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THE ADVANCED COMPUTING SYSTEMS ASSOCIATION

FAST'25

# Archer: Adaptive Memory Compression with Page-Association-Rule Awareness for High-Speed Response of Mobile Devices

**Changlong Li**, Zongwei Zhu, Chao Wang, Fangming Liu, Fei Xu,
Edwin H.-M. Sha, and Xuehai Zhou

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1 **Background & Motivation**

2 Design

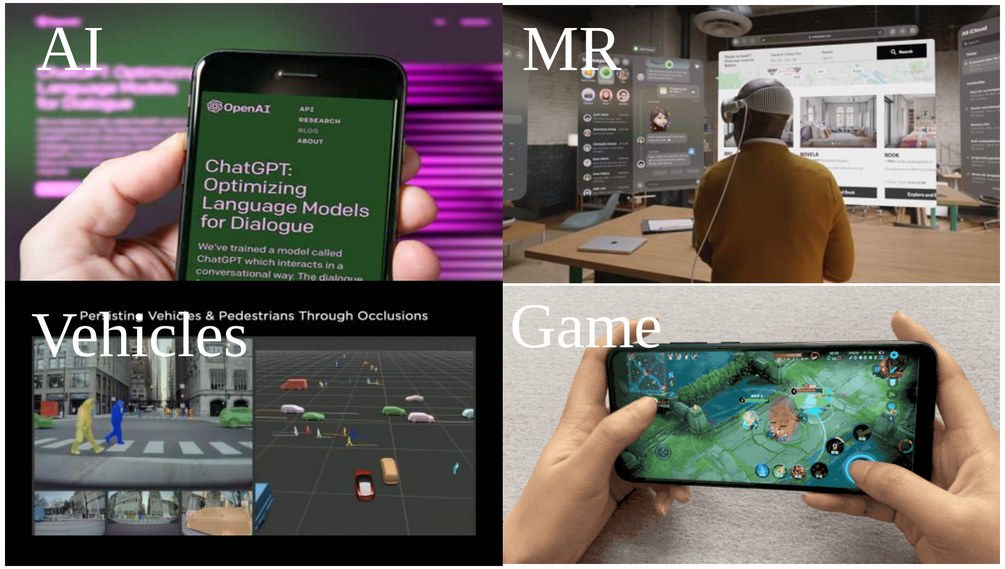
3 Evaluation

4 Conclusion

# Emerging Mobile Scenarios

- People spend more and more time on mobile devices (e.g., smartphones, autonomous vehicles, and robots)
- Emerging scenarios make the memory issue more serious
  - VR/MR, transformer-based models, mobile games, camera-based services

Mobile Devices


AI
OpenAI
ChatGPT: Optimizing Language Models for Dialogue
We've trained a model called ChatGPT which interacts in a conversational way. The dialogue
MR
Vehicles
Persisting Vehicles & Pedestrians Through Occlusions
Game

Memory-intensive apps in mobile scenarios

# Memory Issue in Mobile Scenarios

- Memory compression is widely adopted to save space
- Page compression limits system performance and degrades the user experience
  - Typical scenarios studied: **app launching**, **continuous shooting**, and **short-form video**

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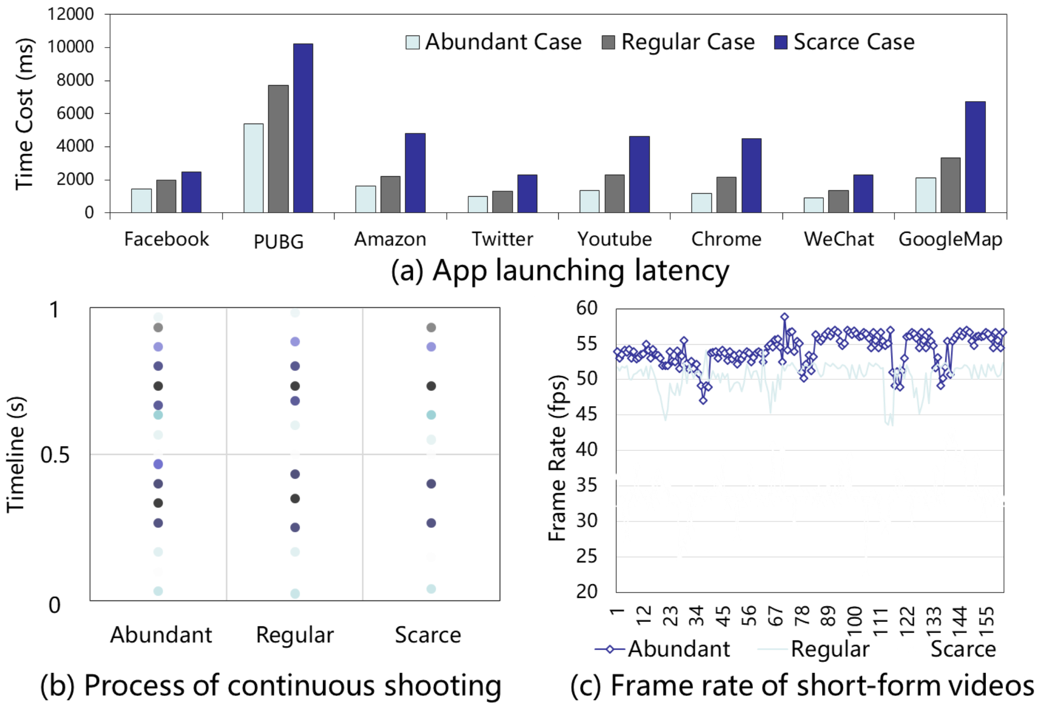

