Adopting Modern Image Codecs at Scale

Zuzanna Mroczek, Erik André

ICIP 2024, Abu Dhabi

Meta

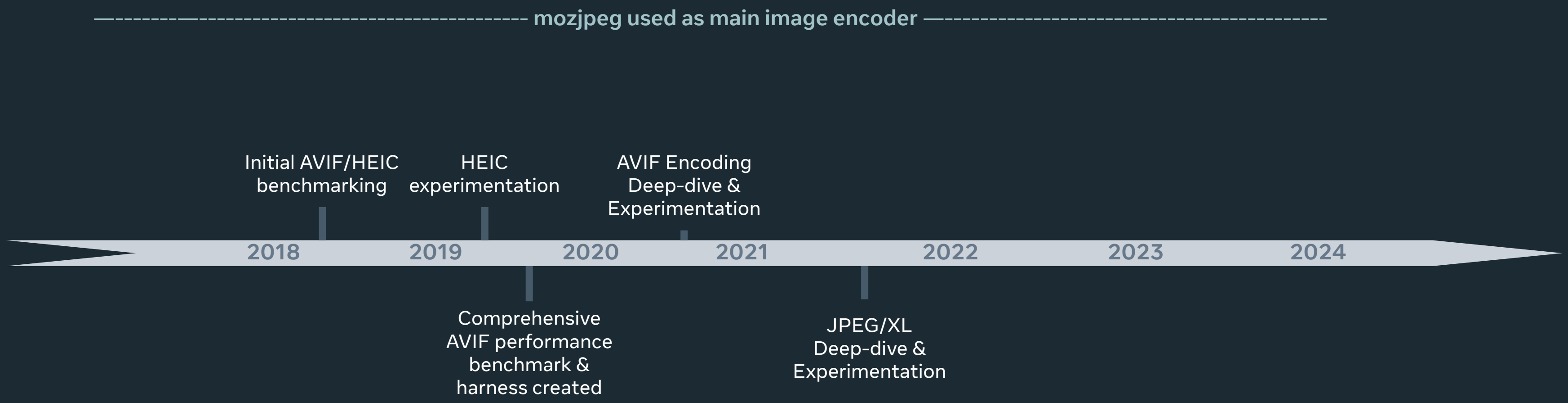
Every day, we handle **billions of image uploads and trillions of image download requests** on our CDN.

Good image quality experience in our apps is highly constrained by **image loading & upload times, data usage, battery life, memory efficiency, encode/decode latencies** and **app-binary size**.

Small changes in efficiency are magnified across each quality experience dimension.

