Where to Encode: A Performance Analysis of x86 and Arm-based Amazon EC2 Instances

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Abstract—Video streaming became an undivided part of the Internet. To efficiently utilise the limited network bandwidth it is essential to encode the video content. However, encoding is a computationally intensive task, involving high-performance resources provided by private infrastructures or public clouds. Public clouds, such as Amazon EC2, provide a large portfolio of services and instances optimized for specific purposes and budgets. The majority of Amazon's instances use x86 processors, such as Intel Xeon or AMD EPYC. However, following the recent trends in computer architecture, Amazon introduced Armbased instances that promise up to 40% better cost performance ratio than comparable x86 instances for specific workloads. We evaluate in this paper the video encoding performance of x86 and Arm instances of four instance families using the latest FFmpeg version and two video codecs. We examine the impact of the encoding parameters, such as different presets and bitrates, on the time and cost for encoding. Our experiments reveal that Arm instances show high time and cost saving potential of up to 33.63% for specific bitrates and presets, especially for the x264 codec. However, the x86 instances are more general and achieve low encoding times, regardless of the codec.

Index Terms—Amazon EC2, Arm instances, AVC, Cloud computing, FFmpeg, Graviton2, HEVC, Performance analysis, Video encoding.

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I. INTRODUCTION

Multimedia streaming content [4], such as live and ondemand video and audio streams, is responsible for most Internet traffic today. Unfortunately, the Internet network connectivity can significantly change over time depending on many factors, such as client location, network congestion, or end-user device [27], [38]. The widely-used HTTP Adaptive Streaming (HAS) technology [30] encodes video content, divided into small segments, in multiple bitrate-resolution pairs to adapt to varying bandwidth fluctuations. Using HAS, a video segment reaches clients at different bitrate-resolution pairs for optimized quality of experience, depending on its network characteristics and technical capabilities (e.g., viewing device, video player) [10]. Additionally, a number of HAS implementations are codec-independent [30] and allow providers to choose from a set of codecs for video encoding, including Advanced Video Coding (AVC) [35], HighEfficiency Video Coding (HEVC) [31], VP9 [28], AOMedia Video 1 (AV1) [12], and Versatile Video Coding (VVC) [9].

Creating segments of a single video encoded with different parameters (e.g., bitrate, resolution) for adaptive streaming is a computationally-intensive process that requires expensive high-performance computers or cheaper cloud resources rented on-demand [20], [34]. For example, Amazon EC2 provides different instance families optimized for specific purposes [24], such as the balanced general purpose m instances, the compute-optimized c instances, the memory-optimized r instances, and the burstable t instances. To further optimize video encoding workloads at a convenient price, leading video encoding companies such as Bitmovin (https://bitmovin.com) combine on-demand instances with EC2 Spot instances for video encoding [1]. Nevertheless, choosing cloud instances for thousands of encoding tasks is critical and can strongly influence the costs for the video service providers [1], [19].

Recently, Amazon launched their second generation Graviton Arm-based processors. *Graviton2* is a 64-core monolithic server chip that uses Arm's new Neoverse N1 cores, which is a derivation of the mobile Cortex-A76 cores. With the second generation of Graviton, Amazon EC2 promises higher performance at a lower cost compared to conventional x86 instances. According to Amazon, Graviton2 instances, such as m6g, c6g, r6g and t4g, provide up to 40% better price performance over comparable instance types with Intel Xeon processor for video encoding tasks [3].

In this paper, we analyze the video encoding performance of EC2 instances based on the Graviton2 Arm and the x86 processors using four instance families optimized for different purposes. As Graviton2 processors are relatively new and its software support is continuously improving, we conduct all experiments using FFmpeg [5] employing the following video codec implementations:

- a) x264 codec: (H.264/AVC compression format) supported by the majority of end-user devices on the market [37].
- b) x265 codec: (H.265/HEVC compression format) for further in-depth analysis with the newest FFmpeg version 4.3. The main contributions of our work are:
- We evaluate the relative video encoding time and cost differences between and x86 and Arm instance families;
- We identify the fastest and cheapest instance types among all instances of the same processor architecture.
- We provide a reference table indicating our recommendation for the fastest and cheapest encoding options for each

instance family, preset, and bitrate.

The paper is organized into six sections. Section II discusses the related work. Section III presents the evaluation methodology. Section IV describes the experimental design and evaluation scenarios, followed by the two codecs' experimental results in Section V-A and Section V-B. Section VI summarizes our recommendations and discusses the results. Finally, Section VII concludes the paper and outlines the future work.

