FIFO can be better than LRU:
the power of LAZY PROMOTION and QUICK DEMOTION




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Software cache and eviction

- Ubiquitous deployments of software caches
- Cache metrics:
  - efficiency / effectiveness: miss ratio
  - throughput and scalability: requests /sec
- One core component of cache: **eviction**

traffic server™

VARNISH CACHE

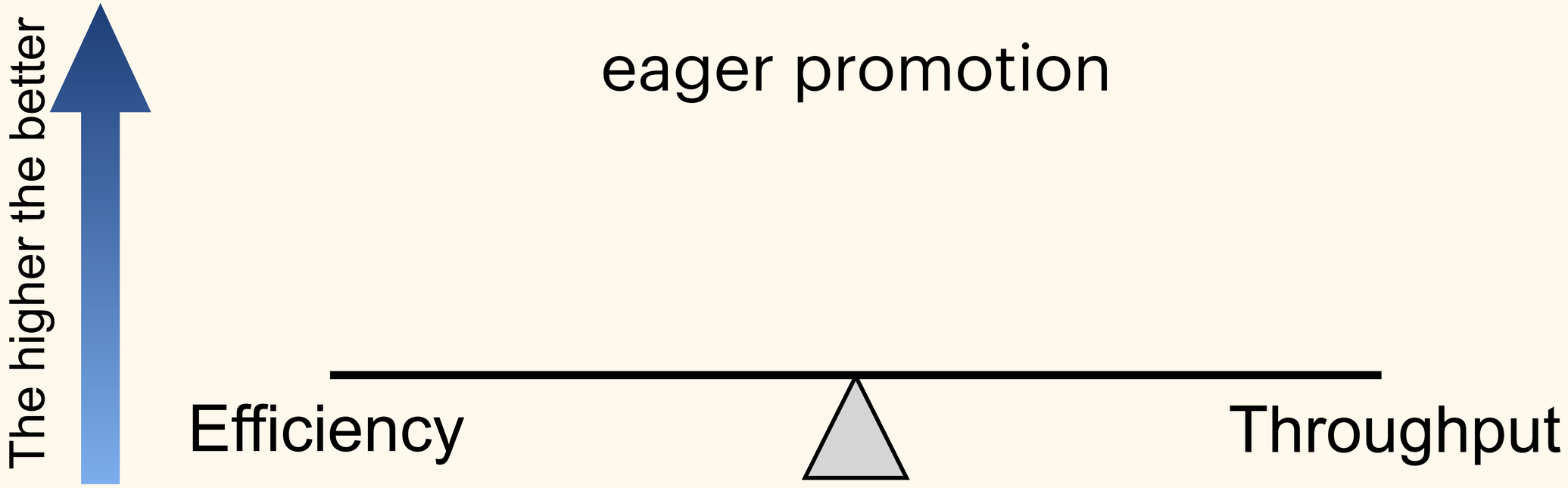
Cachelib

Pelikan

ALLUXIO

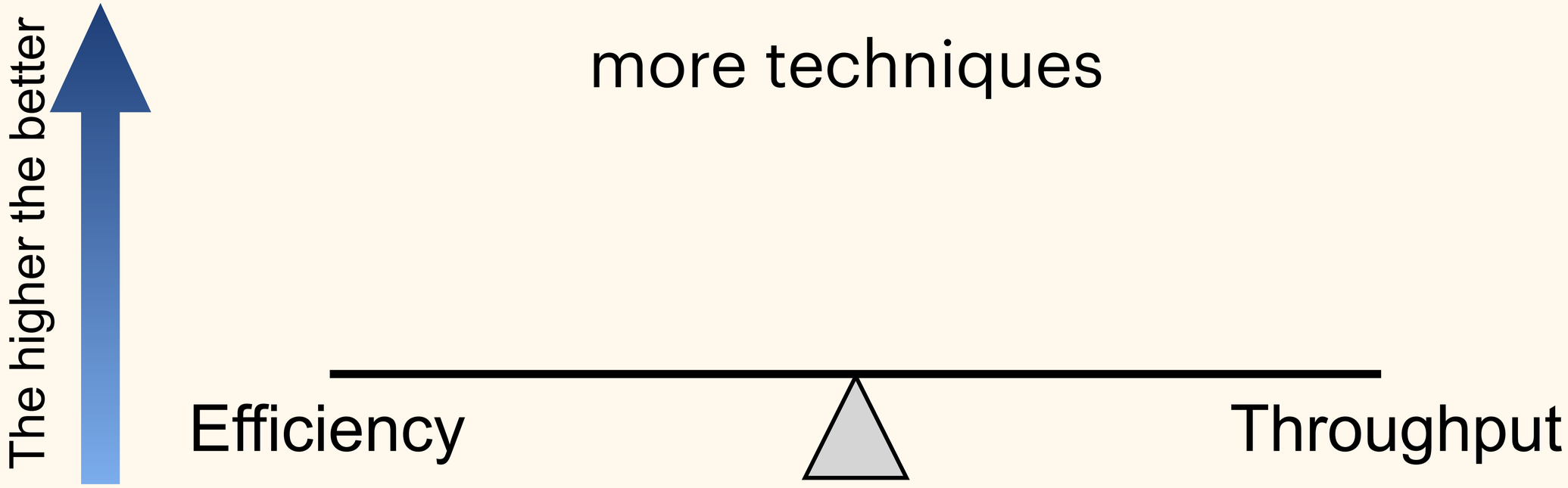
A long history of research centered around LRU

Least-recently-used (LRU)



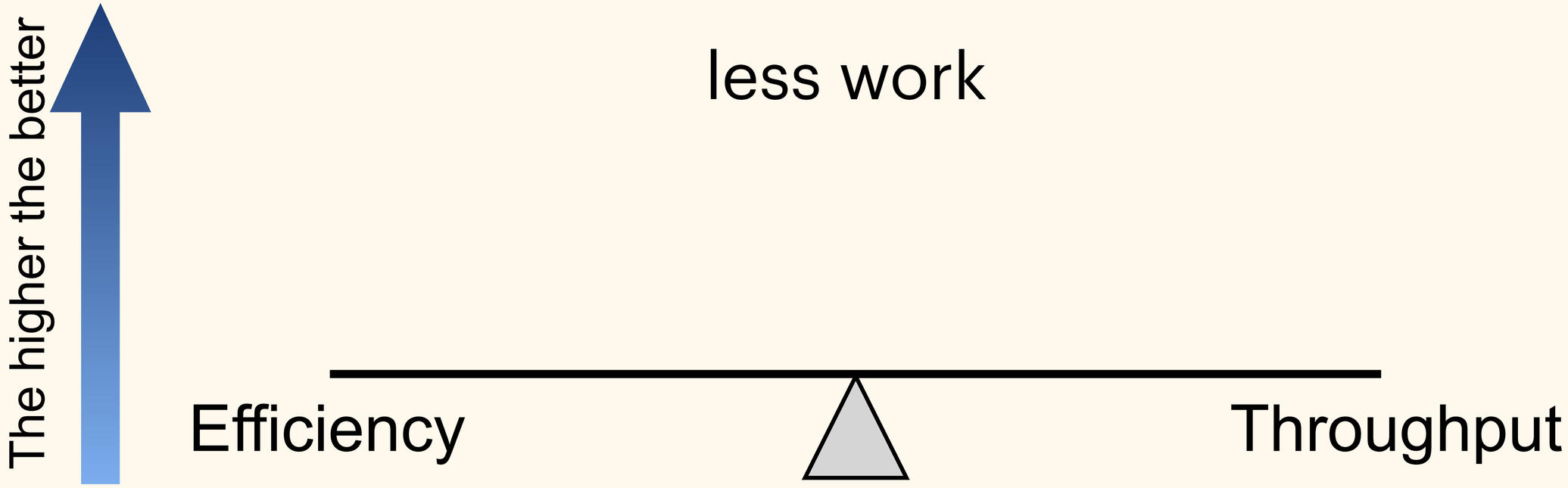
A long history of research centered around LRU

