LEA: A Lazy Eviction Algorithm for SSD Cache in Cloud Block Storage

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Outline

- **Background & Motivation**
- Design & Implementation
- Evaluation
- Conclusion

Background

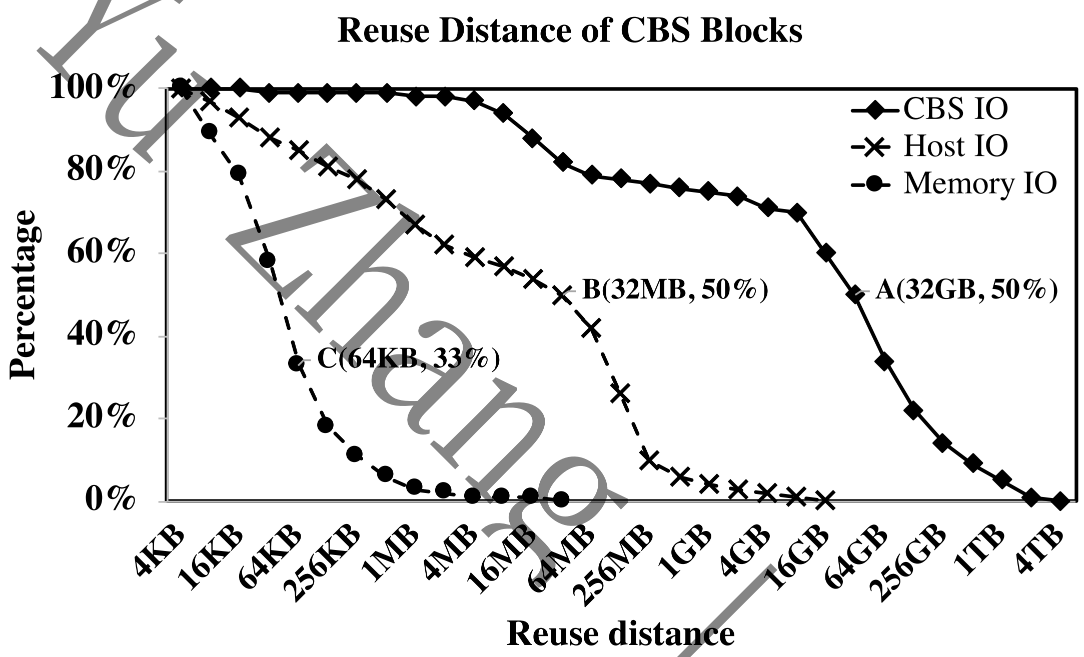
- Great Random IO Performance
- Nonvolatile Feature
- Shock Resistance
- Energy Conservation
- ……

- Solid State Drives have been widely used as a caching layer in cloud storages nowadays.

Motivation

- **Exisiting advanced cache algorithms make replacement on each miss when the cache space is full.**
  - LRU, MRU, LFU, CLOCK and FIFO
  - LRU-K, EELRU, 2Q, MQ, ARC, LIRS and FRD
  - ……

Motivation



- There is a great percentage of blocks with **large reuse distances** in a typical Cloud Block Storage (**CBS**).
- We also found similar phenomena in other scenarios.

Motivation

- So, we propose a novel cache algorithm, **Lazy Eviction Algorithm (LEA)**, for CBS and other similar scenarios.
  - LEA does not make replacement by default.
  - Extending the residence time of blocks in cache largely.
  - Results show that LEA can **improve the hit ratio** and **reduce the number of write to SSD** as well.