Image Formats @ Meta

IMAGE FORMATS TIMELINE



mozjpeg used as main image encoder

Initial AVIF/HEIC benchmarking

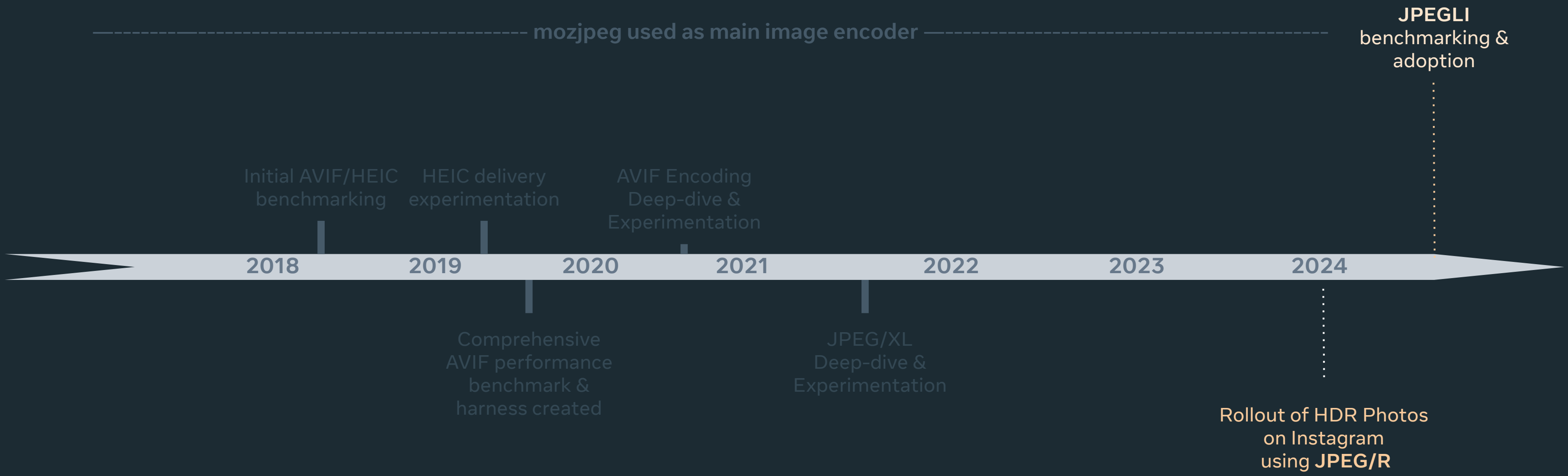
HEIC experimentation

AVIF Encoding Deep-dive & Experimentation

Comprehensive AVIF performance benchmark & harness created

JPEG/XL Deep-dive & Experimentation

IMAGE EXPERIENCE IMPROVEMENTS TIMELINE



mozjpeg used as main image encoder

JPEGLI benchmarking & adoption

Initial AVIF/HEIC benchmarking

HEIC delivery experimentation

