts) on short clips, taking into account the number of rendered frames;
3. **Battery drain.** Long haul playback tests (e.g., 1 hour, or until battery is completely drained) on 1080p25, 720p25 and 540p25 content.

The test clips, both native AV1 and LCEVC-enhanced AV1 were encoded at same CBR bitrate and resolution for each test. For reference, the command lines used to encode the 20 sec. short sequences are the following:

<table>
<thead>
<tr>
<th>TESTED CODECS</th>
<th>COMMAND LINE (2SFPS EXAMPLE OUTPUT)</th>
</tr>
</thead>
</table>
The percentage of frames dropped is calculated as:
\[
1 - \frac{\text{number of rendered frames}}{\text{total frames in the sequence}}
\]
where \text{number of rendered frames} is obtained from Exoplayer’s renderedOutputBufferCount function.

Battery power consumption is measured at regular intervals by calling batteryManager for both current and voltage, accumulating millijoules by taking current * voltage/time and then the average by averageMilliwatts = accumulatedMillijoules / playbackIntervalSecs.

Battery drain is obtained by simply recording the battery level at regular intervals, reading the phone display. For all tests, the phone has been set to ‘flight mode’ with display brightness kept consistent across tests.
Performance Results

a. Percentage of dropped frames

Across all tested devices and contents, LCEVC allowed to smoothly playback at 1080p resolution with average dropped frames of 4% - barely noticeable, and only on the most challenging content and less powerful devices – while native AV1 failed to reliably play back, with average dropped frames of 40%.

While on low bitrate (<1 Mbps) and relatively easy p25/p30 content (e.g., tennis, BBB, Meridian) AV1 could play back reasonably well - though with dropped frames ratio 4x higher than the LCEVC-enhanced version (1.2% vs 0.3%) – at higher data rates and more challenging footage, such as gaming content, playback became unsustainable: video frequently froze, with % of dropped frames between 35% and 90% - clearly a no go even on most recent and powerful devices, such as Nokia 8.3 and Pixel 3. When enhanced with LCEVC, performance improved dramatically, all tested devices could playback smoothly 1080p25/30 content with a percentage of dropped frames consistently <2% for all devices (0.4% on average) and with most powerful devices capable of smoothly decoding even 1080p60 content.

The chart below illustrates the average percentage of dropped frames across all tested devices, where the blue bars are LCEVC-enhanced AV1 and the orange bars are native AV1.

b. Power consumption

LCEVC helps save battery life, giving AV1 a benefit of up to 40-50% vs native under similar circumstances (i.e., with comparable rendered frames). To assess power consumption, we measured the mWatts during playback at regular intervals, then we normalised the data assigning an arbitrary value of 100 to the LCEVC average mWatts and rescaling all data accordingly.

This figure alone – which we plotted in the chart below – may be misleading if not coupled with the percentage of rendered frames.

- On ‘easy’ clips, where the ratio of rendered frames is ballpark similar for both native and LCEVC-enhanced and AV1, the difference in power consumption is in the range of 40-50%;
- On tougher contents, where AV1 natively struggles and drops a large portion of frames (up to 70-90%) power consumption figures get closer, but still with slight advantage for the LCEVC-enhanced version, despite it was actually ‘doing the work’.
This graph shows average power usage in mWatts across all tested devices.

The table below shows the difference in power consumption across the tested devices.

<table>
<thead>
<tr>
<th>Power consumption by phone</th>
<th>avgmW</th>
<th>avgmW</th>
<th>avgmW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LCEVC</td>
<td>AV1</td>
<td>Power Ratio</td>
</tr>
<tr>
<td>Samsung S10 plus 5G</td>
<td>100</td>
<td>178</td>
<td>1.78</td>
</tr>
<tr>
<td>Samsung S20 Note</td>
<td>79</td>
<td>105</td>
<td>1.34</td>
</tr>
<tr>
<td>Pixel2 XL</td>
<td>69</td>
<td>78</td>
<td>1.13</td>
</tr>
<tr>
<td>Pixel 3</td>
<td>65</td>
<td>77</td>
<td>1.19</td>
</tr>
<tr>
<td>Nokia 8.3 5G</td>
<td>81</td>
<td>109</td>
<td>1.35</td>
</tr>
<tr>
<td>Huawei Kirin 980</td>
<td>80</td>
<td>87</td>
<td>1.09</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>79</td>
<td>106</td>
<td>1.31</td>
</tr>
</tbody>
</table>

c. Battery drain over a longer time frame
While the tests above all deal with short form content, we ran a test with 1 hour long content across two phones to measure the longer term impact on battery drain. This test confirmed the previous insights: on a powerful device with a comparable percentage of rendered frames, LCEVC-enhanced AV1 consumes battery at 50% the speed of the native AV1 over a 1h time frame. On a less performing device where native AV1 was dropping a significant portion of the frames, the LCEVC-enhanced version still consumed battery less quickly.

The test was performed on two devices: the most powerful in the test set (Nokia 8.3 5G) and an average one (Samsung S10) playing a looped version of the film Tears of Steel (1080p30). The tests were started with devices fully charged, taking note of the battery level every 5 minutes for an hour.

This graph shows battery tests on an hour-long asset on a Samsung S10, we can see that native AV1 consumed 20% of the battery, while on average dropping 36% of the frames. LCEVC-enhanced AV1 instead consumed only 16% of the battery while dropping only 0.003% of the frames. So, effectively LCEVC consumed 18% less battery while ‘doing more work’.

But what happens when we take the percentage of rendered frames out of the picture? This second experiment shows the same battery tests on the more powerful Nokia 8.3 5G. Here, played back both LCEVC-enhanced AV1 and native AV1 content without dropping frames. Again, the LCEVC-enhanced version used less battery across the hour compared to AV1 (8% vs. 12%), which means AV1 consumes 50% more battery than LCEVC (notice that the battery drain difference attributable to decoding is even higher, considering that a portion of battery drain is due to the display, invariant for both cases).
Battery drain test, 1h - Nokia 8.3 5G
1080p, 1Mbps

Battery drain speed:
- LCEVC AV1: 1.3% every 10 min
- AV1: 2.0% every 10 min
→ Vanilla AV1 consumes battery 50% more quickly, and both were dropping no frames throughout the duration of the test.