Cost-based Memory Partitioning and Management in Memcached

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Outline

Background

Design

Evaluation

Conclusions

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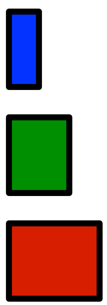
Memcached

- Key-value store
  - Simple APIs: **set**, **get**, **delete**, …
- Common component of Web architectures
  - Caching layer
- All data is kept in **RAM**
  - Fast response time

Memory management: Classes and Slabs

- Memcached divides the objects into ***classes***
  - Based on their sizes
- Example: 3 classes of objects
  - Small
  - Medium
  - Large



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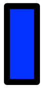
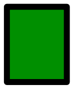
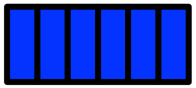
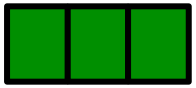
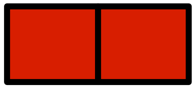
  - Small 
  - Medium 
  - Large 

- Memory is divided into blocks called ***slabs***
  - Default size of a slab: 1 MB
- A slab contains a variable number of objects
  - Many small ones 
  - Some medium 
  - Few large 

Slabs are assigned to *classes* upon request

available memory (divided into slabs)

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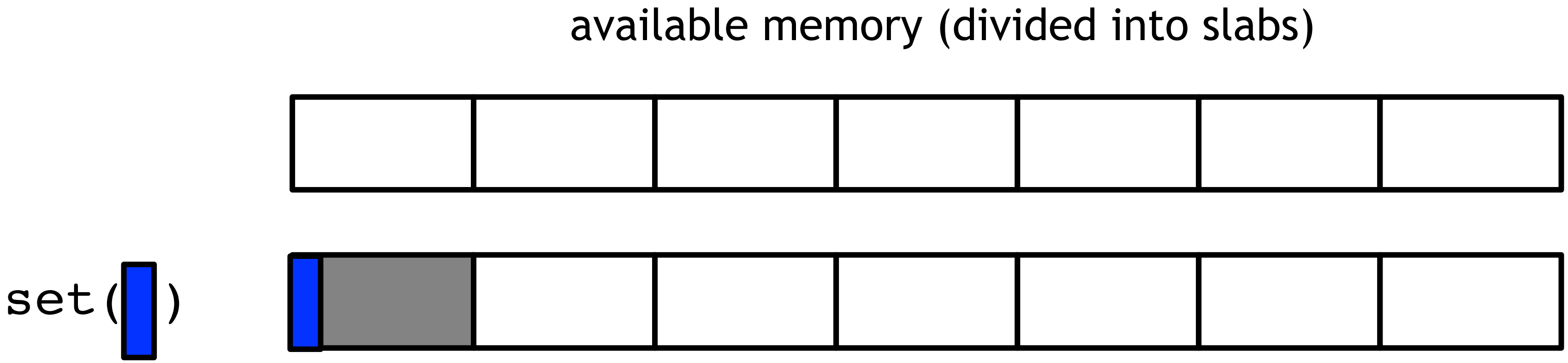

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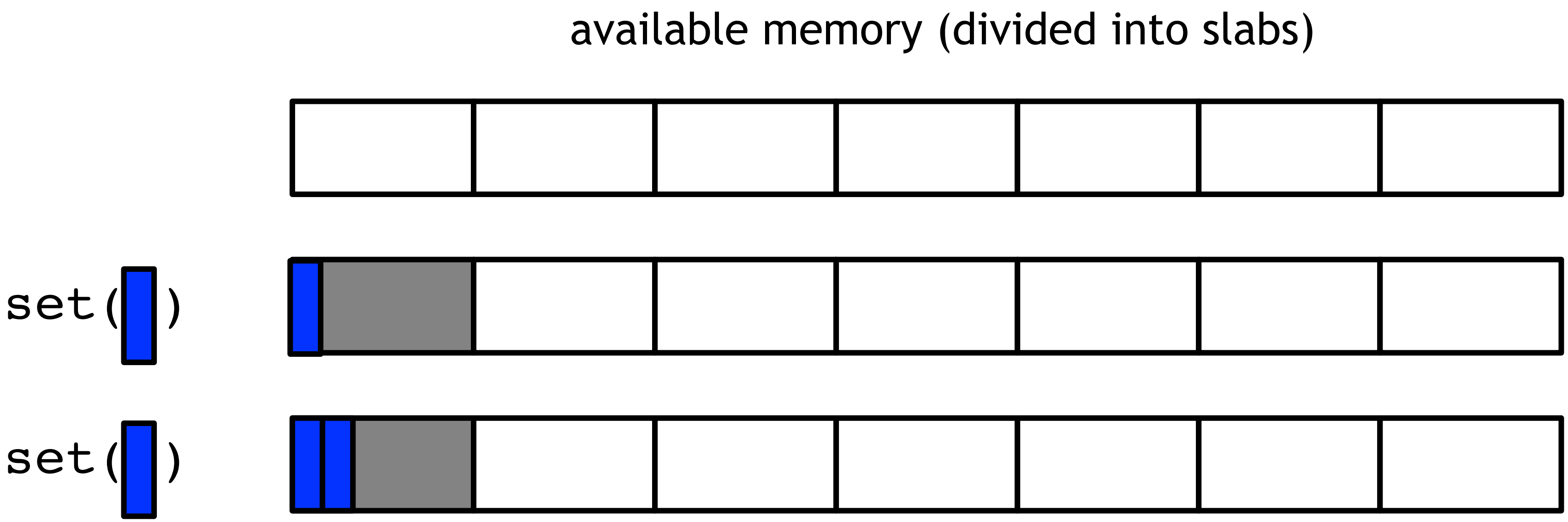

