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Examining Vulkan video extensions for XR applications

Emmanouil Potetsianakis
Emmanuel Thomas, Xiaomi

Outline

1. XR application examples and requirements
2. Vulkan video extension
3. MPEG-I Part 13 Video Decoding Interface (VDI)
4. VDI & Vulkan
5. Performance tests of multiple decoding instances in mobile devices
6. Future Work & Conclusion

XR application examples and their requirements

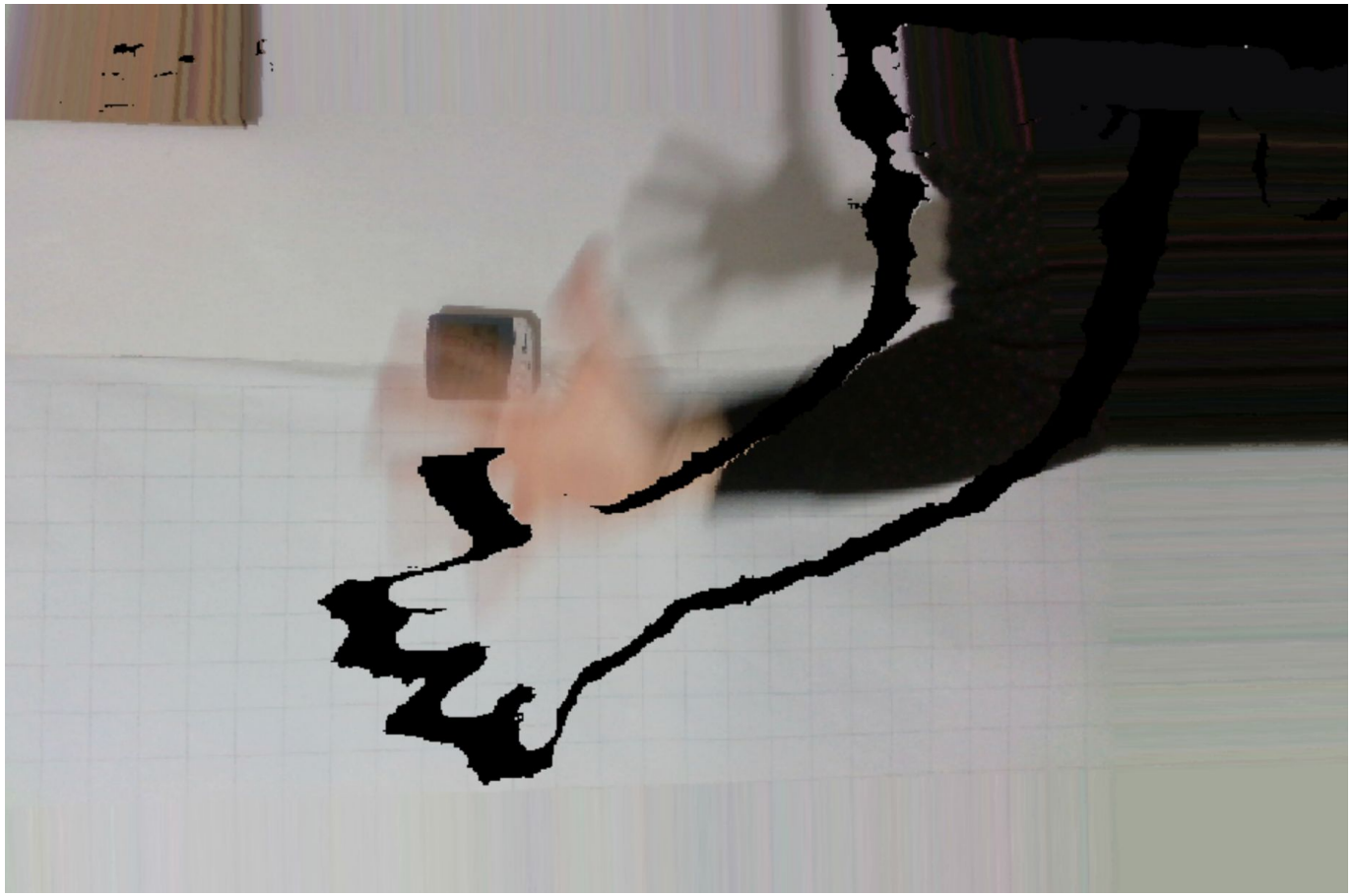
- VR immersive virtual environment
  - 3D models (geometry, texture, atlases), video overlays
  - High-throughput, assets synchronization, ***multiple decoders***, media orchestration
- AR conferencing
  - 2.5D (RGB+D) streams
  - Low-latency, ***multiple decoders***
- XR gaming
  - 2.5D streams (for remote rendering) and/or 3D models (for local rendering)
  - Low-latency, high-throughput, assets synchronization, ***multiple decoders***, media orchestration