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Design & Implementation

- **Summary Description of LEA**

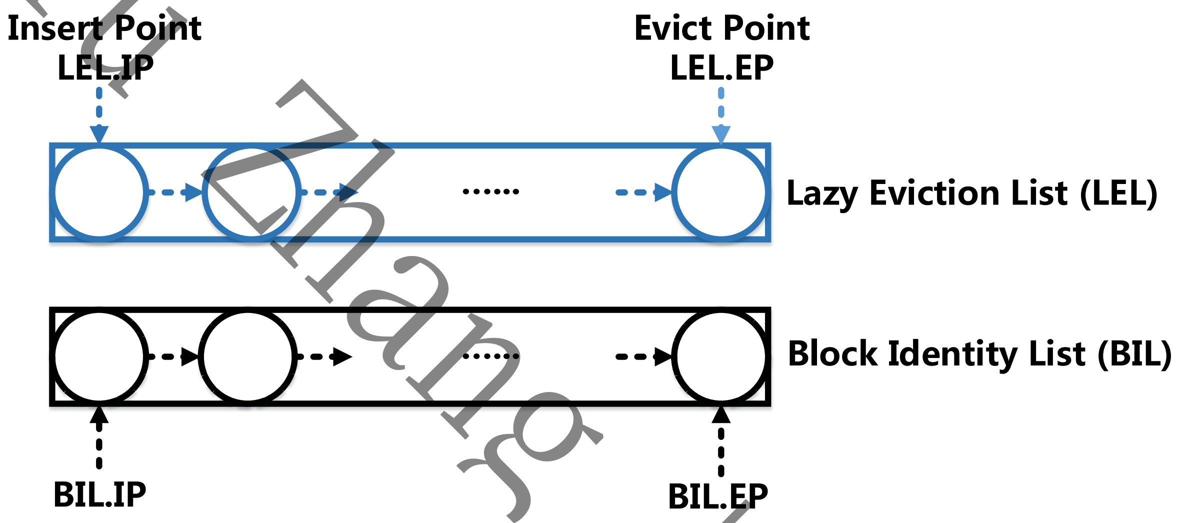
➢ **Assuming that the currently accessed block is X**, LEA does not make replacement by default when there is a cache miss except when the lazy conditions are not met.

➢ The lazy conditions are defined by two aspects, considering both X and the candidate evicted-block. There are two lazy conditions used

  ➢ **Lazy Condition 1 → The First Access of X**
    ➢ Considering the candidate evicted-block in the cache.
  ➢ **Lazy Condition 2 → The Second or More Times Accesse of X**
    ➢ Much more difficult to satisfy than the previous one.

Design & Implementation

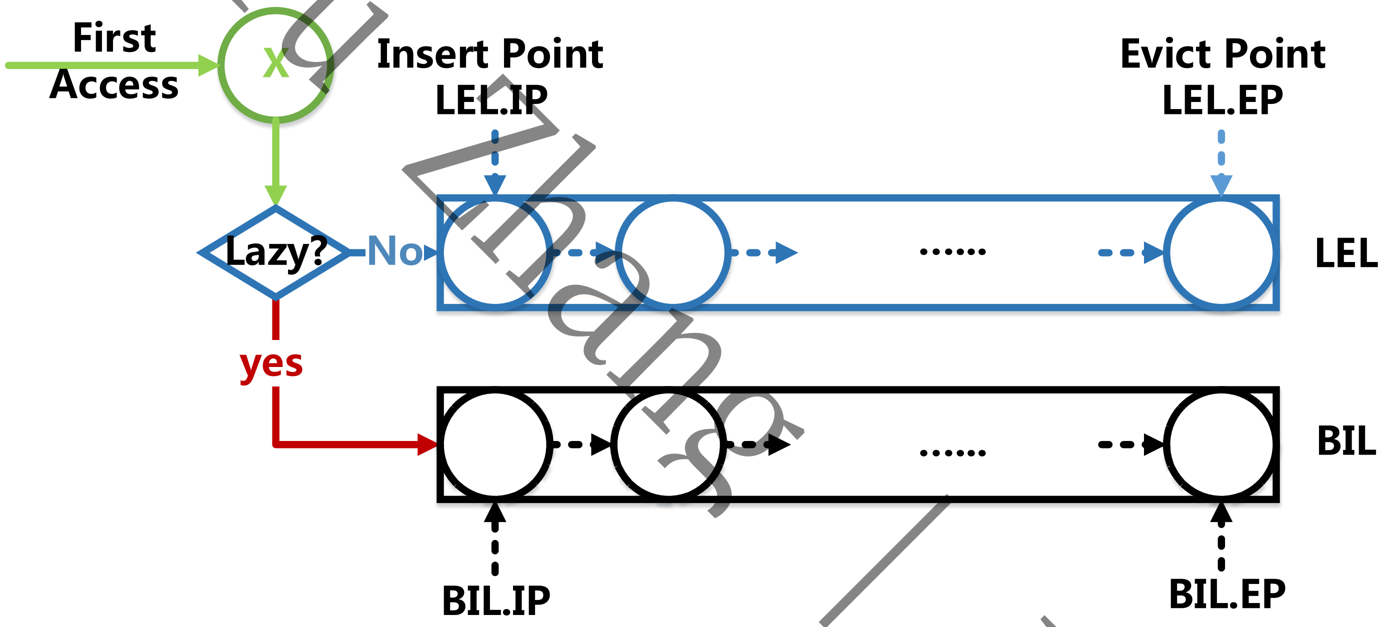
- **Implementation of LEA**



- Lazy Eviction List (**LEL**) and Block Identity List (**BIL**)
  - LEL is the cache list used to store **block entries**.
  - BIL is a ghost list used to store **identities of blocks**.
- Each list has two end points, i.e., Insertion Point (**IP**) and Eviction Point (**EP**)

Design & Implementation

- First Access of X



➢ When block X is accessed for the first time, it will insert the identity of X to BIL **if the first lazy condition is met**, otherwise it will insert the entry of X to LEL.