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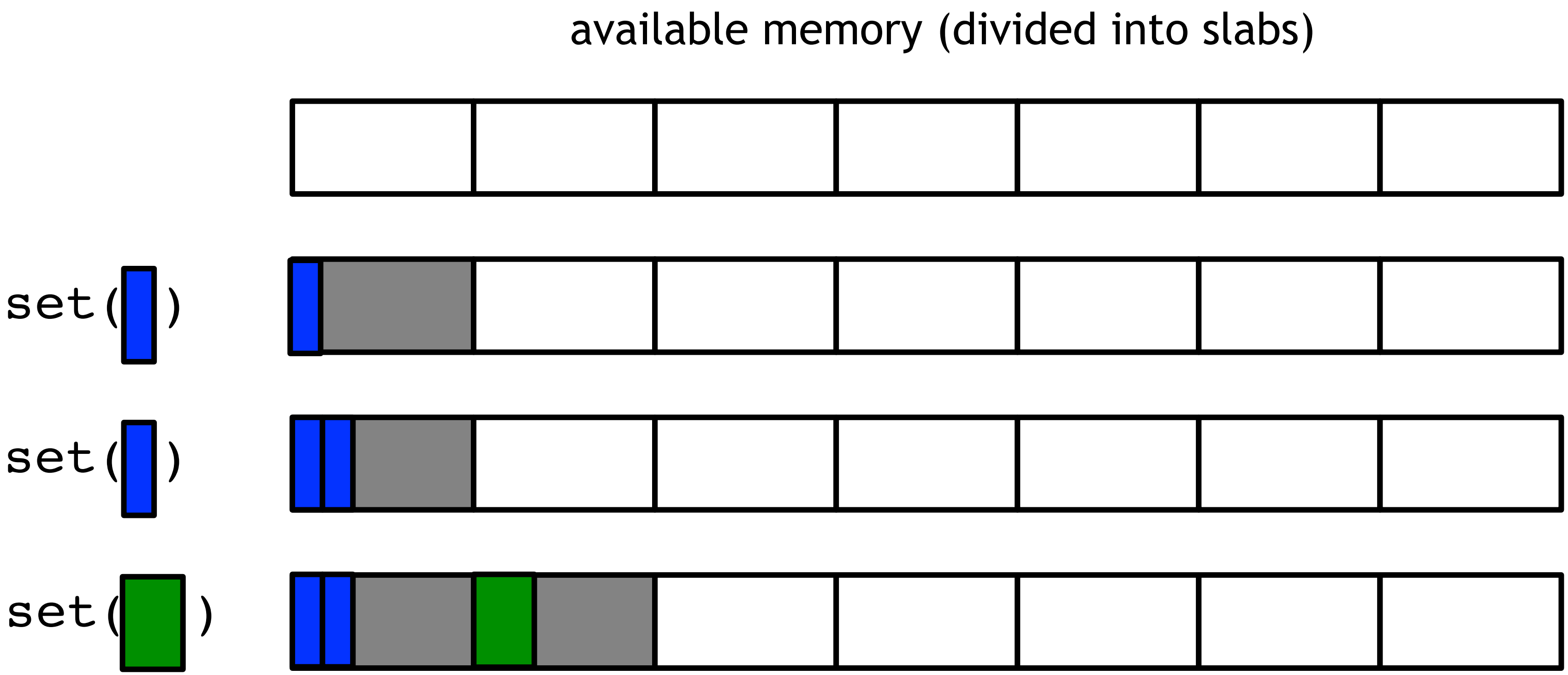

