STORAGE DEVELOPER CONFERENCE
SDC EMEA 21
BY Developers FOR Developers

Virtual Conference
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Evaluating cache performance using cloud storage traces

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The Essence of Caching

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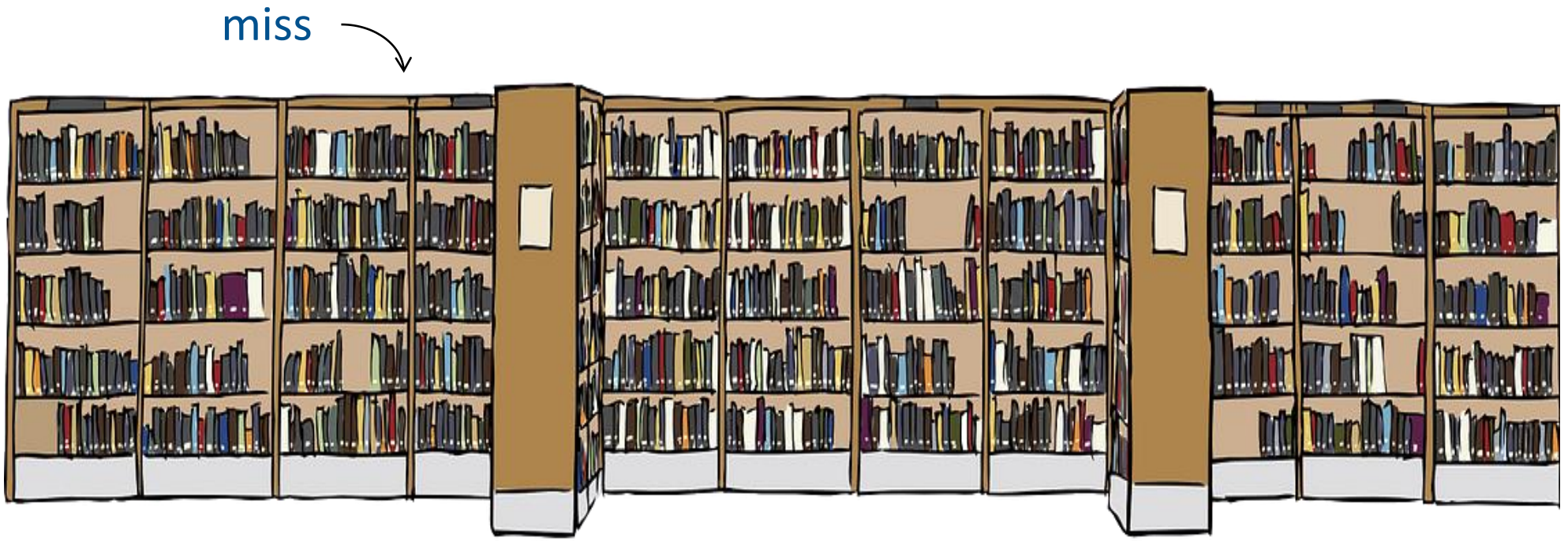
- A fast but relatively small storage location
- Temporarily store items from the “real storage”

The Essence of Caching



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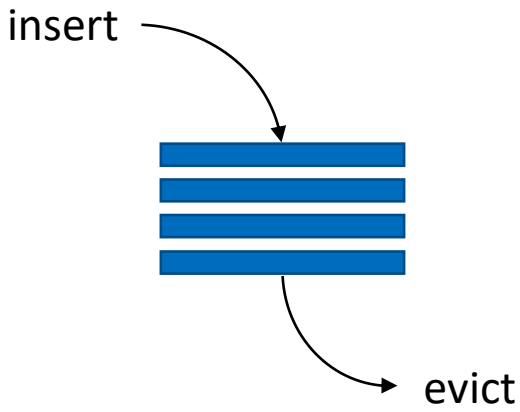
- A fast but relatively small storage location
- Temporarily store items from the “real storage”
- Improves performance if hit-ratio is high

LRU and FIFO – Common Admission / Eviction Policies

- FIFO – items kept in a queue
  - On a miss: admits new item to the queue and evict the next in line
  - On a hit: no update is necessary