XR + multiple decoders (e.g. RGB+D)

- Multiple decoders are often needed
- Even “simple” use-cases that provide RGB+D (for stereo, pose correction etc.) require at least 2 decoders
- Uncertainties of such systems:
  - Number of instances available at runtime
  - Different resolutions per stream
  - Different codec per stream
  - Output sync

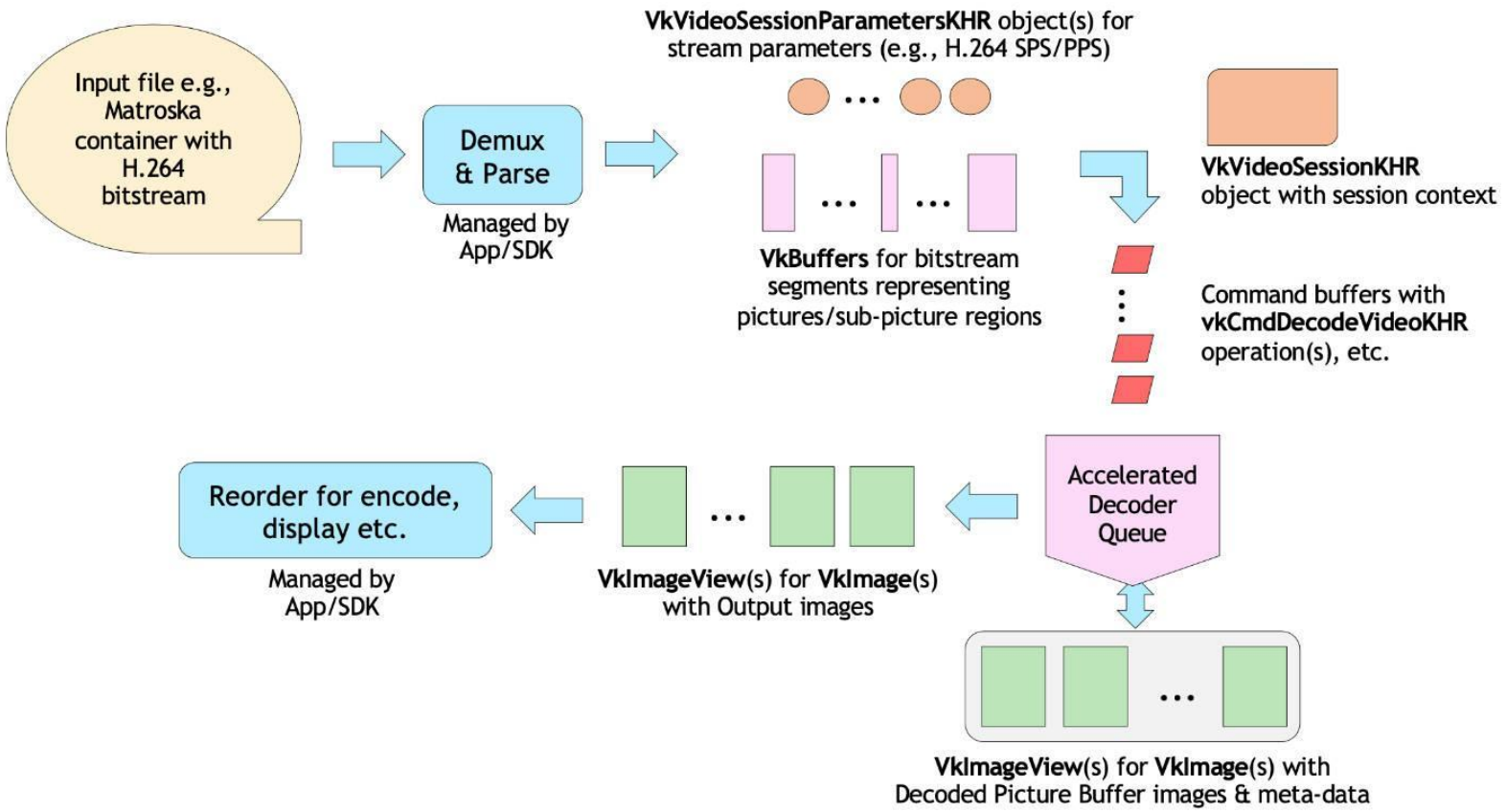
RGB frame & Depth frame misalignment

Example of a capture of a moving hand with a misalignment of 1 frame between the RGB and the Depth frames



Capture Source:
https://github.com/IntelRealSense/librealsense/issues/5675

Vulkan video extensions



Vulkan Video for video-decoding.

