# **Elastic Queue:** A Universal SSD Lifetime Extension Plug-in for Cache Replacement Algorithms

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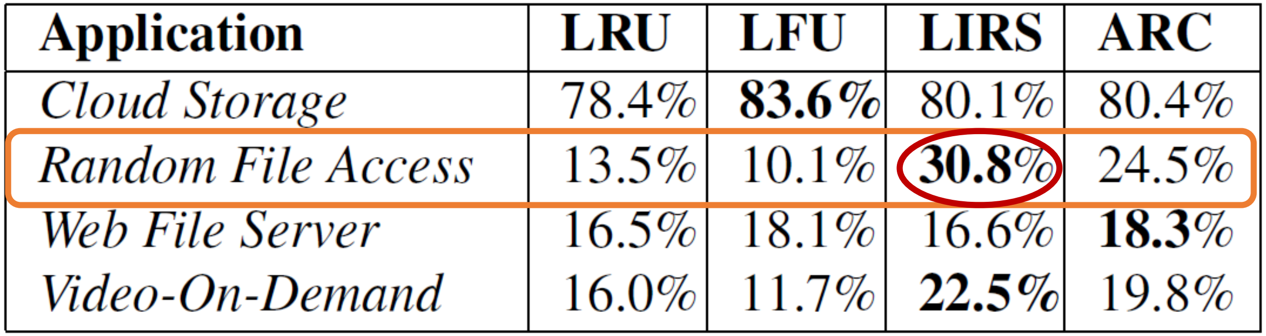
# Traditional Cache Algorithm

- Plenty of researches
  - Different way of qualifying locality
- Adaptability to applications
  - Free to choose the most suitable one for certain senario

LRU
LIRS
LFU
ARC
2Q
…



| **Application** | **LRU** | **LFU** | **LIRS** | **ARC** |
|---|---|---|---|---|
| *Cloud Storage* | 78.4% | **83.6%** | 80.1% | 80.4% |
| *Random File Access* | 13.5% | 10.1% | **30.8%** | 24.5% |
| *Web File Server* | 16.5% | 18.1% | 16.6% | **18.3%** |
| *Video-On-Demand* | 16.0% | 11.7% | **22.5%** | 19.8% |

# SSD-based cache

- Solid State Drives
  - Lower price (vs. DRAM)
  - Higher IOPS, excellent random I/O bandwidth (vs. HDD)

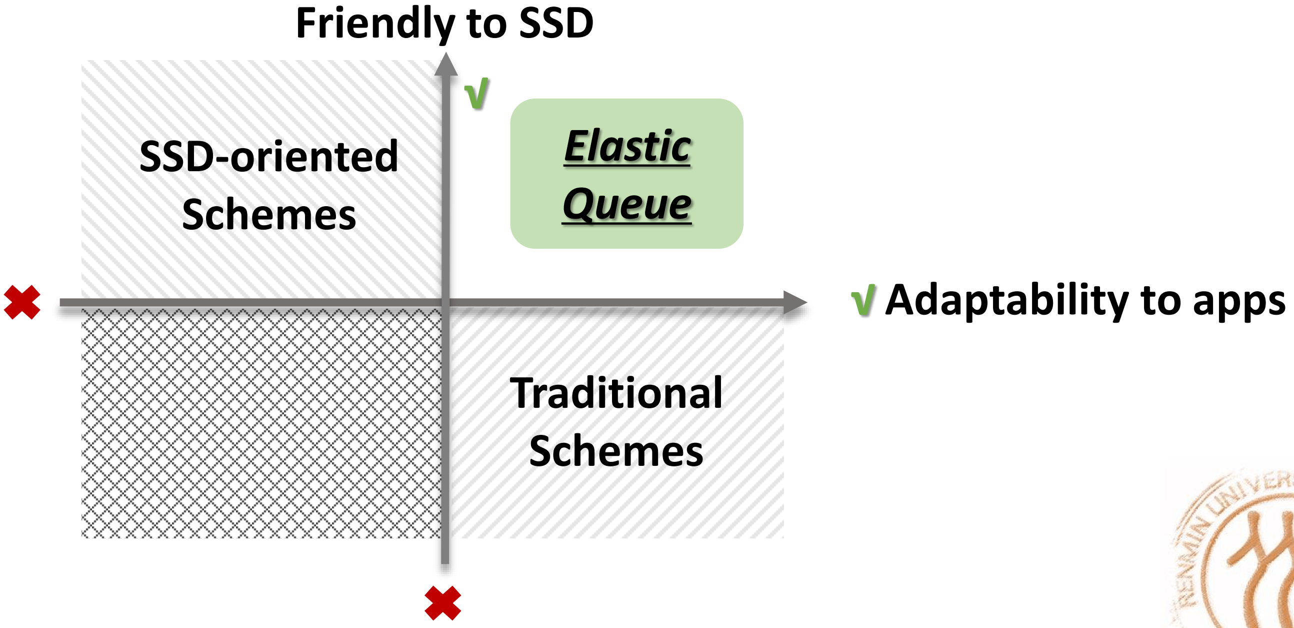
- Challenges
  - Limited times of re-writing for each unit
  - Unbalanced read / write performance