AVIF Encoding Deep-dive & Experimentation

2018

2019

2020

2021

2022

2023

2024

Comprehensive AVIF performance benchmark & harness created

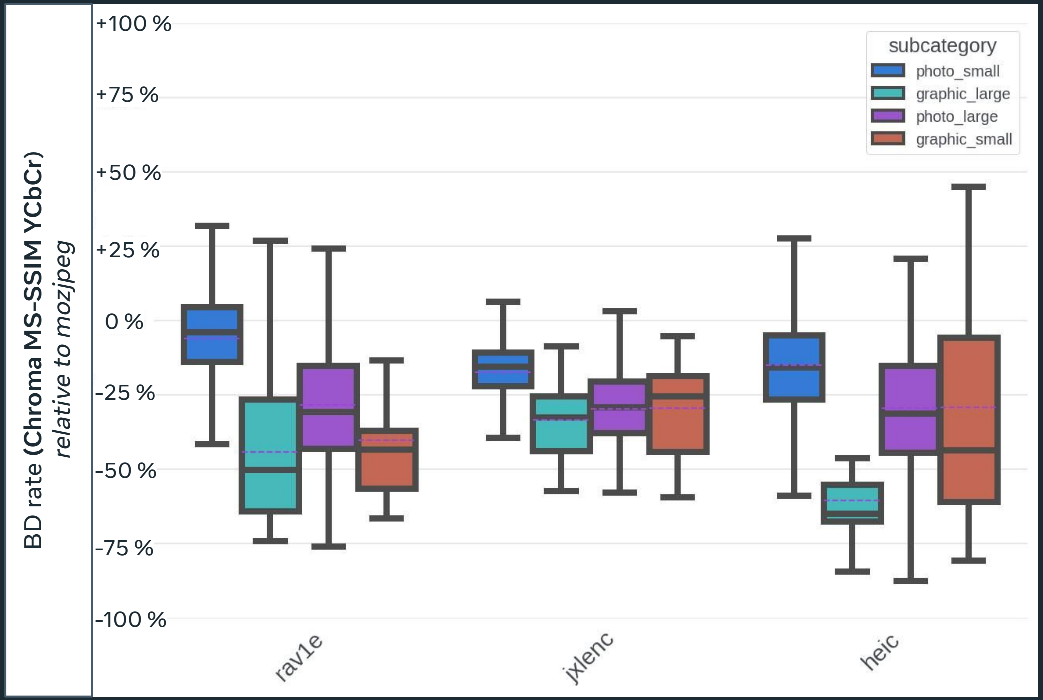
JPEG/XL Deep-dive & Experimentation

Rollout of HDR Photos on Instagram using **JPEG/R**

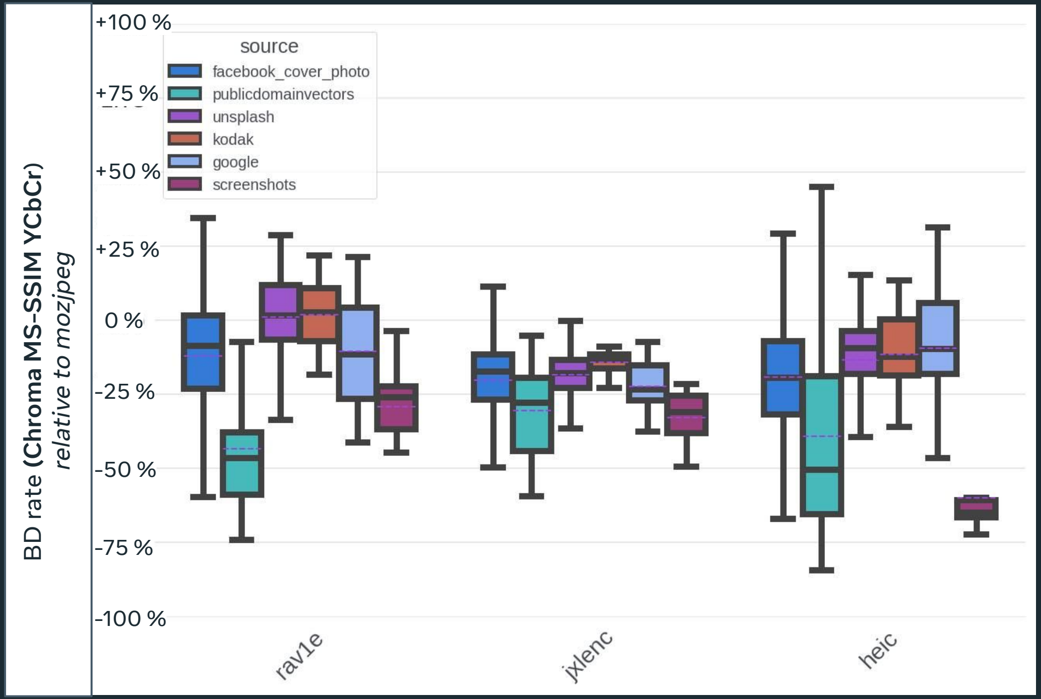
Compression Rate Benchmarks

Meta

Compression Rate Benchmarks: Content Type



Compression Rate Benchmarks: Public Datasets



Compression Rate Benchmarks: Chroma MS-SSIM (YCbCr, public datasets)