ARC, LIRS, SLRU, MQ, CACHEUS…



A long history of research centered around LRU

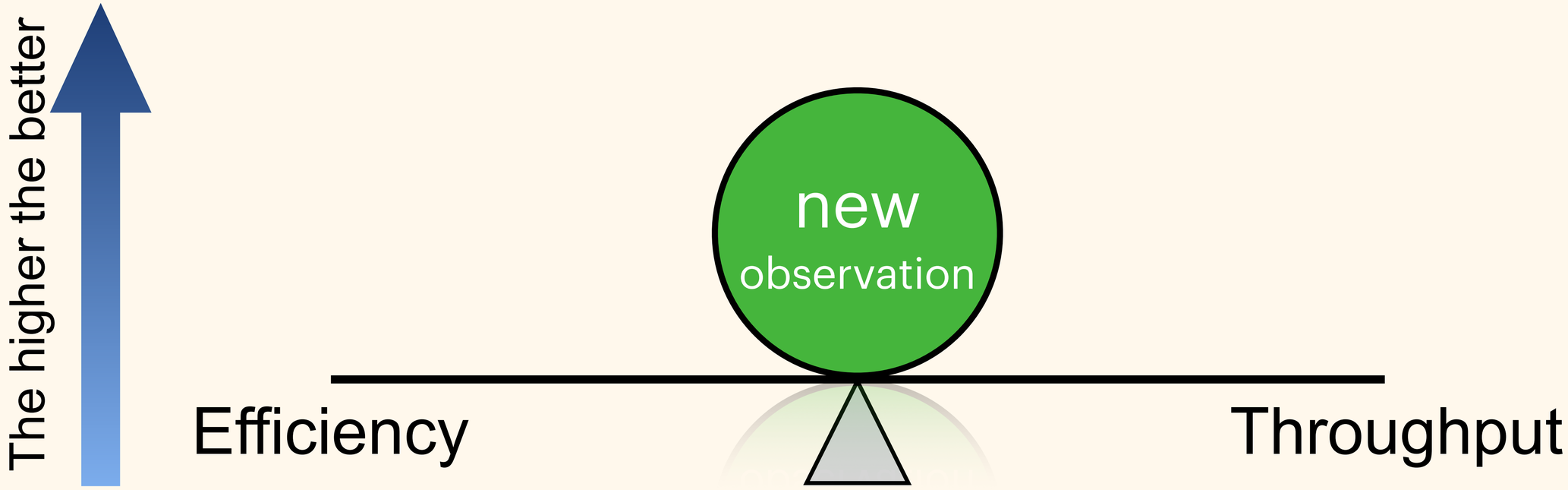
FIFO-Reinsertion, CLOCK variants



Can we have the best of both worlds?

System design is often to make right trade-offs

FIFO can be better than LRU



LRU is ~~bad~~,
let’s start with FIFO

Why FIFO?

- Many benefits
  - fewer metadata
  - less computation
  - more scalable
  - flash friendly

The drawback:

FIFO cannot keep popular objects in the cache

What does FIFO need?