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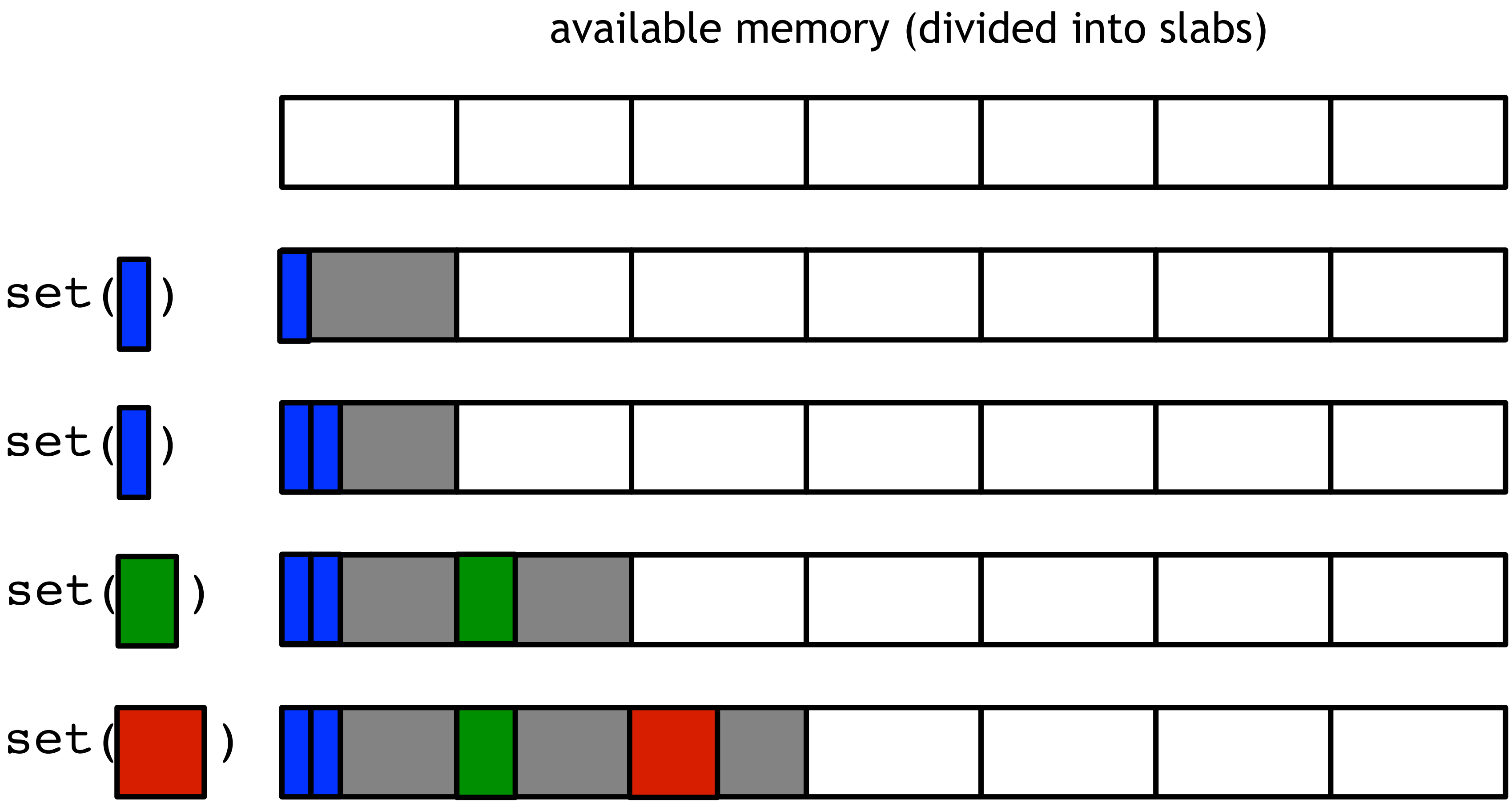
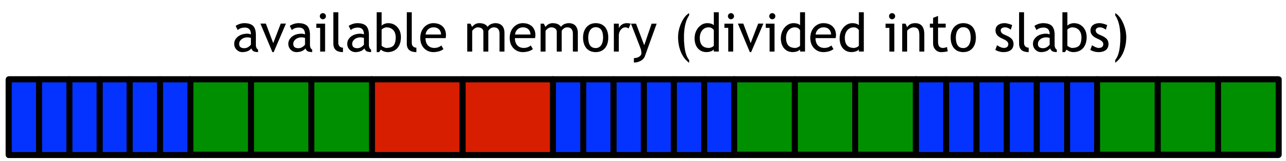


Slabs are assigned to *classes* upon request

- After many requests…

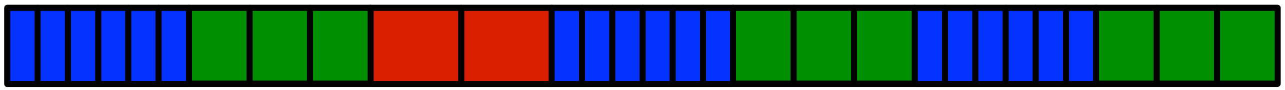


- What happens when the cache receives a new `set(` ■ `)` ?