Dataset	Algorithm	Pearson	Kendall	Spearman	Avg. time (sec)
Kadid-10k	chroma MS-SSIM	**0.70737** (stat-sig)	**0.65774** (stat-sig)	**0.84814** (stat-sig)	0.12136
	grayscale MS-SSIM	0.68416	0.63017	0.82047	0.06241
tid2013	chroma MS-SSIM	**0.7959** (stat-sig)	**0.65811** (stat-sig)	**0.85375** (stat-sig)	0.11151
	grayscale MS-SSIM	0.77625	0.60449	0.7897	0.05231
CLIVE	chroma MS-SSIM	**0.75935**	**0.59028**	**0.79169**	0.13709
	grayscale MS-SSIM	0.74912	0.5844	0.786	0.0625
LIVE	chroma MS-SSIM	**0.63109**	**0.819**	**0.95093**	0.20749
	grayscale MS-SSIM	0.62556	0.80868	0.9454	0.09105
tid2008	chroma MS-SSIM	**0.7959**	**0.65811**	**0.85375**	0.11151
	grayscale MS-SSIM	0.78254	0.64775	0.84775	0.05212

Challenges with Image Quality Metrics across Image Formats

original

JPEG

MS-SSIM: 0.997

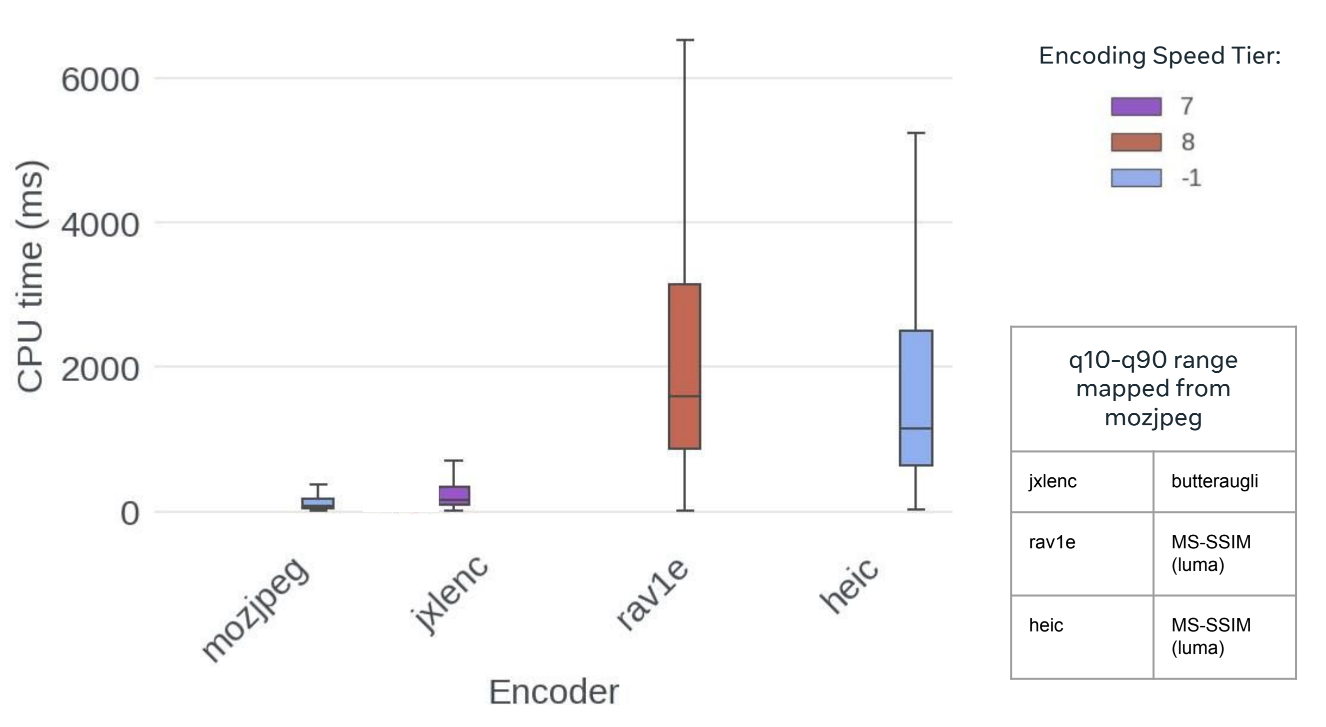
AVIF

MS-SSIM: 0.986

2021 Performance Benchmarks

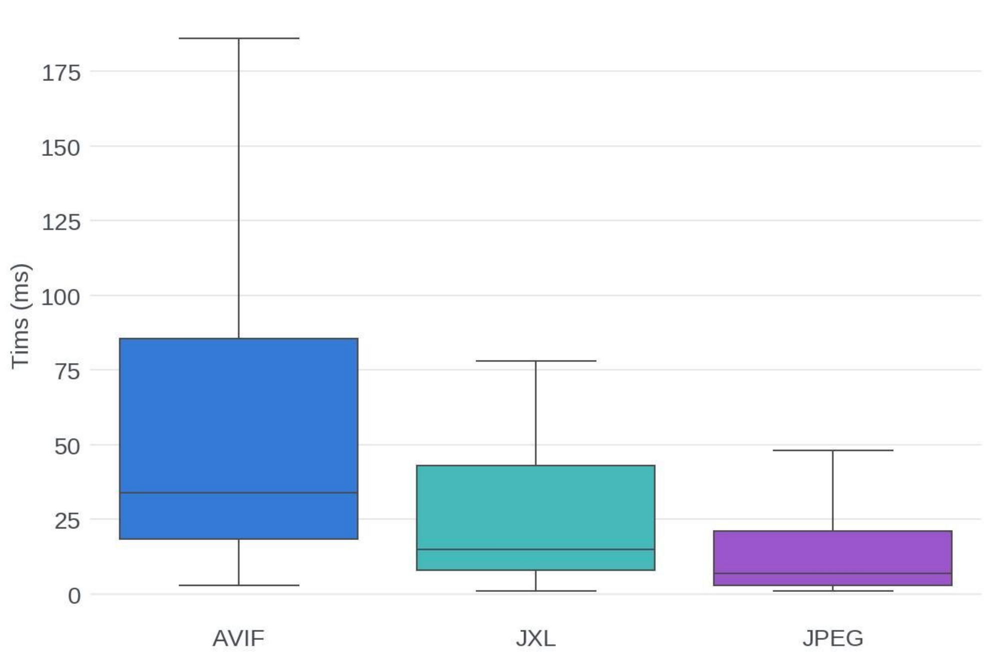
Meta

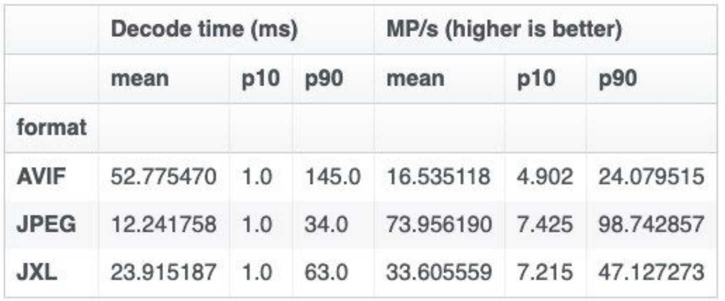
2021 Encoding Speed (Single-threaded): x86-64 CPU



q10-q90 range mapped from mozjpeg	
jxlenc	butteraugli
rav1e	MS-SSIM (luma)
heic	MS-SSIM (luma)