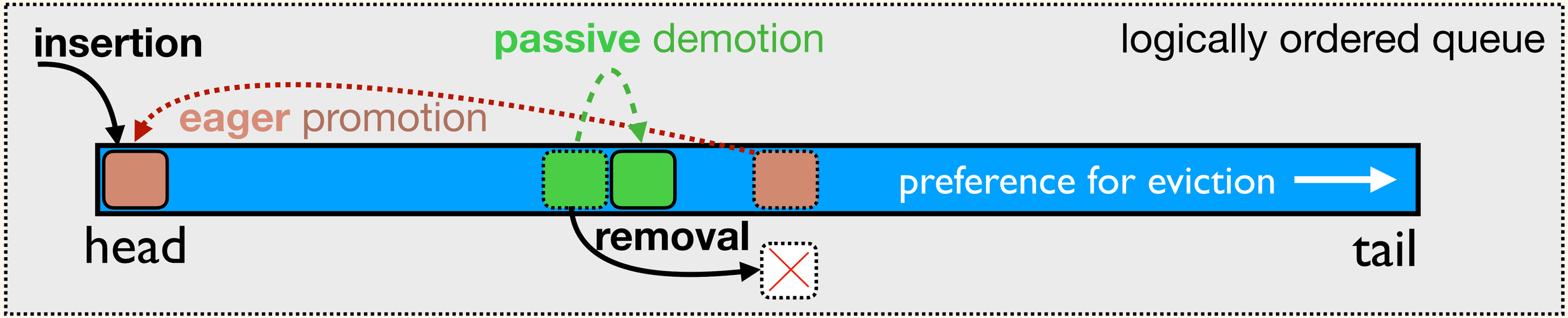
- Retain popular objects in the cache

LAZY PROMOTION

- Evict unpopular objects faster

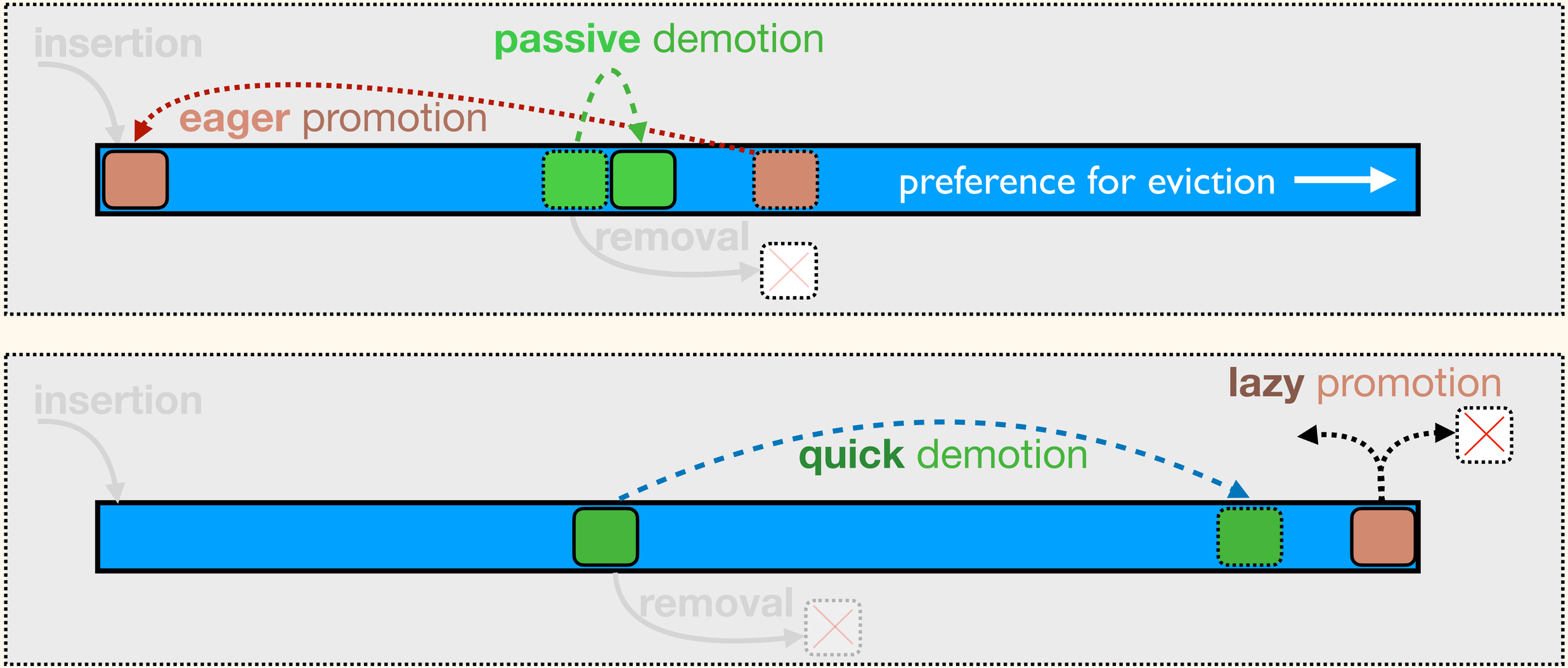
QUICK DEMOTION

An abstraction of cache



Existing cache eviction algorithms = cache **promotion** algorithms!