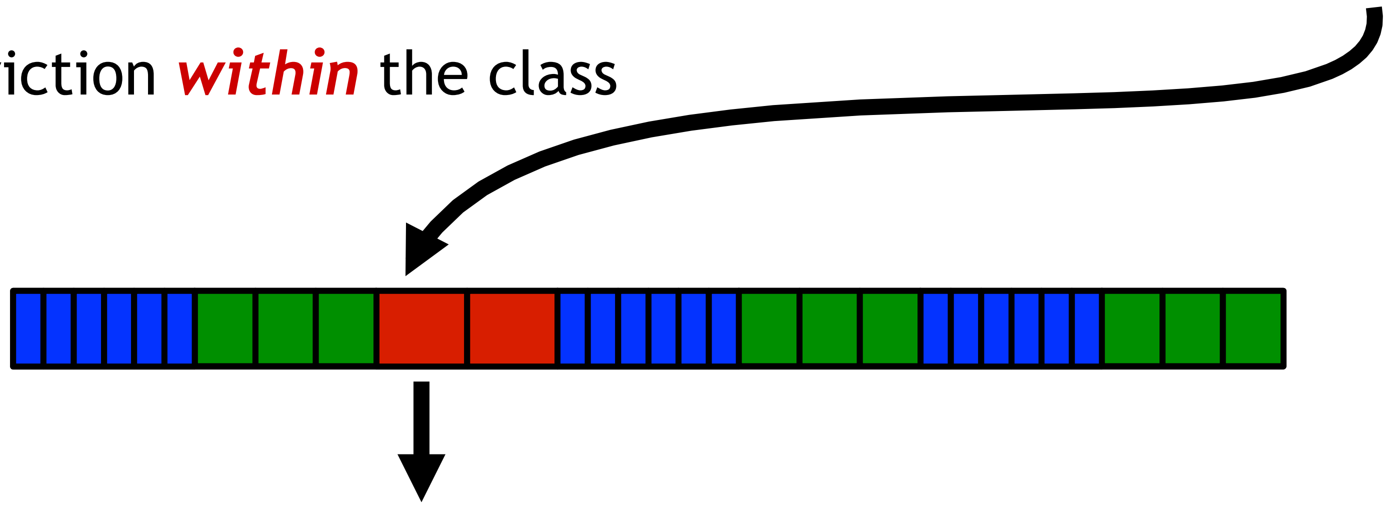
Slabs are assigned to *classes* upon request

- After many requests…

available memory (divided into slabs)



- What happens when the cache receives a new `set`( ) ?
  - **LRU** eviction ***within*** the class



Key challenges

- How the memory can be divided among the classes?
  - Static vs dynamic assignment
- What are the criteria used to assign the memory
  - Hit-ratio vs cost-hit-ratio

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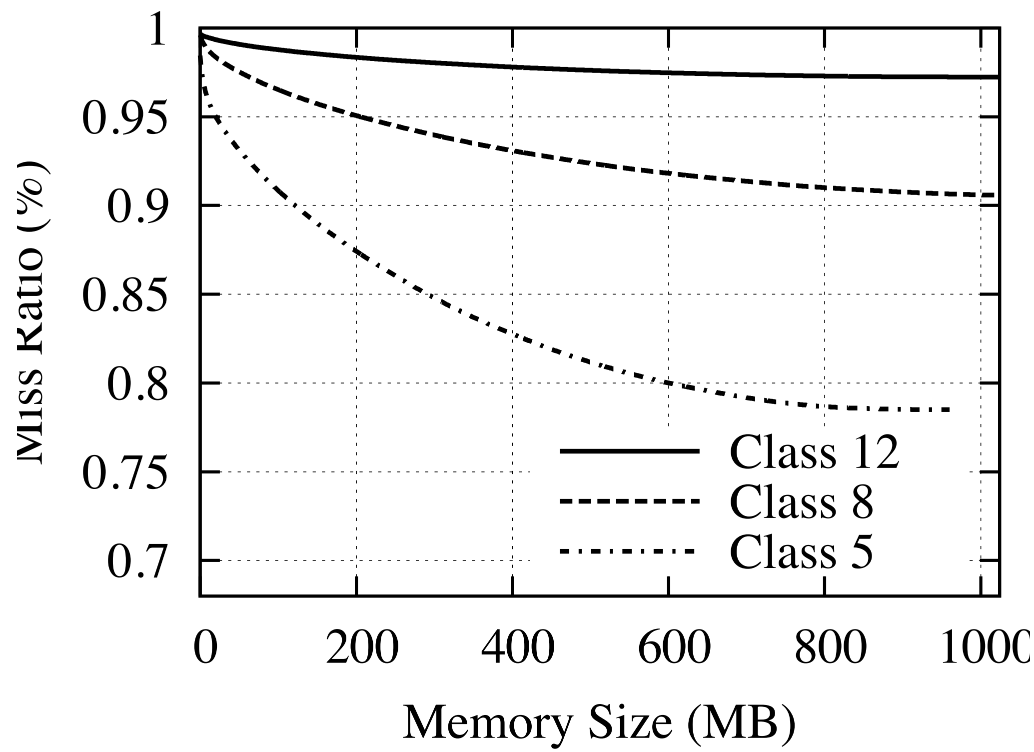
Miss-ratio curves (MRC)