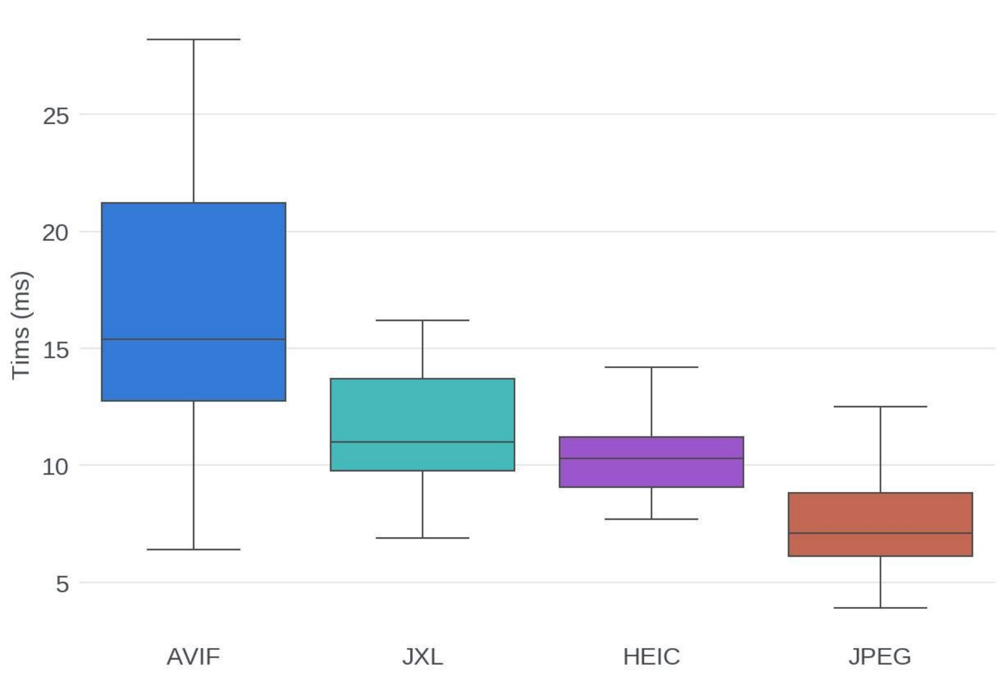
2021 Decoding Speed: Android – Pixel 4

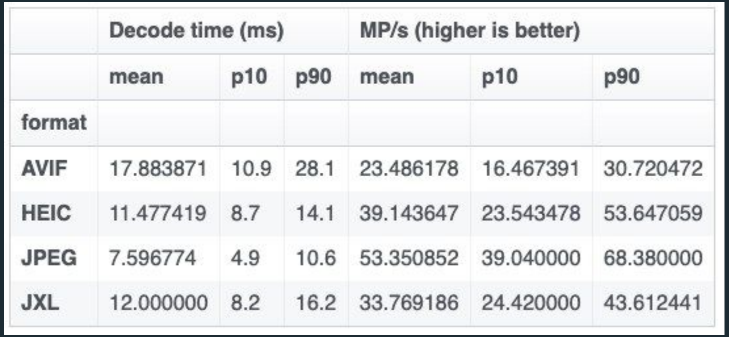




	Decode time (ms)			MP/s (higher is better)		
	mean	p10	p90	mean	p10	p90
format						
AVIF	52.775470	1.0	145.0	16.535118	4.902	24.079515
JPEG	12.241758	1.0	34.0	73.956190	7.425	98.742857
JXL	23.915187	1.0	63.0	33.605559	7.215	47.127273

2021 Decoding Speed: iOS – iPhone 12 Pro



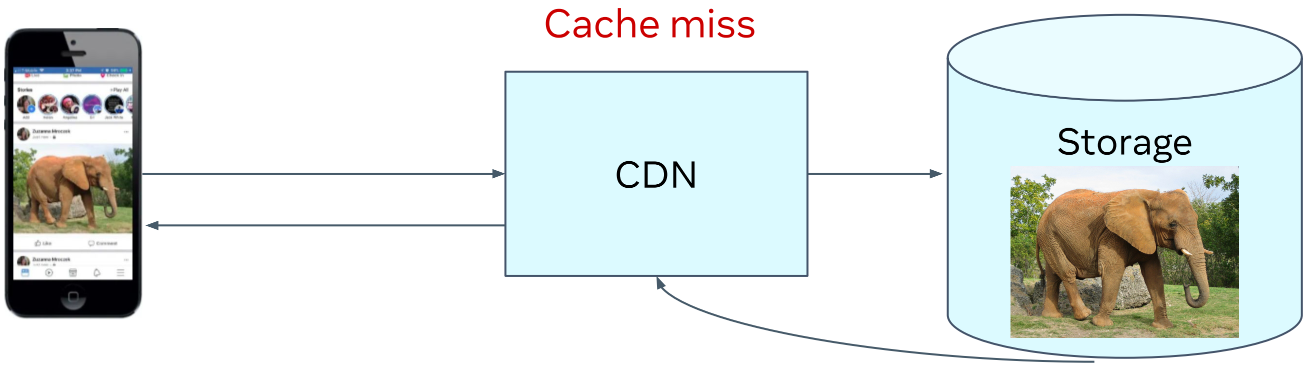


	Decode time (ms)			MP/s (higher is better)		
	mean	p10	p90	mean	p10	p90
format						
AVIF	17.883871	10.9	28.1	23.486178	16.467391	30.720472
HEIC	11.477419	8.7	14.1	39.143647	23.543478	53.647059
JPEG	7.596774	4.9	10.6	53.350852	39.040000	68.380000
JXL	12.000000	8.2	16.2	33.769186	24.420000	43.612441