(a) App launching latency

(b) Process of continuous shooting

(c) Frame rate of short-form videos

**Response time** significantly increases **with compression**.

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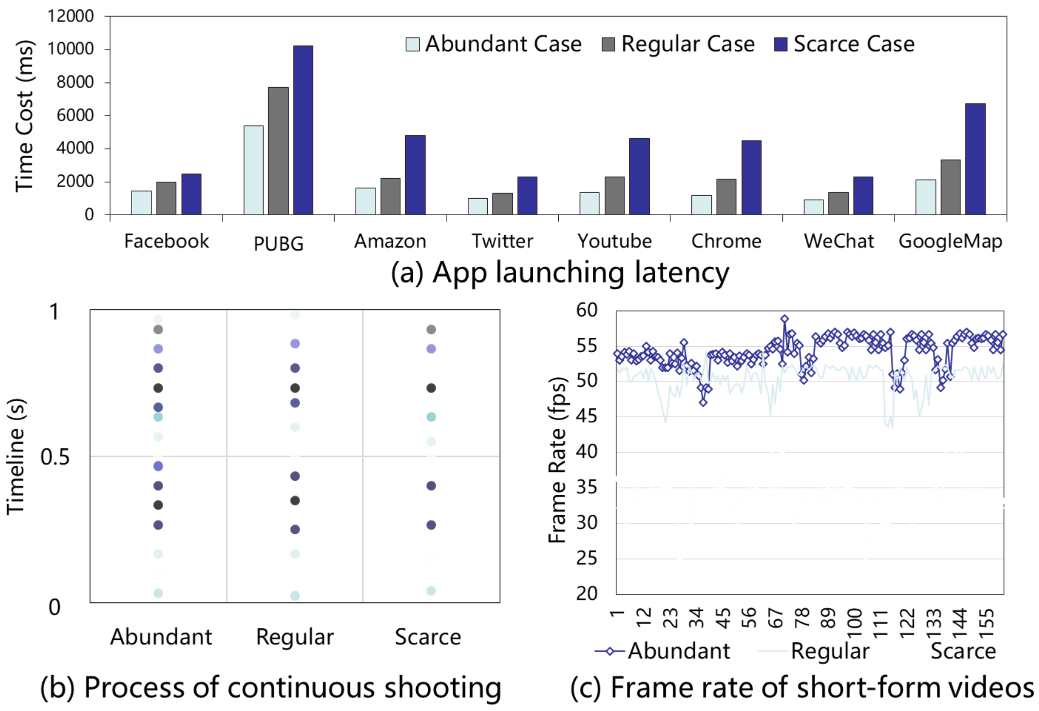

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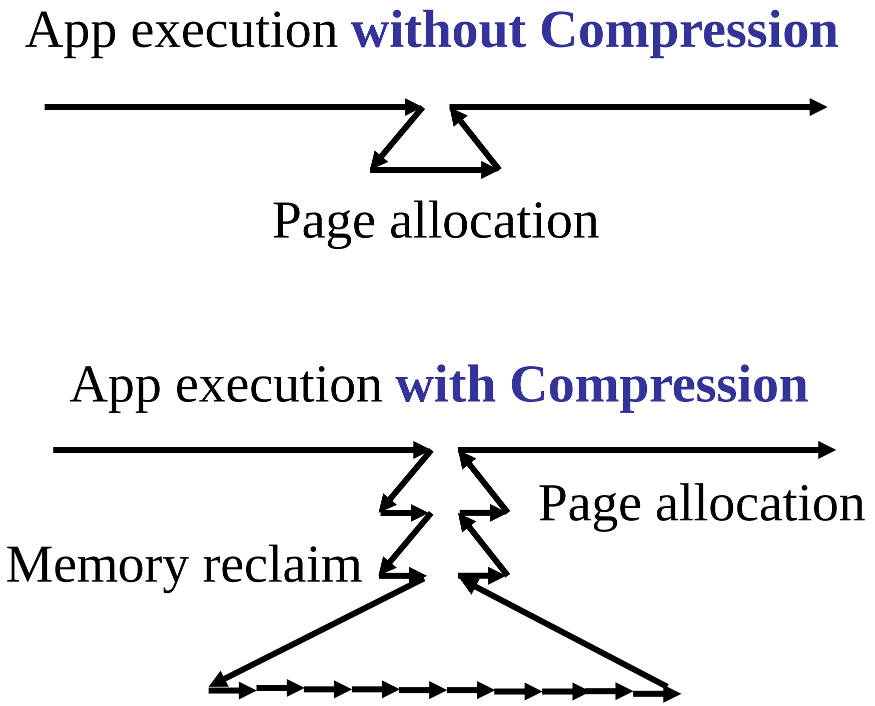
App execution **without Compression**
Page allocation
App execution **with Compression**
Page allocation
Memory reclaim

**Page-by-page compression**

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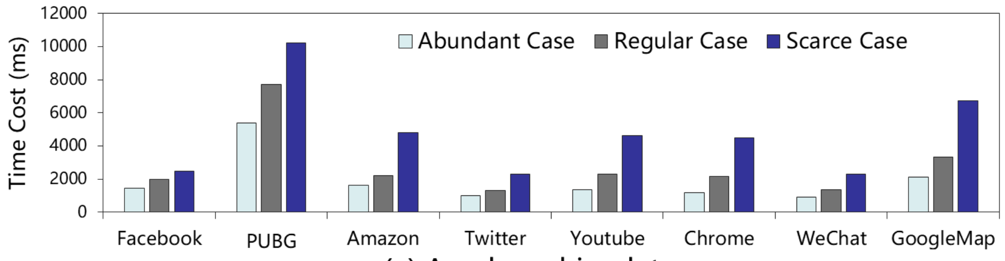