- Given a trace and an eviction policy, we can compute the MRC
  - What would be the miss ratio if the class had that specific memory assigned?
- MRC can be found with a single pass of the traces
  - Mattson stack algorithm



Optimal offline slab assignment

- Goal ➔ Minimize the miss ratio
- Assumptions
  - MRC are concave
  - Memory is divided into finite number of blocks

Algorithm 1 Optimal Off-line Slab Assignment

```
Input: Miss ratio curves for all classes
Input: Number of available slabs

repeat
    Sort classes by their miss ratio difference
    Assign a slab to the class with the highest difference
until All slabs are assigned
```

Online slab assignment

- The offline optimal slab assignment can be used as a reference
  - It can be computed once we have the whole trace
- We provide a heuristic for the online assignment
- Before showing the heuristic, we consider the object costs

A new interface

- The interface `set(k,v)` implies that all the objects have the same cost or weight
- But some objects can be more difficult to obtain
  - E.g., simply because they are larger
  - or because it takes more time to retrieve them from the DB
    - complex query
- We have added a new interface: `set(k,v,c)`
  - The application can associate a cost (or weight) to the object

Slab Allocation Scheme (SAS)

- We define an observation epoch
  - E.g., when the system has experienced M misses
- During each epoch, we collect, for each classes:
  - The number of (weighted) misses
  - The number of (weighted) requests

- High number of misses ➔ The class is suffering
- Low number of miss ratio per assigned slab ➔ The class can lose a slab