2021 Real-world Performance

Meta

2021 JPEG XL Experimentation Architecture

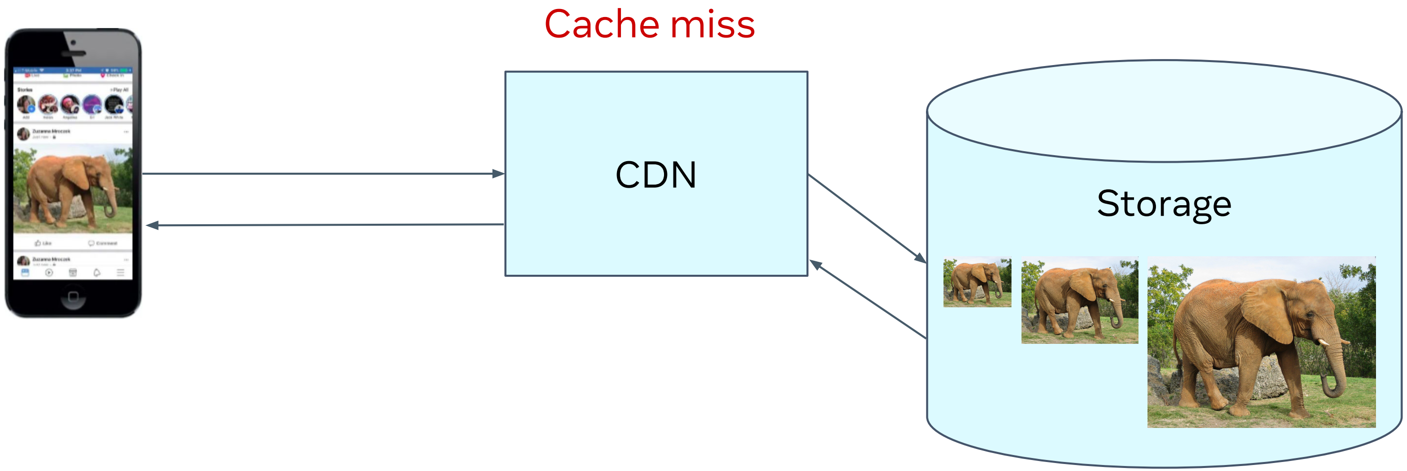


Cache miss

CDN

Storage

2021 AVIF Experimentation Architecture



Cache miss

CDN

Storage

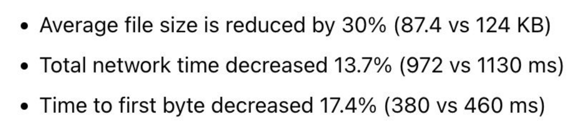
2021 Experimentation Results: AVIF

AVIF in FBiOS Story Viewer
(Vietnam)

No encoding in CDN
+
~30% file-size savings
+
328% increase in avg client decoding time
(141 vs 43 ms)

=

Images Load Slower



- Average file size is reduced by 30% (87.4 vs 124 KB)
- Total network time decreased 13.7% (972 vs 1130 ms)
- Time to first byte decreased 17.4% (380 vs 460 ms)

2021 Experimentation Results: JPEG XL

JPEG XL in Facebook for Android Story Viewer
(BR; CA; MX; US)

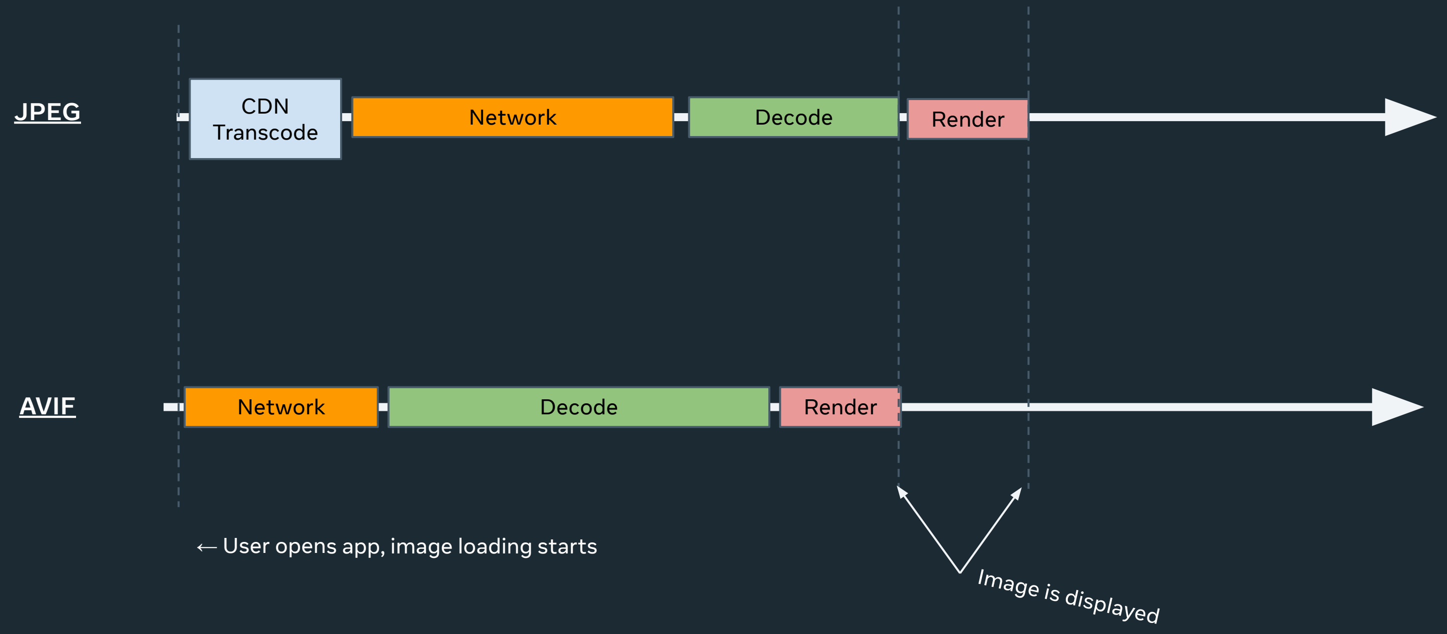
Encoding latency in CDN on par with JPEG
(4 threads)
+
~5-15% file-size savings
+
60-80% regression in avg client decoding time
(96 ms vs 53 ms)