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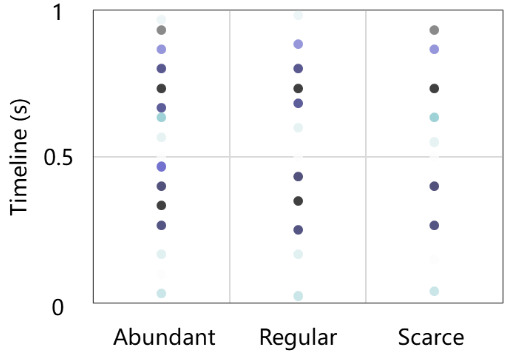
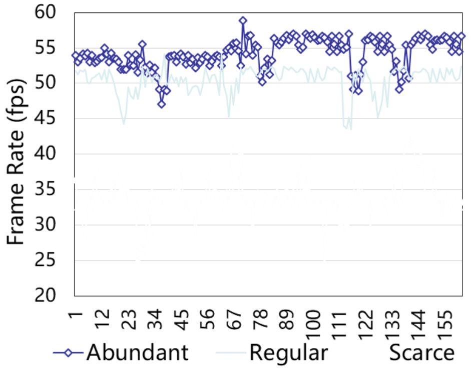
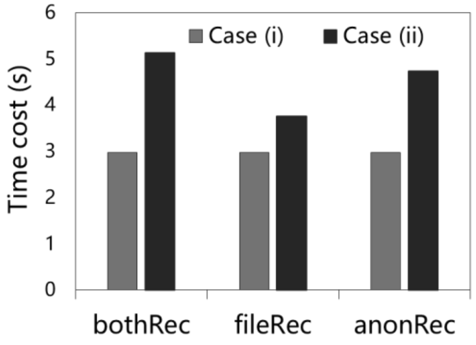


(b) Process of continuous shooting

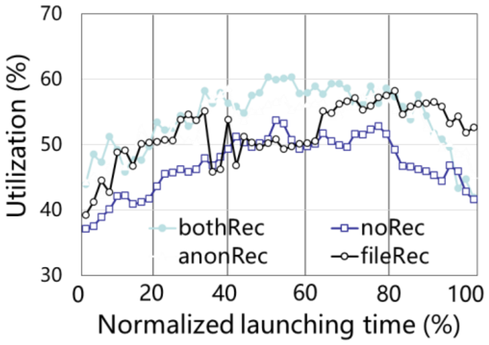


(c) Frame rate of short-form videos

**Response time** significantly increases **with compression**.

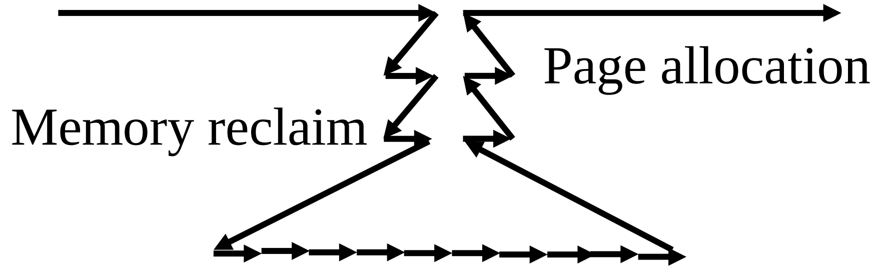


(a) App launching time



(b) CPU utilization

App execution **with Compression**



Page allocation

Memory reclaim

**Page-by-page compression**

# Opportunities of Large-grain Compression

- Page compression is reasonable: minimize the read amplification
- ***Can we do large-grain compression without increasing read amplification?***

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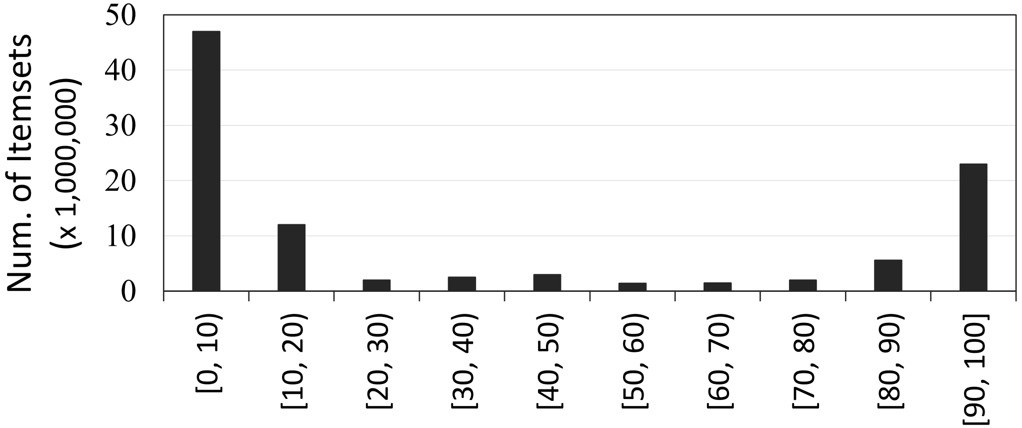
- Page compression is reasonable: minimize the read amplification
- ***Can we do large-grain compression without increasing read amplification?***
- Observation: 26.3% of anonymous pages are strongly associated with others
  - Like **Beer** and **Diaper**, many pages are always accessed together
  - The association is implicit but can be mined
  - If the system is **aware of these highly associated pages** and **does large-grain compression on them**, the performance has the potential to be significantly improved.

