Alice: Low-latency Image Live Co-editing via Adaptation
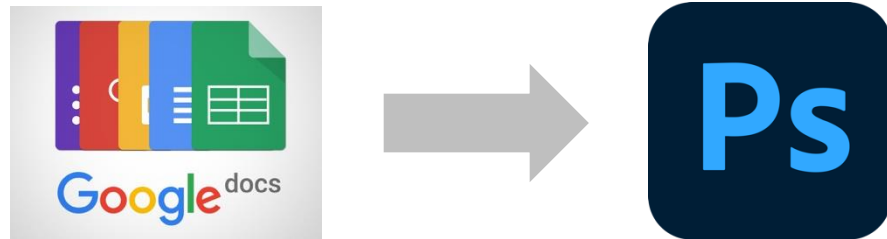
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Image Live Co-editing (LCE)

- Flexible remote collaboration
- Requirements
  - Lossless edit update
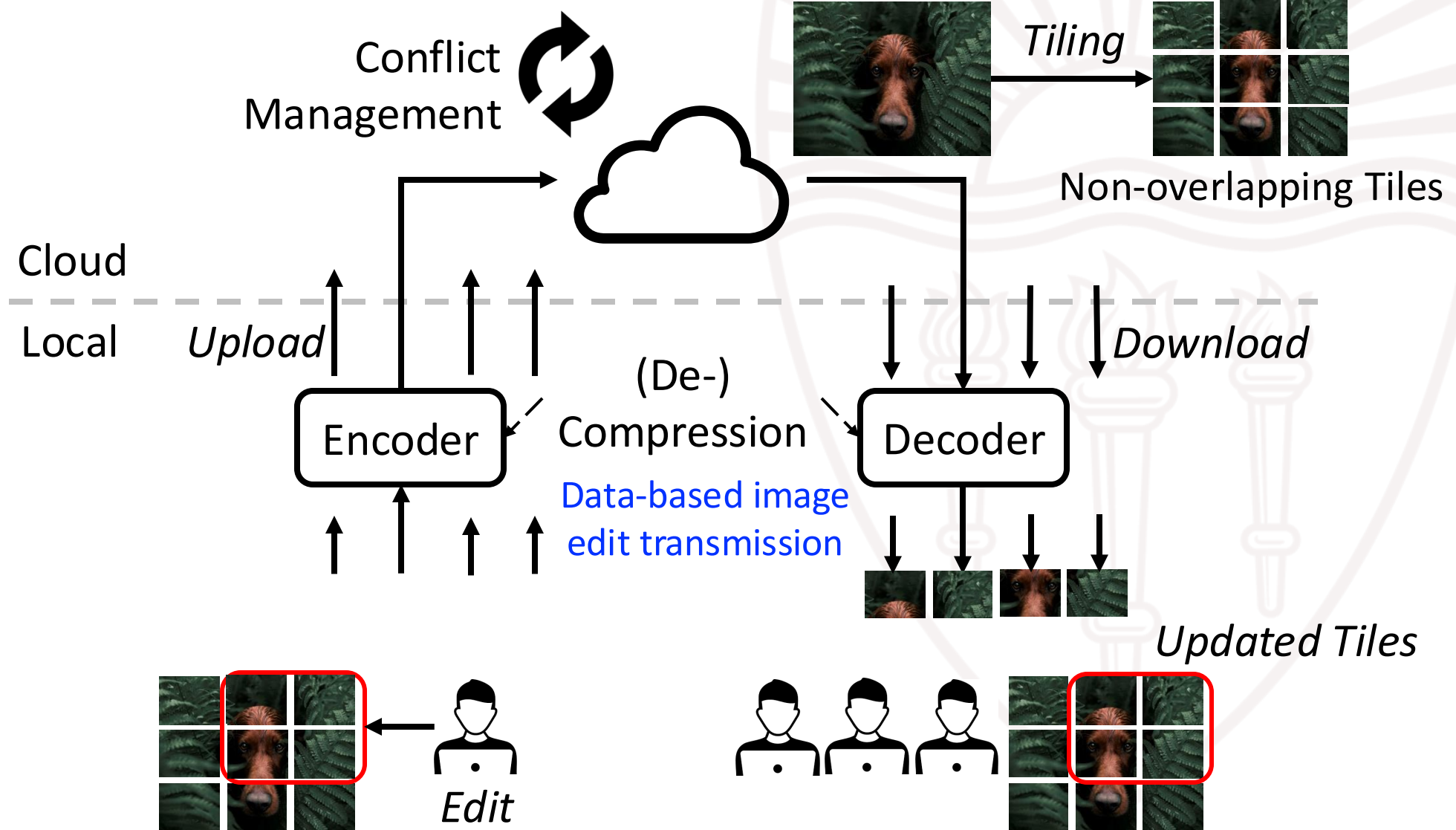 - Low-latency user experience
  - Scalability to large groups