=

Images Load Slower

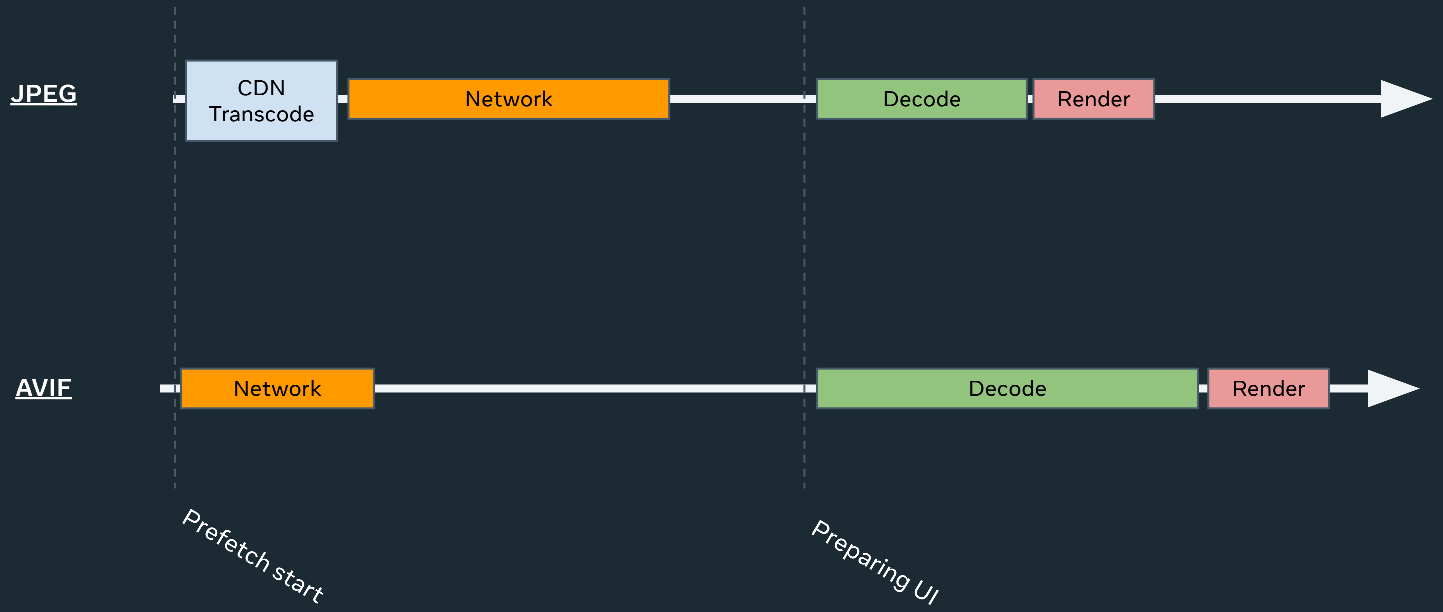
Factors in End-to-end Image Latency

End-to-end Image Rendering Timeline



Meta

End-to-end Image Rendering Timeline (Prefetched)