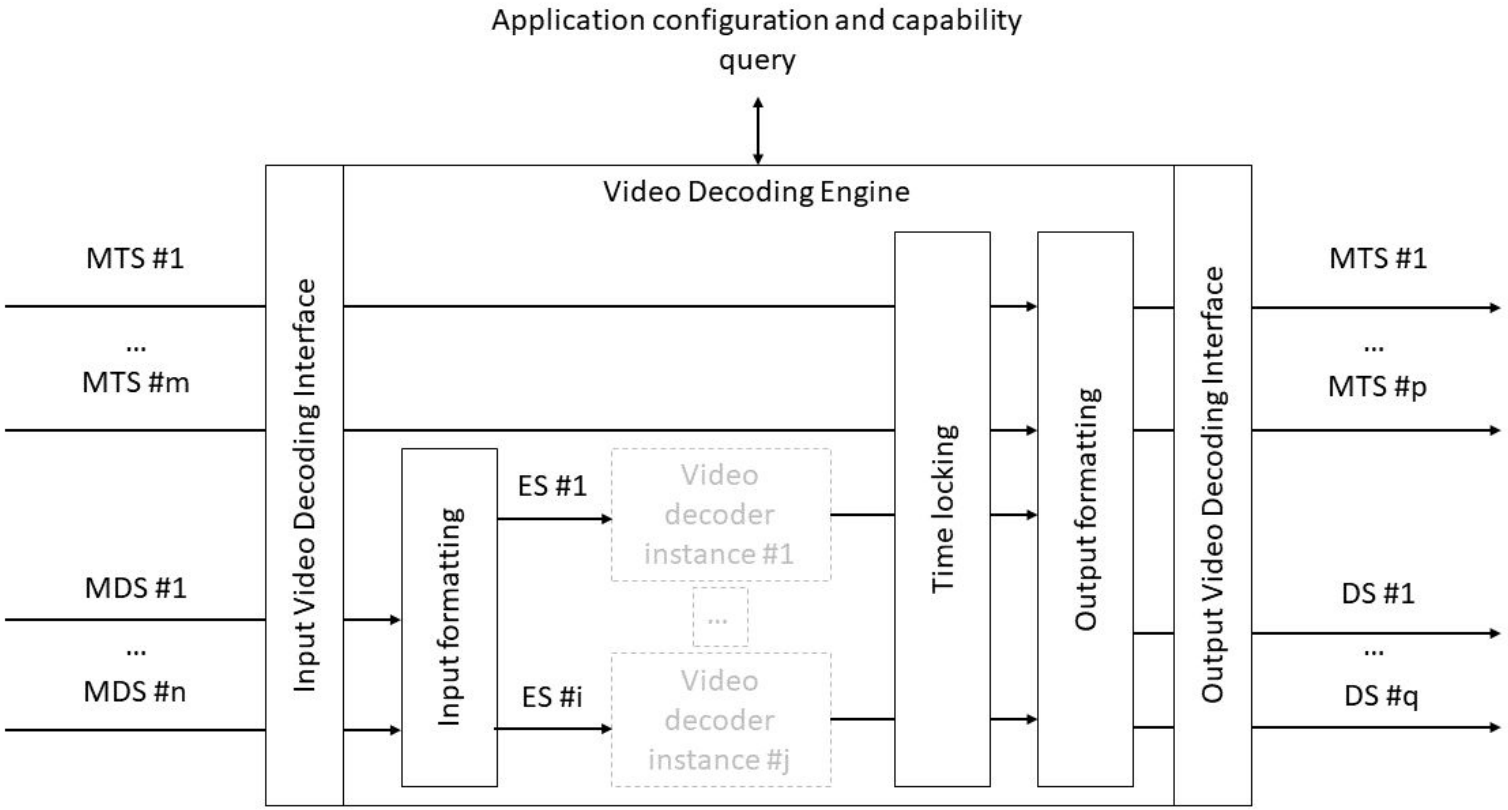
Parsing, Resource management and Synchronization to “application”.

VkBuffer for input bitstream

VkImageView (of **VkImage**) for decoded output and DPB images (inside decoder)

