Replacement Policies

CMPSCI 230 Computer Systems Principles

Objectives

- **Cache Replacement Algorithms**
  - Least Frequently Used (LFU)
  - Least Recently Used (LRU)

Replacement Policies

- **Optimal Data Replacement Algorithm**
  - **Belady's Algorithm**:
    Replace the data that will **not be used** for the *longest period of time* in the future.

- **Problem:**
  - Need to **predict the future**!
  - Not possible, but used as a "yard stick" to compare replacement algorithms to determine improvement.
  - Use heuristics

Caching Algorithms

- Least Frequently Used (LFU)
- Least Recently Used (LRU)

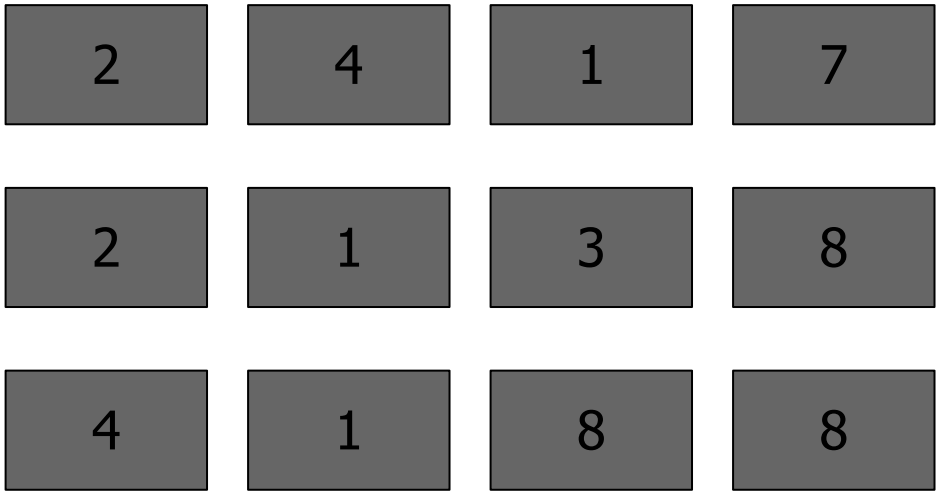
Caching Algorithms (LFU)

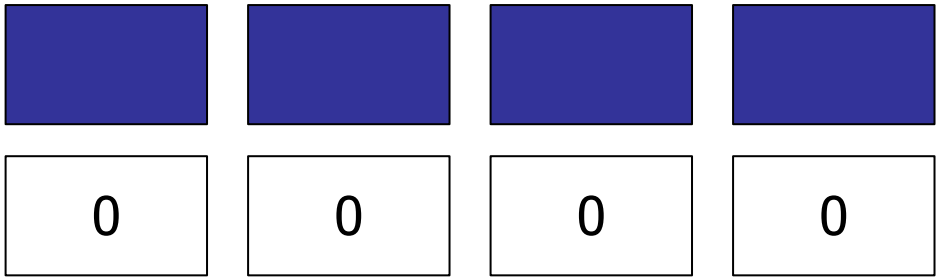
- **Least Frequently Used (LFU)**
  - Count how often an entry is used by incrementing a counter associated with each entry in the cache.
  - Remove the entry with the least frequently used counter first.

- **Request Pattern**
  - Discard entries that are not needed over the longest period.

Miss: 0
Hit: 0

LFU Example



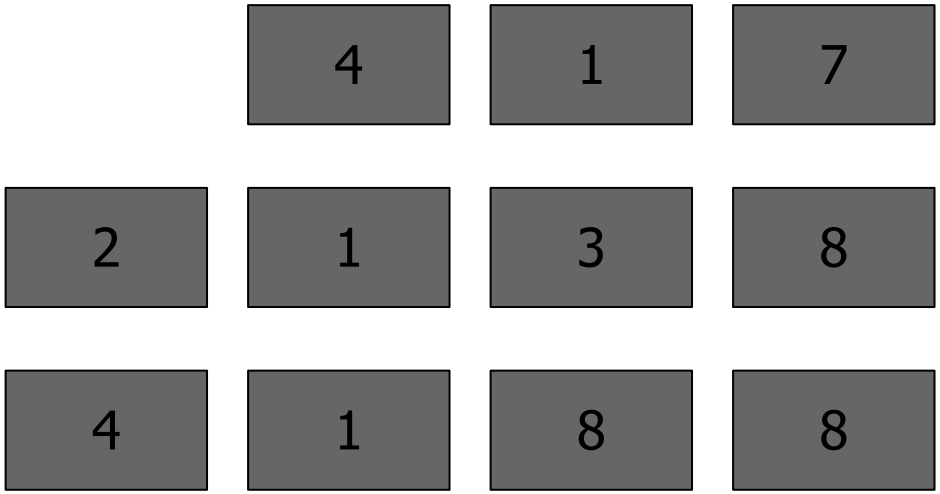


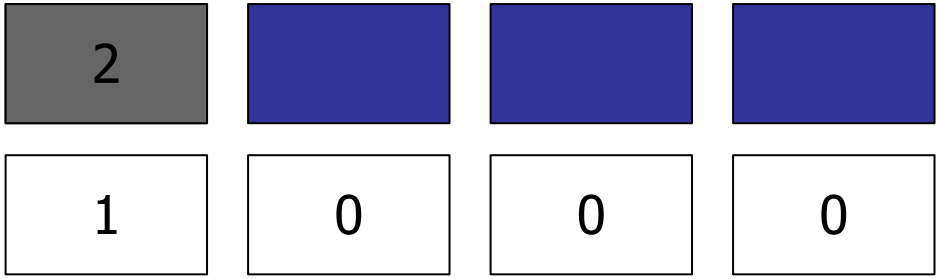
hit count:

0	0	0	0

Miss: 1
Hit: 0

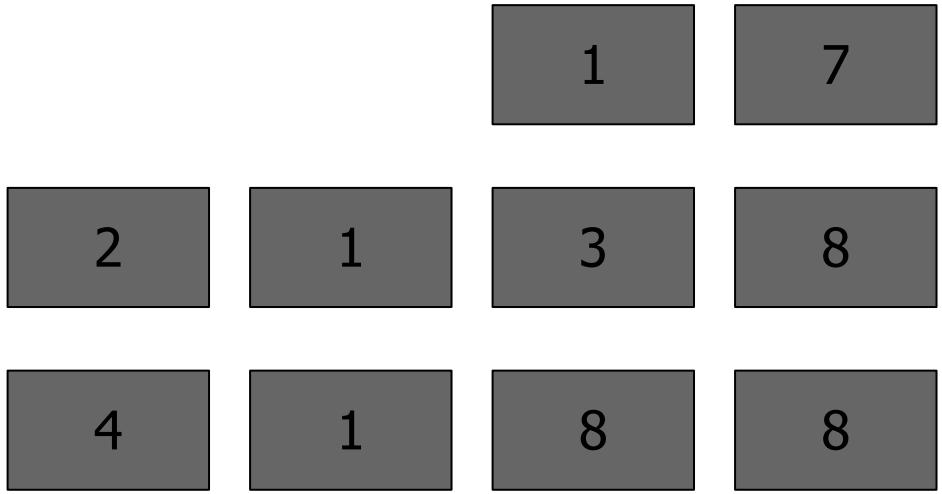
LFU Example

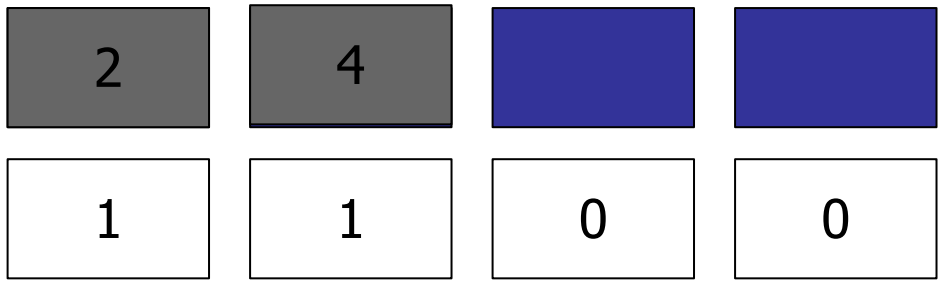




Miss: 2
Hit: 0

LFU Example



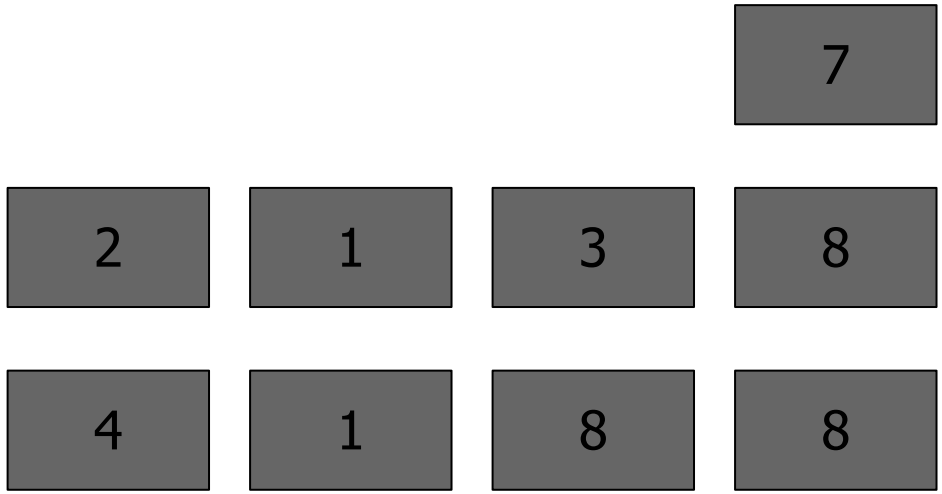


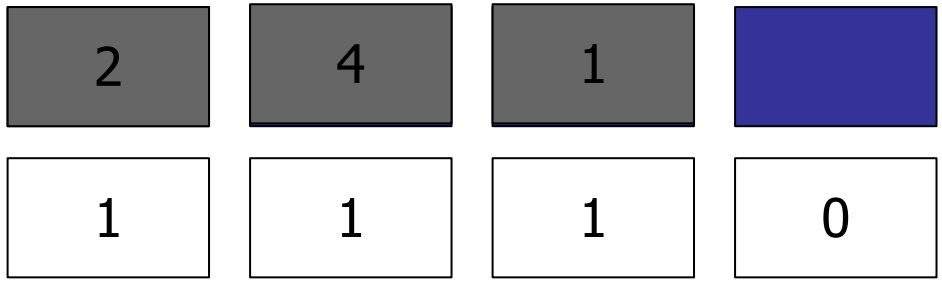
hit count:

1	1	0	0

Miss: 3
Hit: 0

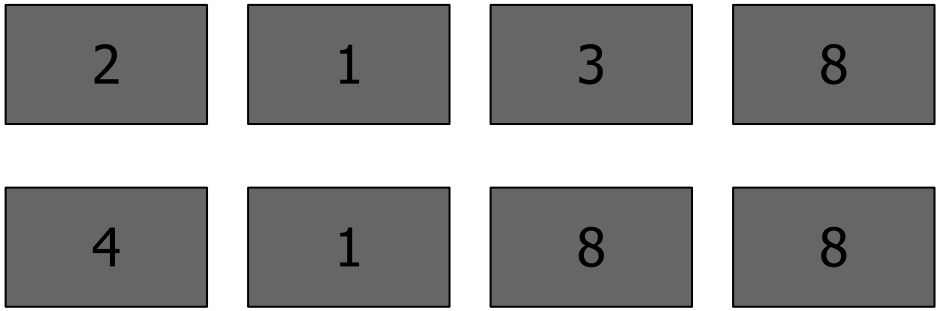
LFU Example

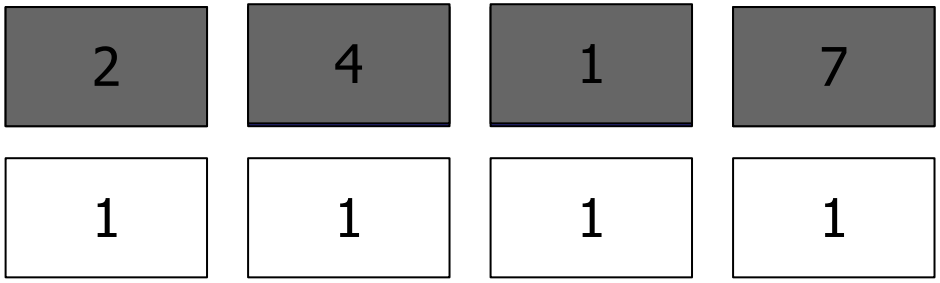




Miss: 4
Hit: 0

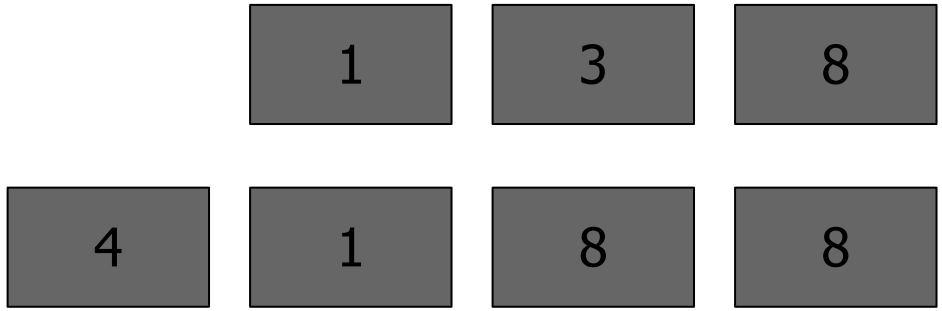
LFU Example

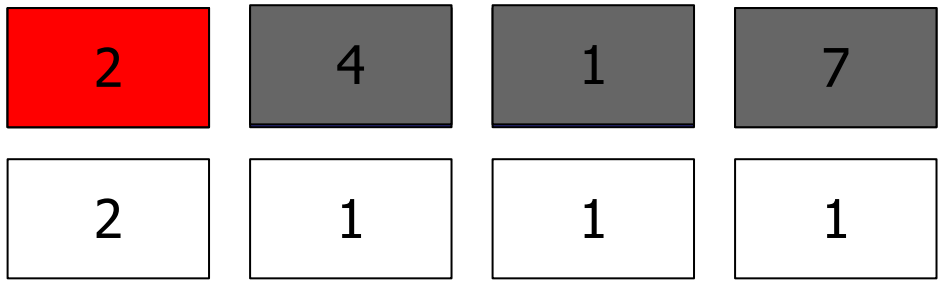




Miss: 4
Hit: 1

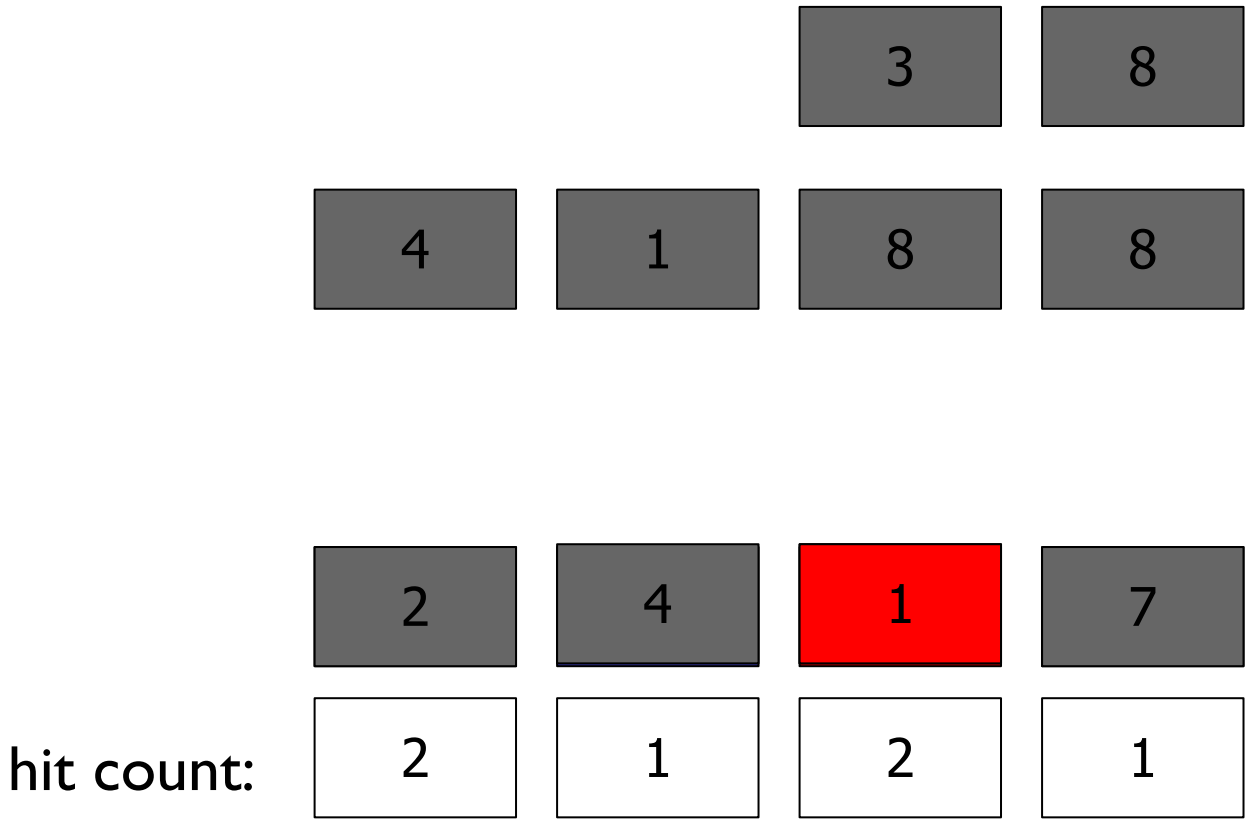
LFU Example





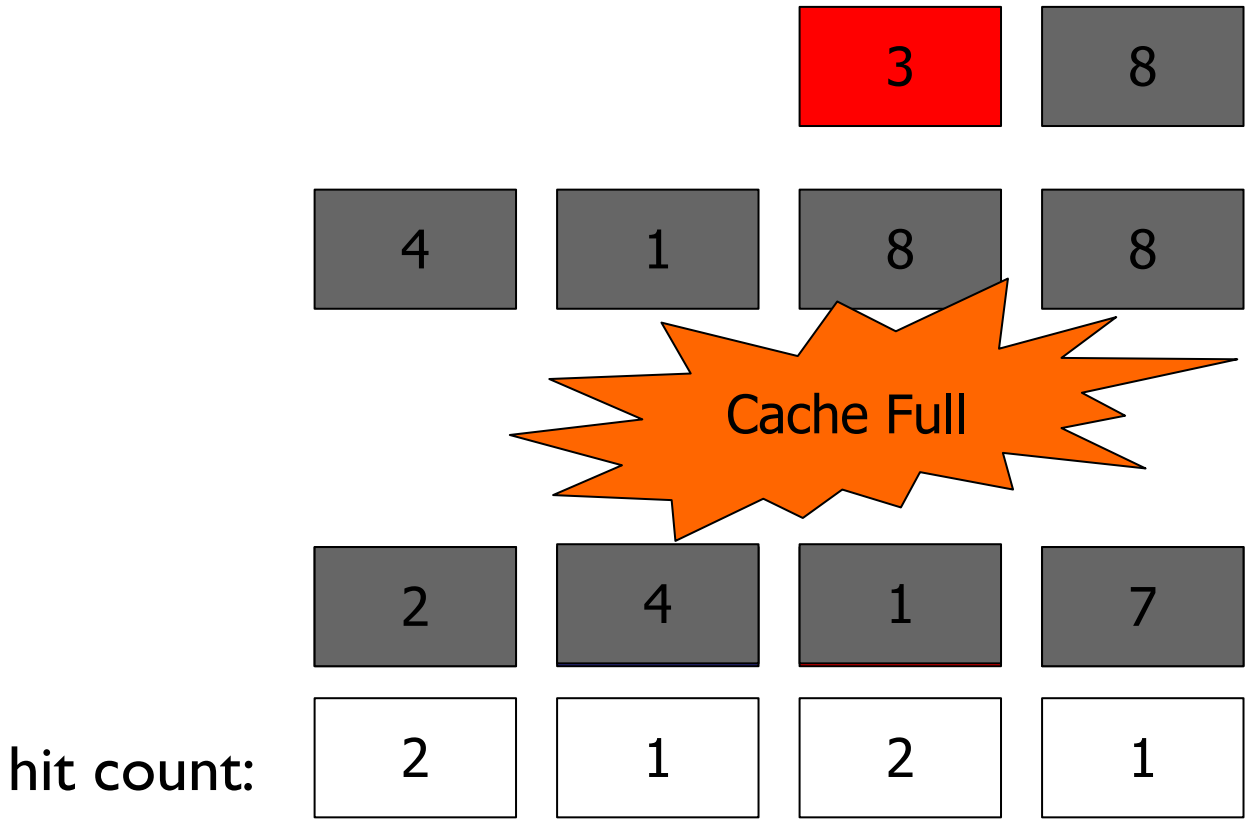
Miss: 4
Hit: 2

LFU Example



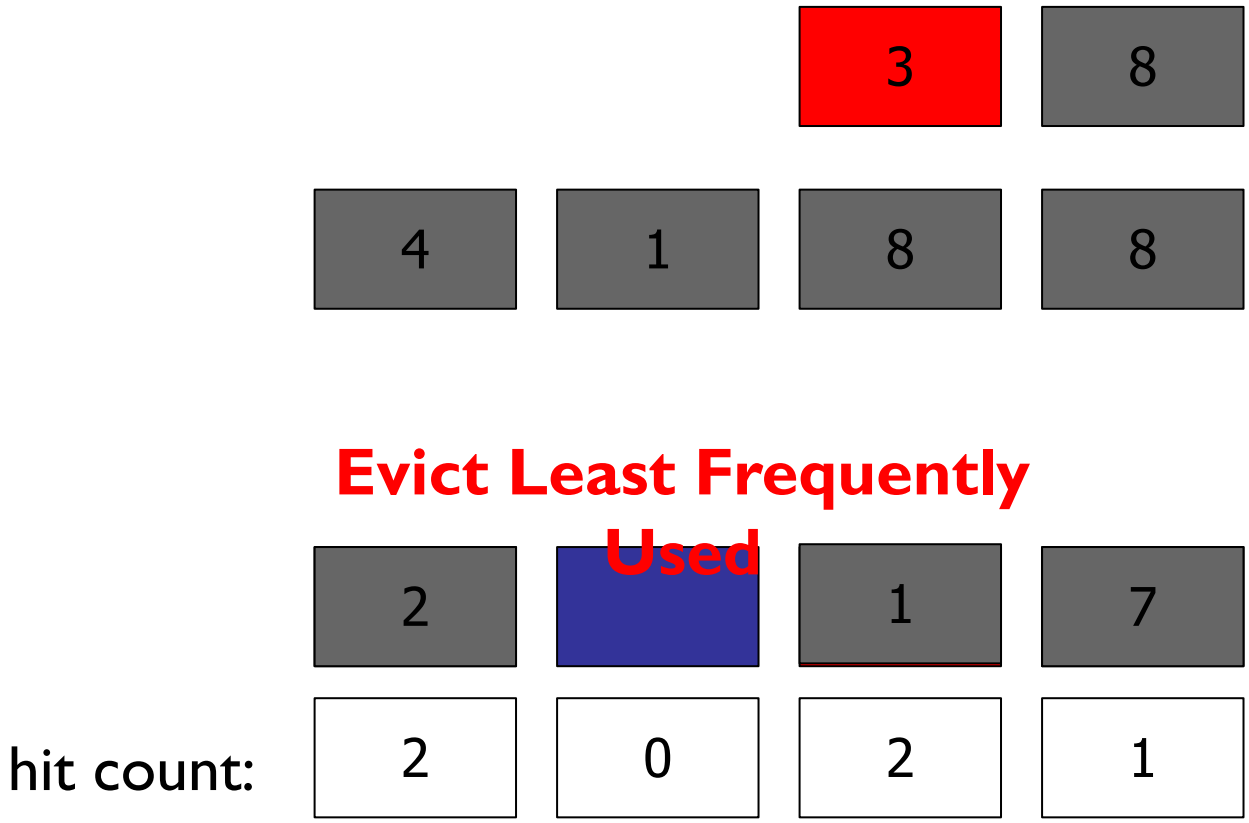