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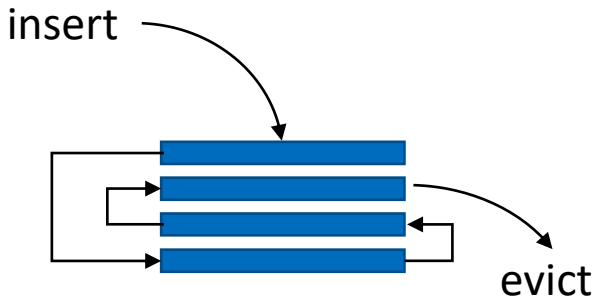
- LRU – items kept in a list
  - On a miss: adds new item to the list tail and evict item from the list head
  - On a hit: move item to the list tail



Traditionally: LRU is Considered Better

Speaker Photo Will Be Placed Here

[redacted] Finally, the LRU policy always performs better than the FIFO policy in all our experiments.

1990

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Practitioners voice

the analysis does not make a distinction between LRU and FIFO, whereas in practice LRU is almost always superior to FIFO

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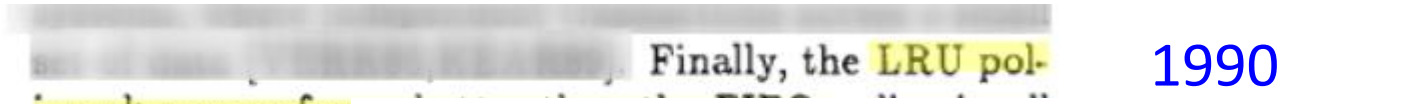

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LRU IS BETTER THAN FIFO UNDER THE INDEPENDENT REFERENCE MODEL

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LRU Is Better than FIFO[1]

Sleator and Tarjan proved that the competitive ratio of LRU and FIFO is k. In practice, however, LRU is known to perform much better than FIFO. It is believed that the superiority of LRU can be attributed to locality

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Does it still hold true?

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It’s a New World

- New Workloads
  - Old world:
    - file
    - block storage
  - Today:
    - object storage
    - multi-media
    - social networks
    - big data
    - AI

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- New Scale of data
  - Orders of magnitude higher
  - cloud storage
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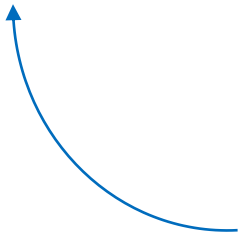

Cache meta-data can potentially surpass memory

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Designing for Cloud Scale

- Data resides on an “infinite scale” remote hub
- Local “limited scale” cache on a local spoke to improve latency
  - Possibly 100s of TBs in size
  - Some of the meta-data will have to reside on persistent storage