Design & Implementation

- **Lazy Condition 1**

➢ LEA defines a **flag** to denote the importance and usefulness of a candidate evicted-block for the cache.

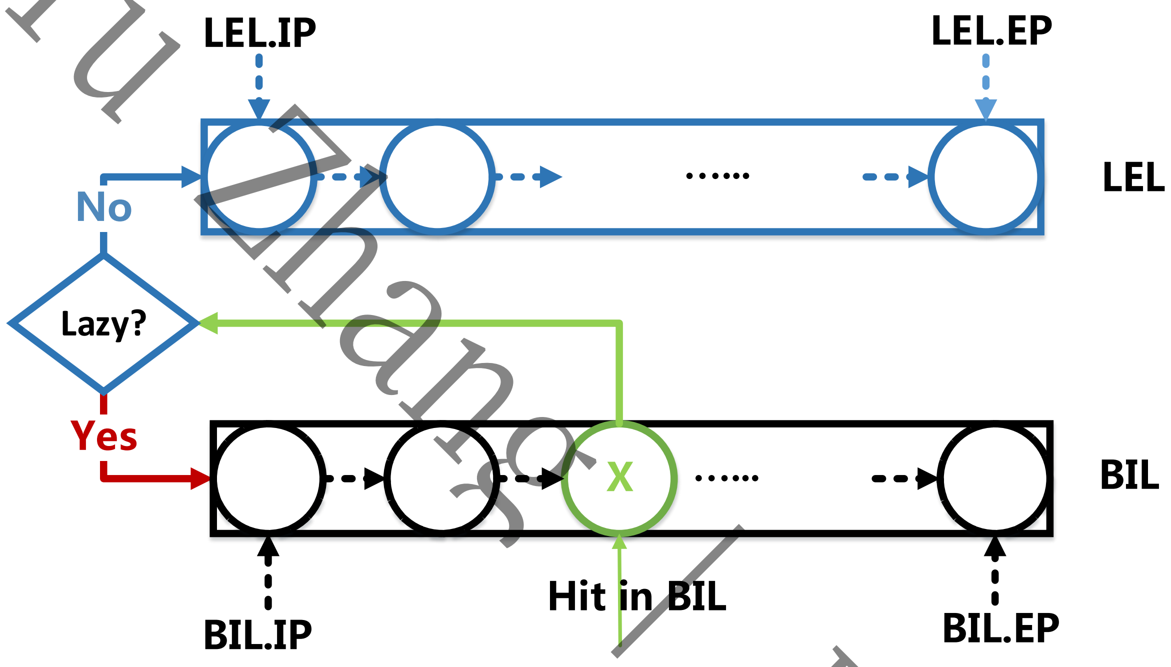
  ➢ If **flag** > 0, lazy condition is met! ☺

  ➢ If **flag** == 0, lazy condition is not met! ☹

➢ The **flag** of a block is increased by 1 when the block is hit in the cache or reduced to the half when the block is a candidate evicted-block and the lazy conditions are met.

Design & Implementation

- Hit in BIL



➢ When the re-reference to block X happens and x is hit in BIL, the processing is similar.

- **Lazy Condition 2**

➢ This lazy condition is much more difficult to satisfy than the previous one.

