It's Time to Revisit LRU vs. FIFO

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HotStorage '20

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The Essence of Caching

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

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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 & FIFO

Least Recently Used and First In First Out Policies

- The core component of the cache is the admission/eviction policy
- **FIFO** - holds the items in a queue:
  - ⋆ On a miss: admit new item to the queue and evict the next in line
  - ⋆ On a hit: no update is needed
- **LRU** - holds the items in a list:
  - ⋆ On a miss: add new item to list tail and evict item from list head
  - ⋆ On a hit: move item to the list tail
- Both are simple & efficient

Traditionally: LRU Considered Better

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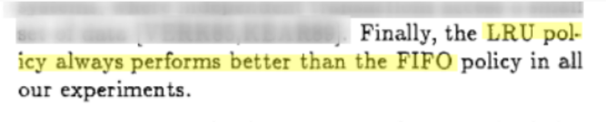

[redacted]. Finally, the LRU policy always performs better than the FIFO policy in all our experiments.

1990

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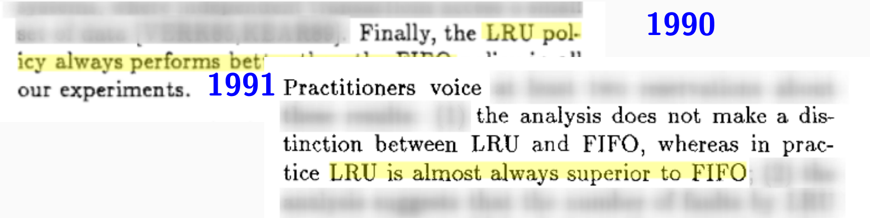

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1991

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

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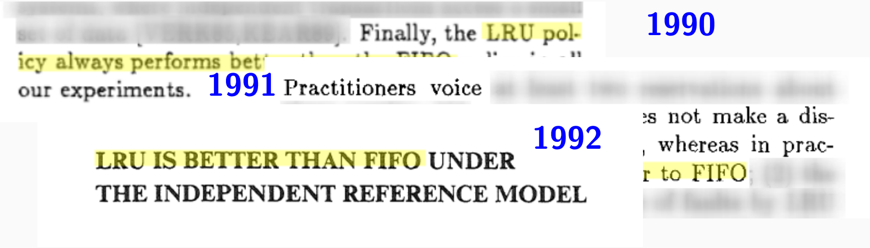

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LRU IS BETTER THAN FIFO UNDER THE INDEPENDENT REFERENCE MODEL

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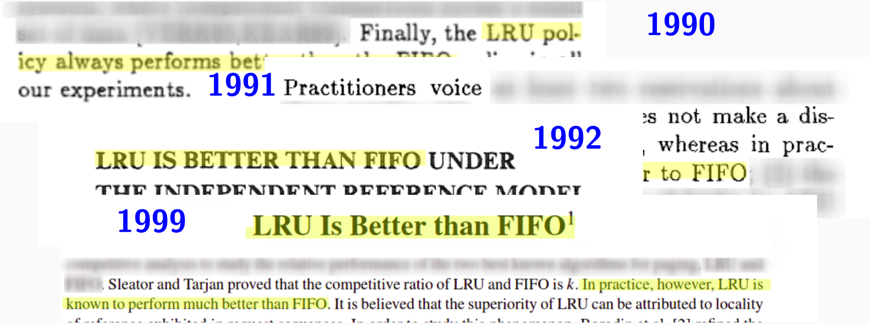

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LRU Is Better than FIFO[1]

. 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 of reference exhibited in request sequences. In order to study this phenomenon, Borodin et al. [2] refined the

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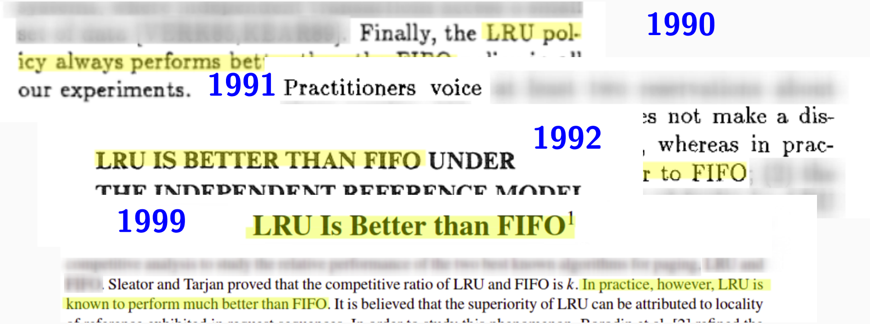

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Does it still hold?