# SSD-oriented Cache Algorithm

- Friendly to SSD lifetime
  - LARC, L2ARC, Sievestore, WEC, ETD-Cache….
- Fixed strategy
  - Few choices
  - Diverse application feature

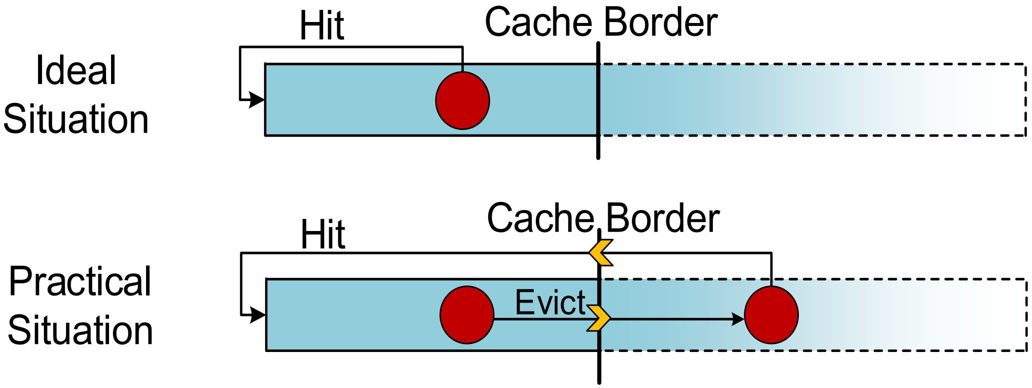
# Our Solution

- Elastic Queue
  - Cover the “blank zone”
  - Cooperate with any other cache algorithm
  - Provide protection to reduce SSD writes



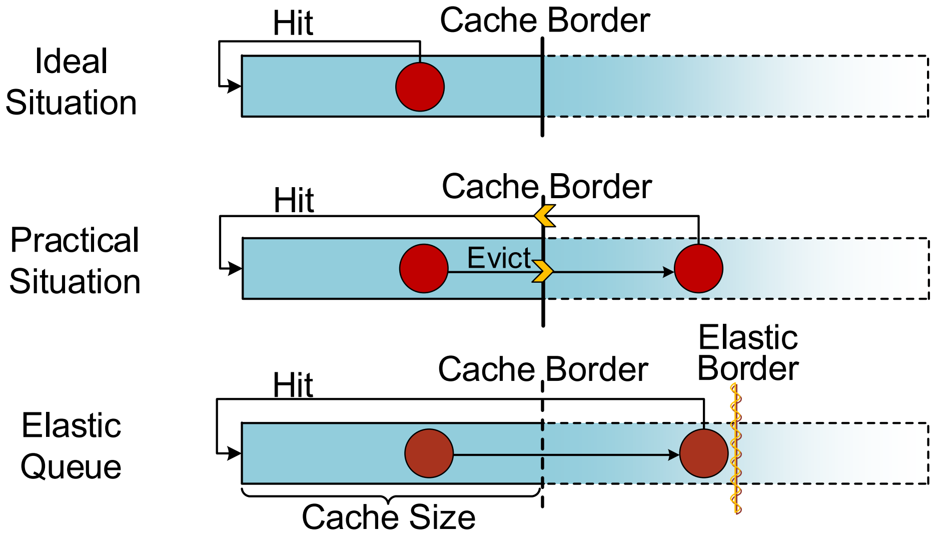
# Unified Priority Queue Model

- Unified queue model of cache algorithms
  - Blocks prioritized by qualified locality
- Common problem
  - Unstable access intervals ([Y. Chai+TOC 2015])
  - Too much unnecessary traversal on the cache border
  - Lead to SSD worn-out rapidly