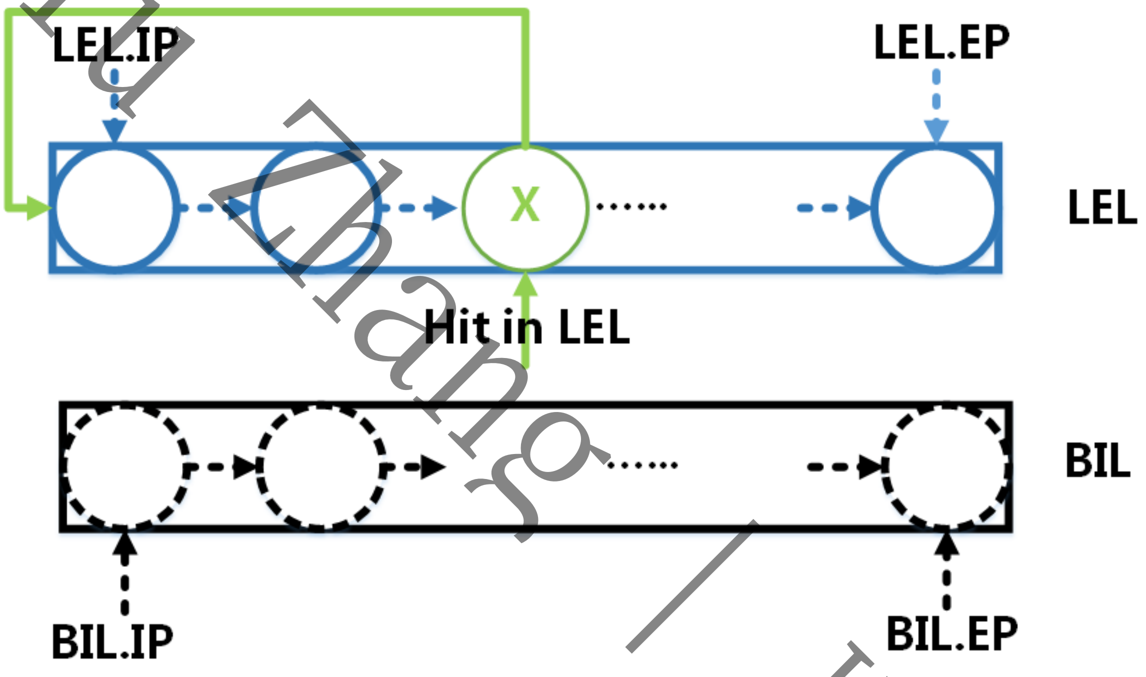
➢ To satisfy this lazy condition, the **flag** of a candidate evicted-block should be greater than 0, **more over** its age in the cache should be smaller than a threshold.

  ➢ The threshold is **K** times of the block's average reuse distance.

  ➢ From the experiments, we found that for most workloads, the best value of **K** is 1.

Design & Implementation

- Hit in LEL



➢ Move X to the Insertion Point of LEL list.

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Evaluation

● Experimental Method

- ➢ We have evaluated the performance of LEA algorithm using a home-made trace-driven simulator BlockCacheSim.
- ➢ We have compared LEA with other four algorithms, including LRU, ARC, LARC as well as OPT .
- ➢ Cache sizes are set as several reasonable values to ensure the hit ratio varies from relatively small to large.
- ➢ All the results are averages of multiple tests with different cache sizes.