II. RELATED WORK

We review the state-of-the-art related to performance analysis and characterization of video encoding on cloud instances.

- a) Cloud performance analysis: Li et al. [24] analyze the performance of heterogeneous cloud instances for encoding video streams and provide a model for quantifying the suitability of cloud instance types for various encoding tasks. Xiangbo et al. [23] present a performance analysis for improved scheduling of encoding tasks on cloud instances, which reduces the cost for the streaming service providers by 85%. Timmerer et al. [33] present a performance analysis of the Bitmovin encoding platform, developed atop the MPEG-DASH open standard over multiple cloud instances. Based on this analysis, the encoding platform utilizes appropriate cloud instances to increase the average media throughput without stalling during operation.
- b) Processor architecture: Jiang et al. [18] present a performance characterization of cloud instances based on the first generation of Graviton compared to a multitude of Intel Xeon processors. The work demonstrates that although the Graviton processor has the slowest encoding speed and scalability ratio, it provides cost savings of around 15% for the same encoding performance. Federman et al. [13] analyze the microarchitectural behavior of x86 processors for a set of video streaming workloads based on the x264 codec. They identify that video encoding suffers from a high amount of stalled instructions and cache misses, which leads to lower scalability and hindered execution. Magaki et al. [26] evaluate GPU and FPGA-based clouds' performance for video encoding with the x265 codec and propose an application-specific integrated circuit tailored for this task.
- c) Large scale video encoding: Jiang et al. [17] evaluate the performance of public cloud infrastructure for large-scale video encoding applications scaling up to one thousand virtual machines. Regarding video encoding benchmarks, Lottatini et al. [25] present a public suite tailored for cloud video services, which encompasses a set of representative videos and metrics that reflect user-perceived characteristics of the video streams, such as quality and encoding speed.
- d) Gap analysis: The presented research works are segregated, utilize a single codec, and exclusively consider user-specific metrics, such a perceived video quality. In this work, we complement the related approaches by characterizing the performance of modern x86 and Arm architectures for a set of commonly used video codec implementations. Furthermore, we consider various video encoding presets (e.g., as known

in x264, x265) and provide a detailed analysis on the performance and the cost savings of using optimized instances in the cloud. Lastly, we examine the suitability of the Armbased processors for performing video encoding tasks.

III. EVALUATION METHODOLOGY

This section presents the performance evaluation methodology comprising two phases. 1) *Encoding data generation* describes the selection of representative video sequences, identifies video codecs, and selects encoding parameters. 2) *Instance selection and metric definition* describes the selection of cloud instances based on the processor micro-architecture and defines the relevant performance evaluation metrics.

A. Encoding data generation

Encoding data generation involves video sequence, video codec, and encoding parameter selection.

- 1) Video sequence selection: We select video segments with a duration below 10 s according to HAS requirements and industry best practices [22]. The segment length is a key parameter in HAS, as each video segment starts with a random access point to enable adaptive and dynamic switching to other representations (bitrate resolution pairs) at segment boundaries [11]. In addition, the selected video segment must contain movements that exploit different features of the video coding algorithms. Therefore, we use spatial and temporal information metrics to select a video segment and identify the computation requirements for its encoding [15].
- a) Spatial Information (SI): measures the spatial complexity of video frames through the physical position of an object in the frame and its spatial relationship to other objects:

$$SI = \max_{\forall F_n} \{ \sigma \left[Sobel \left(F_n \right) \right] \}, \tag{1}$$

where F_n is the luminance component of the video frame at time instance n, σ is the standard deviation across all the pixels in the Sobel filter, and the max operator calculates the maximum standard deviation of all frames in a video sequence. A high SI value indicates complex spatial relations between multiple objects and higher differences between subsequent frames, which increases the complexity of the encoding tasks and leads to longer encoding times.

b) Temporal Information (TI): shows the amount of motion in a video content, calculated as the maximum standard deviation σ of a motion difference function $M_n(i,j)$. This function represents the difference in luminance for two sequential frames F_n and F_{n-1} across all the pixels (i,j):

$$TI = \max\{\sigma[M_n(i,j)]\}; \tag{2}$$

$$M_n(i,j) = F_n(i,j) - F_{n-1}(i,j), \tag{3}$$

where $F_n(i,j)$ is the luminance of the frame pixel (i,j) at time instance n in the video sequence. A high TI value indicates higher motion differences between the video segment frames, which requires more computational resources for performing the encoding tasks.