# Elastic Queue Principle

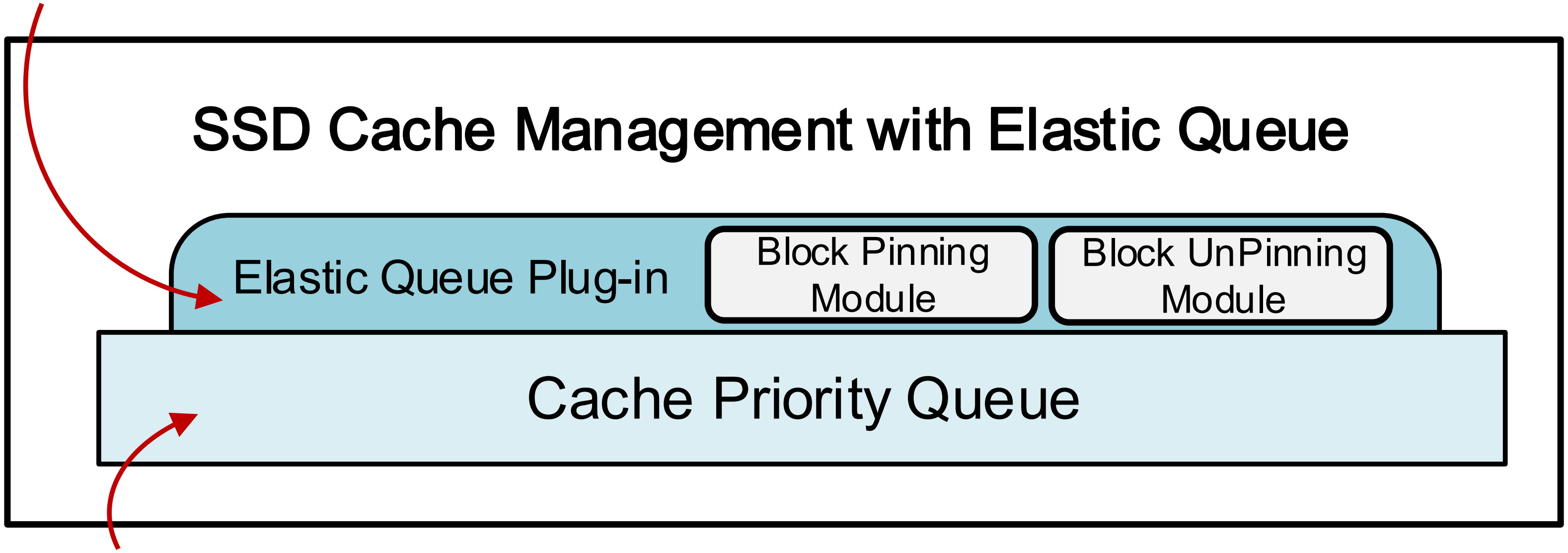
- Prevent hot blocks from early eviction
  - Pin blocks in SSD
  - Assigns Elastic Border (EB)
  - Enhance SSD endurance