New World

- New workloads:
  - ⋆ Old world: file and block storage
  - ⋆ Today: videos, social networks, big data, machine/deep learning
    - ◦ In particular we are interested in **object storage** (e.g. Amazon S3, IBM COS)

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- New workloads:
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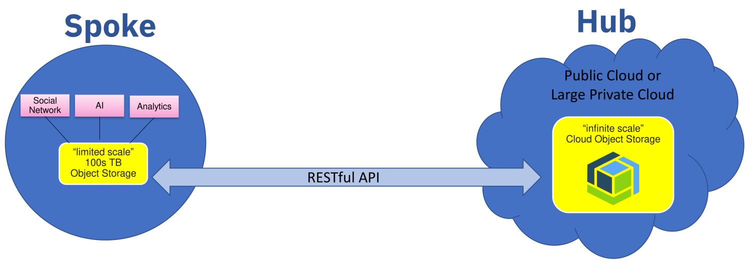
    - ◦ In particular we are interested in **object storage** (e.g. Amazon S3, IBM COS)
- New scale of data:
  - ⋆ Orders of magnitude higher
  - ⋆ Emergence of cloud storage and persistent storage caches
  - ⋆ Cache metadata can potentially surpass memory

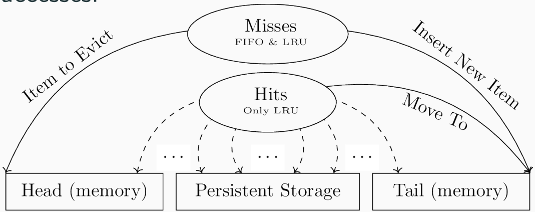
Motivation - Cloud Object Storage

- Data resides on an "infinite scale" remote hub
- Local "limited scale" on a local spoke to improve latency
  - ⋆ Possibly 100s of TBs in size
  - ⋆ Some of the metadata will have to reside on persistent storage


Spoke
Hub
Social Network
AI
Analytics
"limited scale" 100s TB Object Storage
RESTful API
Public Cloud or Large Private Cloud
"infinite scale" Cloud Object Storage

Our Cost Model

- Metadata accesses:



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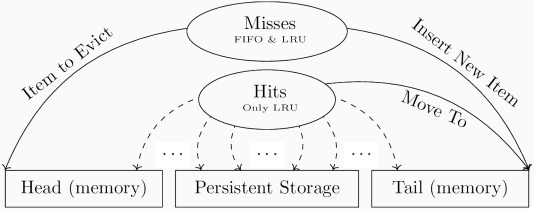

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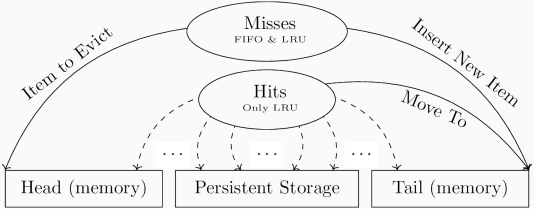

- Hit rate paints only part of the picture
- We formulated a cost model that accounts also for persistent storage latency:

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

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

IBM Cloud Object Storage Traces

- We collected 99 traces from IBM public Cloud Object Storage service
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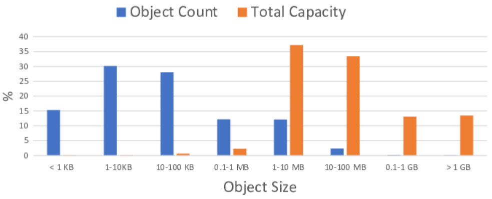
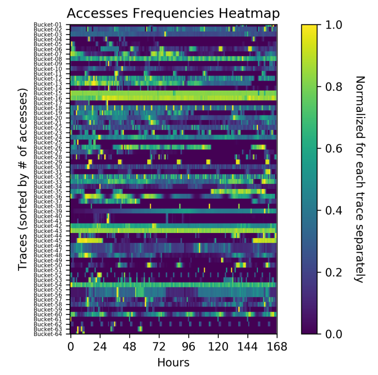
- Some observations about the IBM traces:

Great variance in object sizes

Great variance in access patterns





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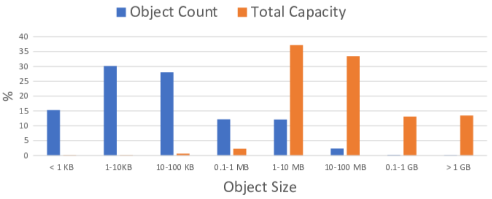

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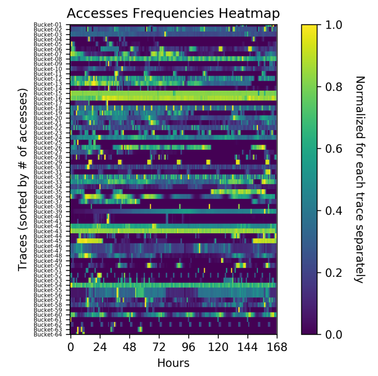


- We are publishing the traces and encourage you to use it

Evaluation

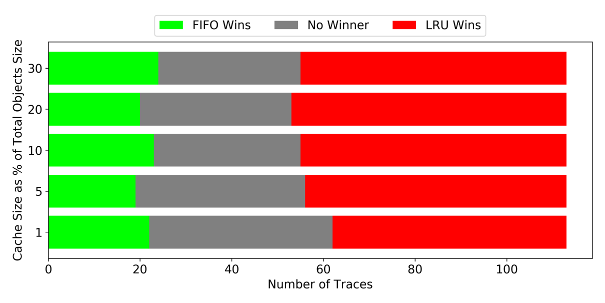
- We evaluated FIFO vs. LRU using 4 sets of traces:

Group	**Traces**	**Accesses**	**Objects**	**Objects Size**
Name	#	*Millions*	*Millions*	*Gigabytes*
MSR	3	68	24	905
SYSTOR	3	235	154	4,538
TPCC	8	94	76	636
IBM COS	99	858	149	161,869

- Tested different cache sizes (as percentage of trace object size)
- Simulated different ratios between latency of cache and remote

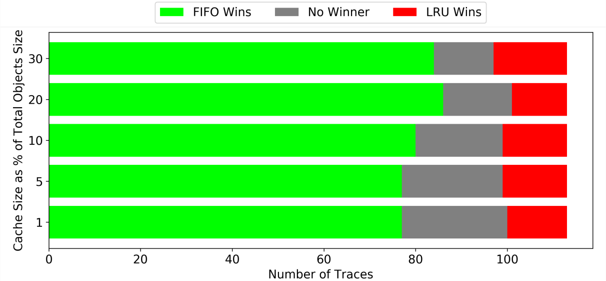
Results

Pure Hit Rate:



Results

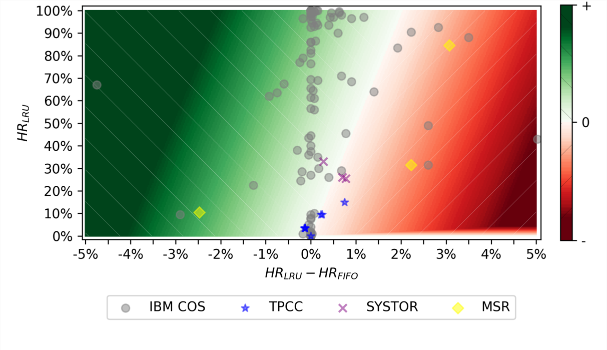
Cost Winners:



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

Results

Cost Heatmap:



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

$$Cache\ Size = 30\%$$

Conclusions & Discussion

- It's no longer clear that LRU is a better choice than FIFO
- Hit rate doesn't tell the entire story
- Our IBM COS traces can provide new insights and opportunities for research

Thank You!

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