Table I: Bitrate ladder	(bitrate – re	solution 1	pairs).
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#	Bitrate [kbps]	Resolution	#	Bitrate [kbps]	Resolution
1	100	256×144	11	4300	1920×1080
2	200	320×180	12	5800	1920×1080
3	240	384×216	13	6500	2560×1440
4	375	384×216	14	7000	2560×1440
5	550	512×288	15	7500	2560×1440
6	750	640×360	16	8000	3840×2160
7	1000	768×432	17	12000	3840×2160
8	1500	1024×576	18	17000	3840×2160
9	2300	1280×720	19	20000	3840×2160
10	3000	1280×720			

- 2) Video codec selection: We identify x264 and x265 [37] as the most widely spread codecs for executing video encoding tasks, deployed by more than 90% of the video streaming industry [16]. The x265 video codec typically requires more computing resources than x264 but achieves a higher video quality for the same encoding parameters [14].
- 3) Encoding parameters selection: We select 19 bitrates from 100 kbps to 20 Mbps (see Table I) and nine encoding presets that define the quality to encoding speed ratio: ultrafast, superfast, veryfast, faster, fast, medium (default preset), slow, slower, and veryslow [6]. A slower preset uses more features for the same bitrate, which leads to a relatively slower encoding speed and better video quality [29]. Similarly, faster presets produce lower video quality. According to the official FFmpeg video encoding guide, we do not use the placebo preset that does not provide a significant quality improvement compared to the veryslow preset according to the official FFmpeg video encoding guide [6].

B. Instance selection and metric definition

- 1) Instance type selection: We selected instance types based on three commonly used processors for video encoding.
- a) Intel Xeon Platinum: is a multi-purpose processor based on the latest extension of the x86 architecture with the Advanced Vector Extension (AVX-512) instruction set. It is a 28-core server chip that can execute 56 concurrent threads.
- b) AMD EPYC: is a multi-purpose processor based on the x86 Zen architecture. For the majority of instance types, AWS provides the first generation EPYC processor with up to 32 cores and 64 concurrent threads. However, for the c instances, AWS provides the second-generation EPYC processors with up to 64 cores and 128 threads per server chip.

The $\times 86$ processors of Intel and AMD represent 87% of the cloud instances [2] and the majority of personal computers.

- c) Graviton2: is the second generation of Graviton Arm processors recently released by Amazon. It is a 64-core monolithic server chip that uses Arm's new Neoverse N1 cores, derived from the mobile Cortex-A76 cores. The Arm processors dominate the mobile segment with a 90% market share [2]. Nevertheless, there is a trend [32] from leading companies, such as Apple and Amazon, for using Arm-based processors to power personal computers and cloud instances.
- d) Instance families: Based on these processor architectures, we select four instance families from the Amazon EC2

cloud (see Table II) [24]: 1) balanced general purpose m instances, 2) compute-optimized c instances, memory-optimized r instances, and 3) burstable t instances. We selected eight vCPUs for all instance types, corresponding to the largest available sizes of t3, t3a, and t4g instances. For a fair comparison, we equalize the number of vCPUs. However, the memory size of different instance types might still differ due to their instance type definitions. Nonetheless, the carefully selected video segment's encoding does not exceed the smallest memory size in our set of instances.

- 2) Evaluation metrics: We compare the new Arm instances with the Intel and AMD based x86 instances using three metrics.
- a) Relative encoding time: $\Delta t_{enc}(V_{b,p})$ of a video segment $V_{b,p}$ with a bitrate b and a preset p is the normalized time difference of the Arm encoding time $t_{Arm}(V_{b,p})$ to the reference $\times 86$ encoding time $t_{x86}(V_{b,p})$:

$$\Delta t_{enc}(V_{b,p}) = \frac{t_{Arm}(V_{b,p}) - t_{x86}(V_{b,p})}{t_{x86}(V_{b,p})} \cdot 100.$$
 (4)

A positive relative encoding time indicates that the Arm instance is slower than the reference x86 instance, while a negative value indicates that Arm is faster.

b) Encoding cost: $c_{enc}(V_{b,q})$ of a video segment $V_{b,q}$ is the product between the instance price c_i (in \$) per second and the segment encoding time $t(V_{b,q})$ in seconds:

$$c_{enc}(V_{b,q}) = c_i \cdot t(V_{b,q}), \tag{5}$$

Although cloud providers typically charge for their on-demand instances on an hourly basis, we scale the price down to seconds for a more fine-grained encoding cost understanding.

c) Relative encoding cost: $\Delta c_{enc}(V_{b,p})$ for a video segment $V_{b,p}$ with a bitrate b and a preset p is the normalized difference of the Arm encoding cost $c_{Arm}(V_{b,p})$ to the reference x86 encoding cost $c_{x86}(V_{b,p})$:

$$\Delta c_{enc}(V_{b,p}) = \frac{c_{Arm}(V_{b,p}) - c_{x86}(V_{b,p})}{c_{x86}(V_{b,p})} \cdot 100.$$
 (6)

Similarly to relative encoding time, a positive relative encoding cost indicates that Arm is more costly than the reference x86 instance, while a negative value indicates that Arm is cheaper.