# Elastic Queue Architecture

- 1 Queue + 2 Modules

Provide protection



SSD Cache Management with Elastic Queue

Elastic Queue Plug-in

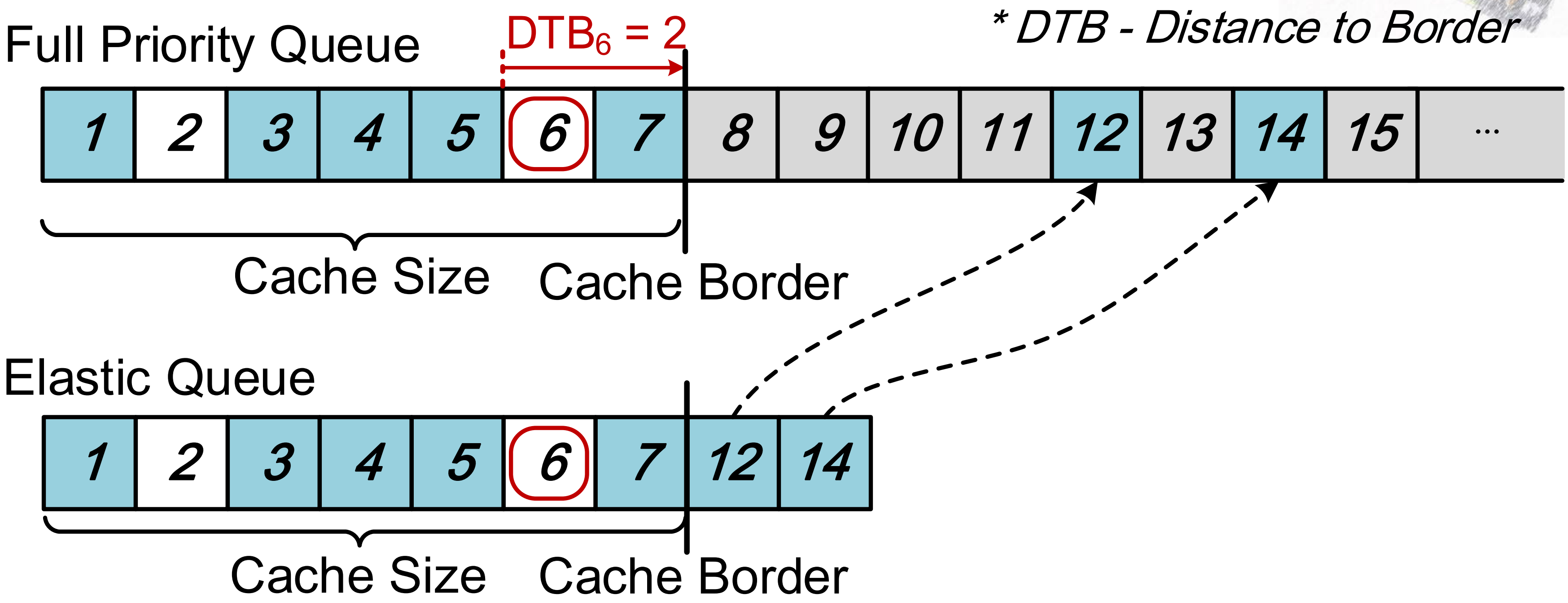
Block Pinning Module

Block UnPinning Module

Cache Priority Queue

Any cache policy

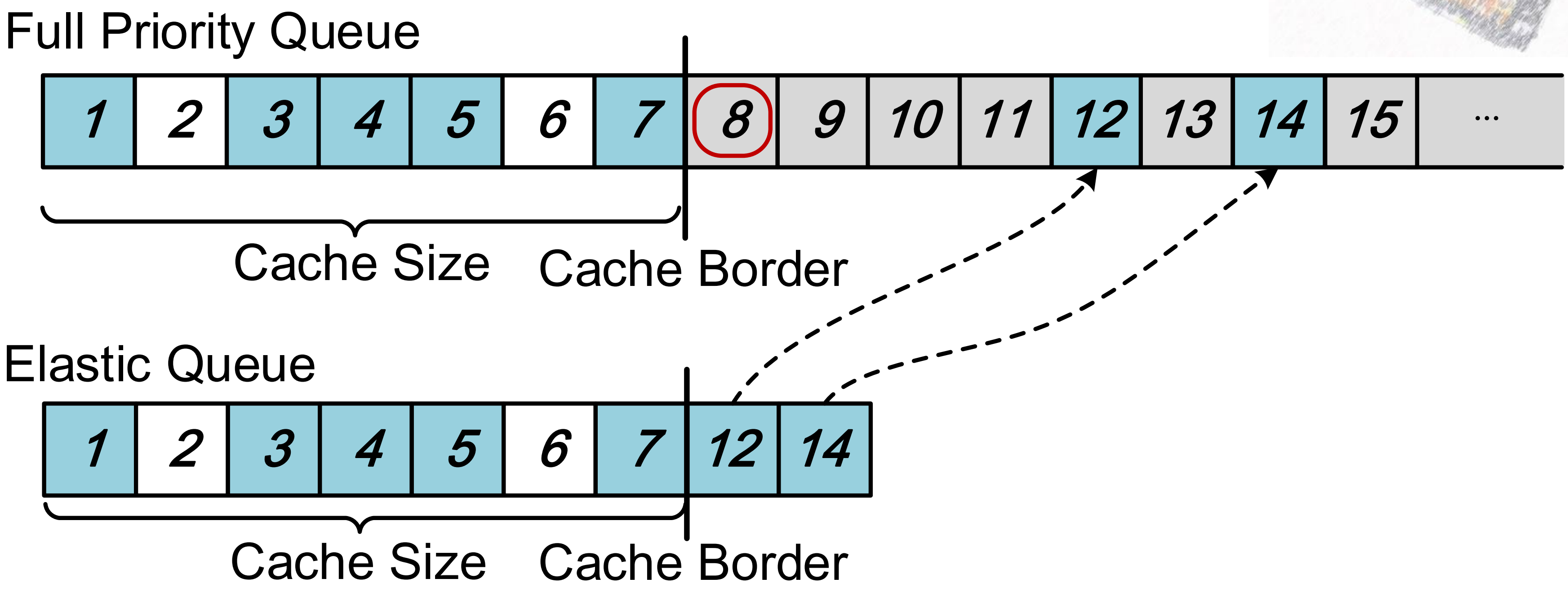
# Elastic Queue Design



□ **General blocks ahead of cache border**

- Only have metadata recorded in EQ
- e.g. block 6

# Elastic Queue Design



Full Priority Queue

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | … |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

Cache Size

Cache Border

Elastic Queue

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 12 | 14 |
|---|---|---|---|---|---|---|---|---|