Source: https://www.khronos.org/blog/an-introduction-to-vulkan-video

MPEG-I VDI : Video Decoding Engine and Interfaces



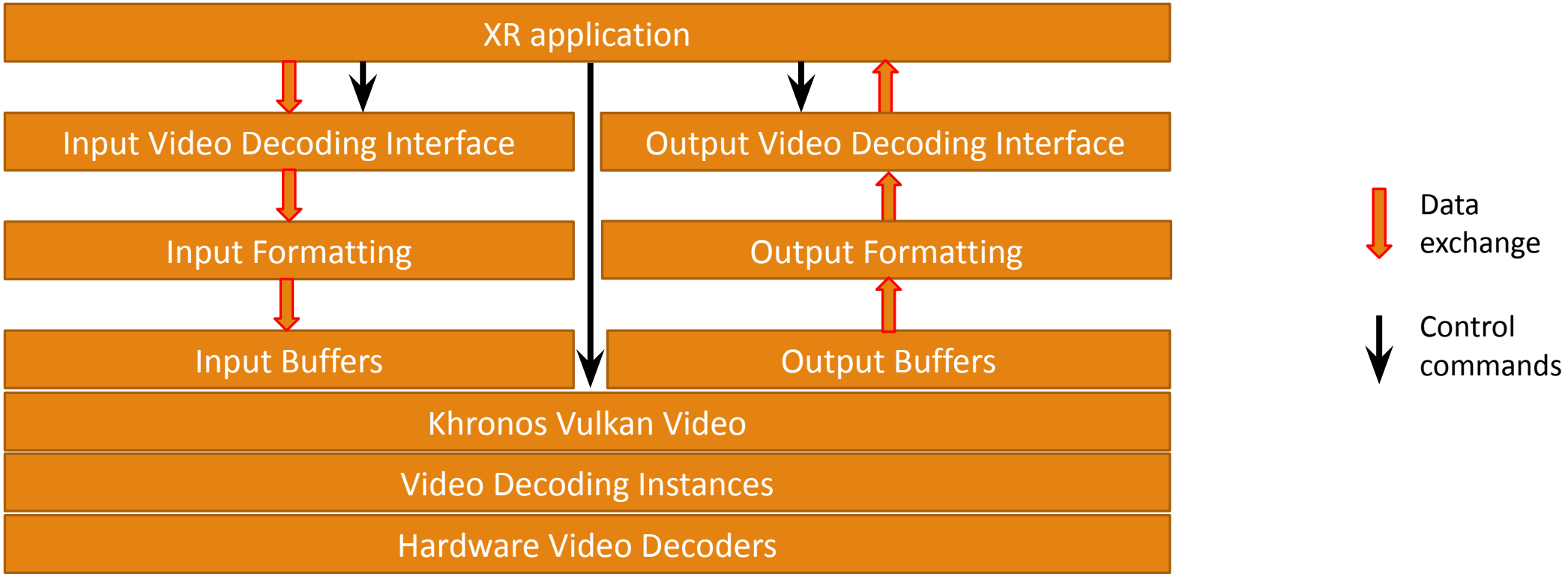
Legend

MDS	media stream
ES	elementary stream
MTS	metadata stream
DS	decoded sequence
m	number of input metadata streams
n	number of media streams
j	number of video decoder instances
p	number of output metadata streams
q	number of decoded sequences

MPEG-I VDI

- Group decoder instances together for more efficient management
- Inputs media streams to merge/split bitstream
- Outputs decoded image sequences in synchronized fashion
- Provides global decoding capabilities and configuration
- Builds on existing technologies (e.g. Khronos Vulkan)

VDI and Vulkan



Decoding in mobile devices

Decoding in mobile devices is relevant because they share some characteristics with (standalone) XR devices such as :

- Have limited processing capabilities
- Energy consumption is essential
- Used for immersive communication
- Share same family of (mobile) chipsets – thus having similar APIs

Therefore decoder instance management is imperative for both device types.

Multiple decoding instances performance

Motivation: demonstrating the benefits of Vulkan and VDI for XR applications

Target: measuring performance and scalability of multiple decoders in AR-enabled devices

Methodology: we measure the decoding times of frames using the Android video decoder (since it is the current alternative to the Vulkan/VDI stack)