[1] https://blog.adobe.com/en/publish/2025/01/14/photoshop-unlocks-creative-collaboration-with-live-co-editing-join-private-beta

A Cloud-based Image LCE System

A Cloud-based Image LCE System
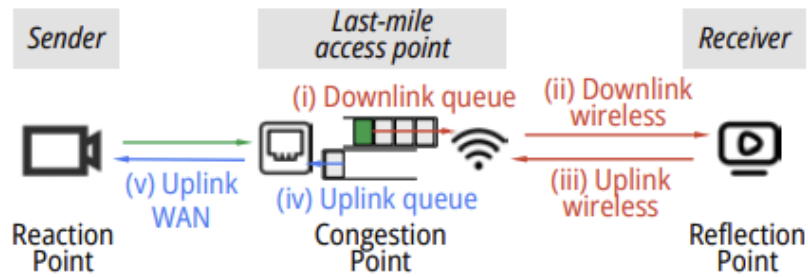
Conflict Management

Tiling

Non-overlapping Tiles

Cloud

Local

Upload

Download

(De-) Compression

Encoder

Decoder

Data-based image edit transmission

End-to-end latency of image edit transmission

Edit

Updated Tiles

USC

A Cloud-based Image LCE System

Conflict Management

Tiling

Non-overlapping Tiles

Cloud

Local

Upl...

Hard to keep consistently low latency under dynamic network/compute resources.

Download

Data-based image edit transmission

End-to-end latency of image edit transmission
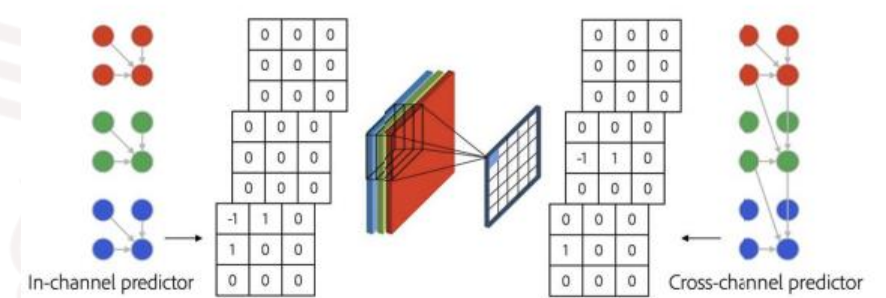
Updated Tiles

Edit

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Latency Reduction: Existing Work

Reducing in-network delay, e.g., Zhuge [SIGCOMM'22]

Adaptive streaming (a lot)

GPU-accelerated compression, e.g., Shen et al. [ISM'23]

[1] Meng, Zili, et al. Achieving consistent low latency for wireless real-time communications with the shortest control loop. ACM SIGCOMM 2022.
[2] Shen, Yu, et al. Gpu-accelerated lossless image compression with massive parallelization. IEEE ISM. 2023.

Latency Reduction: Existing Work

Adaptive streaming is designed for lossy compression

Restricted ratio of lossless compression may still bottleneck the latency

Reducing in-network delay,
e.g., Zhuge [SIGCOMM'22]

Adaptive streaming (a lot)

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Our Solution: Alice

- Hybrid image edit transmission
  - Data-based: pixels
  - Operation-based: operation API and parameters

- Adaptive data-based transmission
  - Multiple lossless compression frameworks

- Unified transmission strategy decision framework
  - Lookup table (LUT)