An abstraction of cache



Lazy Promotion

Promotion only at eviction

LAZY PROMOTION: promotion only at eviction

Retain popular objects with minimal efforts

- Example: FIFO-Reinsertion/CLOCK
  - reinserts an object back during eviction if it has been requested

- Higher throughput (than LRU)
  - fewer operations
  - more scalable

- Higher efficiency (than LRU)
  - more information at eviction time

LAZY PROMOTION: promotion only at eviction

Retain popular objects with minimal efforts

Common wisdom

CLOCK has

~~higher~~ → lower

miss ratios

than LRU

We find

Dataset:

- 10 datasets, 5307 traces from 2007-2020
- block, key-value, object
- 814 billion requests , 55.2 billion objects

LAZY PROMOTION: promotion only at eviction

Retain popular objects with minimal efforts

Common wisdom

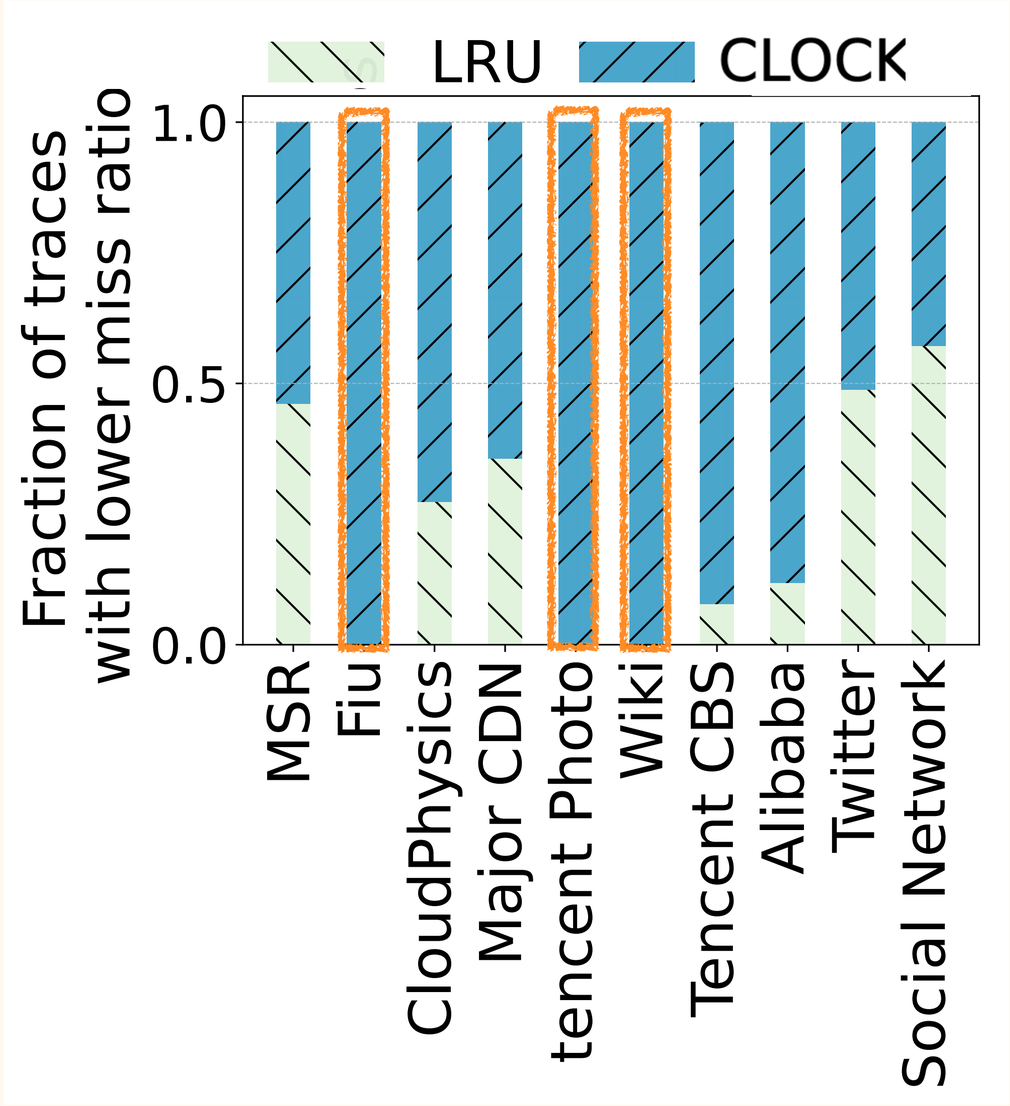
CLOCK has

~~higher~~ miss ratios

than LRU

We find

lower



CLOCK (FIFO + LP) is also simpler, faster, and more scalable

Quick Demotion

Quickly remove most new objects

QUICK DEMOTION: quickly remove most new objects

Evict unpopular / short-lived objects faster

- Removing less valuable objects faster is not new
  - Remove scan pages/data

- Why use quick demotion
  - Zipf workloads: unpopular objects are the majority of objects
  - Belady spends fewer resources on unpopular objects