Cache Size

Cache Border

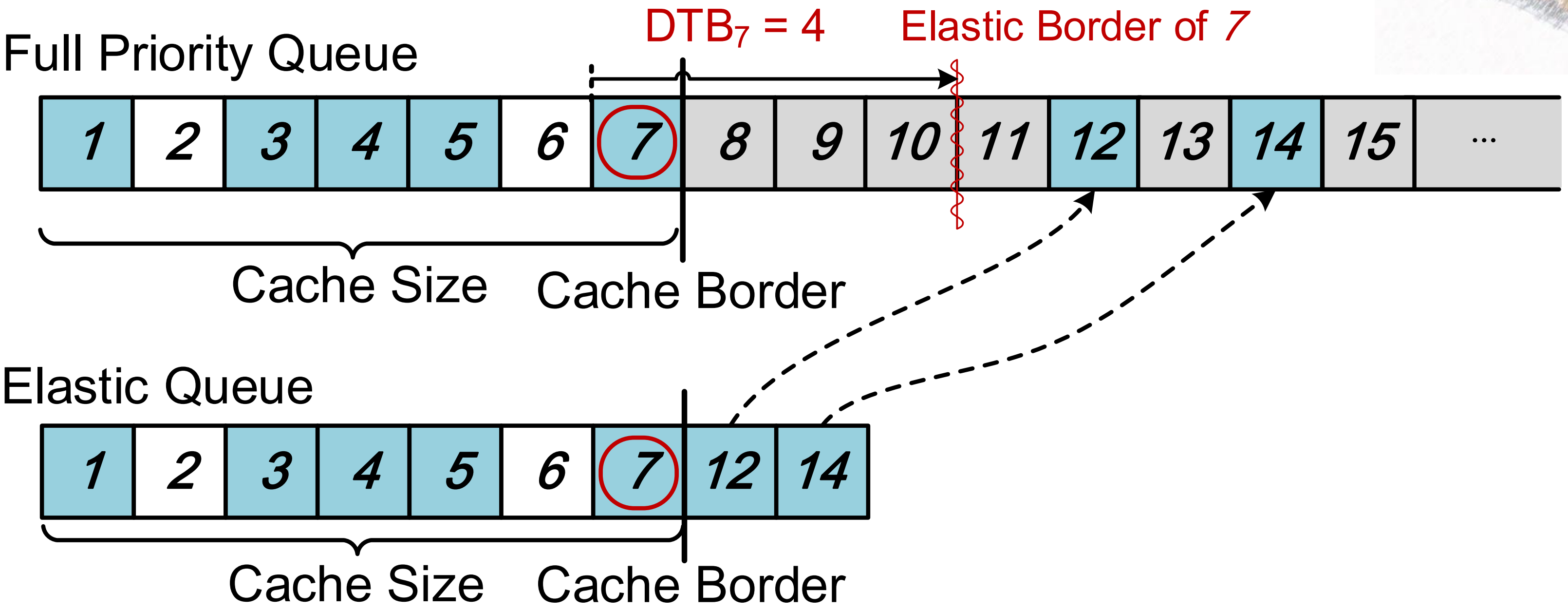
□ **General blocks ahead of cache border**

- Only have metadata recorded in EQ

▨ **General blocks behind cache border**

- Evicted, with no metadata in EQ
- e.g. block 8

# Elastic Queue Design



□ **General blocks ahead of cache border**

- Only have metadata recorded in EQ

▨ **General blocks behind cache border**

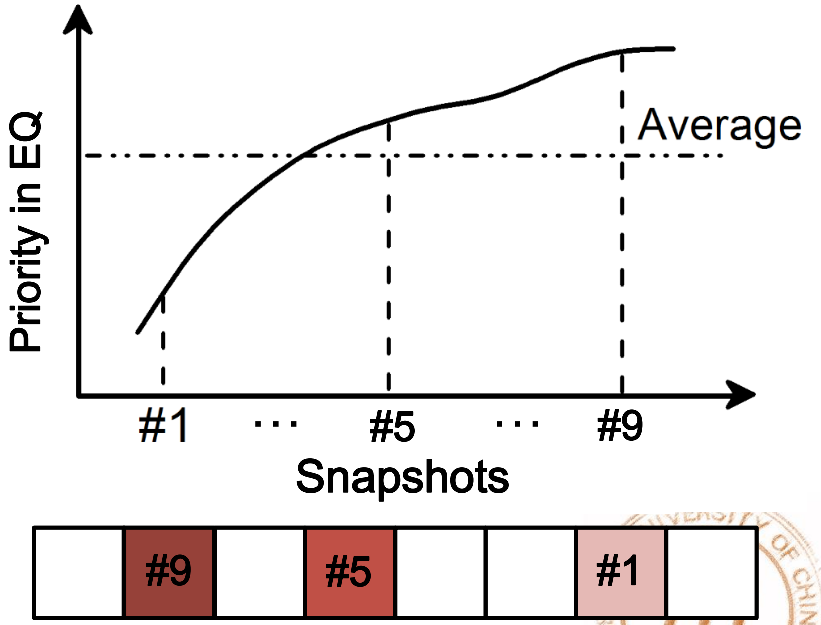
- Evicted, with no metadata in EQ

🟦 **Pinned blocks**

- Actually locate in SSD
- Assigned with elastic border
- e.g. border of block 7 is 4 steps further