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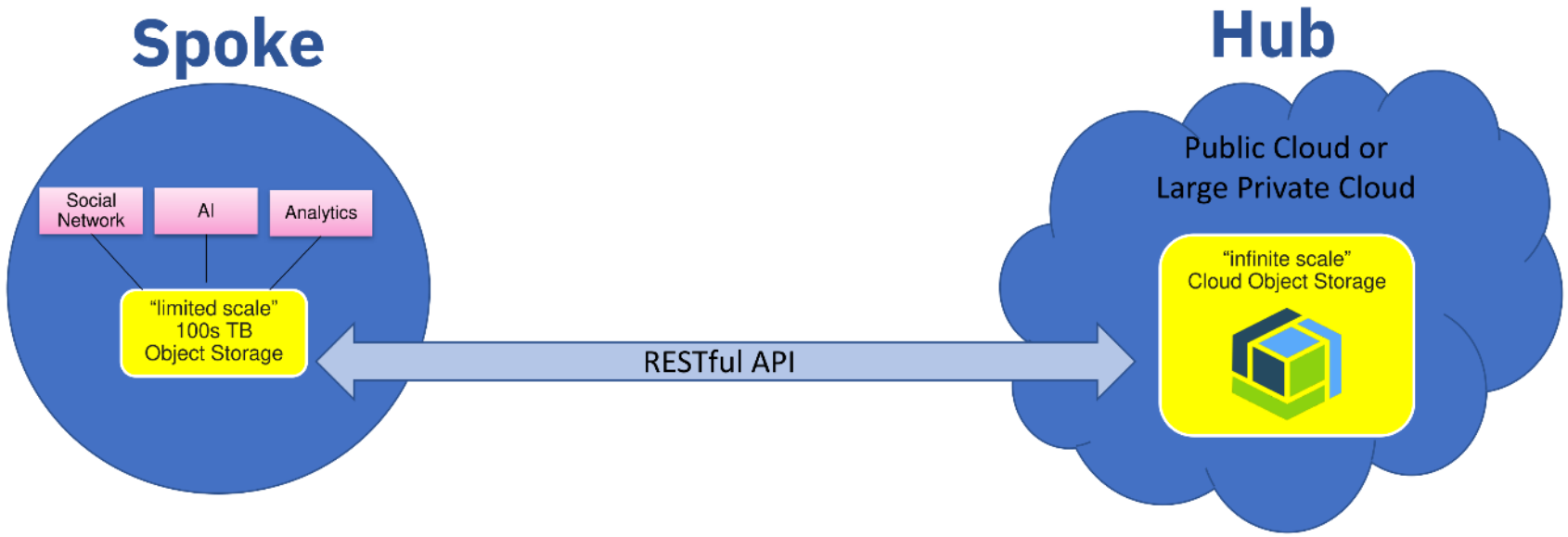
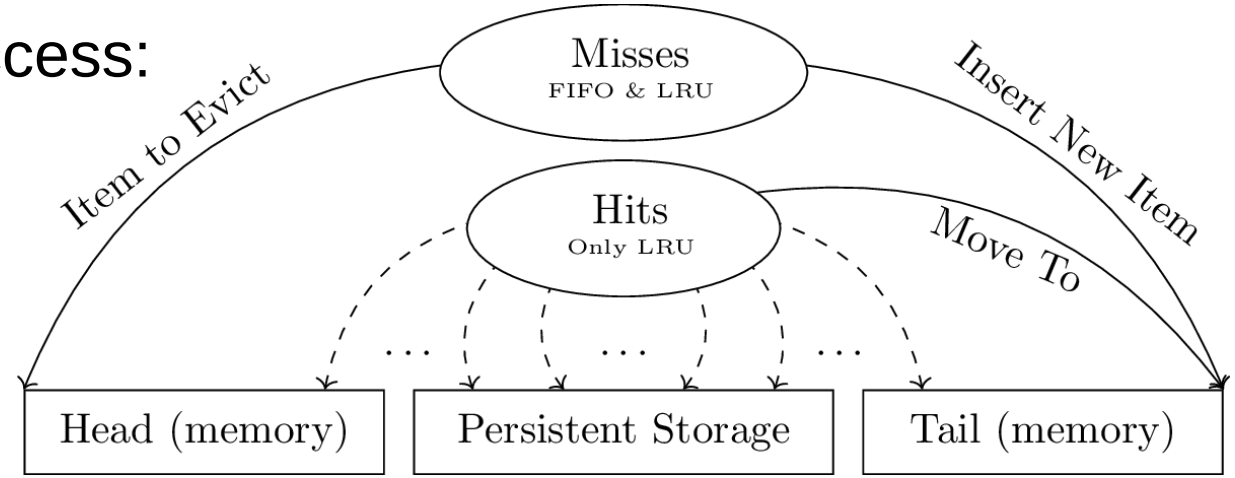


Designing for Cloud Scale

- Meta-data access:



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Designing for Cloud Scale

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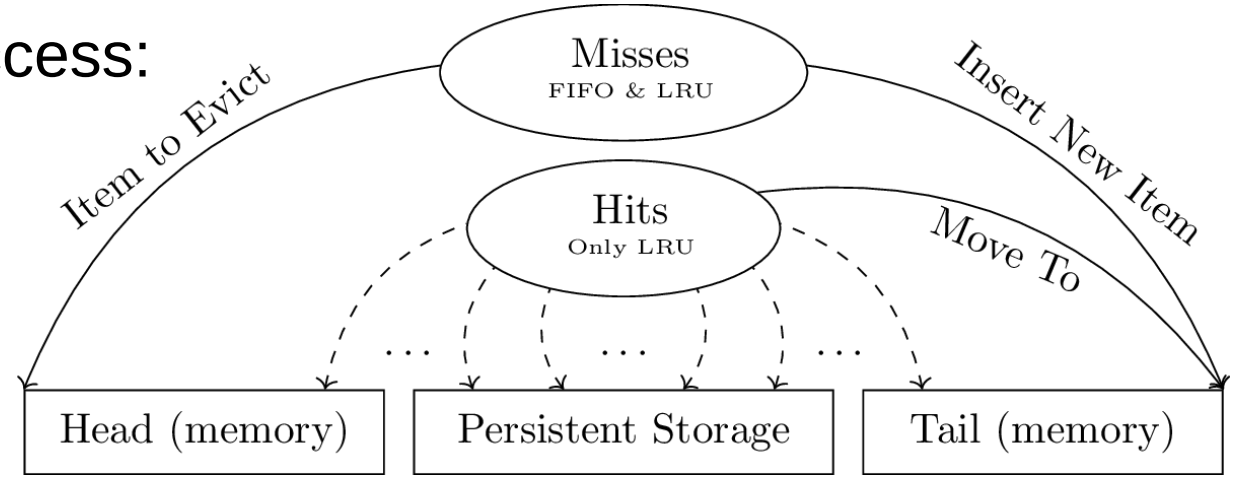

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- Hit rate reveals only part of the picture
- Account for persistent storage latency:

$$Cost_{LRU} = HR_{LRU} \cdot \overbrace{(\ell_{Cache} + \ell_{CacheMD})}^{data+metadata} + (1 - HR_{LRU}) \cdot \overbrace{\ell_{Remote}}^{data}$$

$$Cost_{FIFO} = HR_{FIFO} \cdot \overbrace{\ell_{Cache}}^{data} + (1 - HR_{FIFO}) \cdot \overbrace{\ell_{Remote}}^{data}$$

IBM Object Store Traces

- We collected traces from the public IBM Cloud Object Store
- Available on SNIA IOTTA Repository: http://iotta.snia.org/tracetypes/17

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IBM Object Store Traces

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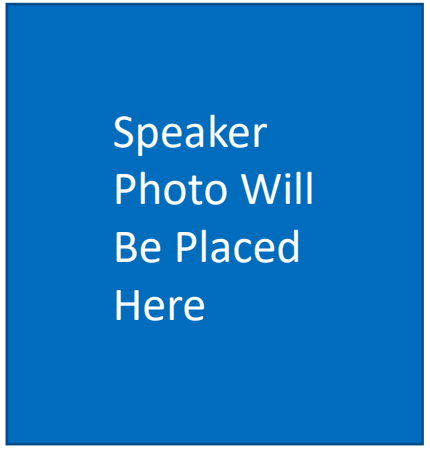
- Each trace contains
  - REST operations issued against a single bucket in IBM Cloud Object Storage
  - During a single week in 2019
- Each trace was selected based on a single criteria:
  - contains some read requests
- Some Statistics
  - 98 traces
  - 88 GB in size
  - 1.6 Billion requests
  - 342 Million unique objects



IBM Object Store Traces

```
1219008 REST.PUT.OBJECT 8d4fcda3d675bac9 1056
1221974 REST.HEAD.OBJECT 39d177fb735ac5df 528
1232437 REST.HEAD.OBJECT 3b8255e0609a700d 1456
1232488 REST.GET.OBJECT 95d363d3fbdc0b03 1168 0 1167
1234545 REST.GET.OBJECT bfc07f9981aa6a5a 528 0 527
1256364 REST.HEAD.OBJECT c27efddbeef2b638 12752
1256491 REST.HEAD.OBJECT 13943e909692962f 9760
1256556 REST.GET.OBJECT 884ba9b0c6d1fe97 23872 0 23871
1256584 REST.HEAD.OBJECT d86b7bfefc63995d 12592
```