Evaluation

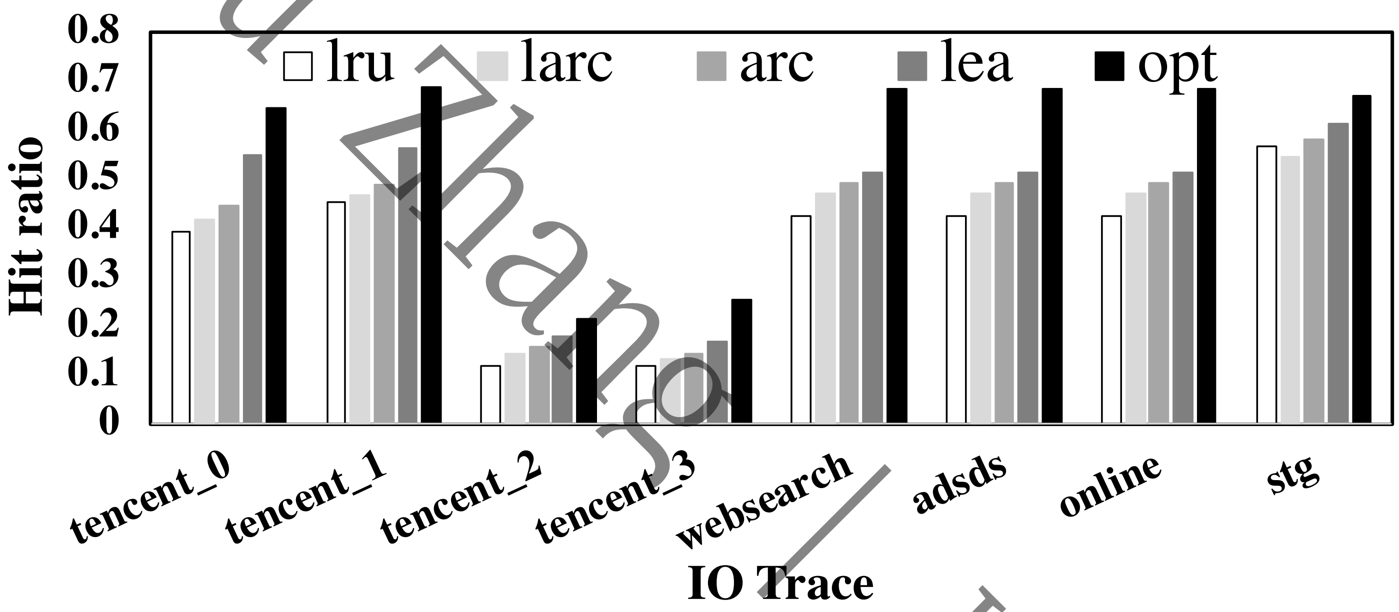
- **Trace Collection**

  - **IO traces collected from Tencent CBS (*tencent_1 to tencent_4*).**
    - IO traces from Tencent CBS have been sampled because the amount of original data is specifically large, reaching the scale of petabyte magnitude.
  - **Several public IO traces (*websearch, adsds, online and stg*).**

TRACE NAME	Total Traffic (GB)	Read Ratio	Description
tencent_0	149.91	13.95%	write-intensive
tencent_1	156.67	8.05%	write-intensive
tencent_2	108.48	68.44%	read-intensive
tencent_3	82.2	42.49%	read-write balanced
tencent_4	9972.14	19.72%	1 week trace from CBS
websearch	65.82	99.99%	web search
adsds	48.47	96.84%	display ads platform data server
online	54.53	21.80%	course management system of FIU
stg	23.26	31.76%	web staging

Evaluation

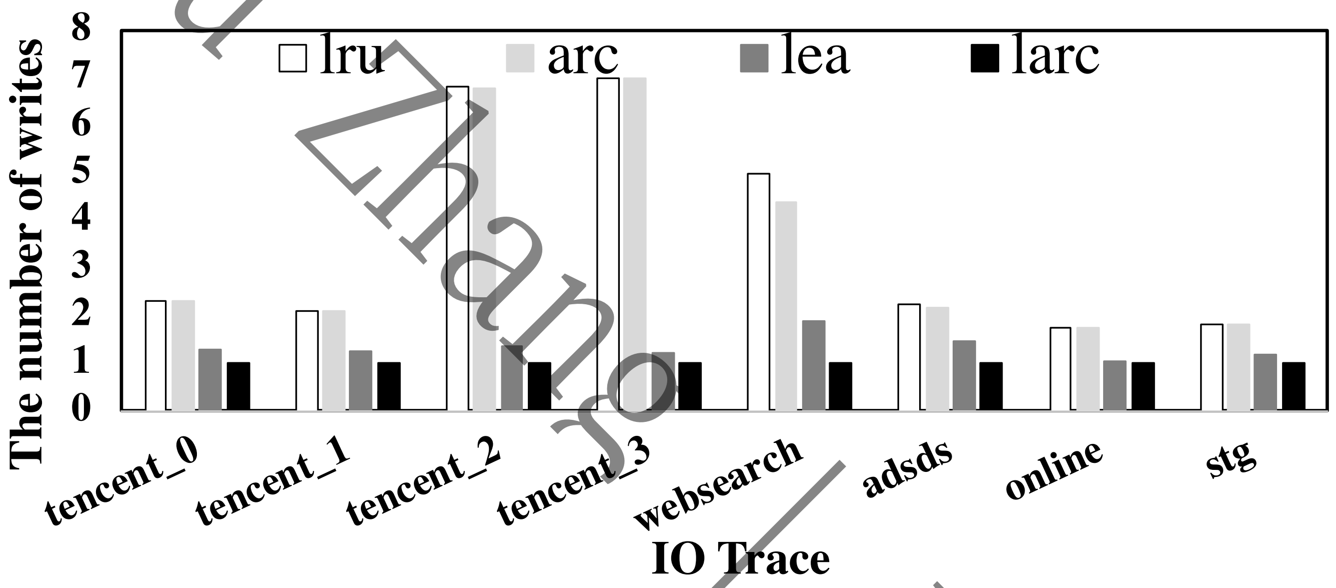
- **Hit ratio**



➢ On average, the hit ratio of LEA (45.13%) exceeds LRU (36.45%) by **23.80%**, LARC (39.00%) by **15.70%** and ARC (41.15%) by **9.66%**.