Association Rule Mining



Association *confidence* of page combinations (%)

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# Overview

- **Archer:** an Association-rule aware memory compression framework for the high speed response of mobile devices

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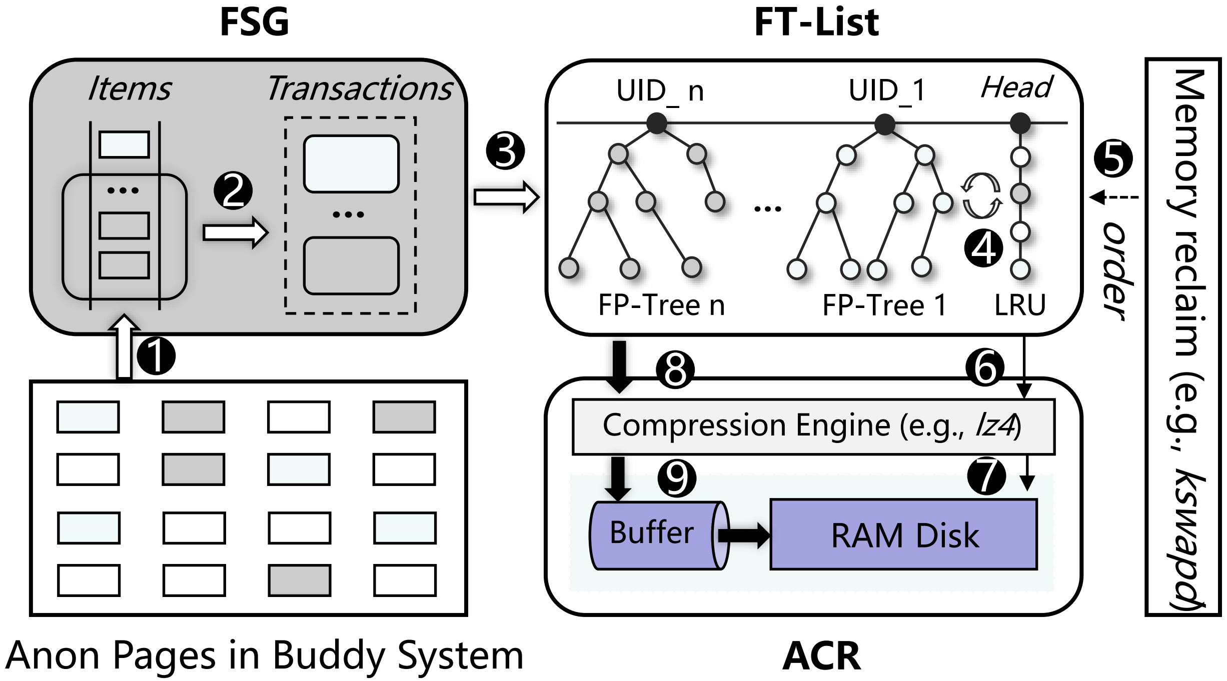
  - **FSG**: Footprint Stream Generator
  - **FT-List**: Frequent-pattern Tree List
  - **ACR**: Adaptive Compression Region



# Component: FSG

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  - ➢ **FSG**: Footprint Stream Generator
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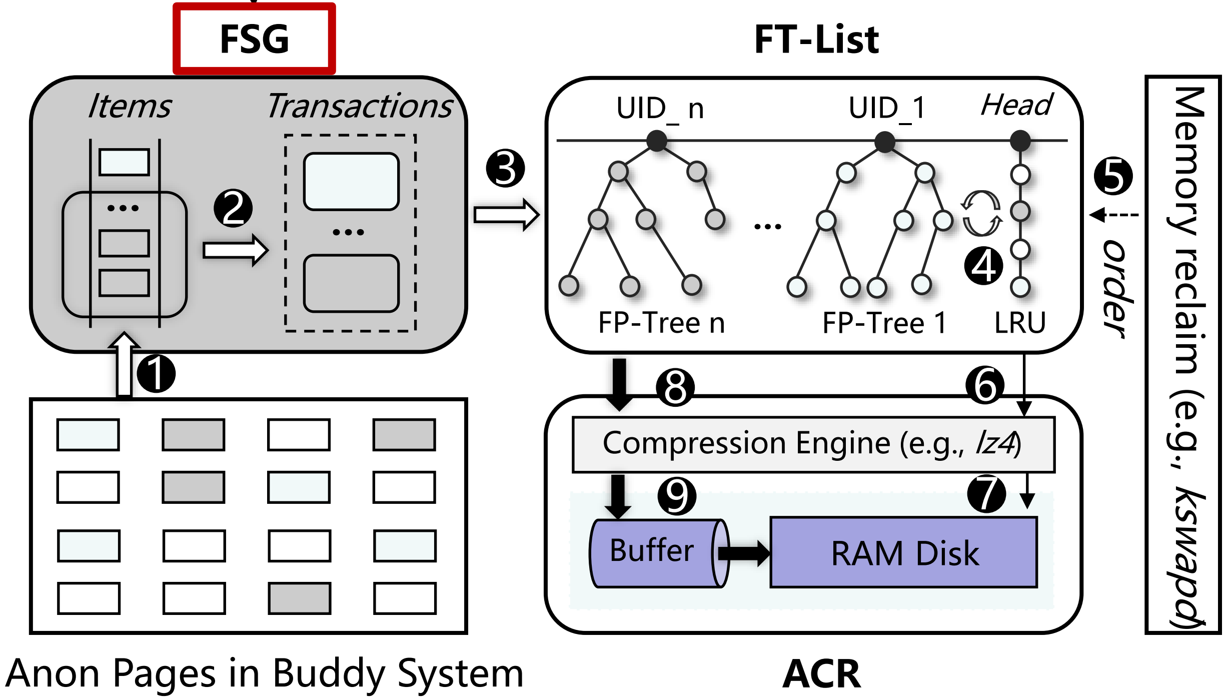
□ FSG maintains a sliding window to generate footprint stream