Edit operation   API & Params   Replay

Pixels
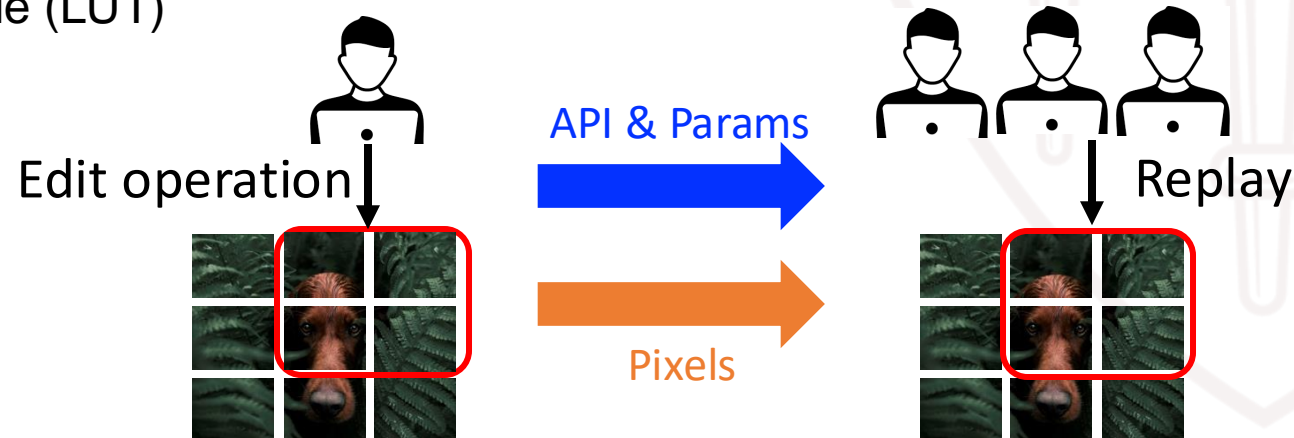
Hybrid Image Edit Transmission

- Key insight
  - Heterogeneity of operation-based and data-based approaches
  - Many commonly-used operations require little computation resource (from our user study)

- Combine operation- and data- based approaches
  - Keep a common operation set for any platform
  - Monitoring if operation involves any private asset

Low bandwidth demand, compatibility issue due to asset ownership, computation requirement, etc.

API & Params

Edit operation

Replay

Pixels
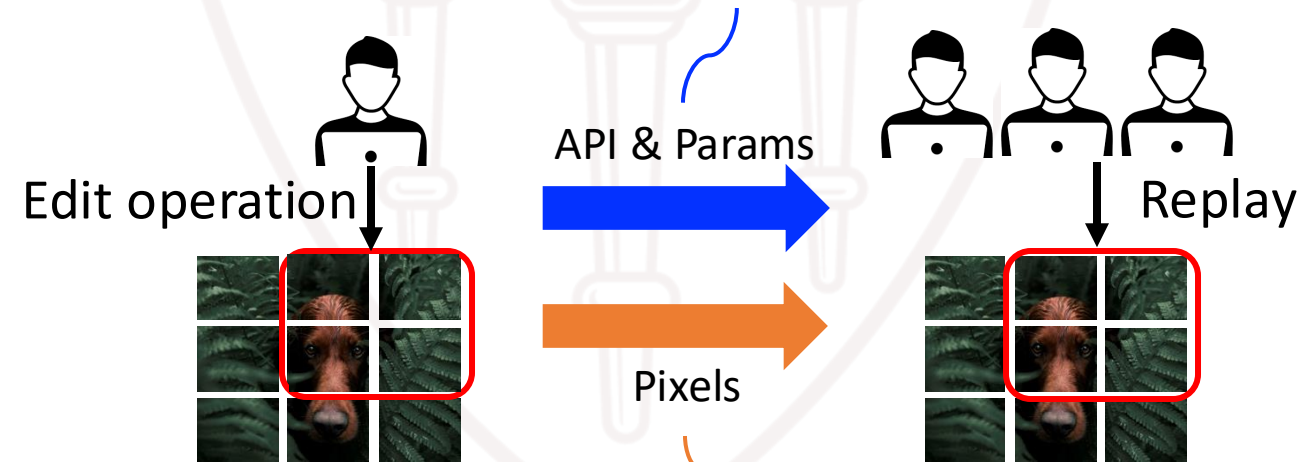
High bandwidth demand, high cross-platform compatibility