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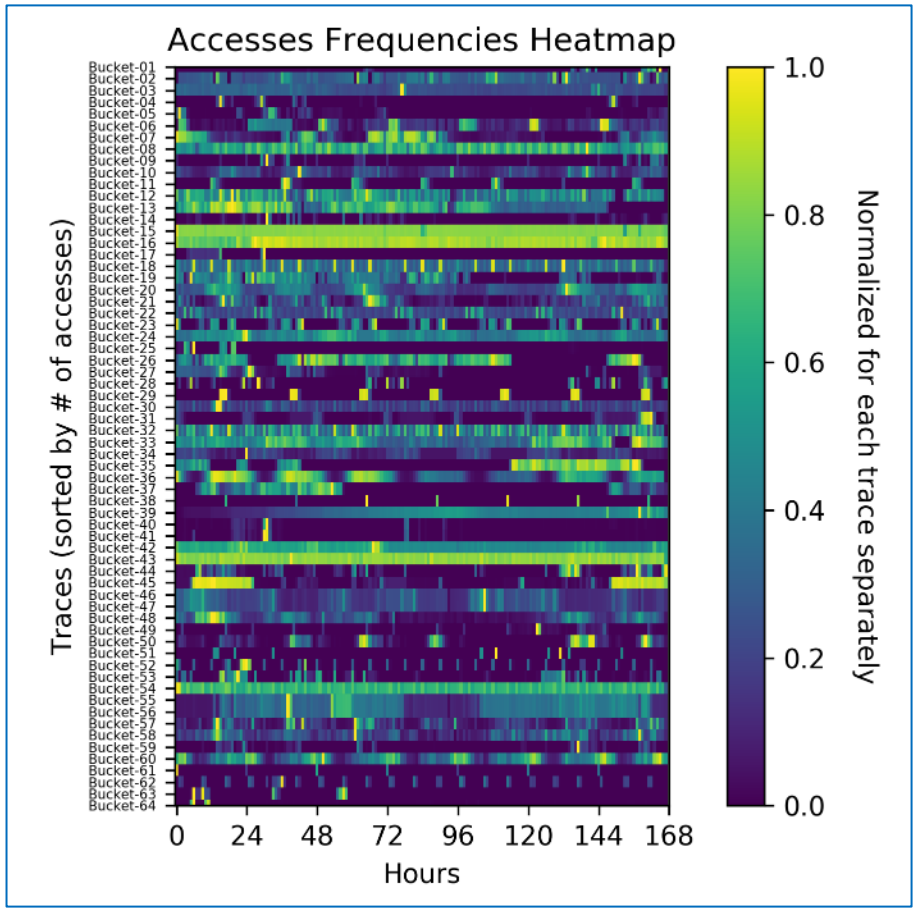
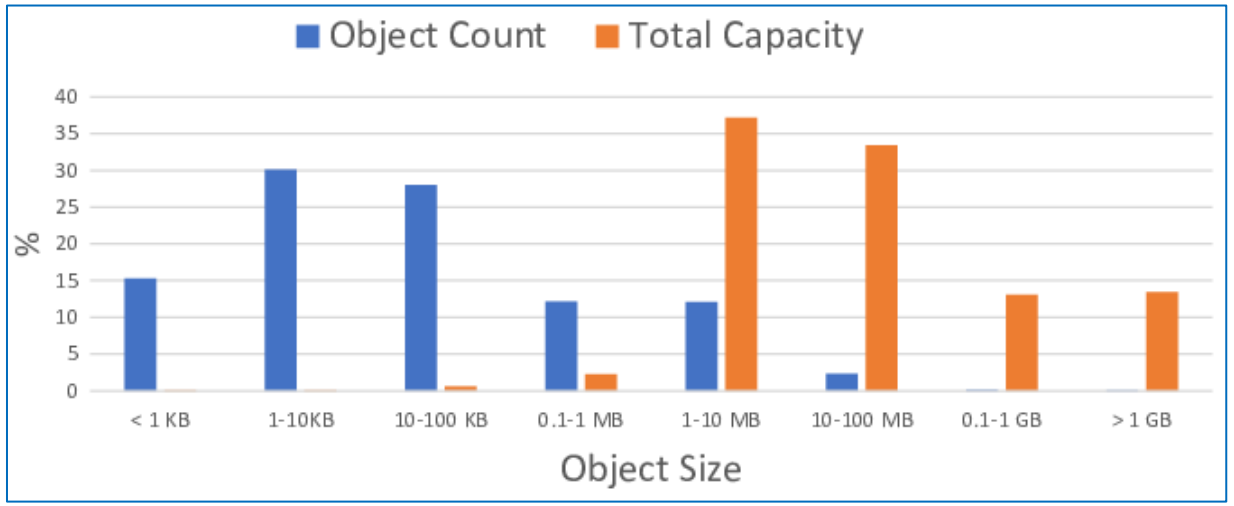
- Each trace contains:
  - GET OBJECT
  - PUT OBJECT
  - HEAD OBJECT
  - DELETE OBJECT
- Requests include:
  - Timestamp in ms from the point in time where we began collecting the traces
  - Request type
  - Object ID
  - Size of the object
  - Start and end offset (optional)
- For typical latencies of the IBM Cloud Object Storage see: https://www.ibm.com/cloud/object-storage/resiliency.