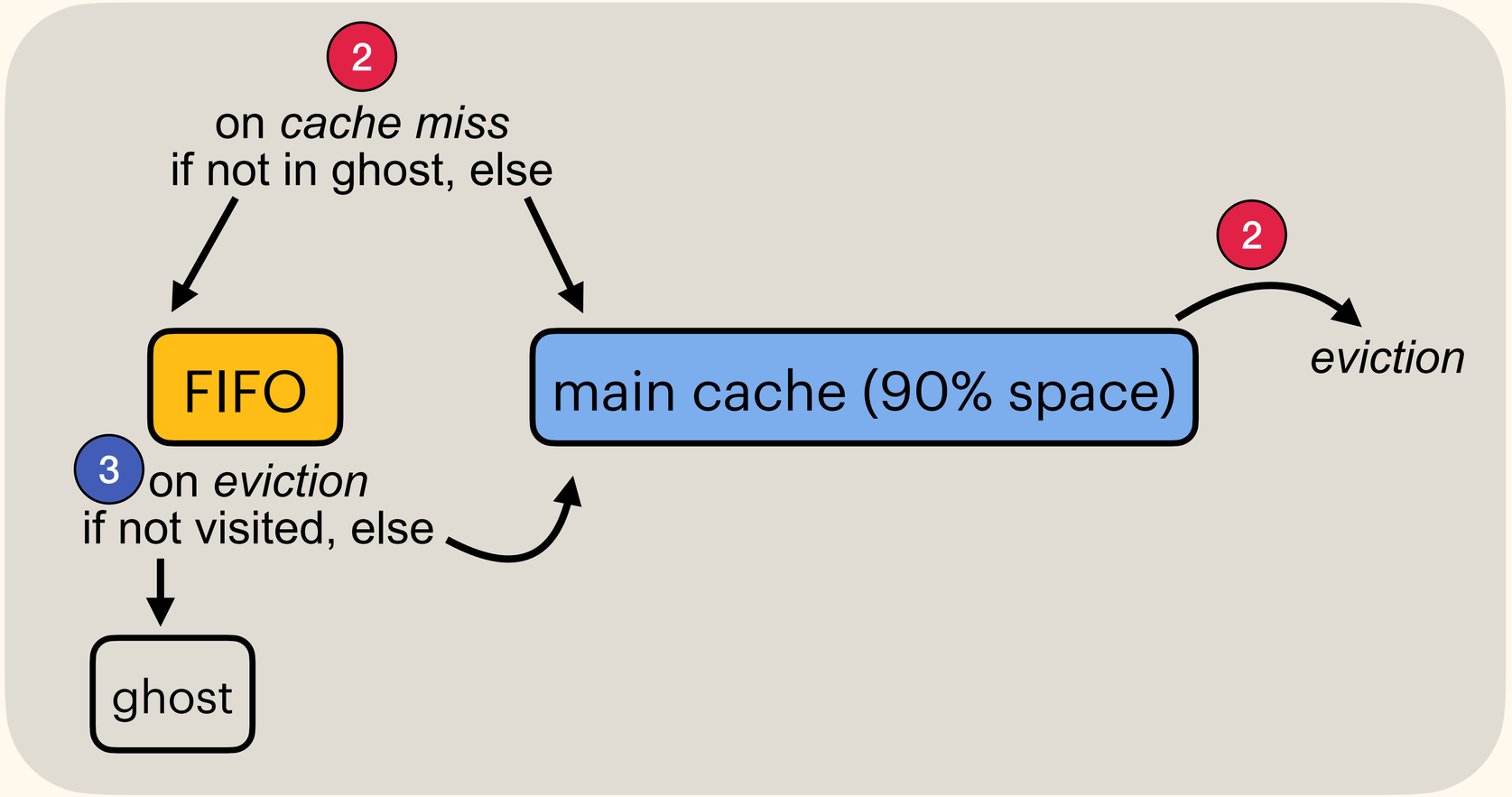
QUICK DEMOTION

A simple design to illustrate the power

1

```
struct object {
  …
  bool visited;
}
```