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Improve the Adaptability of Data-based Approach

- Key insight
  - Heterogeneity of different lossless compression techniques

- Dynamically configure lossless compression based on network/compute resource
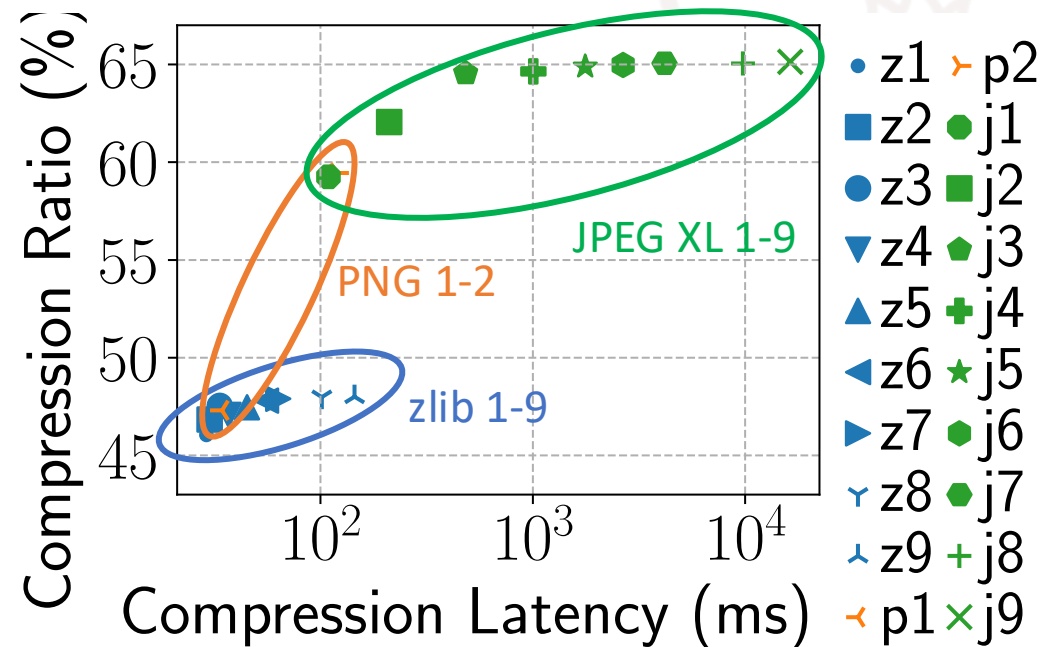
Compression ratio vs. latency of zlib, PNG, JPEG XL

Real-time Strategy Selection

- Challenges
  - Large search space
  - The latency of each strategy is unknown at runtime
  - The decision-making algorithm needs to be lightweight, fast, and cross-platform compatible

- A unified lookup table (LUT) based fast strategy decision
  - Built through offline profiling

Bandwidth	Cmpr Latency	Cmpr Ratio	Cmpr Config
0 − B1			
B1 − B2			
B2 − B3			
...	...		
> Bn			

dataLUT

OpID	Sub-LUT
1	
2	
...	...