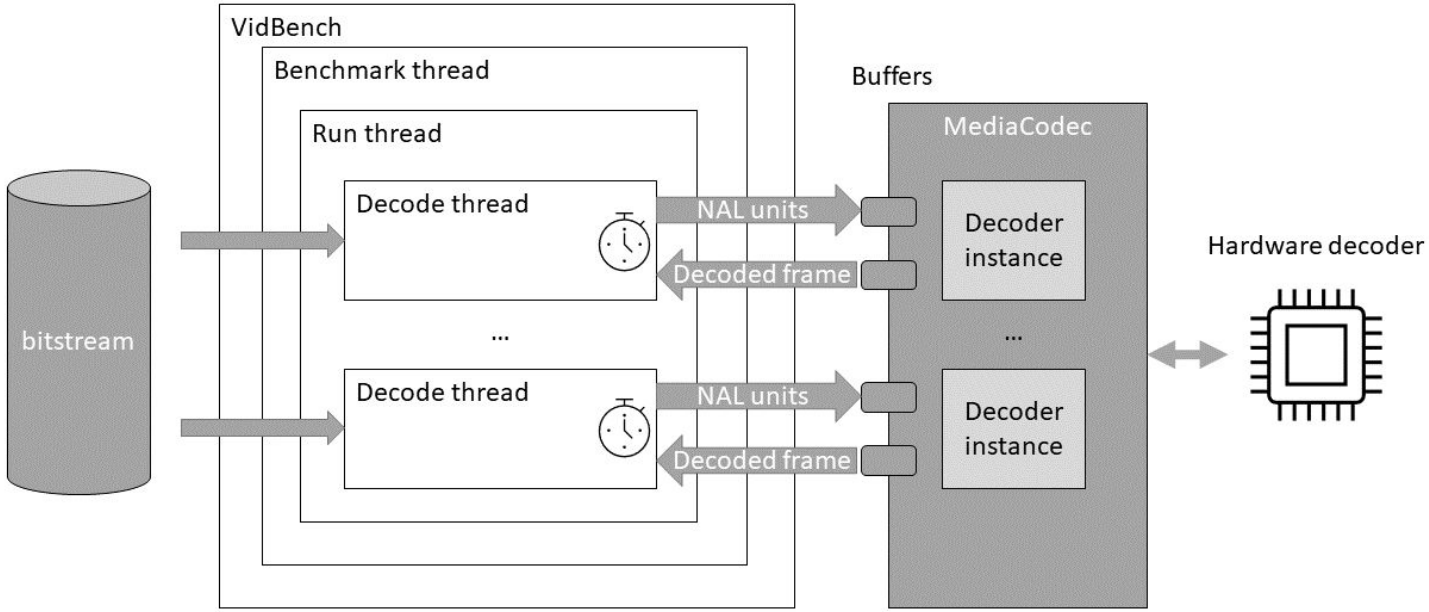
Tool: *VidBench* – in-house video decoding benchmark tool for Android

Device: we selected smartphones as they are comparable to hardware capabilities of other XR devices (e.g. AR Glasses)

Content: AVC-encoded FullHD video of test sequence Big Buck Bunny. Duration: 2mins. Two versions: 1. I-Frame only (live-like) 2. I-Frames and P-Frames (low-delay)

The VidBench tool

- In-house Android application using the Android MediaCodec and MediaFormat APIs
- Characteristics:
  - single-thread per decoder
  - user defines the number of decoders (per test)
  - user defines the number of runs (per test)
- Benchmark settings:
  - 12 input buffer slots observed
  - each test has 20 runs



VidBench logic extract (pseudocode)

1. Getting the input buffer

3. Queue the input buffer

4. Getting the output buffer

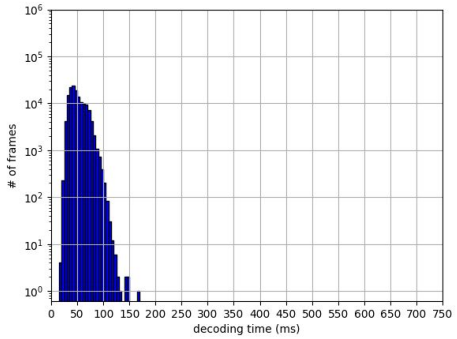
```
1   private void decode() {
2       MediaCodec codec = MediaCodec.createDecoderByType("video/avc");
3       MediaFormat format = MediaFormat.createVideoFormat("video/avc", 1920, 1080);
4       do {
5           int inputBufferId = codec.dequeueInputBuffer(timeoutUs);
6           if (inputBufferId >= 0) {
7               ByteBuffer inputBuffer = codec.getInputBuffer(inputBufferId);
8               byte[] naluBytes = getNextNAL(stream);
9               inputBuffer.put(NalUnitUtil.NAL_START_CODE);
10              naluBytes = getNextNAL(stream);
11              startTimes[sampleCount(inID)] = now();
12              codec.queueInputBuffer(inputBufferId, 0, sampleLength, timestamp, flags);
13          }
14          MediaCodec.BufferInfo buffer_info = new MediaCodec.BufferInfo();
15          int outputBufferId = codec.dequeueOutputBuffer(bufferInfo, timeoutUs);
16          if (outputBufferId >= 0) {
17              endTimes[sampleCount(outID)] = now();
18              ByteBuffer outputBuffer = codec.getOutputBuffer(outputBufferId);
19              codec.releaseOutputBuffer(outputBufferId, false);
20          }
21      } while(endOfStream);
22  }
```