on *cache hit*
`visited = true`



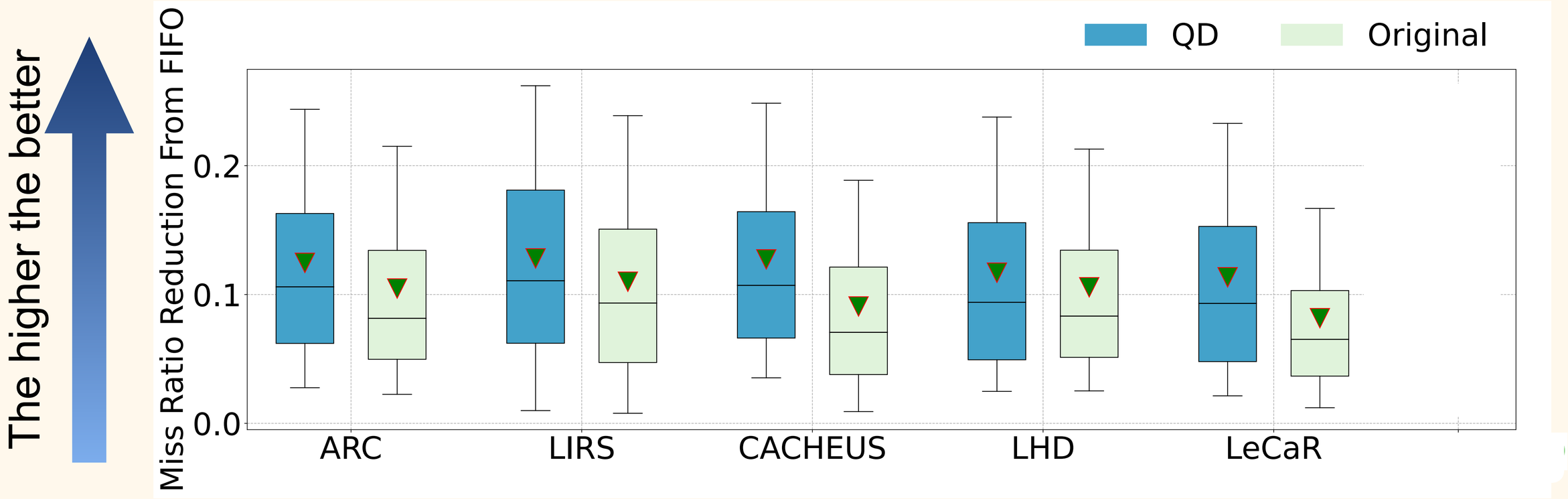
QUICK DEMOTION (QD): probationary FIFO quickly removes many new objects