# Component: FT-List

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  - ➢ **FSG**: Footprint Stream Generator
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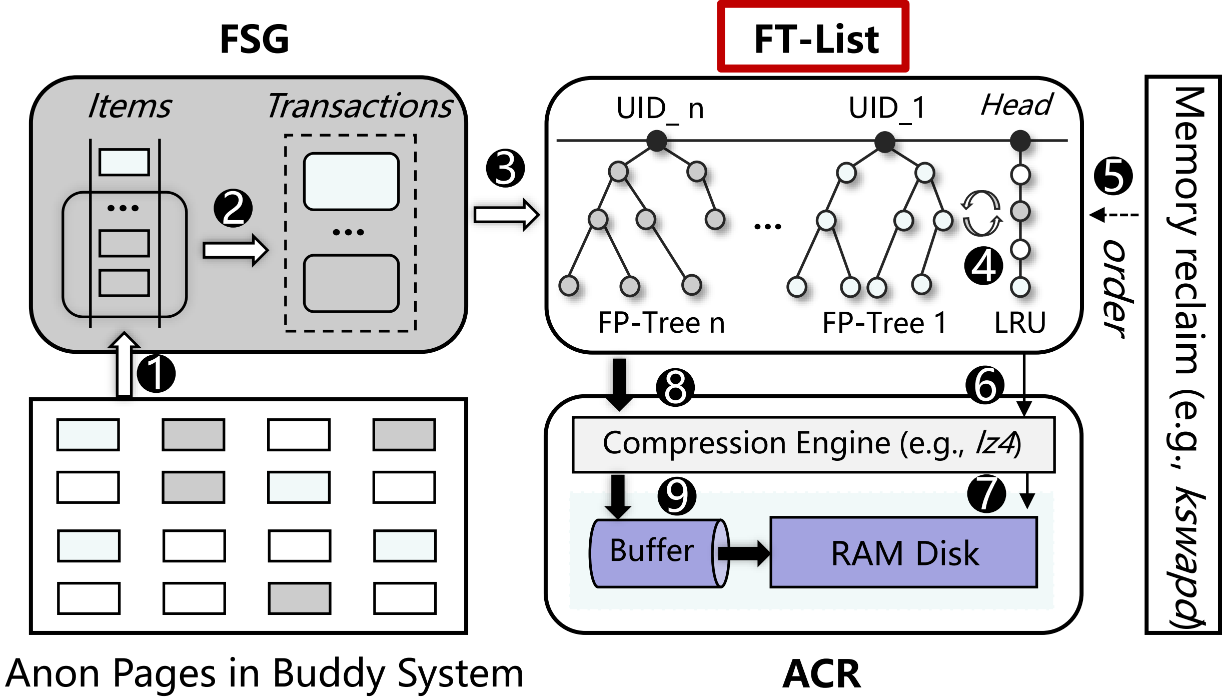
□ Codesign LRU with FP-Tree. Pages are managed and mined on the novel structure: FT-List.



# Component: ACR

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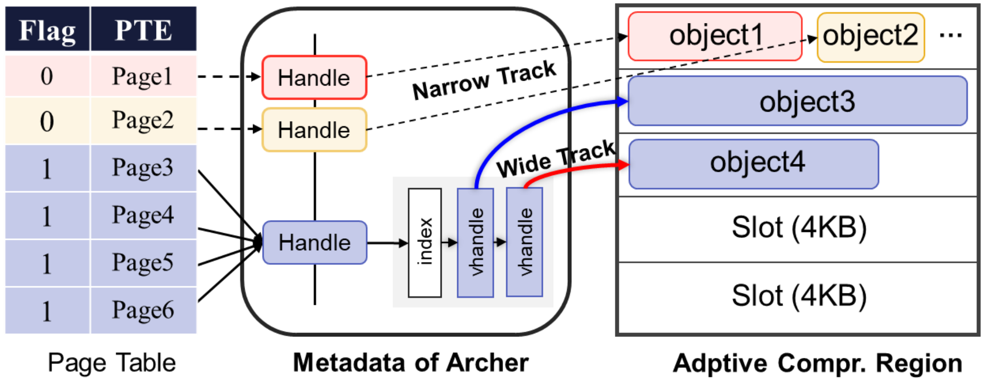
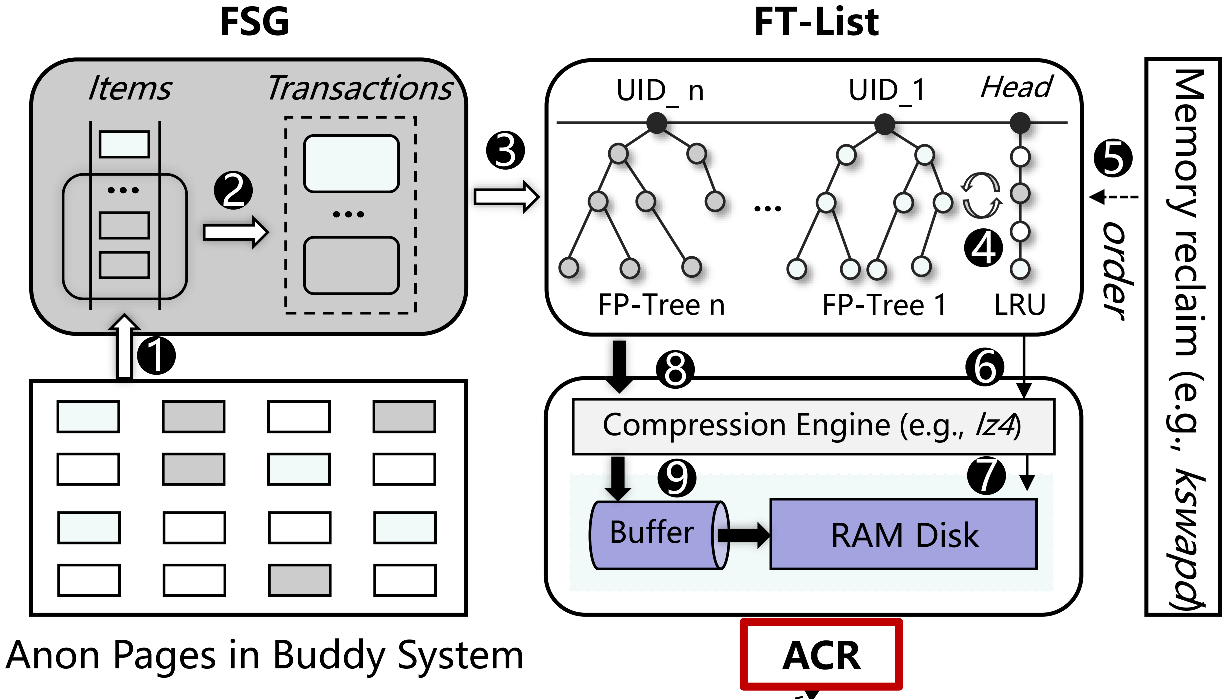
□ ACR is implemented based on the original ZRAM region in the Linux kernel.