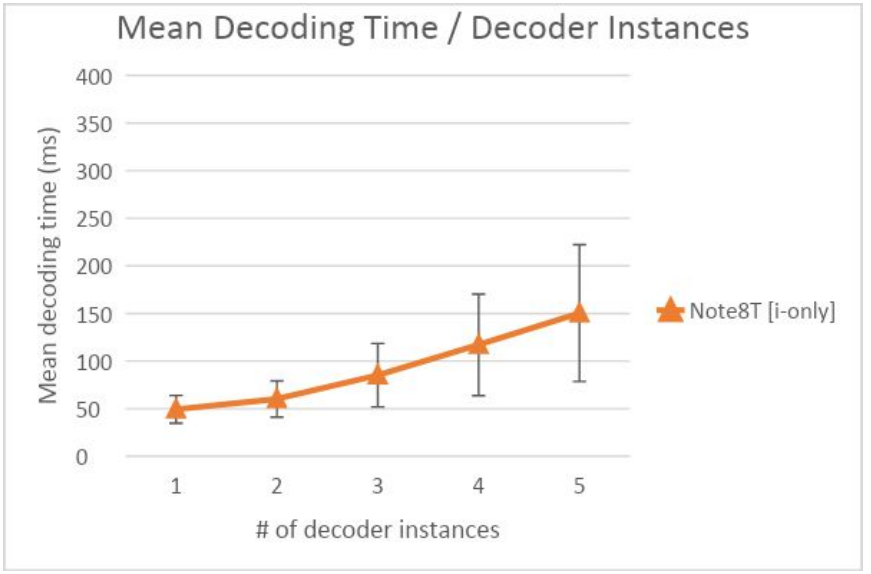
2. Writing NAL to the input buffer

5. Release output buffer (without rendering)

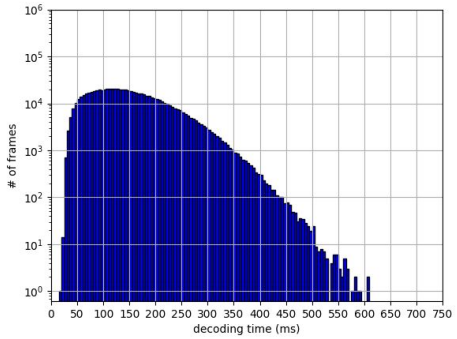
Measuring performance of decoding in mobile devices (number of decoders)