IBM Object Store Traces

- Some observations about the data





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Evaluation

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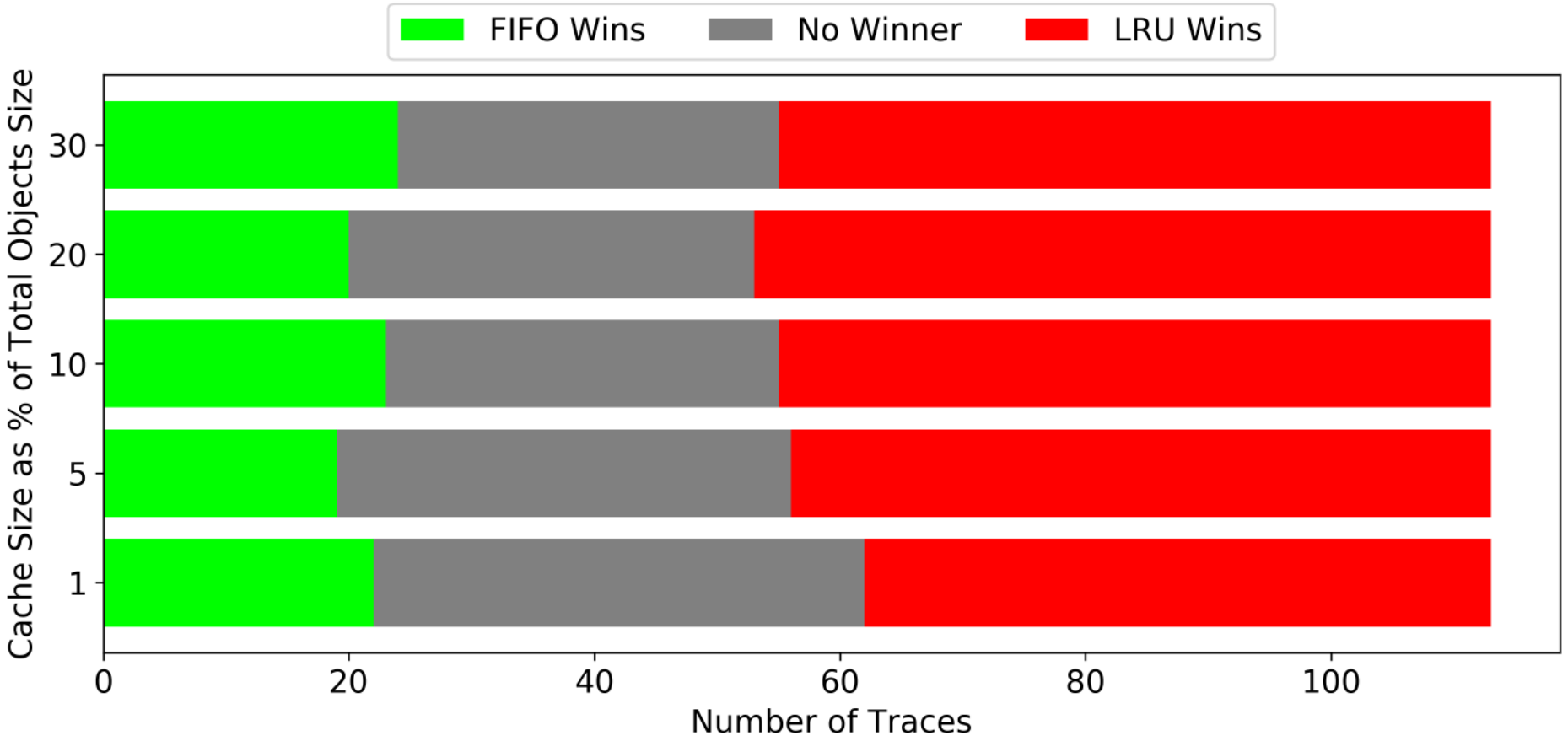
- We evaluated FIFO vs LRU using 4 different sets of traces
  - MSR
  - SYSTOR
  - TPCC
  - IBM Object Storage