IV. EXPERIMENTAL DESIGN

This section describes the implementation and evaluation scenarios of the encoding methodology.

A. Video sequence selection

We selected for encoding a two-second segment from a computer-animated movie [36] with high TI and SI metrics [21], as described in Section III. The selected video segment's TI metric has a value of 22, which is three times higher than the average TI value (8.2) of the other movie segments. This implies high motion between the frames. In turn, the SI metric of this segment has a value of 18.1, which is slightly above the average SI value (16.3) of all movie segments, which implies higher spatial complexity.

Table II: Experimental Amazon EC2 Cloud instance types.

Instance type	Architecture	vCPUs	Memory [GiB]	Storage [GiB]	Network	Physical processor	Clock [GHz]	Price[\$/h]
m5.2xlarge			32			1st or 2nd generation	≤ 3.1	0.383
c5.2xlarge	64-bit x86	8	32	EBS	$\leq 10 \text{ Gbps}$	Intel Xeon Platinum 8000	≤ 3.4	0.34
r5.2xlarge	04-011 800	0	64	EDS		series (Skylake-SP or	≤ 3.1	0.504
t3.2xlarge			32	32	$\leq 5 \text{ Gbps}$	Cascade Lake)	≤ 3.1	0.3341
m5a.2xlarge			32			AMD EPYC 7000 series	≤ 2.5	0.344
c5a.2xlarge	64-bit x86	8	16	EBS	$\leq 10 \text{ Gbps}$	AMD EPYC 7002 (2nd gen.)	≤ 3.3	0.308
r5a.2xlarge	04-011 800	64 32	64 EBS		AMD EPYC 7000 series	≤ 2.5	0.452	
t3a.2xlarge				$\leq 5 \text{ Gbps}$	AMD EPYC	≤ 2.5	0.3008	
m6g.2xlarge			32					0.308
c6g.2xlarge		16 EBS	EDC	$\leq 10 \text{ Gbps}$	AWS Graviton2	≤ 2.5	0.272	
r6g.2xlarge		0	64	மம்		AWS Gravitoriz	≥ 2.5	0.4032
t4g.2xlarge			32		$\leq 5 \text{ Gbps}$			0.2688

B. Encoding software

We perform the encoding for AVC and HEVC video codecs using the libx264 (short x264) and libx265 (short x265) FFmpeg [5] library, as follows:

```
ffmpeg -y -i sintel_2sec0030.y4m
  -r {fps} -vf scale={WxH} format=yuv420p
  -c:v {libx264, libx265}
  -preset {preset} -b {bitrate}
  output.mp4
```

- a) fps: is the number of video frames per second, which is the same as in the original video segment (i.e., 24);
- b) $W \times H$: specifies the width W and height H (in pixels) of the encoded video segment (see Table I);
 - c) preset: defines the encoding preset (e.g., fast, slow);
- *d)* bitrate: in a encoded video file measured in kbps, as defined in Table I.

We used the latest FFmpeg version 4.3 which uses the libx265 version 3.4 with Huawei enhancements for faster Arm encoding [8]. We carefully select the number of encoding threads equal to the number of available vCPUs of each instance type. We run all instances in the US East Amazon EC2 region with two default Ubuntu Server 18.04 LTS images that include Python packages: ami-0ac80df6eff0e70b5 for 64-bit x86 instances, and ami-0d221091ef7082bcf for 64-bit Arm instances. We manually deployed the latest FFmpeg version 4.3 to replace the default 3.4.6 version of Ubuntu 18.04 LTS.

C. Evaluation scenarios

We created two evaluation scenarios for each of the codec. We repeated all experiments five times for a total of 10,260 experiments for both $\times 264$ and $\times 265$ codec. This translates into a total cloud instance time of over $260\,\mathrm{h}$. We report the average values of the metrics described in the following paragraphs.

- 1) Instance family: comparison uses two metrics:
- a) Relative encoding time: difference $\Delta t_{enc}(V_{b,p})$ of each x86 and Arm instance from the same instance family, as presented in Table II (i.e., m, c, r, t);
- b) Relative encoding cost: difference $\Delta c_{enc}(V_{b,p})$ across both processor architectures from the same instance family.
 - 2) Processor architecture: comparison uses two metrics:

- a) Fastest encoding time: of Arm $t_{Arm}(V_{b,p})$ and x86 instances $t_{x86}(V_{b,p})$ independent of the instance family.
- b) Lowest encoding cost: $c_{enc}(V_{b,p})$ across all instance families from the same processor architecture.