Miss: 5
Hit: 2

LFU Example



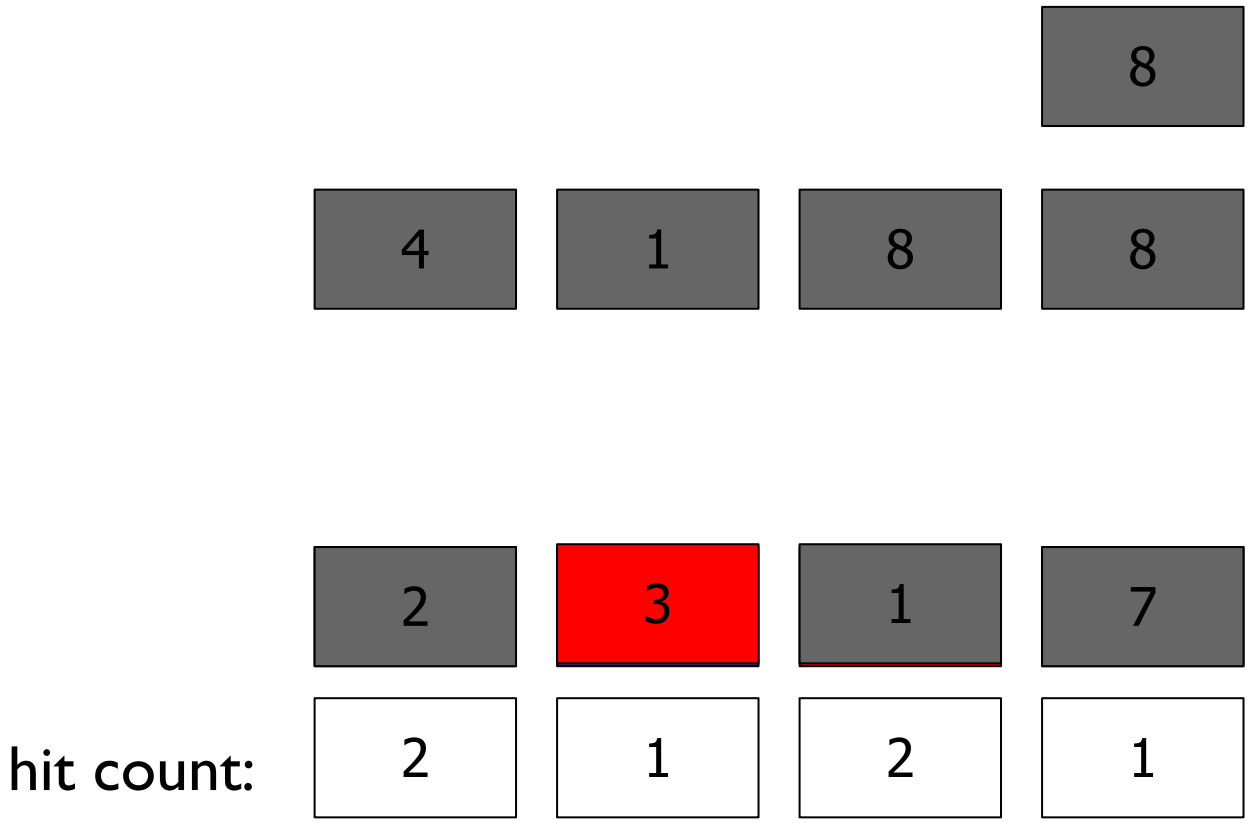
Miss: 5
Hit: 2

LFU Example



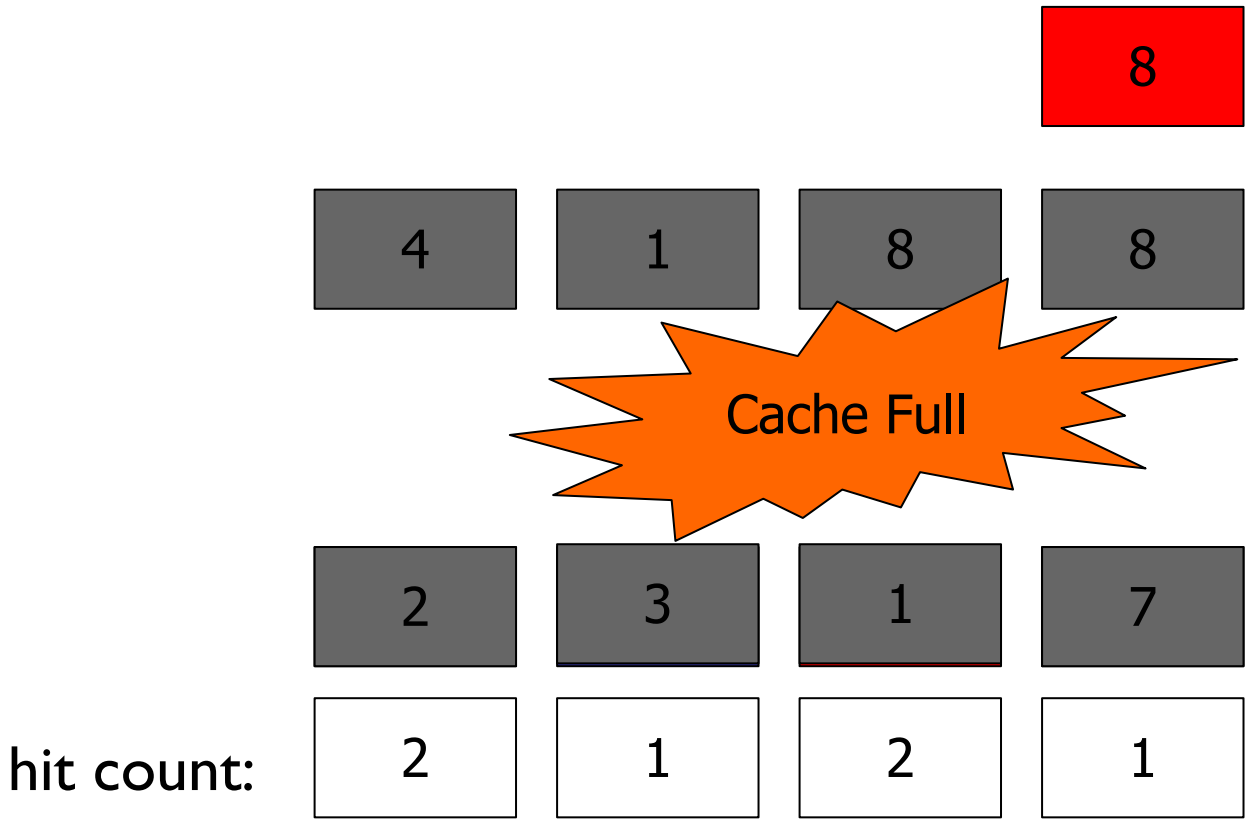
Miss: 5
Hit: 2

LFU Example



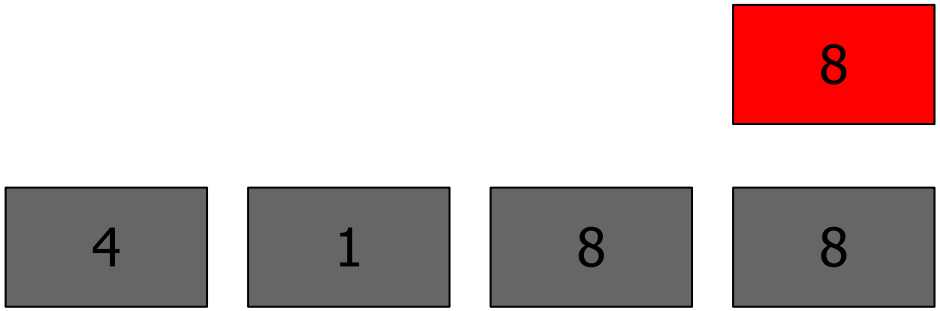
Miss: 6
Hit: 2

LFU Example

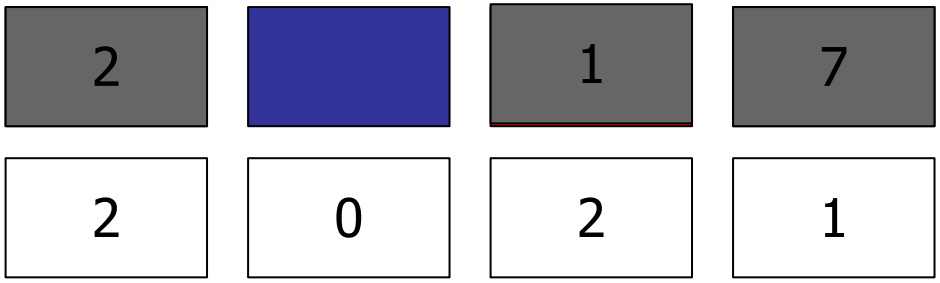


Miss: 6
Hit: 2

LFU Example



Evict Least Frequently Used

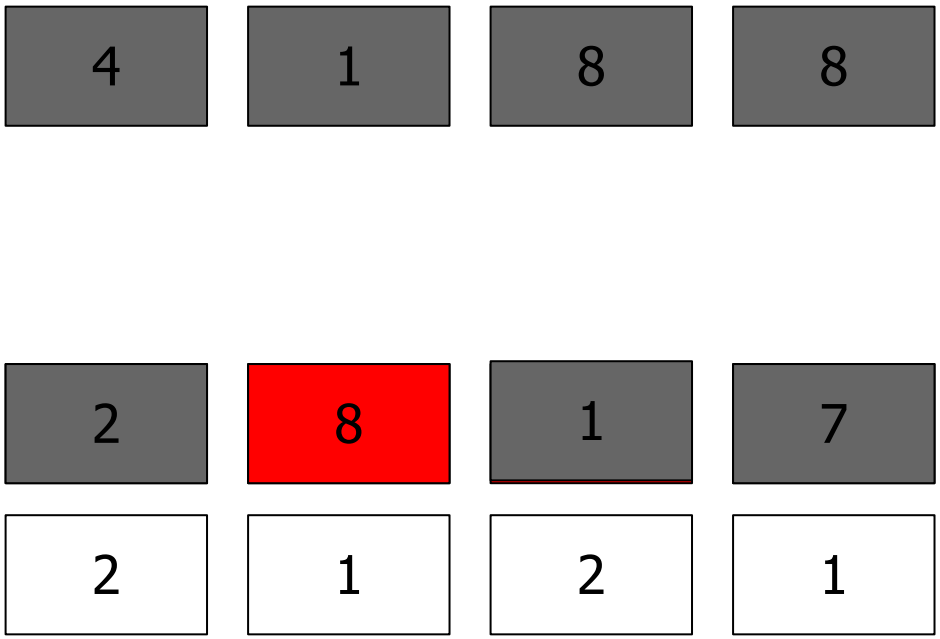


hit count:

2	0	2	1

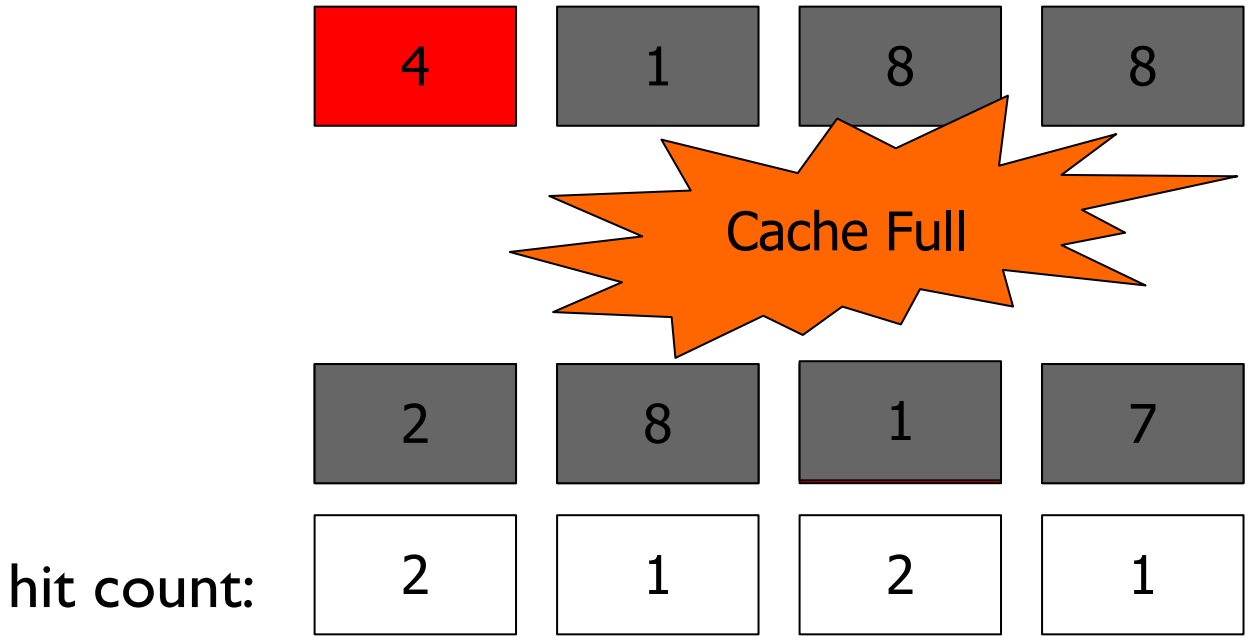
Miss: 6
Hit: 2

LFU Example



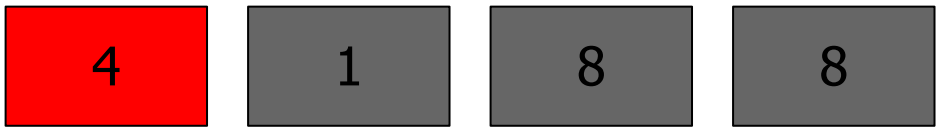
Miss: 7
Hit: 2

LFU Example

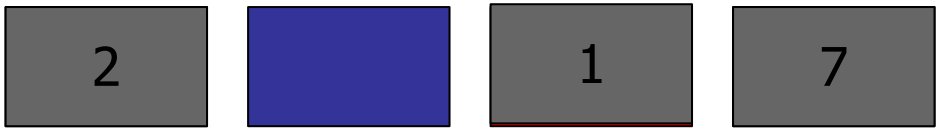


Miss: 7
Hit: 2

LFU Example



Evict Least Frequently Used

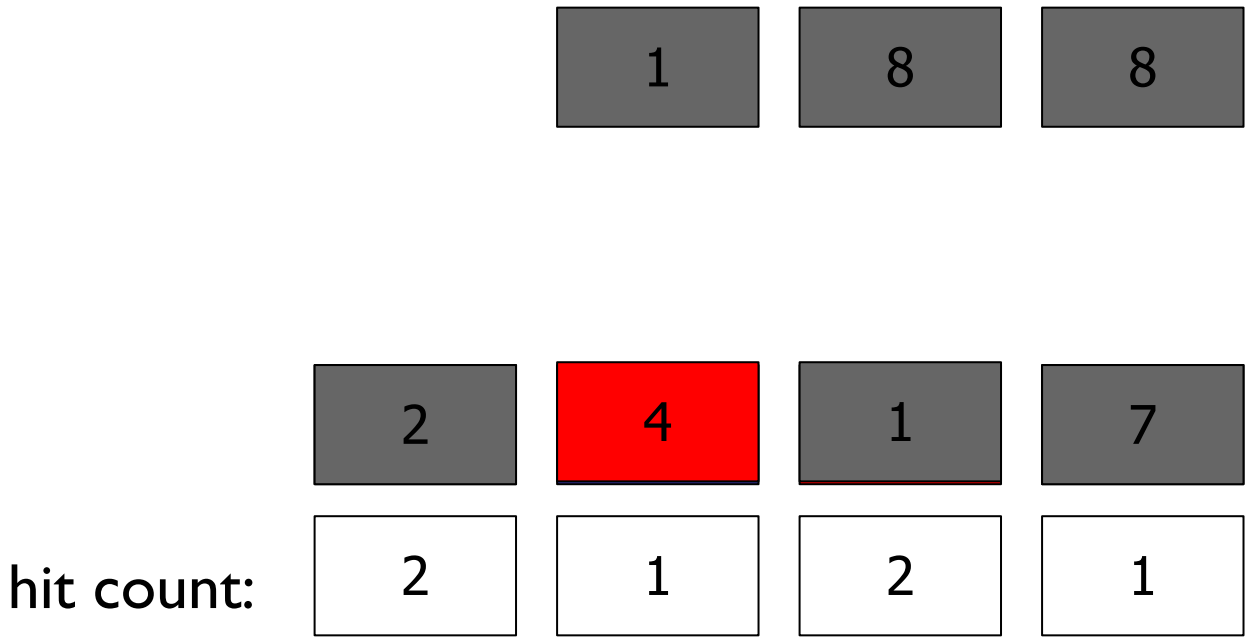


hit count:

2	0	2	1

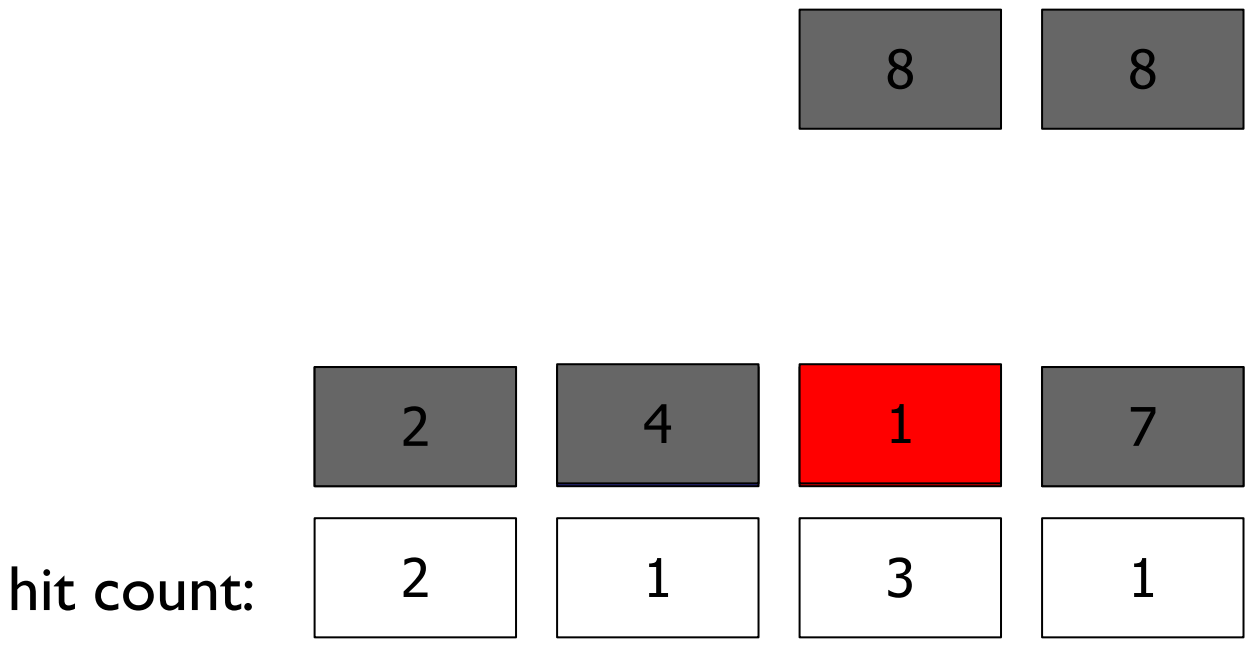
Miss: 7
Hit: 2

LFU Example



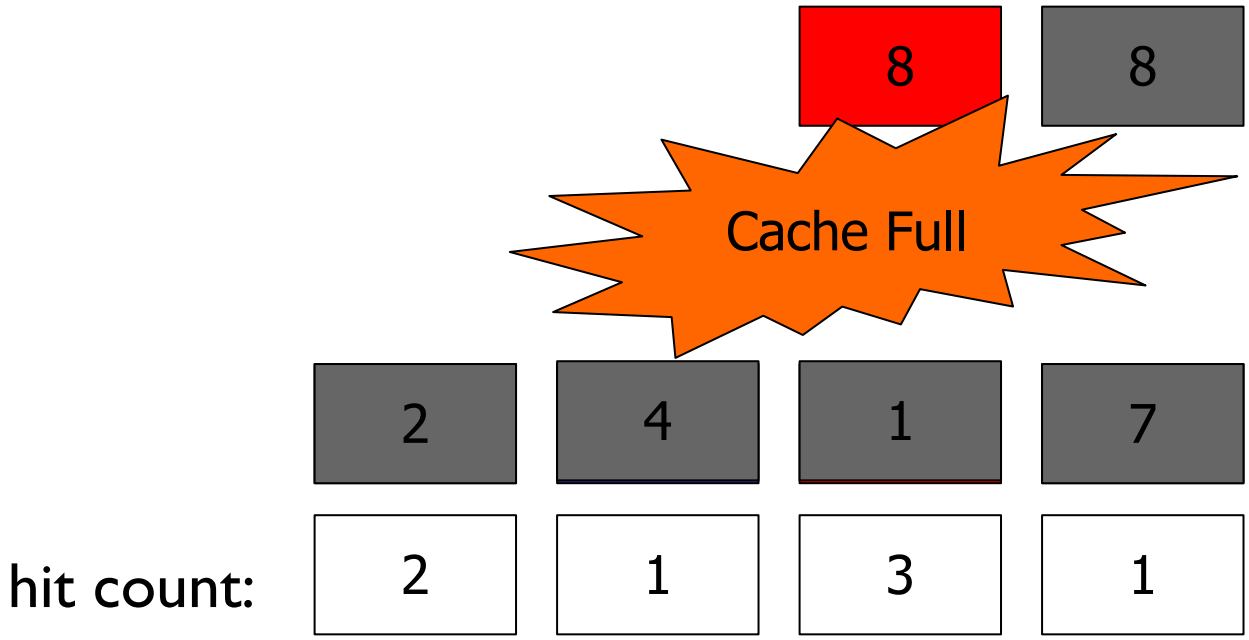
Miss: 7
Hit: 3

LFU Example



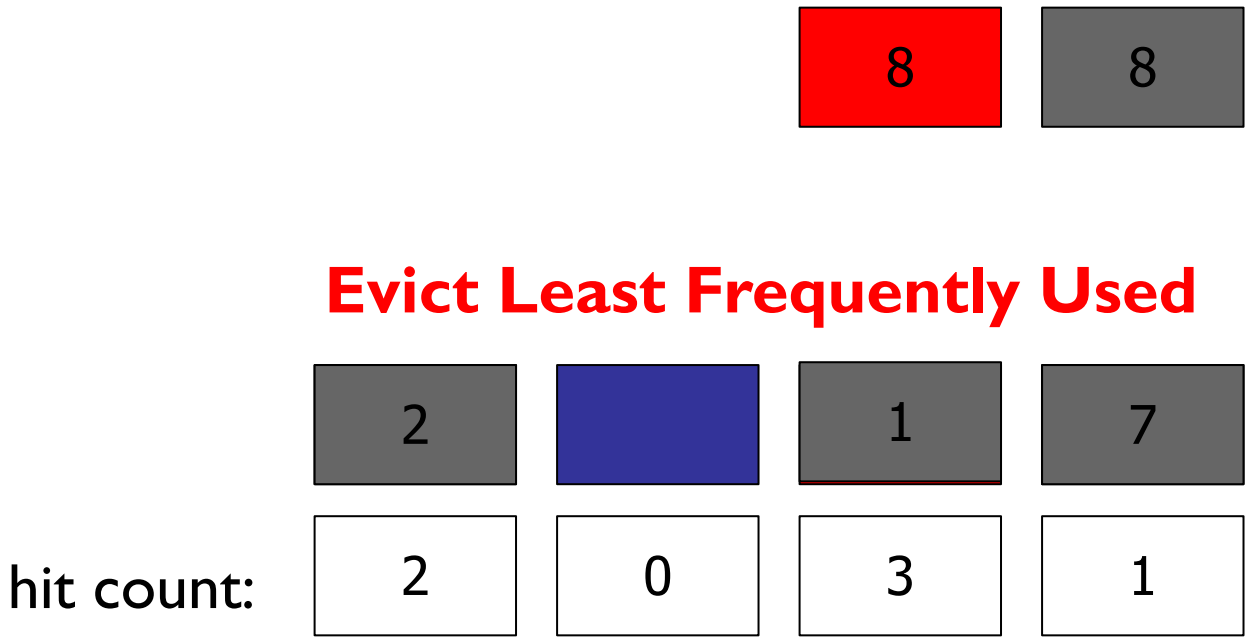
Miss: 7
Hit: 3

LFU Example



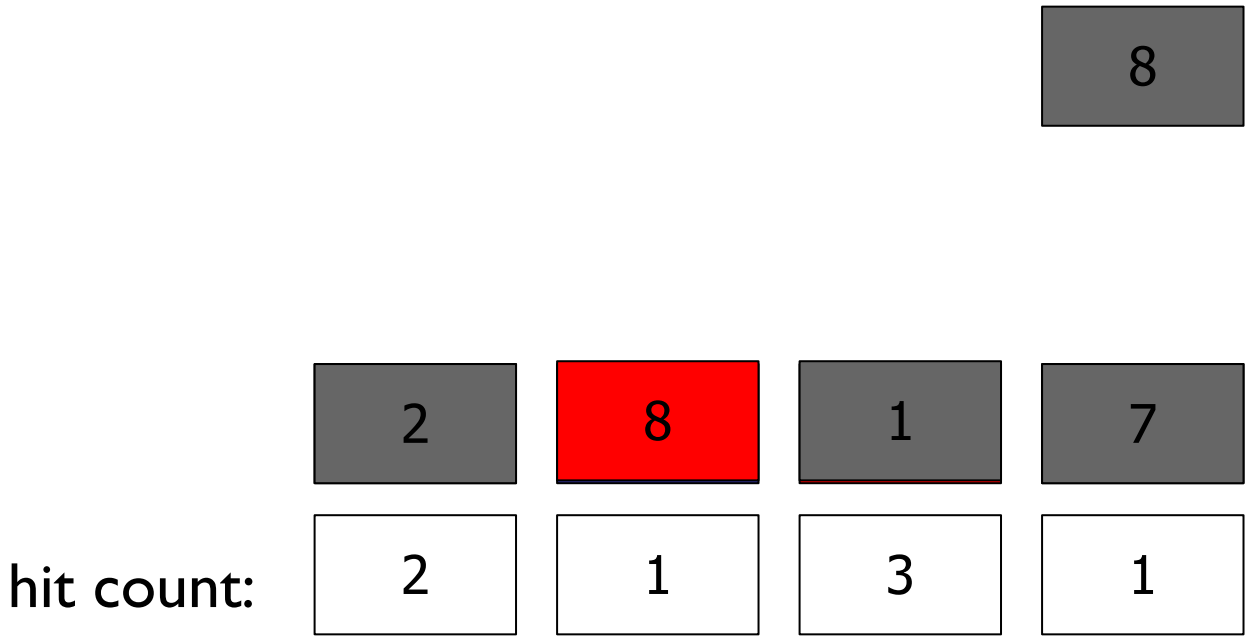
Miss: 7
Hit: 3

LFU Example



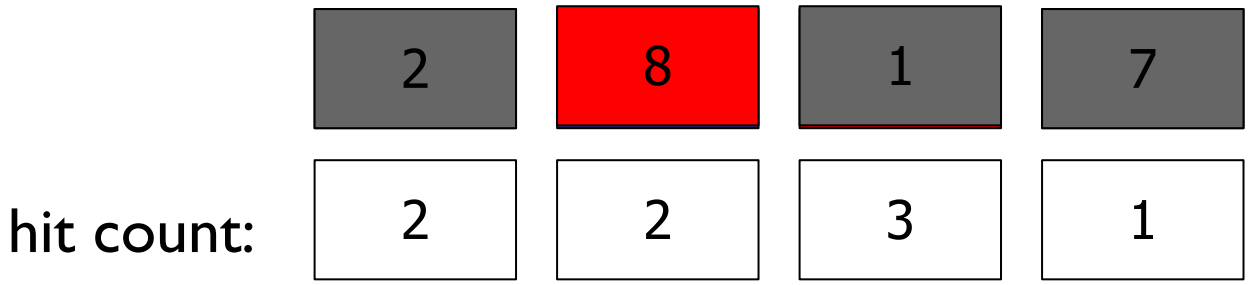
Miss: 8
Hit: 3

LFU Example



Miss: 8
Hit: 4

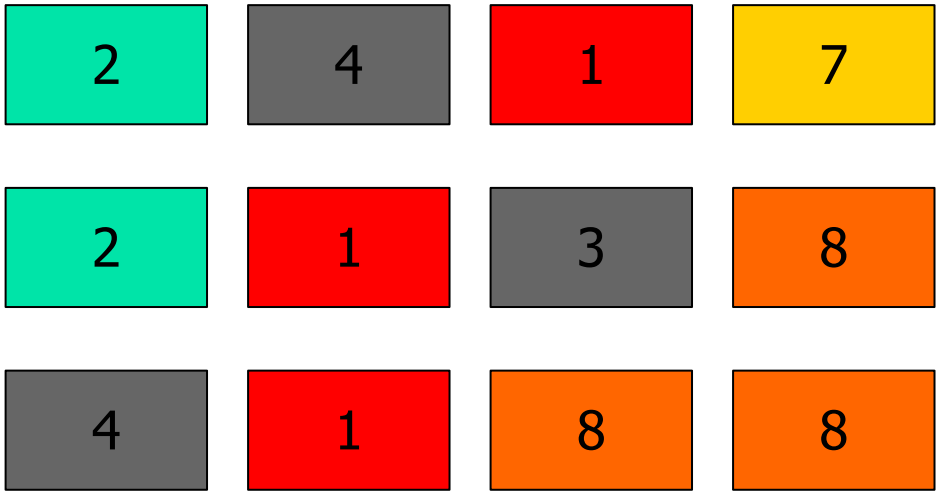
LFU Example