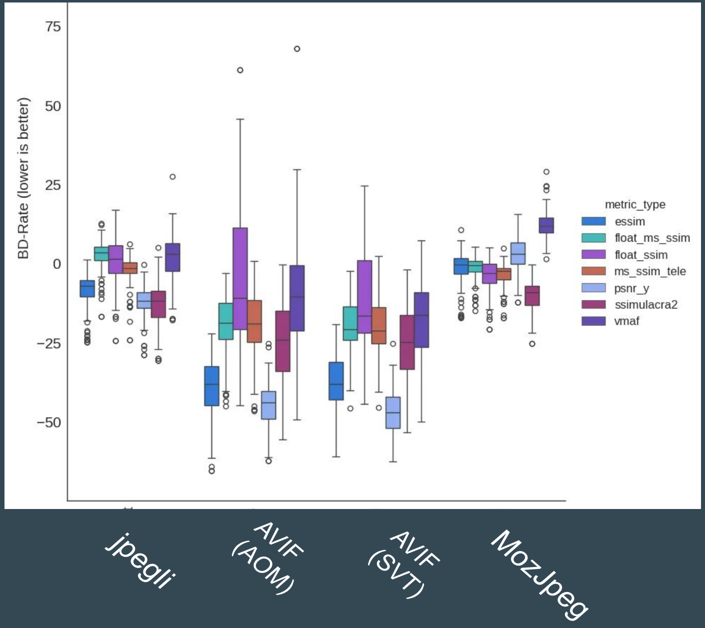
Meta

Improvements in Legacy Formats

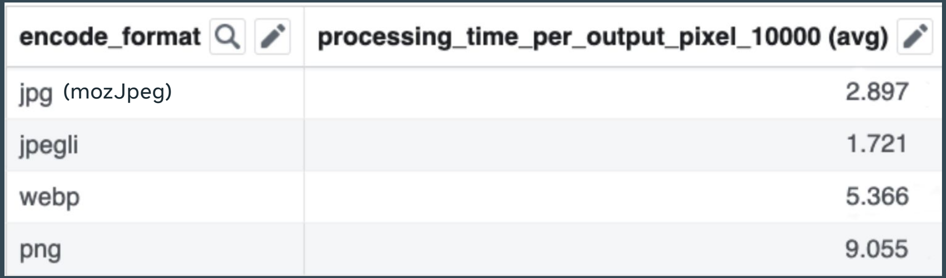
Meta

Jpegli compared to MozJpeg / AVIF

Compression BD-rates
(compared to libjpeg-turbo)



Encode Latency



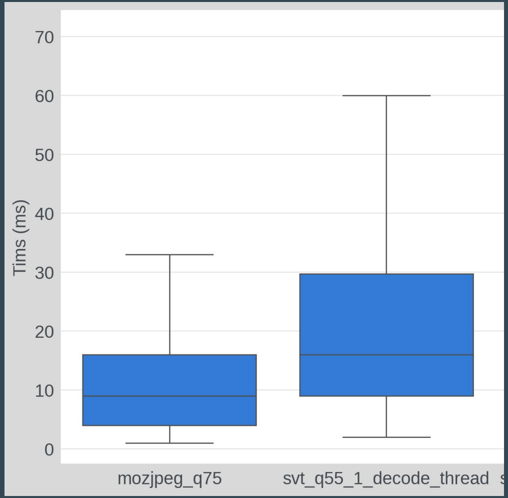
encode_format	processing_time_per_output_pixel_10000 (avg)
jpg (mozJpeg)	2.897
jpegli	1.721
webp	5.366
png	9.055

The future is looking bright for AVIF

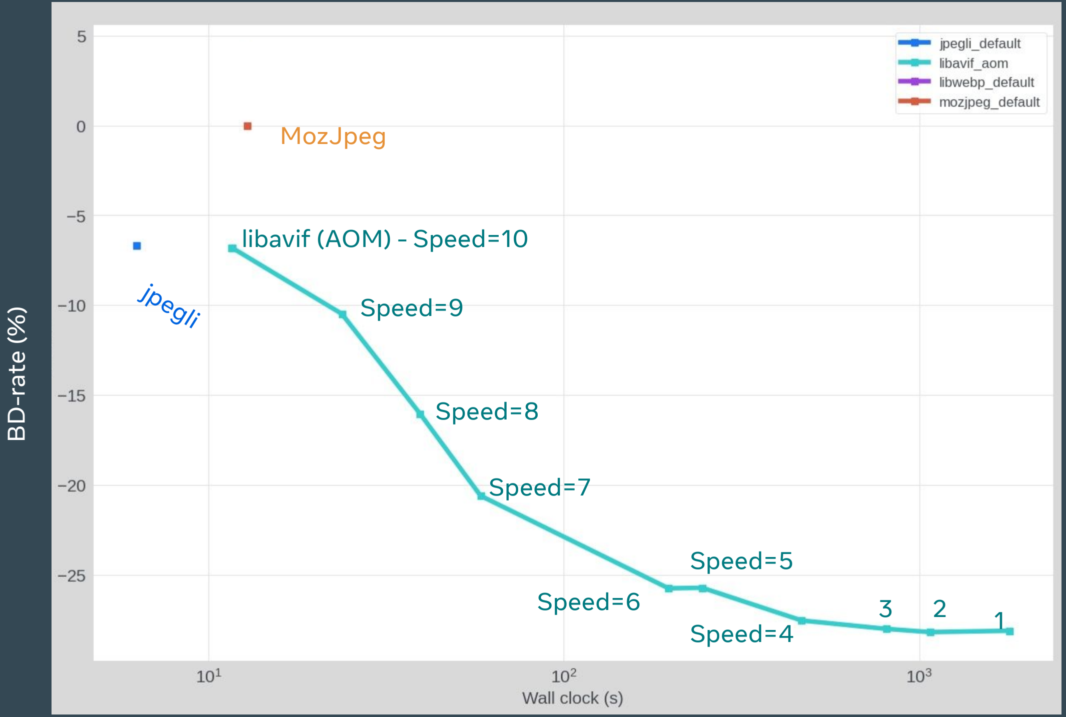
Meta

AVIF Codec Performance Revisited

Mobile decode latency
Software decoder (dav1d)
Pixel 8 (Android)



Encode latency vs BD-rates
SSIMULACRA 2.1



All time measurements in wall time, which for single threaded operations = system + user CPU

Key takeaways

- Compression efficiency is not enough when considering to adopt a modern image format at scale
- SW codec performance more critical than HW performance
- Quality comparison between formats is highly subjective
- HDR images is still an evolving field, with competing standards

Meta