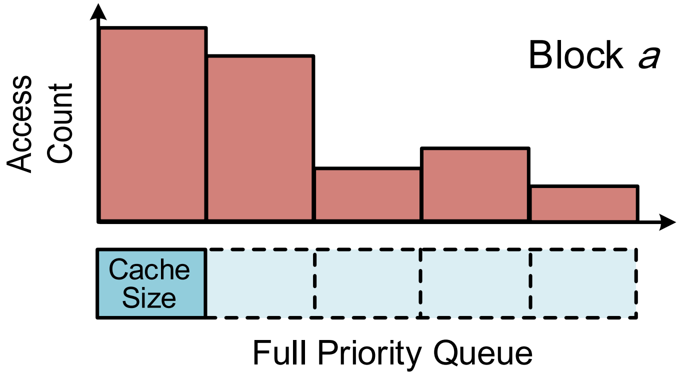
# Pinning Blocks

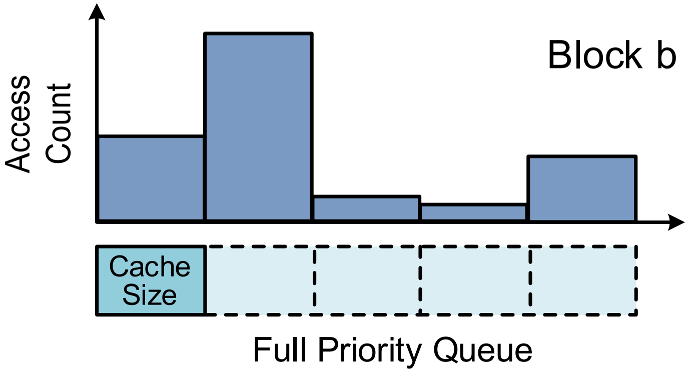
- Purpose
  - Loading the most popular blocks to SSD
- Timing
  - A free slot is available in SSD
- Selection criterion
  - Average priority
  - Changing tendency
- Mechanism
  - “Snapshot”
    - Short-term observation



# Unpinning Blocks

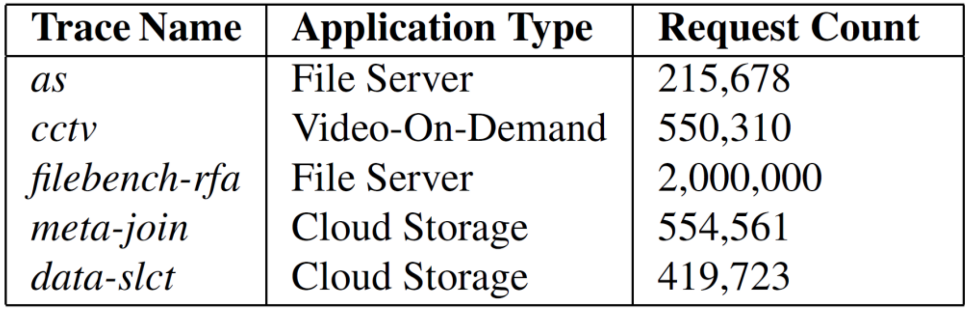
- Purpose
  - Determining where elastic borders should locate (DTB)
  - Evicting pinned blocks behind elastic borders
- DTB determination
  - Classifying data with access distributions
    - Long-term observation





# Evaluation

- Evaluation criterions
  - Cache hit ratio
  - Amounts of SSD written data
  - Write efficiency of SSD
- Traces



| Trace Name | Application Type | Request Count |
|---|---|---|
| *as* | File Server | 215,678 |
| *cctv* | Video-On-Demand | 550,310 |
| *filebench-rfa* | File Server | 2,000,000 |
| *meta-join* | Cloud Storage | 554,561 |
| *data-slct* | Cloud Storage | 419,723 |