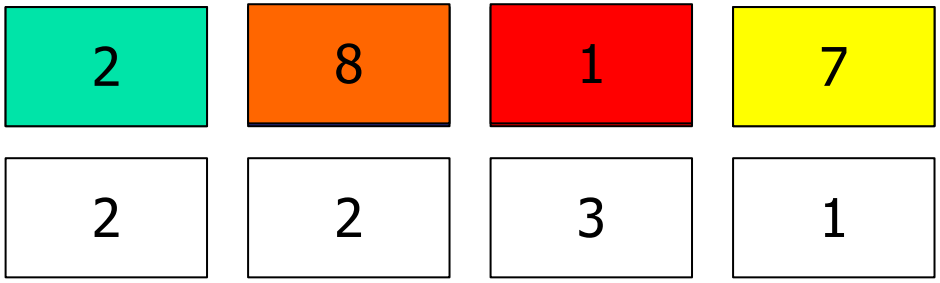
LFU Example

Miss: 8
Hit: 4

MR = 67%
HR = 33%



Final State of the Cache



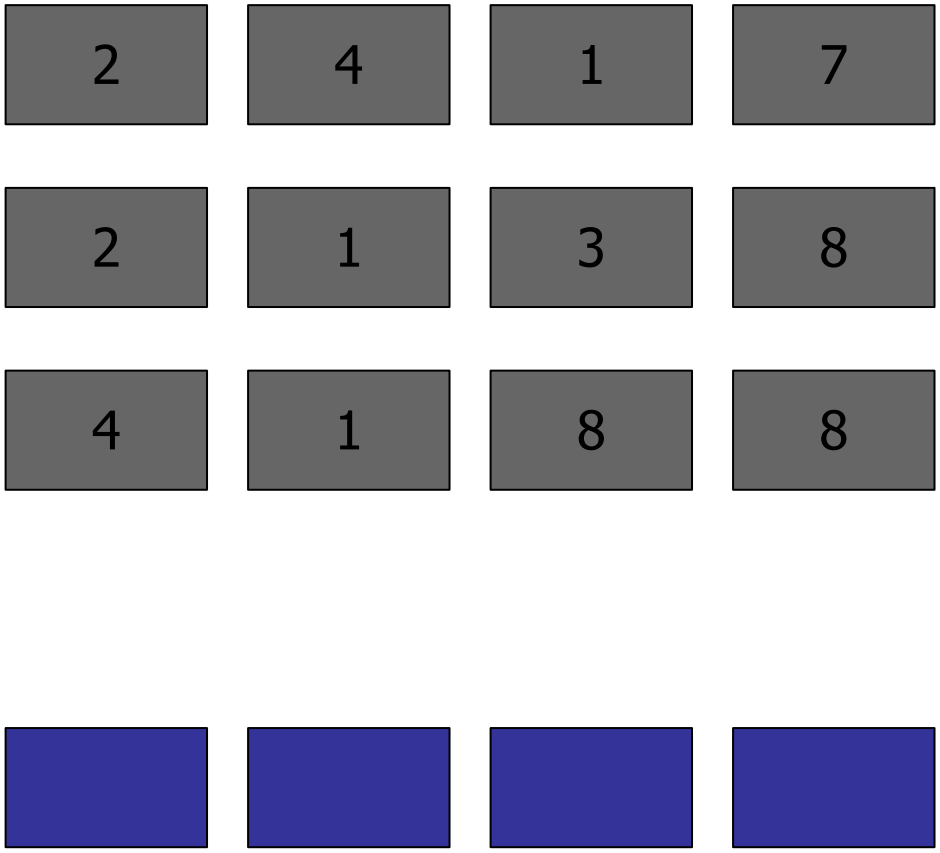
Caching Algorithms: LRU

- **Least Recently Used (LRU)**
  - New items are placed in the top of the cache. When cache exceeds size limit, discard items from the bottom.
  - **Remove the least recently used item first**

- **Request Pattern**
  - Discard entries that are least recently used
  - ***Fast!***