- Tested different cache size configurations
- Simulated different latencies of both the cache and the remote store

Evaluation

- Pure hit rate



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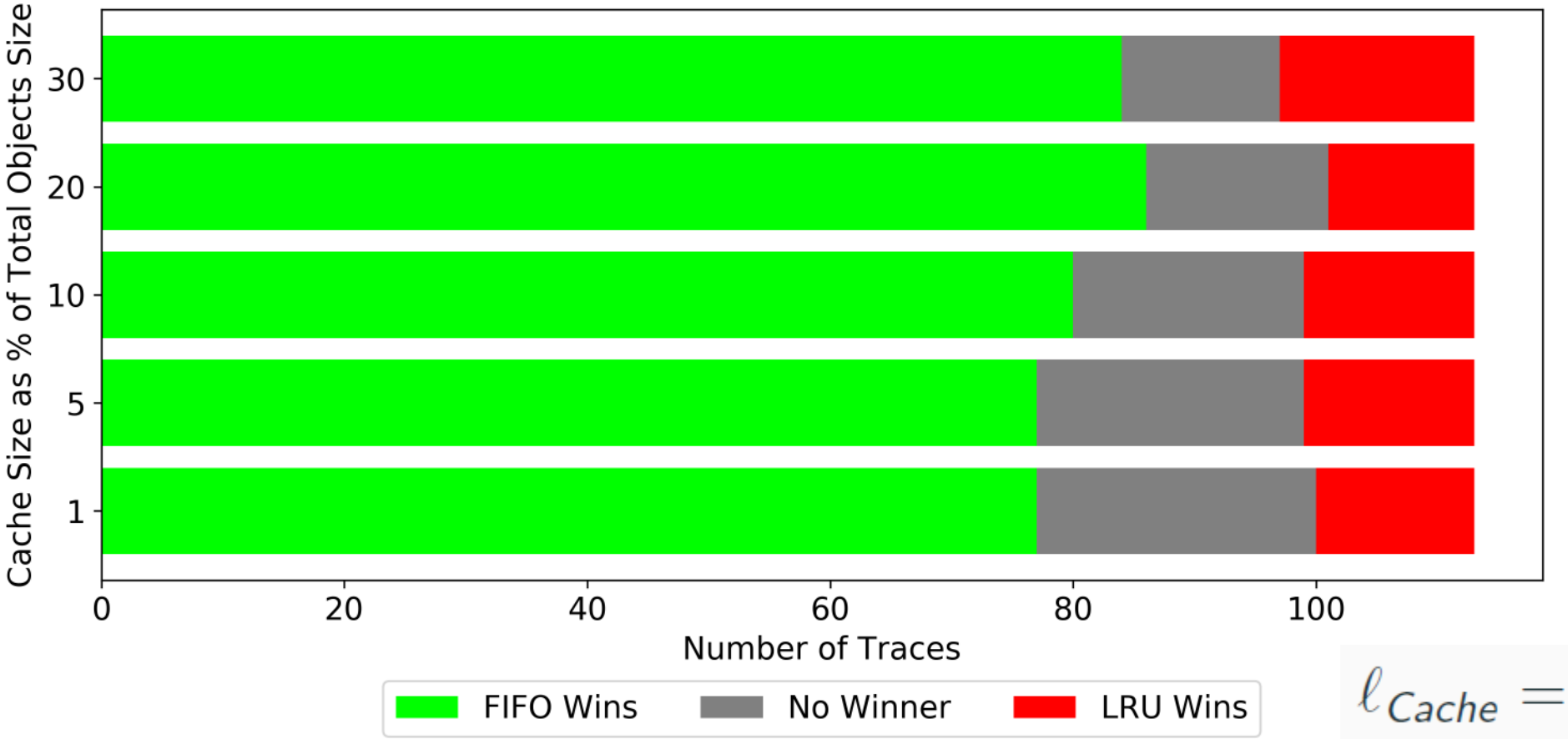
Evaluation