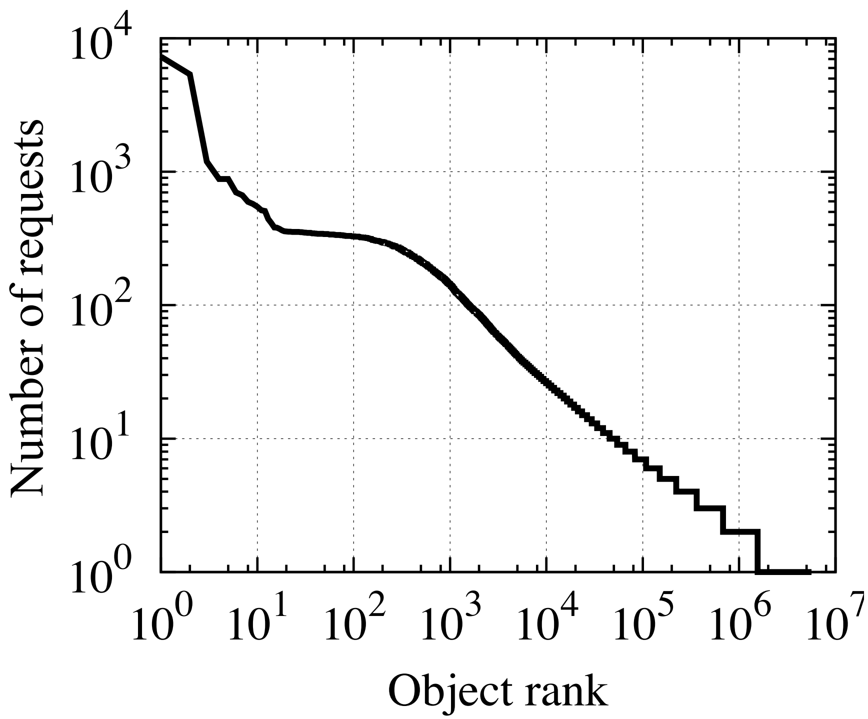
Outline

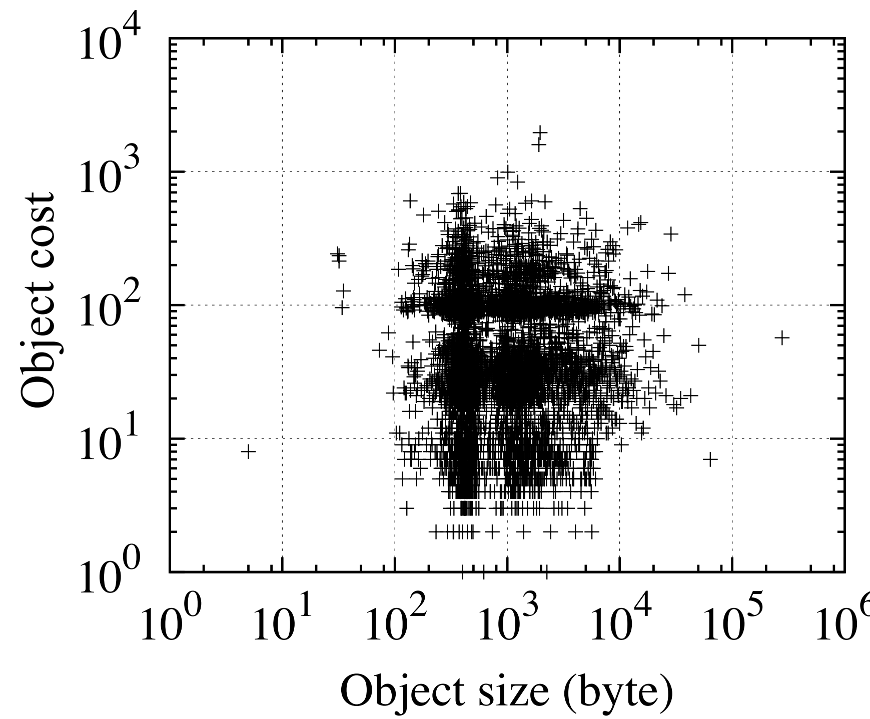
Settings

- We use a representative Web architecture
  - Application server, cache, database
- Trace driven experiment
  - Traces collected by a major CDN operator
  - The objects in the trace are stored in the database
  - The cost of retrieving the objects is stored in the application server
  - The sequence of the requests is issued by a client

About the traces

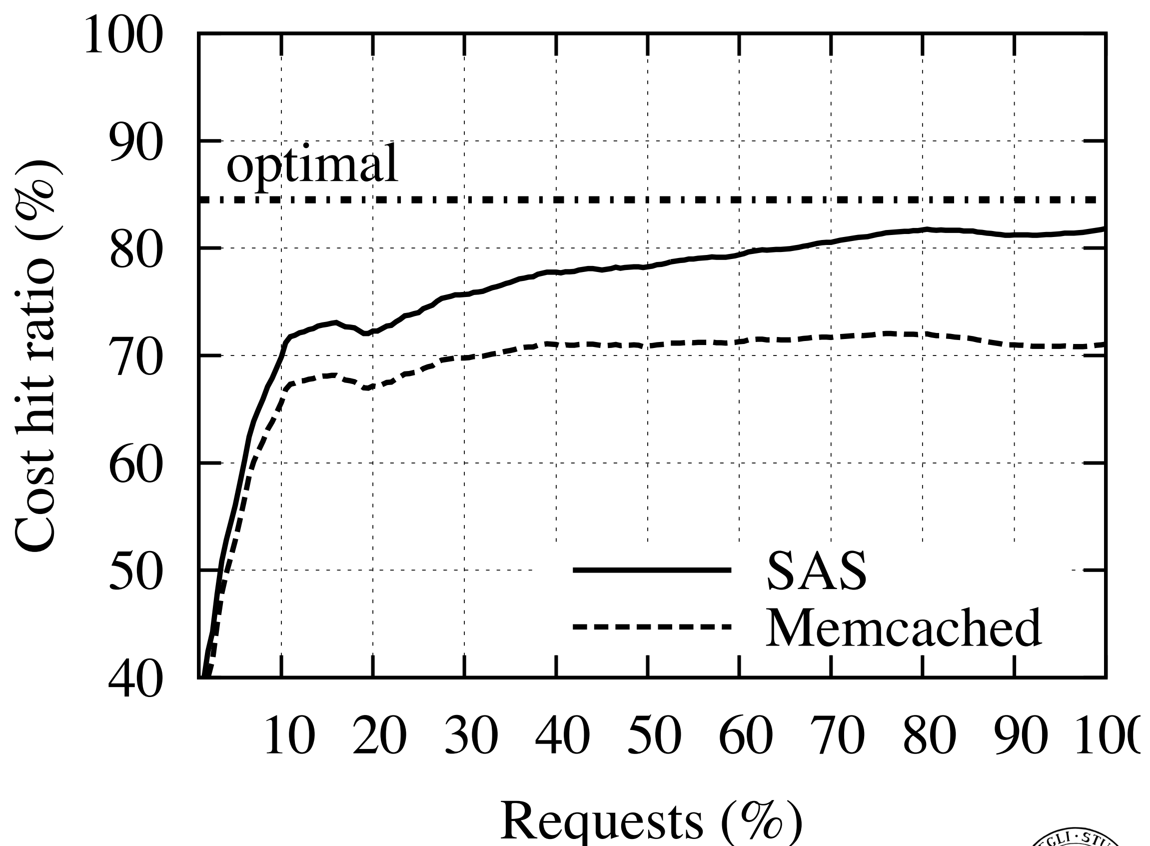
- The costs of the objects are not correlated with the sizes
  - Correlation coefficient → 0.013