V. EVALUATION RESULTS

We present the encoding results that compare the x86 and Arm instances for the x264 and x265 codecs, following the evaluation scenarios from Section IV-C. We use heatmaps to simplify the three-dimensional visualization of the encoding time and cost dependency on the encoding bitrates and presets.

A. x264 Codec

1) Instance family:

a) Relative encoding time: Figure 1a displays the relative encoding time $\Delta t_{enc}(V_{b,p})$ between Arm and x86 instances (Intel and AMD) with various encoding presets and bitrates. We observe that the $\times 86$ c instances achieve for all presets and bitrates on average 30,78% faster encoding times than the Arm c6g instances. For the other instance families, the x86 instances are faster than the Arm instances, primary for lower bitrates (≤8 Mbps) and presets between "ultrafast" and "veryfast". The Arm instances t4g, m6g and r6g reveal faster encoding times than the Intel x86 instances, especially for presets between "very fast" and "fast", and for bitrates higher than 750 kbps. In particular, m6g and r6g achieve up to 7.51%, while t4g achieves up to 17.82% faster encoding times than the Intel x86 instances. Considering the x86 instances of AMD, the Arm instances t4g, m6g and r6g achieve faster encoding times especially for presets between "very fast" and "very slow", and for bitrates higher than $750 \, \mathrm{kbps}$.

Overall, t4g.2xlarge shows the shortest relative encoding time due to the burstable behavior.

b) Relative encoding cost: Beside relative encoding times, we closely analyze the relative encoding costs $\Delta c_{enc}(V_{b,p})$ with various encoding presets and bitrates (see Figure 1b). For m, r, and t instances, the Arm instances reveal the highest cost saving potential for presets between "very fast" and "fast", and bitrates over 750 kbps. For example, t4g.2xlarge shows on average 19.67%, r6g.2xlarge 13.75%, and m6g.2xlarge 12.84% lower encoding cost

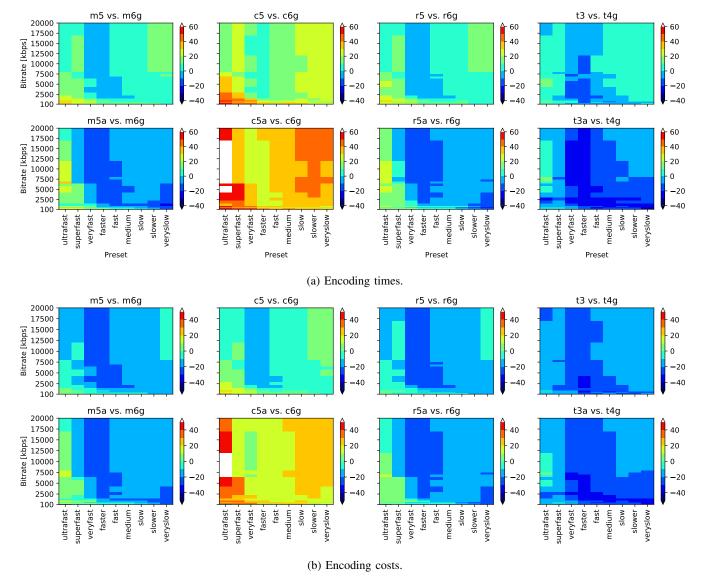


Figure 1: Relative encoding time and cost for four instance families with different presets, bitrates, and x264 codec.

than the corresponding x86 instances. The c instances, especially the AMD based c5a, show highest cost saving potential for all presets and bitrates. The combination of lower cost and faster encoding performance than Intel based c5 make the c5a to the first choice for the x264 codec.

c) Recommendation: For fast encoding, we recommend using x86 instances for bitrates lower than 8 Mbps and presets between "ultrafast" and "veryfast". Arm instances are faster for bitrates higher than $750\,\mathrm{kbps}$ and presets between "very fast" and "fast". For a low encoding cost, we recommend Arm over x86 for m, r, and t instances. However, for c instances, we recommend x86, and especially the AMD based c5a, over Arm.