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# Evaluation

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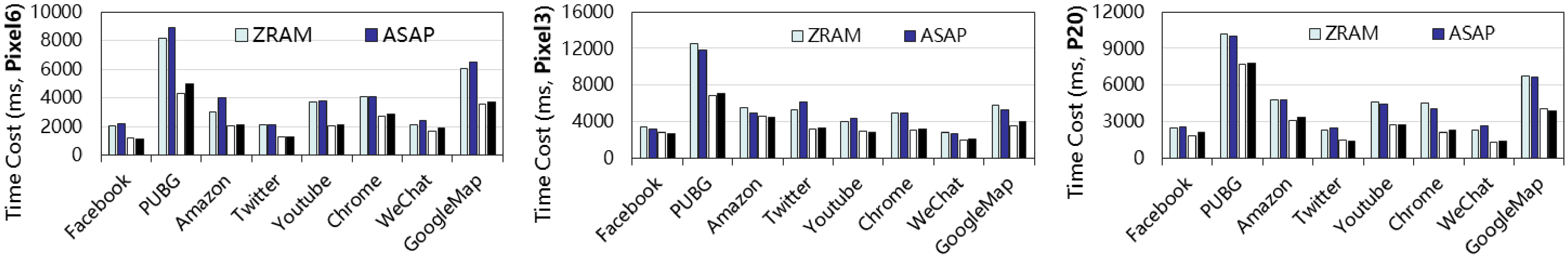
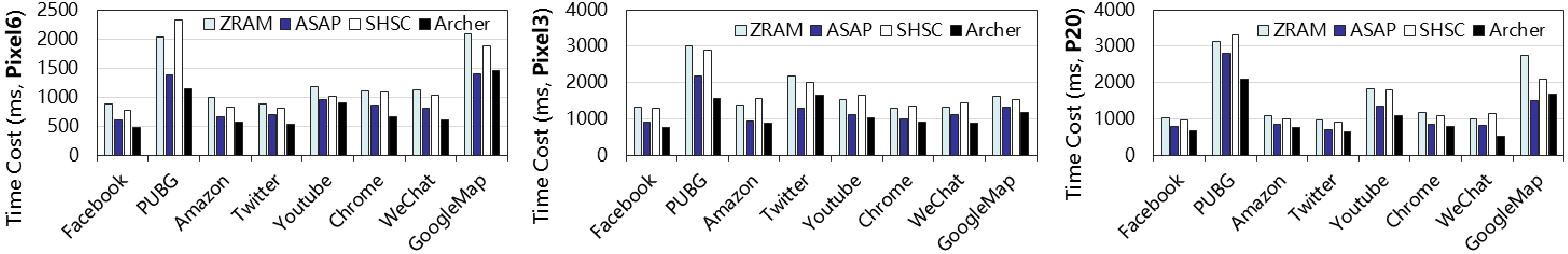
- User experience measurement: **App launching speed**, **photographic performance**, and **frame rate**.



(a). Time cost of cold launching on Pixel6, Pixel3, and P20 phones



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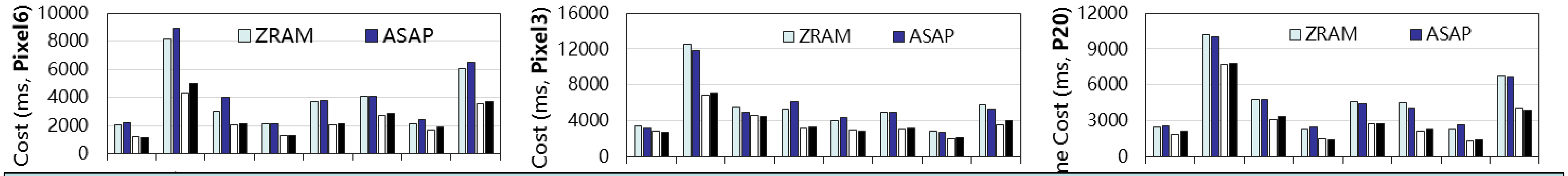
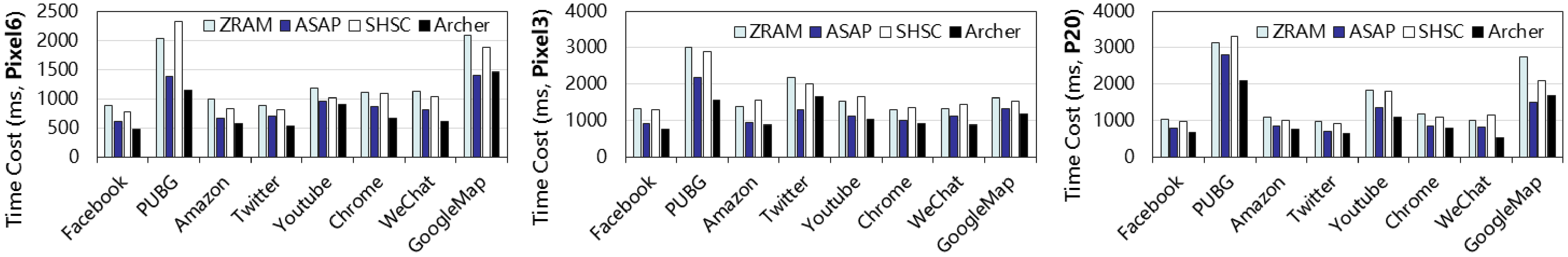