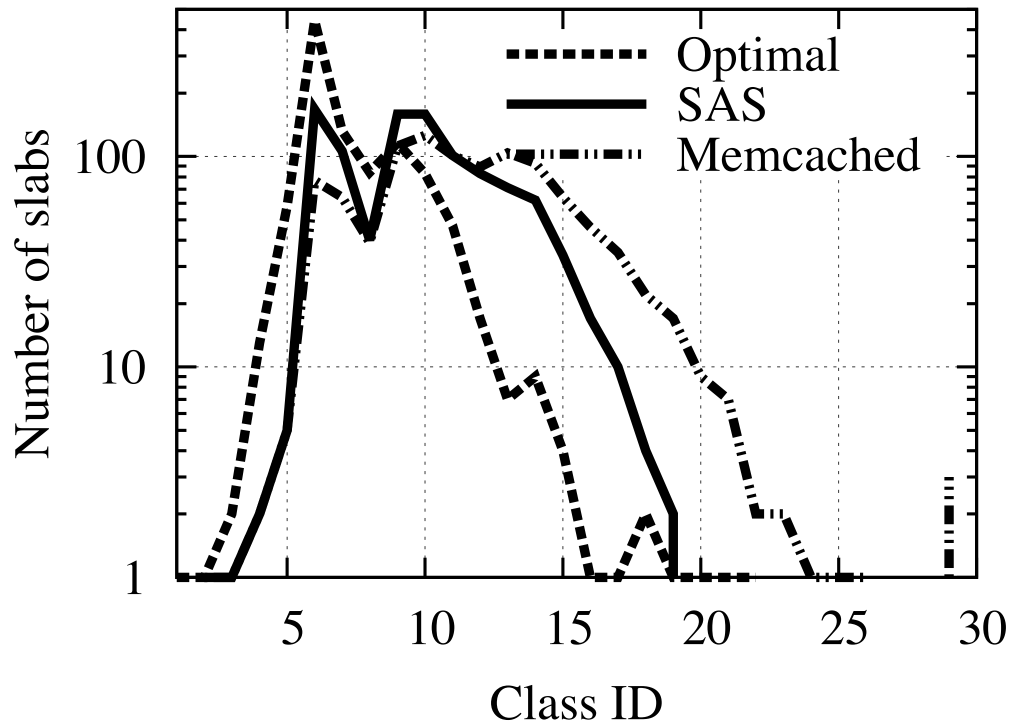
Results

- We compute the optimal cost hit ratio with the offline algorithm
- Our scheme progressively adapts the slab assignment
  - It converges to the optimal
  - While Memcached (static assignment) is far from optimal