2) Processor architecture:

a) $\times 86$ encoding time: The c instance family achieves the fastest encoding times in all experiments. Considering only Intel's $\times 86$, c5 is on average 10.44% faster than other three

Intel $\times 86$ instances due to its higher clock speed. However, the direct comparison of the Intel $_{\odot}5$ and the AMD $_{\odot}5$ a reveal, that the AMD based $_{\odot}$ instance is on average 10.17% faster. This performance difference is expected because the compute-optimized $_{\odot}5$ a instances use the second generation AMD EPYC processors, which are based on newer architecture and production processes than the Intel Xeon processors used in $_{\odot}5$.

b) Arm encoding time: Figure 2a shows the fastest encoding Arm instances. Overall, the encoding times among Arm instances are negligibly small with encoding time differences of less than 0.85% on average. Furthermore, Figure 2a confirms that m6g.2xlarge is fastest in 90% of the experiments with 1.15% faster average encoding times. The t4g.2xlarge instance is fastest for bitrates higher than 12 Mbps and presets between "slower" and "veryslow". The

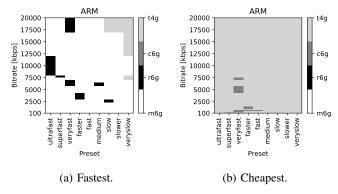


Figure 2: Fastest and cheapest encoding architecture per instance type for different presets, bitrates, and x264 codec.

r6g.2xlarge instances are fastest in few cases with no detectable pattern, mainly for bitrates between 2.5 Mbps and 12 Mbps, and presets between "ultrafast" and "slow".

- c) Encoding cost: The c instance and especially the AMD-based c5a instance achieves the lowest x86 encoding costs in all experiments thanks to its fast encoding times and low price compared to the other three x86 instances. Figure 2b shows the lowest encoding cost for Arm instances. In particular, the t4g.2xlarge instance achieves the lowest encoding costs, followed by c6g.2xlarge. The low encoding cost of t4g.2xlarge in the majority of experiments is due to its low price and burstable performance.
- d) Recommendation: Among x86 instances, we recommend using c instances for fastest encoding and lowest cost. Among c instances, we recommend to prioritize c5a over c5 instances, as c5a are based on latest processor architecture from AMD. Among Arm instances, we recommend m6g.2xlarge for fastest encoding times, and t4g.2xlarge for lowest encoding cost.

B. x265 codec

To analyze the different codecs' impact, we repeat the same set of experiments using the x265 codec.

1) Instance family:

a) Relative encoding time: Figure 3 reveals that the Arm instances are on average 329.42% slower than the x86 instances in all experiments. We observe higher relative encoding times of at least 279.92% for presets between "slow" and "veryslow" and lower for presets between "ultrafast" and "superfast". In particular, t4g.2xlarge shows the smallest difference of 16.48% for a bitrate of 100 kbps, and c5a the highest differences of up to 847.67% compared to Arm c6g instance for presets between "slow" and "veryslow". The m6g.2xlarge and r6g.2xlarge instances achieve comparable results depending on the x86 processor. We identify a higher average relative encoding time difference of 360.79% for Intel based instances, and 229.76% for AMD based instances.

In contrast to the x264 codec, Arm instances show in all experiments slower relative encoding times. Moreover, we

identify different areas in the heatmaps with small relative encoding time for both codecs. For example, the $\times 265$ codec shows the smallest difference for areas with low bitrate and "ultrafast" preset, where the $\times 264$ codec shows highest $\Delta t_{enc}(V_{b,q})$.

b) Relative encoding cost: For completeness, Figure 3b depicts the relative encoding cost $\Delta c_{enc}(V_{b,p})$ between x86 and Arm instances with various encoding presets and bitrates. The Arm instances introduce 382.58% higher encoding costs on average than the corresponding x86 instances in all experiments.

As Arm instances imply 31.66% to 635.01% higher encoding costs compared to Intel-based and 4.09% to 736.90% for AMD basedx86 instances. Therefore, we do not identify any cost-saving potential. We explain the higher costs due to the high relative encoding time, as presented in the previous section.

c) Recommendation: The experimental results confirm that the x265 support in FFmpeg 4.3 is not yet optimized for Arm instances. We recommend using x86 instances.