Op1 Params Config	Execution Speed
Config 1	
Config 2	
...	...
default	

opLUT

Holistic View of Alice
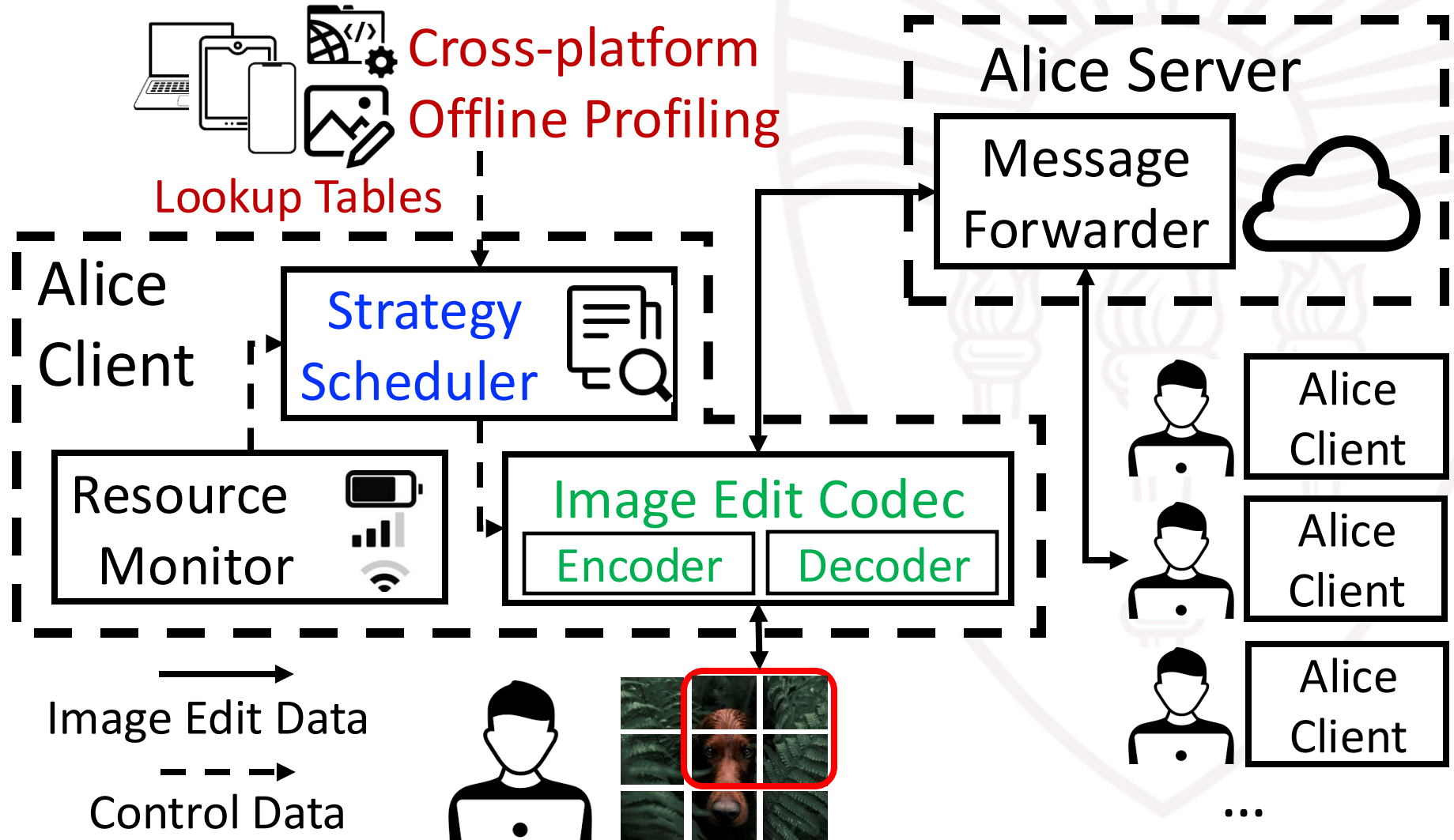
Cross-platform Offline Profiling