The average speed of cold launching with Archer increased by **37.2%** on Pixel6, **30.6%** on P20, and **32.9%** on Pixel3, compared to ZRAM.



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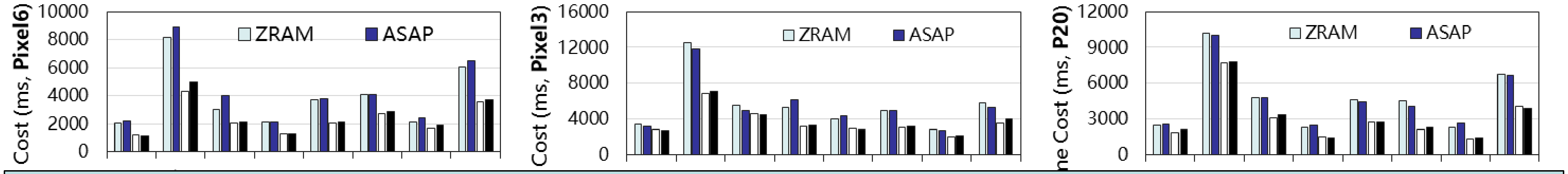

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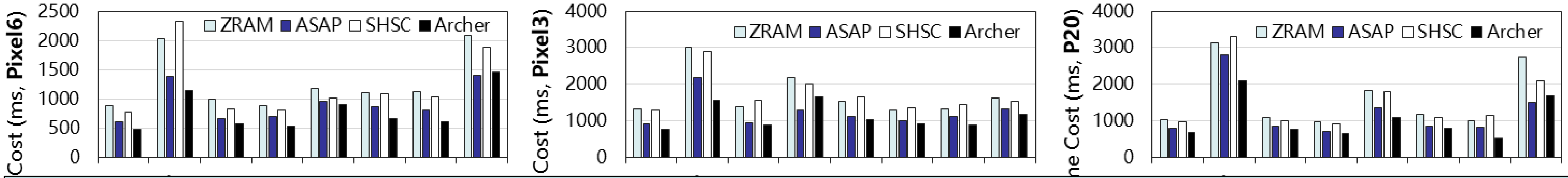

The average hot launching speed on the three platforms is enhanced by **55.3%**, **47.5%**, and **29.6%**, respectively.

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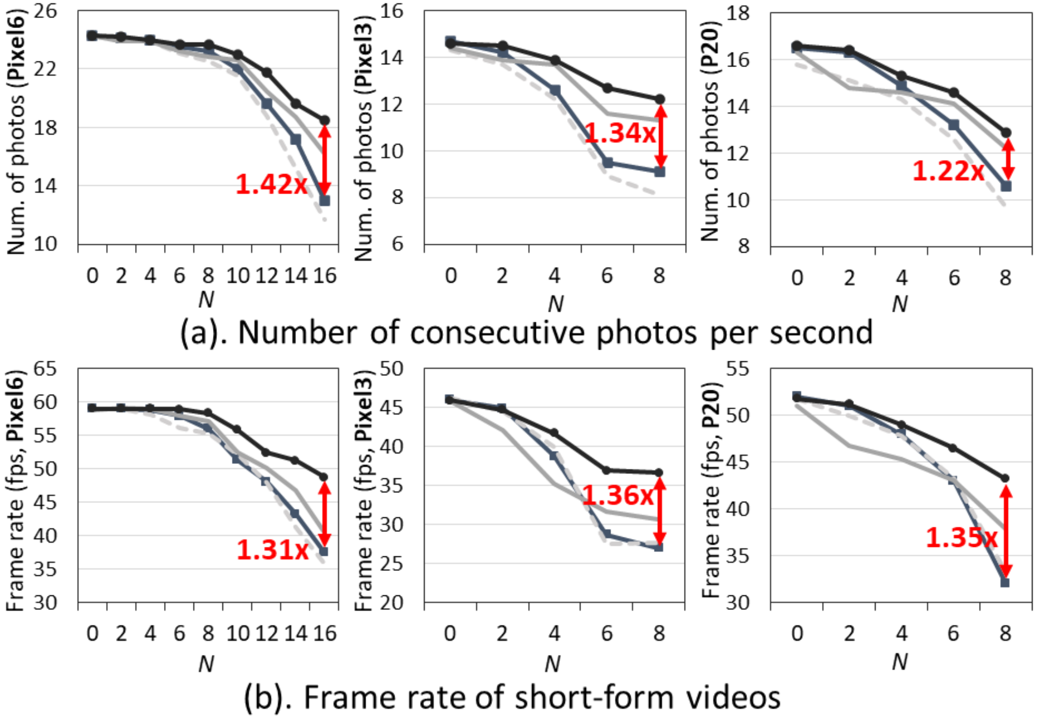