Evaluation

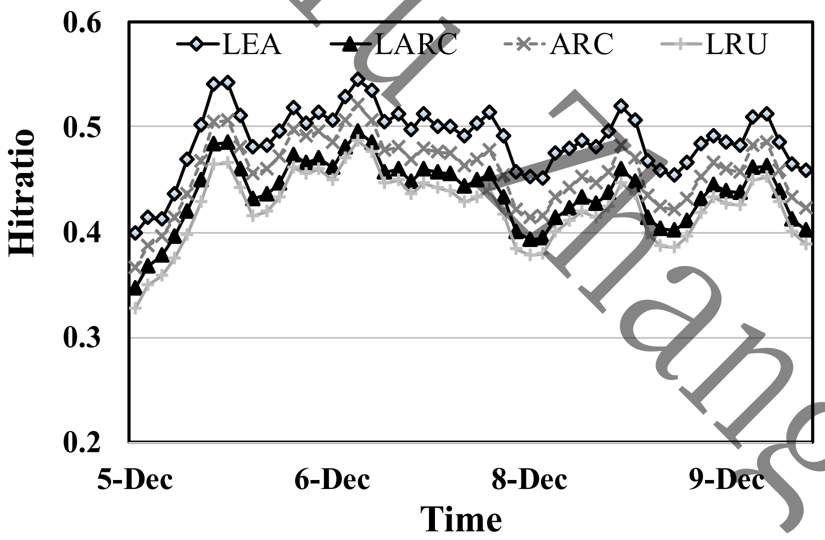
- **The number of writes to SSD**

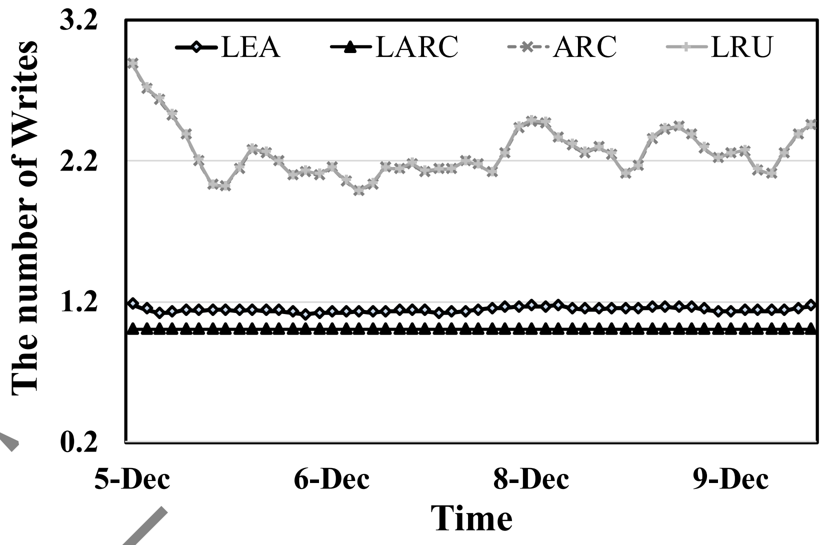


- Numbers in this figure are normalized.
- LEA is of **62.85%** lower than LRU and of **61.85%** lower than ARC.
- LARC has the lowest write traffics, which is of **34.65%** lower than LEA. However this is achieved at the expense of hit ratio.

Evaluation

The Consistence and Flexibility of LEA





- We use ***tencent_4*** to test theconsistence and Flexibility of LEA.
- On average, the hit ratio of LEA (47.63%) exceeds LRU (40.90%) by **16.45%**, LARC (42.39%) by **12.32%** and ARC (44.48%) by **7.08%**.
- The number of writes to SSD when using LEA is of **50.64%** lower than LRU and **50.21%** lower than ARC.

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Conclusion

- We propose a novel cache algorithm LEA which is suitable for cloud block storages and other similar scenarios.
- LEA has very low overhead of complexity of O(1).
- Experimental results show that LEA not only outperforms the state-of-the-art cache algorithms in hit ratio, but also reduces the number of writes to the SSD cache significantly.

Thank You & Questions?