1 decoder

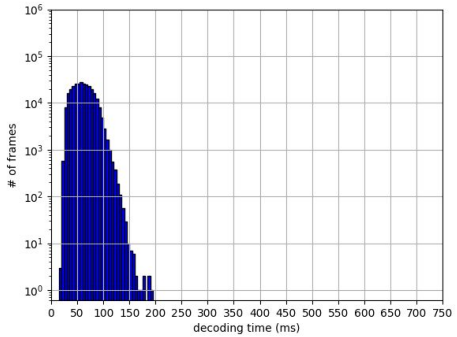




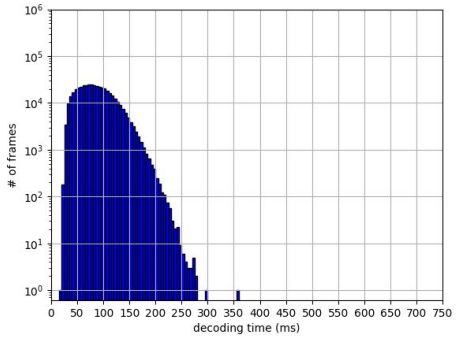
5 decoders



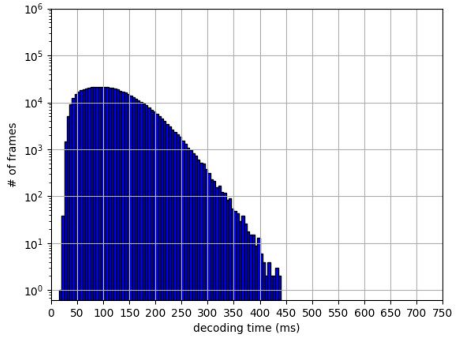
2 decoders



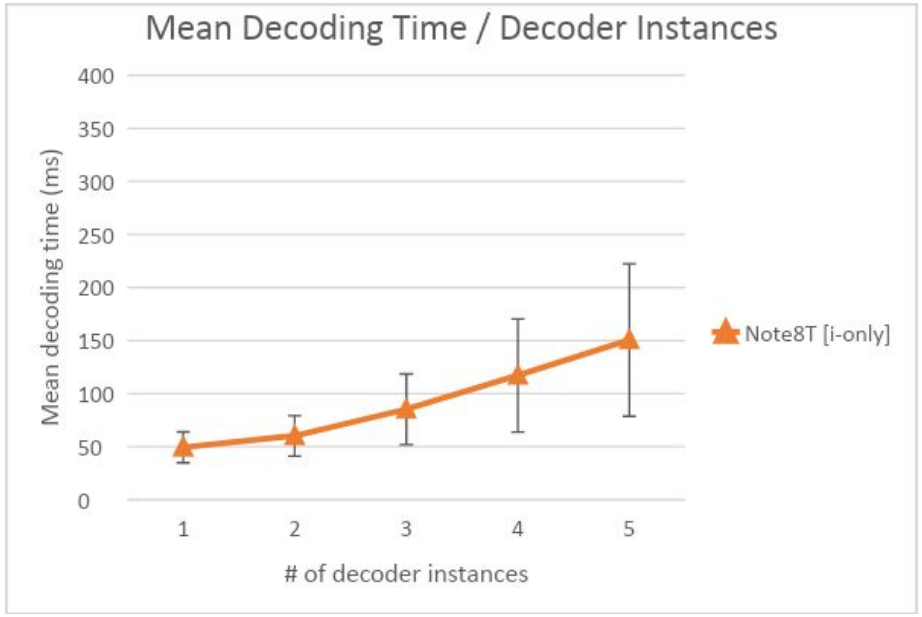
3 decoders

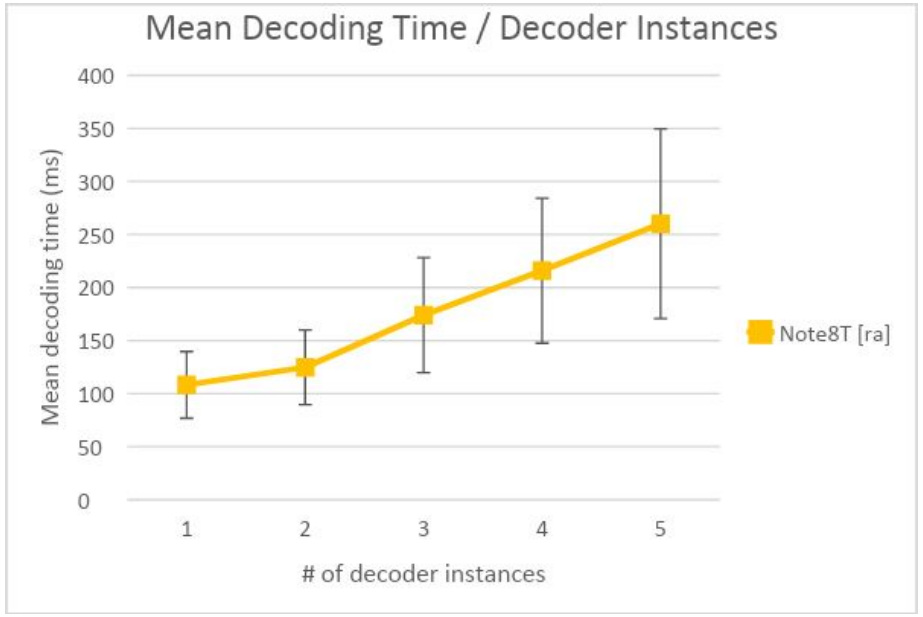


4 decoders



Measuring performance of decoding in mobile devices (coding parameters)