QD improves over all state-of-the-art algorithms

ARC → QD-ARC: up to 59.8% miss ratio reduction

Mean miss ratio reduction across all algorithms and sizes: 2.7%

FIFO + LP + QD better than state-of-the-art



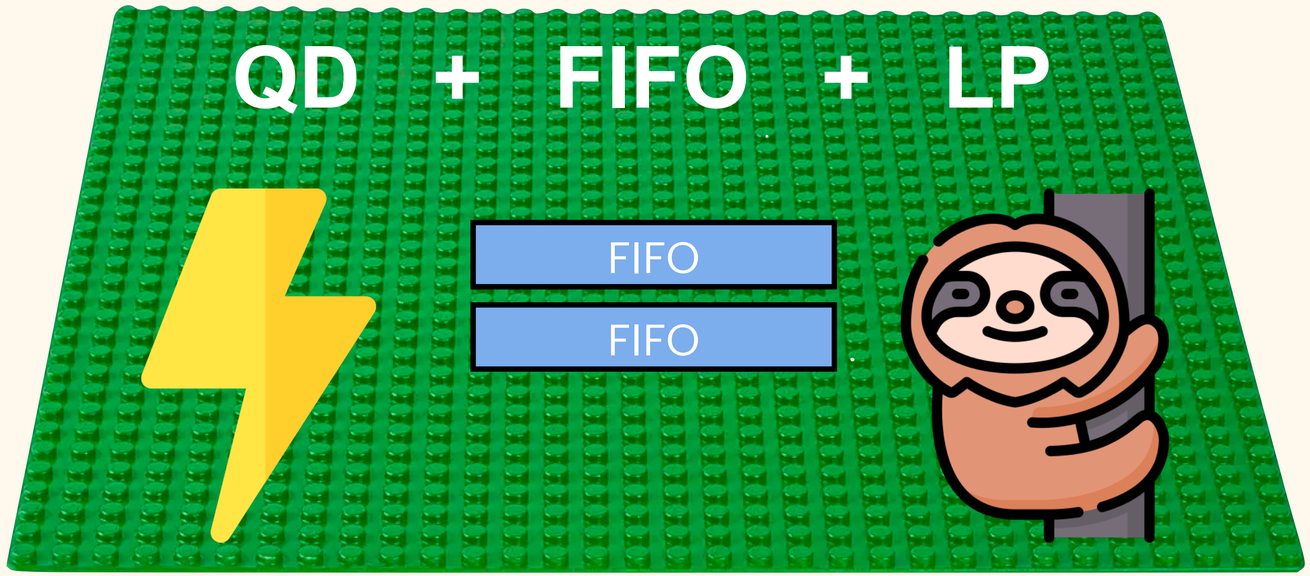
FIFO + LP + QD:

- more **efficient** than state-of-the-art
- **simple**, **fast**, **scalable**

More lazy promotion and quick demotion techniques

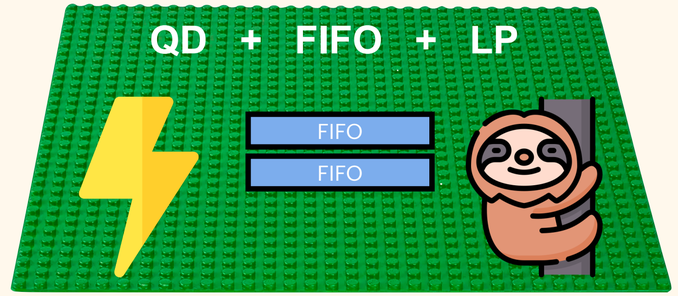
- LAZY PROMOTION
  - reinsertion
  - periodic (FrozenHot)
  - batched (CliqueMap)
  - probabilistic
- QUICK DEMOTION
  - small FIFO
  - new metric

Design cache eviction algorithms like building LEGOs



Takeaways

FIFO is better than you would have expected



- **FIFO + Lazy Promotion can be more efficient than LRU**
- **QUICK DEMOTION enables state-of-the-art efficiency**
- Design new eviction algorithms using

FIFO + LAZY PROMOTION + QUICK DEMOTION

simple, fast, scalable, yet efficient

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