- Cost winners



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$$\ell_{Cache} = 1, \quad \ell_{Remote} = 50$$

Evaluation

- Cost heatmap

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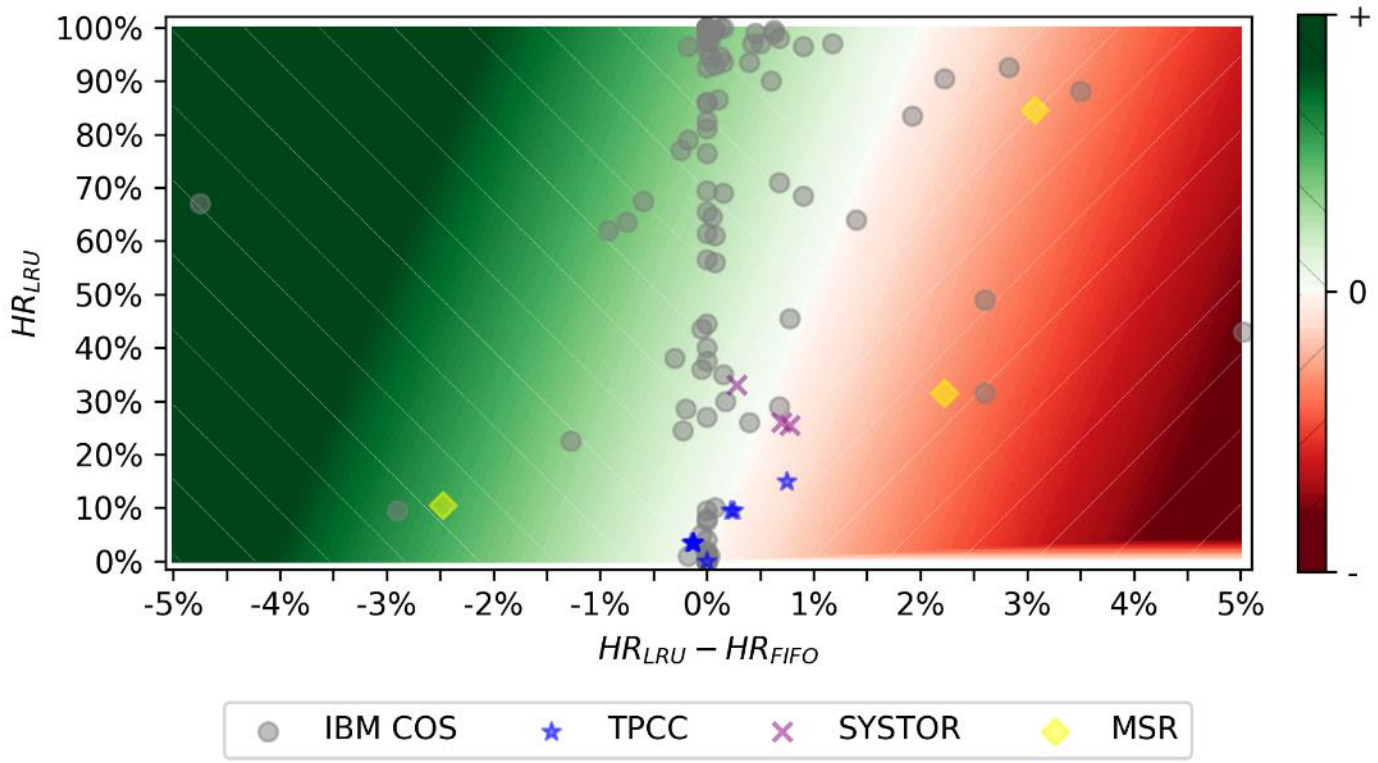

$$\ell_{Cache} = 1, \quad \ell_{Remote} = 50$$

$$Cache\ Size = 30\%$$

Discussion

- No longer clear that LRU is better than FIFO
- Hit rate does not tell the entire story
- IBM Object Store traces provide new insight and opportunities for research

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Thank You!

Ohad Eytan

Effi Ofer

Danny Harnik

Roy Friedman

Ronen Kat

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