Cross-device decoding performance

Experiment 3: Performance of different devices

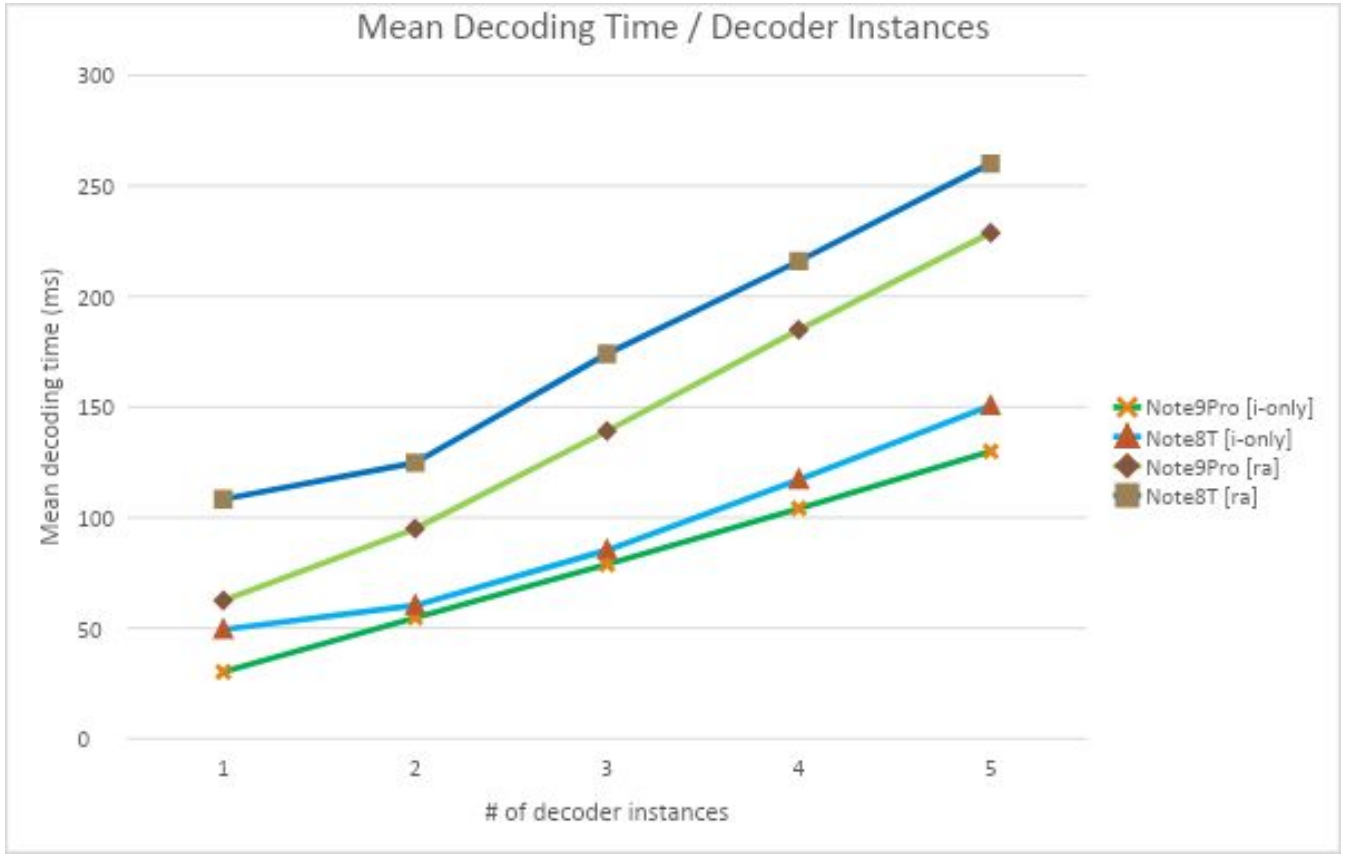
Note 8T

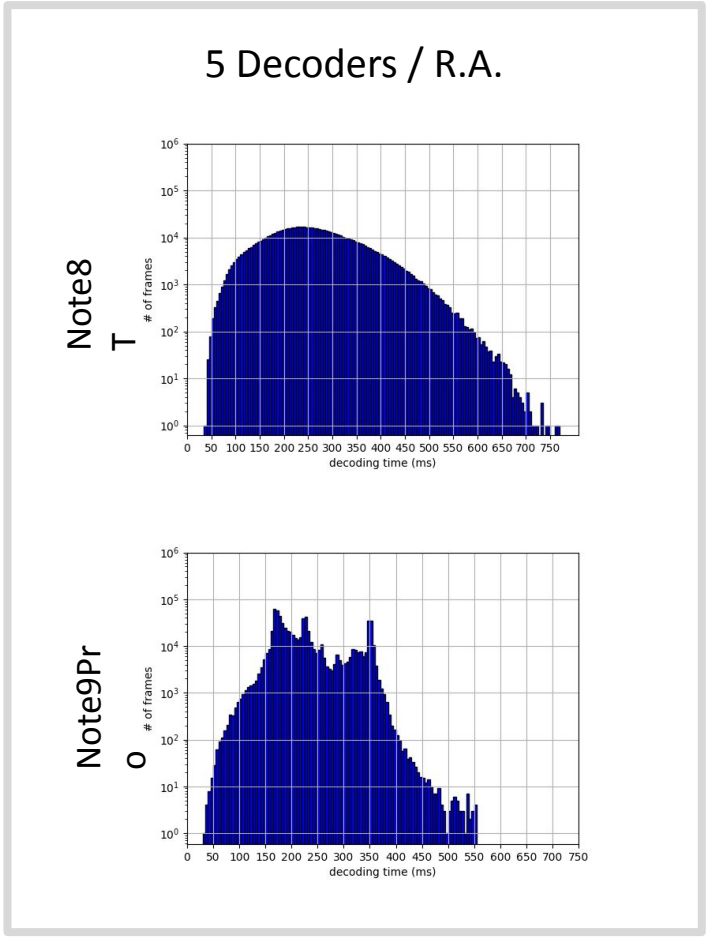
Chipset	Qualcomm SDM665 Snapdragon 665 (11 nm)
CPU	Octa-core (4x2.0 GHz Kryo 260 Gold & 4x1.8 GHz Kryo 260 Silver)
GPU	Adreno 610
OS	Android 9

Note 9 Pro

Chipset	Qualcomm SM7125 Snapdragon 720G (8 nm)
CPU	Octa-core (2x2.3 GHz Kryo 465 Gold & 6x1.8 GHz Kryo 465 Silver)
GPU	Adreno 618
OS	Android 11

Measuring performance of decoding in mobile devices (device)





Future Work

On benchmarking

- Tests with different codecs.
- Port VidBench on a Vulkan-based platform (if and when available in Android)
  - Include mixed assets in the tests

On VDI status

- MPEG is finalizing the first edition of the VDI specification (Q1 ‘23).
- Discussion of 2nd edition of VDI has already started, focusing on extending support for other codecs, defining metadata streams and validation/conformance framework.