Lookup Tables

Alice Client

Strategy Scheduler

Resource Monitor

Image Edit Codec

Encoder | Decoder

Alice Server

Message Forwarder

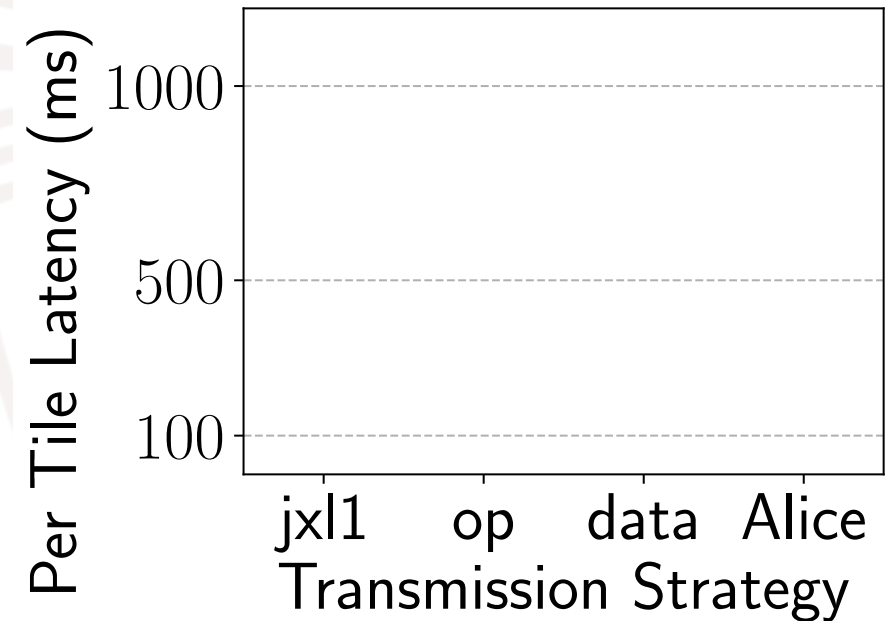Alice Client

Alice Client

Alice Client

...

→ Image Edit Data

⇢ Control Data

Implementation & Evaluation

- Implementation (4.9k+ LoC in C/C++)
  - An image LCE evaluation platform
  - Our Alice framework
    - zlib, PNG, JPEG XL (jxl)

- Trace-driven evaluation (single thread)
  - *jxl1*: always JPEG XL-1
  - *op*: always operation-based
  - *data*: always data-based

Tile resolution = 1024^2, # of editors = 2

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Lowest medium and average latency!
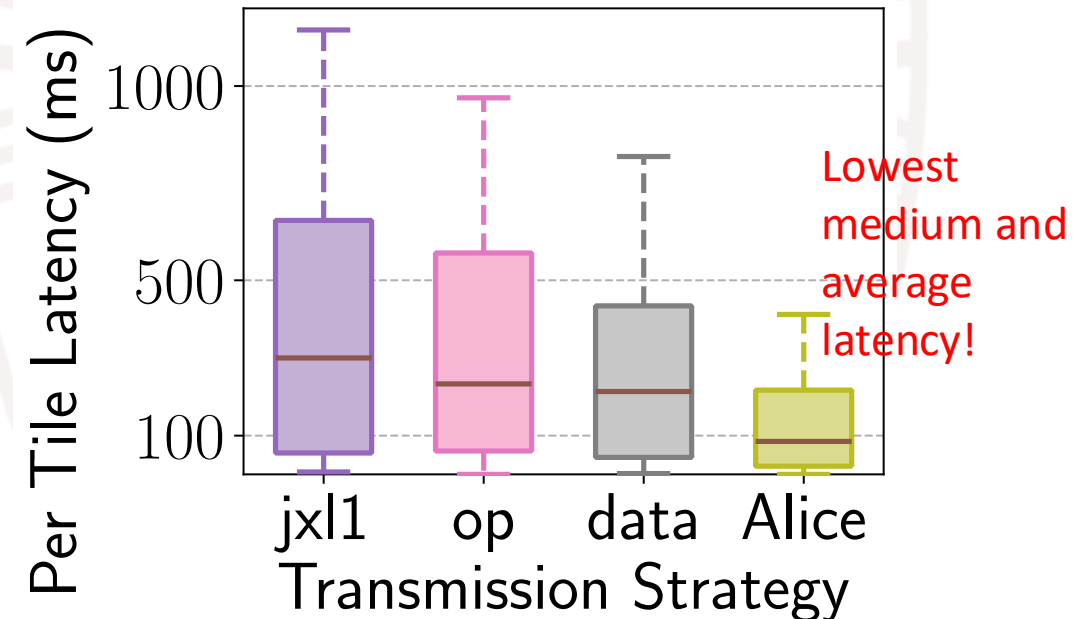
Tile resolution = 1024^2, # of editors = 2

- Alice outperforms all the baselines in terms of medium and average per-tile latency
- Alice consistently outperforms all the baselines when scaling up to 10 editors
- Alice incurs negligible overhead

Summary

- Challenges for low-latency image live co-editing

- The design of Alice: a cross-platform compression adaptation framework
    - Hybrid image edit transmission
        - data-based + operation-based
    - Improve adaptability of data-based approach
    - A LUT-based unified real-time strategy selection solution

- The implementation, integration, and thorough evaluation of Alice

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