(a). Number of consecutive photos per second

(b). Frame rate of short-form videos

Benefit on photographic and frame rate

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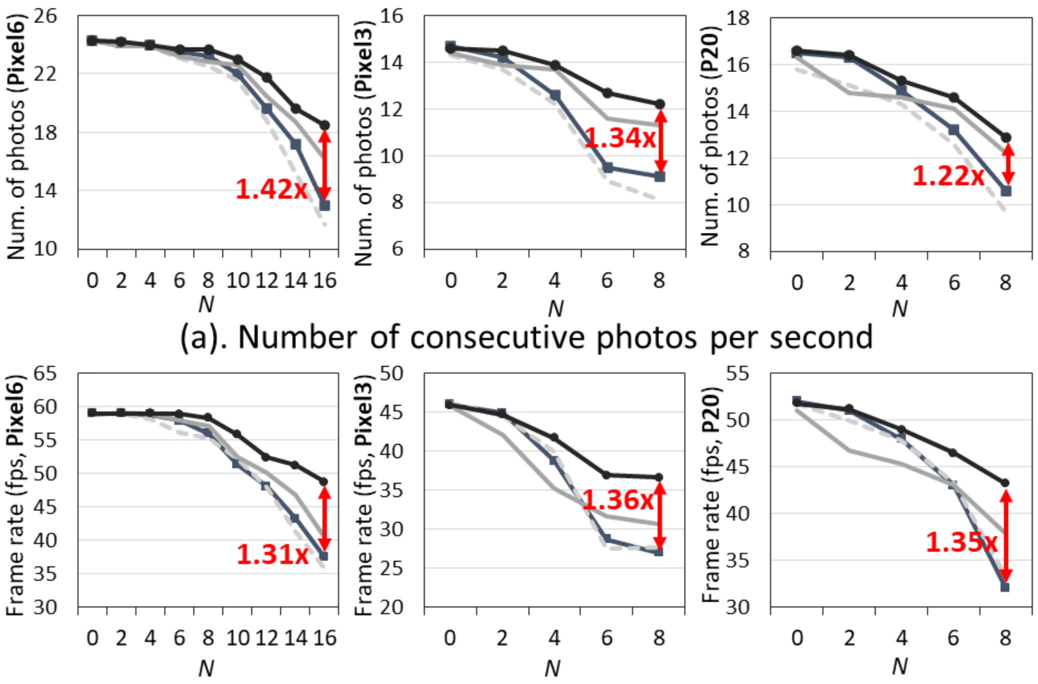

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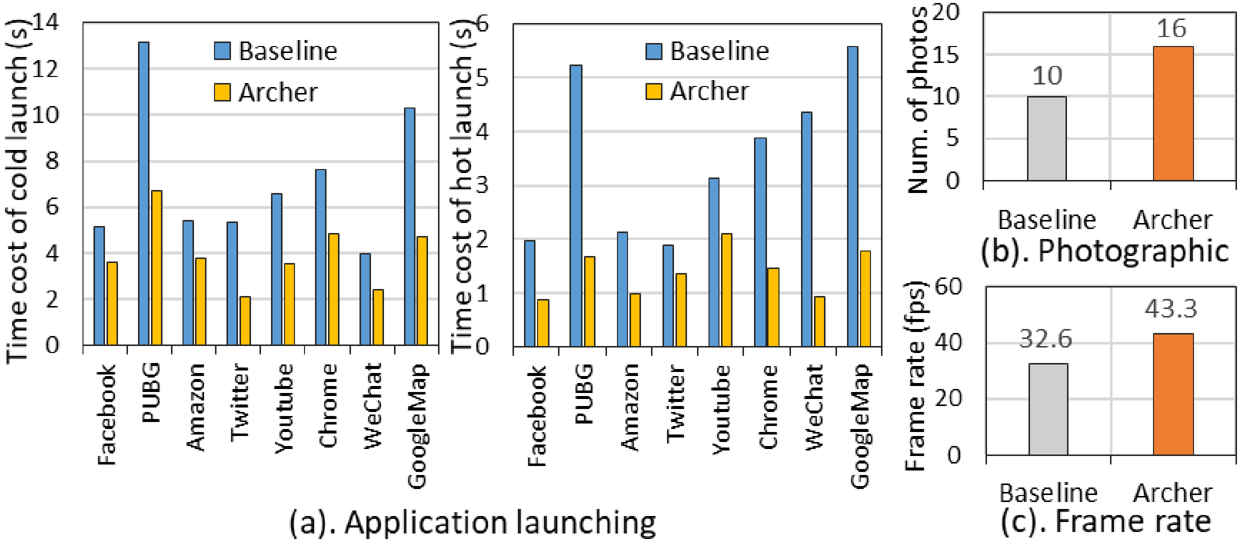

(a). Application launching

(b). Photographic

(c). Frame rate

- □ The tail launching latency is reduced by **44.9%** for cold launches and **60.3%** for hot launches.
- □ The worst-case performance in continuous shooting and frame rendering improves by**1.6x** and **1.3x**.

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# Conclusion

**Problem: page compression is not suit for memory intensive applications in mobile scenarios**

The user experience degraded when suffering high memory pressure

**Key insight**: by **mining the page association rule**, large-grain compression is feasible in mobile systems

**Challenge**: collecting page footprint dynamically and in lightweight, do compression adaptively

**Archer**: **Adaptive Memory Compression with Page-Association-Rule Awareness for High-Speed Response of Mobile Devices**

Archer can improve the app launching speed by 1.55x on average over the state-of-the-art mechanisms.

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# THANK YOU!

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