- Coupled cache algorithms
  - LRU, LIRS, LARC

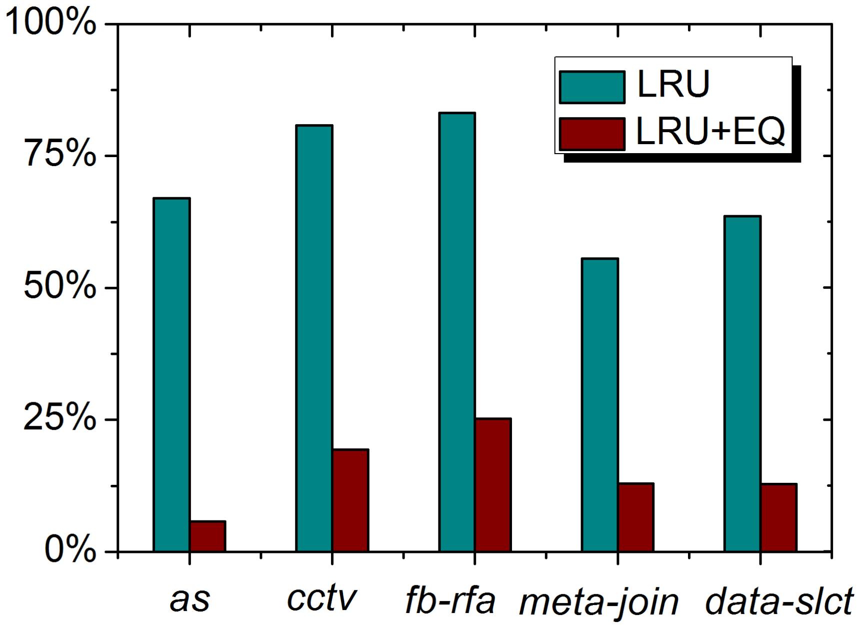
# Overall Results

* For LRU, LIRS, and LARC under all the five traces

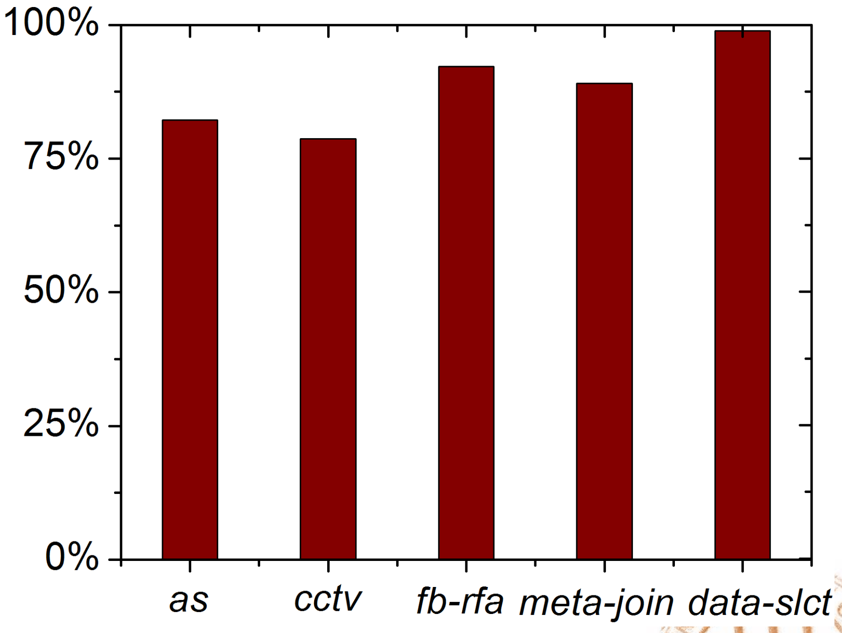
- Cache hit ratio
    - Higher in 66.67% of the cases
    - Average improvement – 17.30%
- Amounts of SSD written data
    - Reduce 39.03 times on average
- Write efficiency of SSD
    - 45.78 times enlarged on average