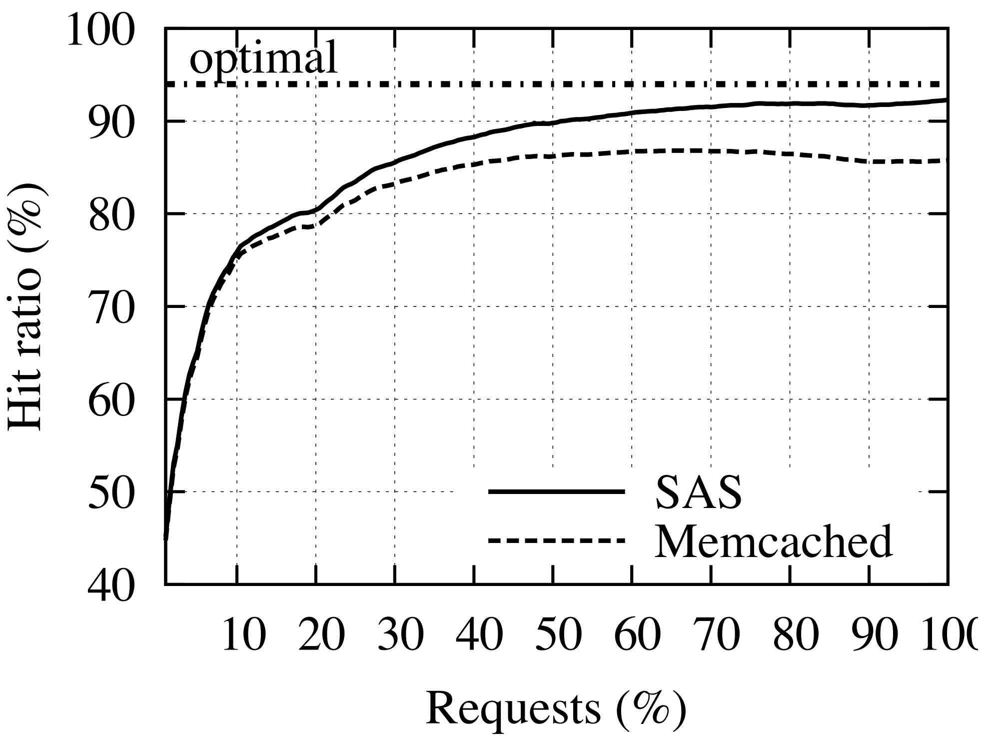
Results: slab assignment

- Snapshot taken when half of the requests has been processed by the client
- Comparison with the
  - Optimal assignment (offline)
  - Static assignement (Memecached)

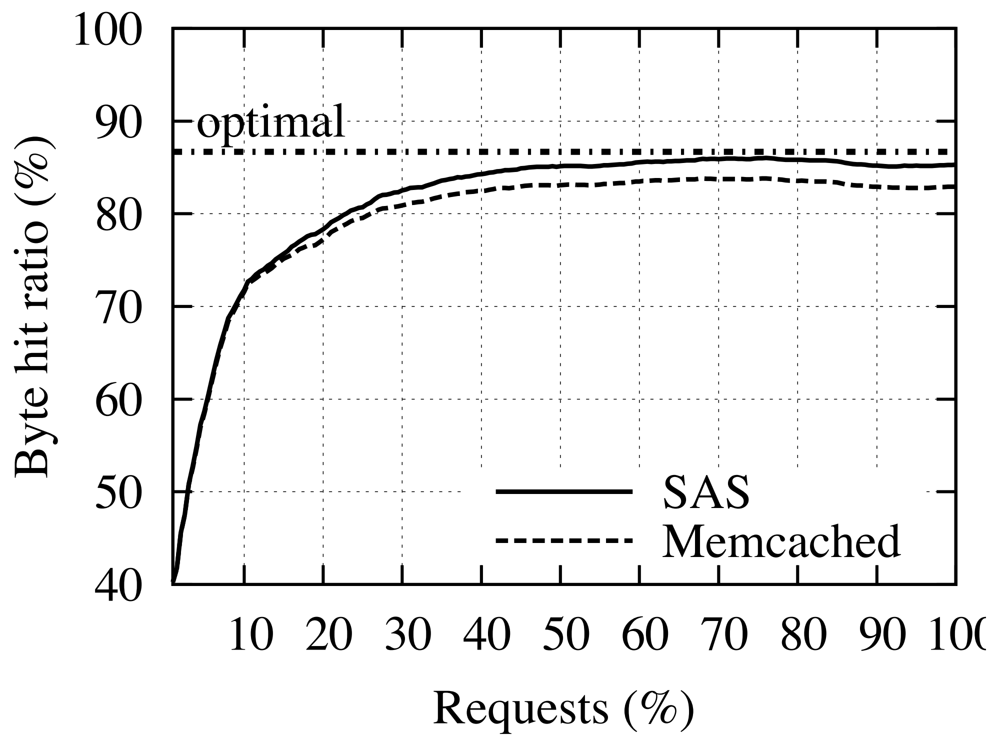


Results: Different Costs

- All objects have the same cost



- The cost of the object is given by its size



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Discussion

- Synthetic traces
  - We tested different traces derived from the literature
- Calcification
  - What happens if the statistical properties of the requested objects change?
  - The dynamic nature of the scheme solves a problem known in the literature as calcification

Conclusions

- Memcached: in-memory key value store largely adopted…
  - Facebook, Twitter
- .. with a specific memory allocation scheme
  - Slabs, Classes, LRU within the same class
- We provide a scheme for dynamically assigning the slabs to the different classes
  - Trying to minimize the number of (weighted) misses
  - Many solutions proposed in the literature not applicable to Memcached due to its memory allocation scheme

Thanks!