2) Processor architecture:

- a) x86 encoding time: Figure 4a shows that the c family delivers the fastest encoding time in all experiments on x86 instances. Especially, the c5a instance with AMD processors is on average 15.65% faster than all other x86. In particular, c5a is on average 31.64% faster than t instances, 27.19% faster than x86 m and r instances, and 4.67% faster than c5 instances with Intel processor.
- b) Arm encoding time: Figure 4b shows that m6g.2xlarge is fastest in 66.08% of the experiments, followed by t4g.2xlarge in 23.39%. Overall, the relative encoding time among the Arm instances is negligibly small and in the range of measurement noise. More precisely, m6g.2xlarge is on average only 0.21%, t4g.2xlarge 0.13%, r6g.2xlarge 0.23%, and c6g.2xlarge 0.07% faster.
- c) Encoding cost: For all experiments, c5a.2xlarge achieves lowest encoding costs among x86 instances, and t4g.2xlarge among Arm instances. Specifically, the c5a instance with AMD processors reveals on average 15.65% lower cost than all other x86 instances and 13.65% lower average cost than the corresponding c5 instance with Intel processors. For comparison, the t4g.2xlarge reports only 1.34% lower cost among all Arm instances.
- d) Recommendation: The c5a.2xlarge instance shows the fastest encoding times and the lowest encoding cost for x86 instances in all experiments. Among the Arm instances, t4g.2xlarge competes with m6g.2xlarge for the fastest encoding time. However, t4g.2xlarge achieves the lowest encoding cost in all experiments.

VI. SUMMARY AND DISCUSSION

A. Summary

We summarize in this section our recommendations related to the video encoding time and cost for both codecs and processor architectures. In Figure 5 we provide accurate visual

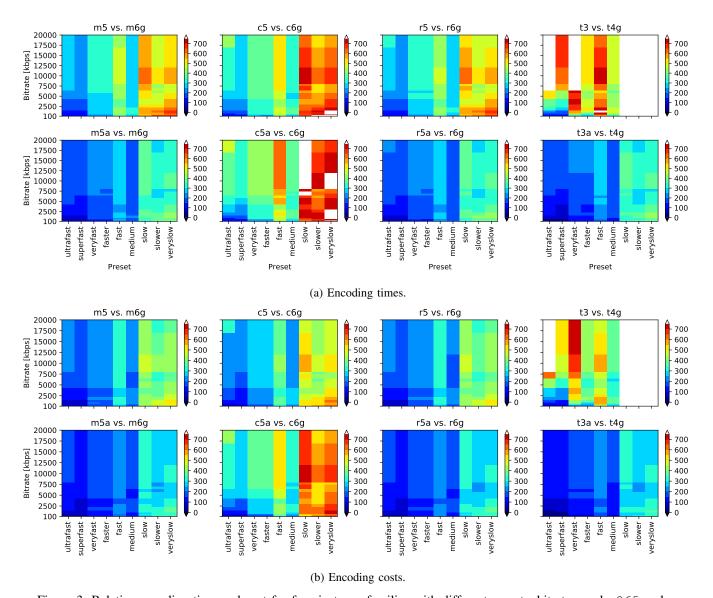


Figure 3: Relative encoding time and cost for four instance families with different presets, bitrates, and x265 codec.

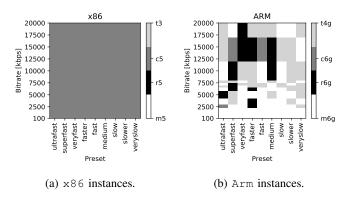


Figure 4: Fastest encoding instance for different encoding presets, bitrates, and x265 codec.

reference tables indicating the fastest and cheapest options for all evaluated instance families, presets, and bitrates for the $\times 264$ codec. As the results for $\times 265$ codec report a clear best performing instance family for the fastest time and lowest cost, independently from the preset and bitrate, we describe these results only textually.

1) Fast encoding:

a) x264 codec: Overall, we recommend x86 instances especially for bitrates lower than 8 Mbps and presets between "ultrafast" and "veryfast". As depicted in Figure 5a, we recommend Arm instances mainly for bitrates higher than 750 kbps and presets between "very fast" and "fast". Among all x86 instances, we recommend to use c instances and especially to prioritize the AMD based c5a over the Intel based c5 instance. Among all Arm instances, the m6g.2xlarge instance is the fastest, but with an advantage of only 1.15% on average.

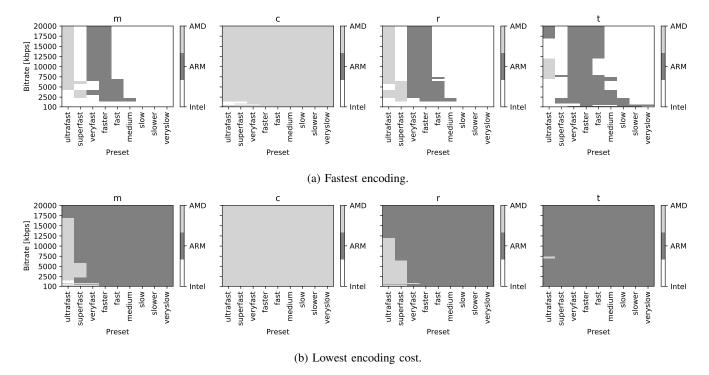


Figure 5: Reference table for fastest encoding times and lowest cost for four instance families with different presets, bitrates, and x264 codec.

b) x265 codec: We recommend x86 instead of Arm instances, as the x265 implementation in the latest FFm-peg version is not yet optimized for Arm. Among x86 instances, we recommend the AMD based c5a.2xlarge, which is on average 4.67% faster than the Intel based c5.2xlarge instance. Among the Arm instances, we recommend m6g.2xlarge as it achieves the fastest encoding times in most experiments.