# Effectiveness of EQ

- Reduction of no-hit percentage

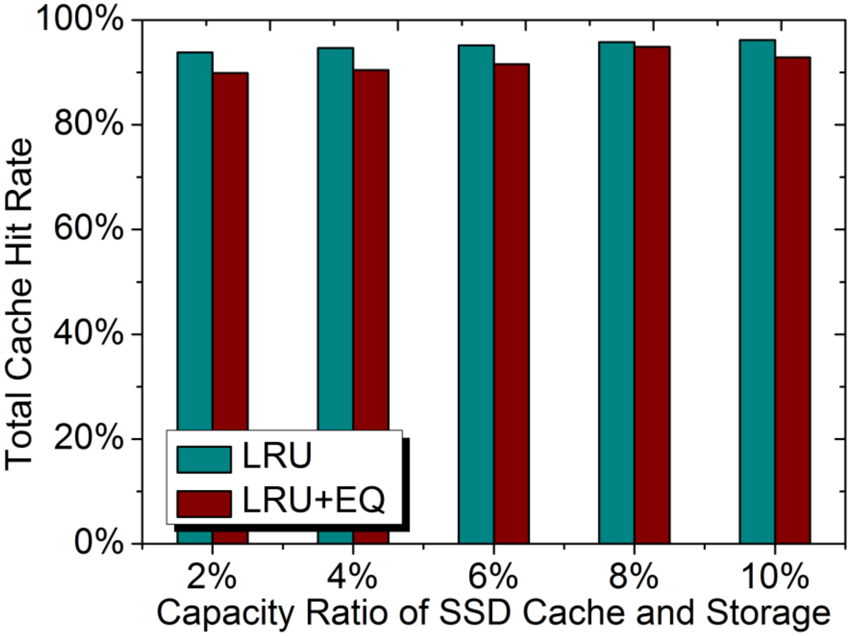


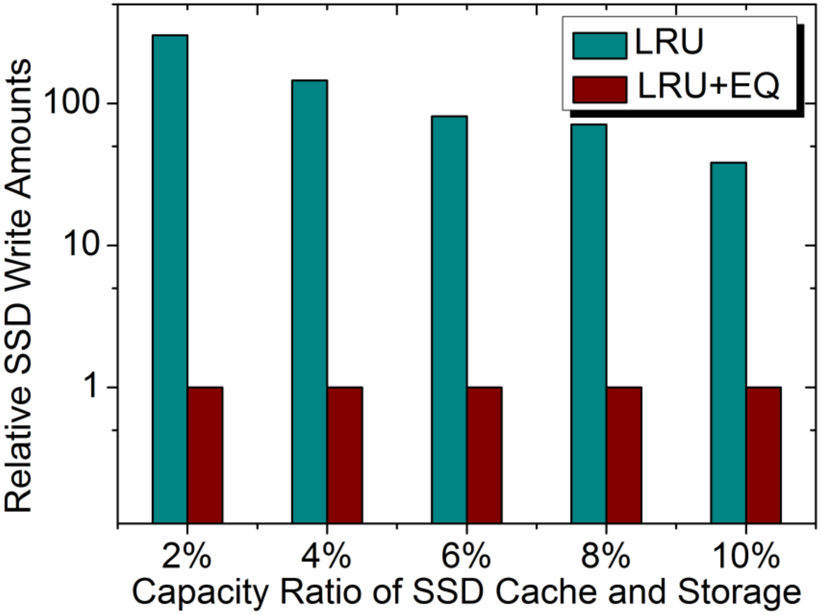
- Hotness of pinned blocks



# Parameter Settings

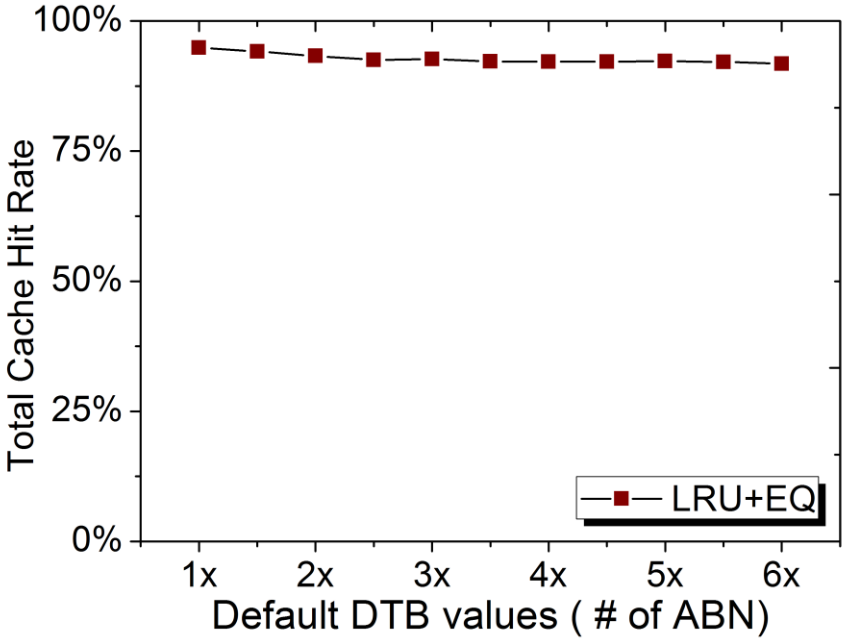
- Impact of SSD Size

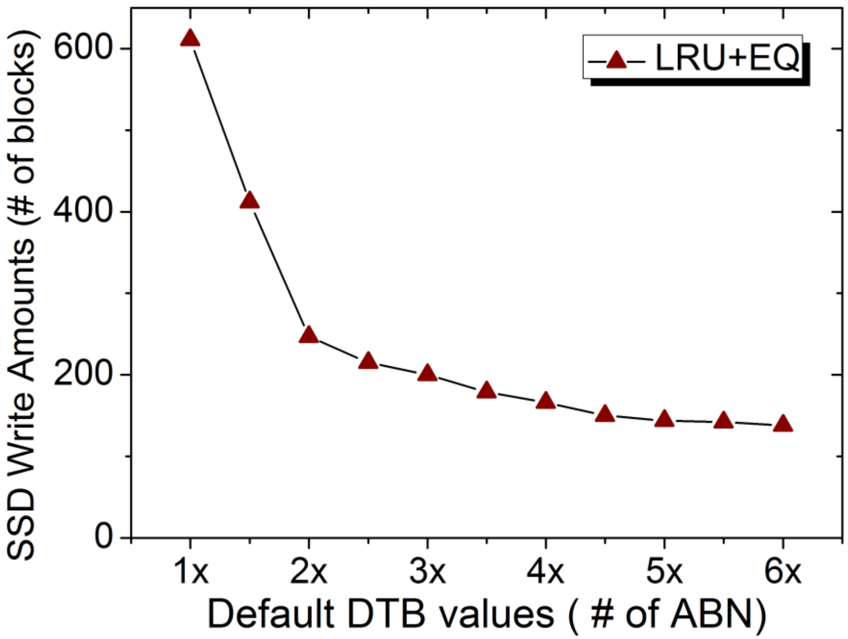




# Parameter Settings

- Impact of default distance-to-border





# Summary

- A universal SSD lifetime enhancement plug-in
  - Couple with any cache algorithm
  - Reduce SSD write amount
- A unified priority queue model for cache algorithms
- Make use of coupled cache policy
  - Priority Snapshot
  - Priority Distribution

# Thank you !

Q&A