2) Low cost encoding:

a) x264 codec: Overall and as presented in Figure 5b, we recommend x86 instances for bitrates lower than 8 Mbps and presets between "ultrafast" and "superfast". Among all x86 instances, we recommend to use c instances and to prioritize the AMD based c5a instance. We recommend Arm instances for m, r, and t instances especially for presets between "very fast" and "veryfast". In particular, Arm instances reduce the encoding cost of up to 33.63% compared to x86. We observe that c5a achieves the lowest encoding cost among x86, and t4g.2xlarge among Arm instances.

b) x265 codec: We recommend using x86 instances that generate on average 382.58% lower encoding costs than Arm instances. The c5a.2xlarge instance achieves 15.65% lower average cost among x86 instances and on average 13.65% lower cost than c5.2xlarge instances. Among Arm instances, the t4g.2xlarge reveals lowest cost in all experiments, but the advantage is just 1.34%.

B. Discussion

The pricing model of AWS ranks the instances in descending order with Intel x86 instances with highest cost, followed by AMD based x86 as middle cost, and Arm instances as low-cost alternatives. We observe that the instance performance primarily follows this pricing model. However, as cost and performance are two conflicting objectives, we also analysed the cost to performance ratio. We revealed that for specific settings and codecs the low cost Arm instances can outperform faster and higher price x86 instances. We explain this observation by the different instruction set architecture (ISA) of both processors types.

In particular, the x86 CPUs use Complex Instruction Set Computing (CISC) while Arm uses Reduced Instruction Set Computing (RISC). With other words, the former uses more complex instructions with several cycles while Arm uses only one cycle to execute a single instruction. Consequently, we identified the software support for Arm instances as an important aspect that affects the performance. For example, we observed a high performance discrepancy between Arm and x86 instances for the compute intensive x265 codec. We explain the discrepancy through the fact that the FFmpeg 4.3 is not yet optimised for Arm instances.

Besides, the performance depends on the hardware allocation of the cloud provider. For example, the default allocation of Amazon EC2 uses hyper-threading that assigns on x86 instances one logical hyper-threaded core to a vCPU (except t2). In contrast, the Arm instances assign one physical core

Table III: Encoding recommendation summary.

Goal Codec	Fast encoding	Low cost		
x264	x86 (c5a) Arm (m6q)	Arm (t4g)		
	AIM (Mog)			
x265	x86 (c5a)	x86 (c5a)		

to a vCPU [7] in the absence of hyper-threading. This fact enables companies 1 , such as Snap Inc reducing CPU utilization by roughly 10%, Honeycomb.io running 30% fewer instances, and NextRoll saving up to 50% cost compared to previous generation EC2 instances for their workloads.

Overall, with continuously improving software support and optimisation for Arm, we forecast a decreasing performance difference between Arm and x86 instances which also applies for video encoding tasks.

VII. CONCLUSION

In this paper, we provide a performance analysis for video encoding tasks of Arm and $\times 86$ instances of four Amazon EC2 instance families with three different processors. We conducted a total of 20.520 experiments in two evaluation scenarios for the two most widely used video codecs.

Table III summarises our recommendations based on the evaluation results related to the encoding time and cost.

The evaluation results clearly reveal that the Arm instances can achieve faster encoding times at a lower cost than the corresponding $\times 86$ instances. However, the encoding performance of Arm and $\times 86$ instances depends on many factors such as bitrate, preset, and codec. Independently from the codec, we show that the $\times 86$ c instance and specifically the AMD based c5a instance achieves fast encoding times at a lower cost in most experiments, which makes it suitable for general encoding use.

In summary, regarding the measured encoding performance potential for specific encoding settings and the continuously improving support of Arm instances, we forecast a decreasing performance difference between Arm and x86 instances.

In the future, we plan to extend our analysis with different emerging codec implementations and longer video segments to generalize our recommendations. Furthermore, we will perform an in-depth analysis of overprovisioning by evaluating x86 instances with various CPU options [7] for the fastest instance setup.

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