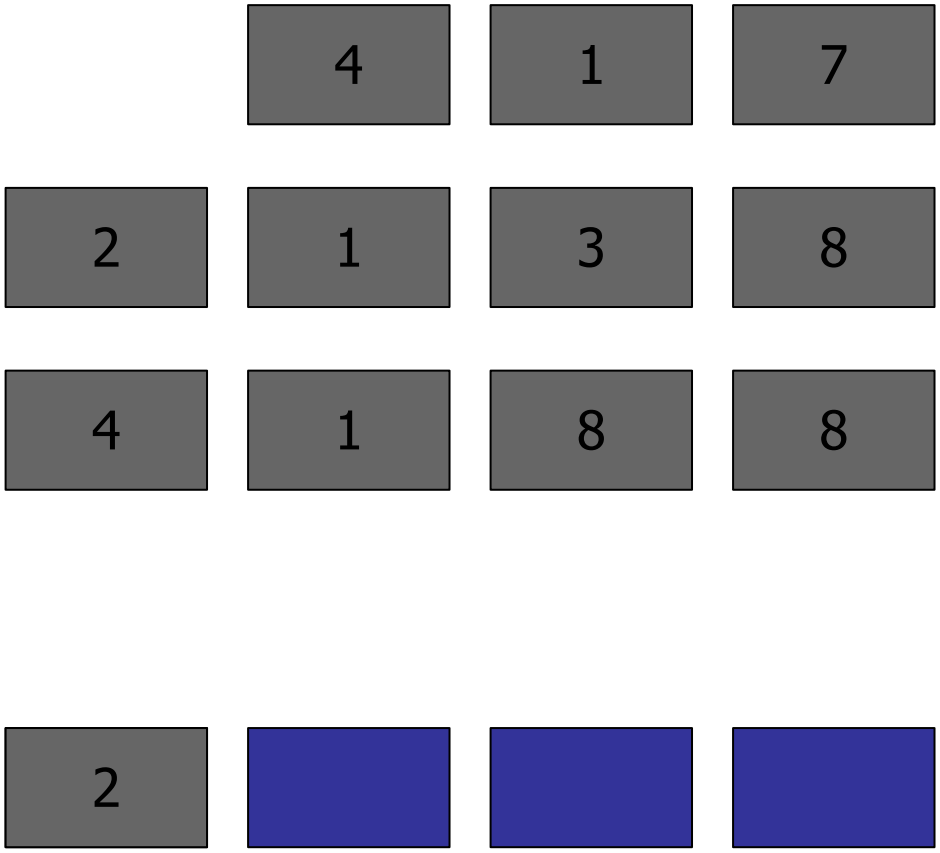
Miss: 0
Hit: 0

LRU Example



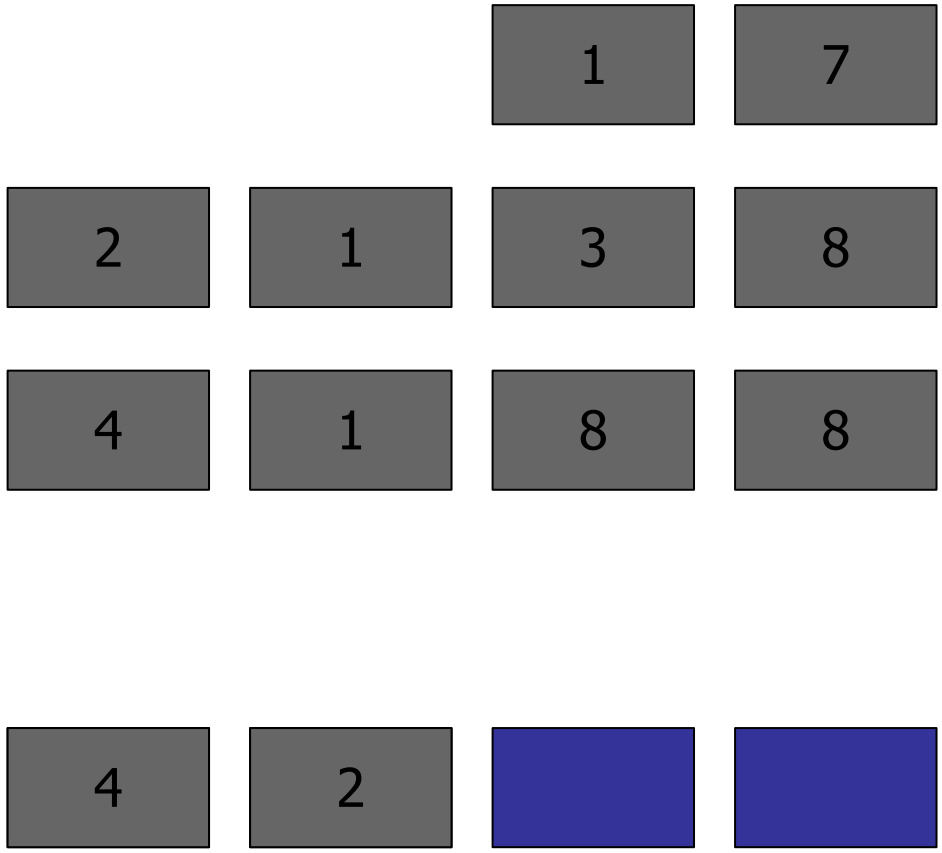
Miss: 1
Hit: 0

LRU Example



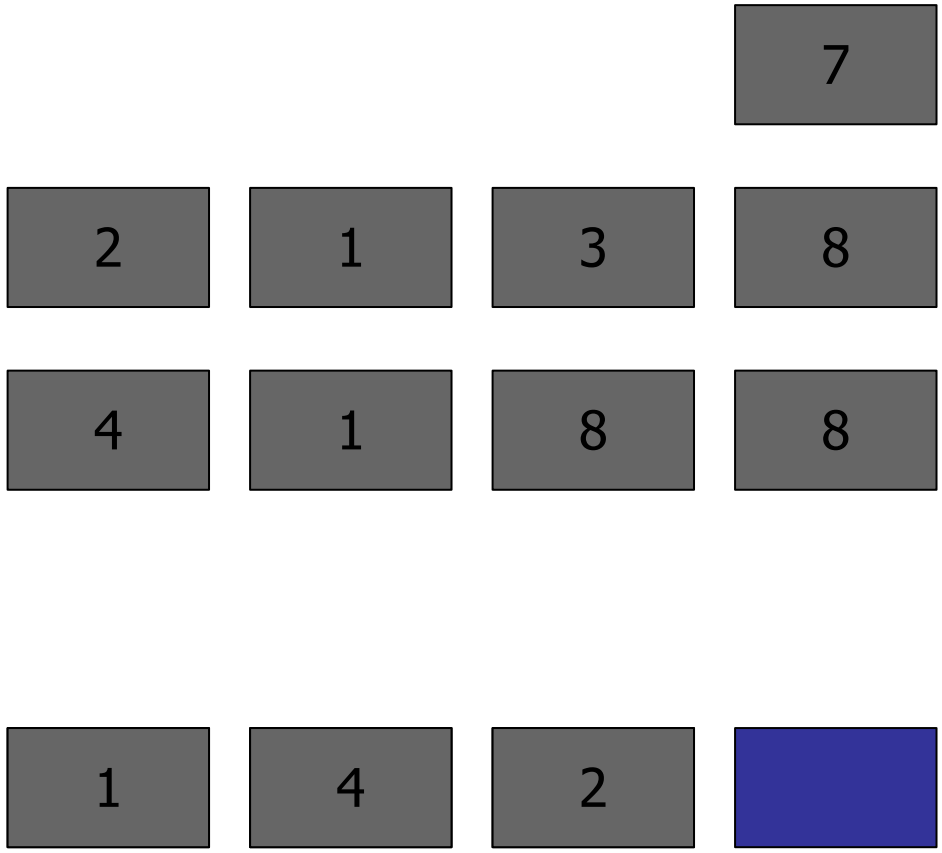
Miss: 2
Hit: 0

LRU Example



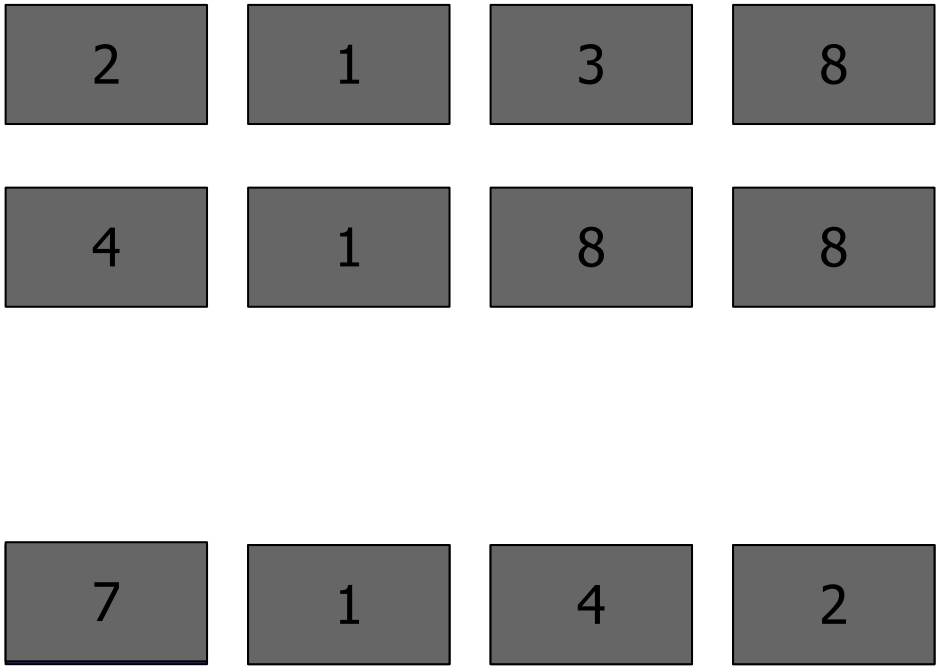
Miss: 3
Hit: 0

LRU Example



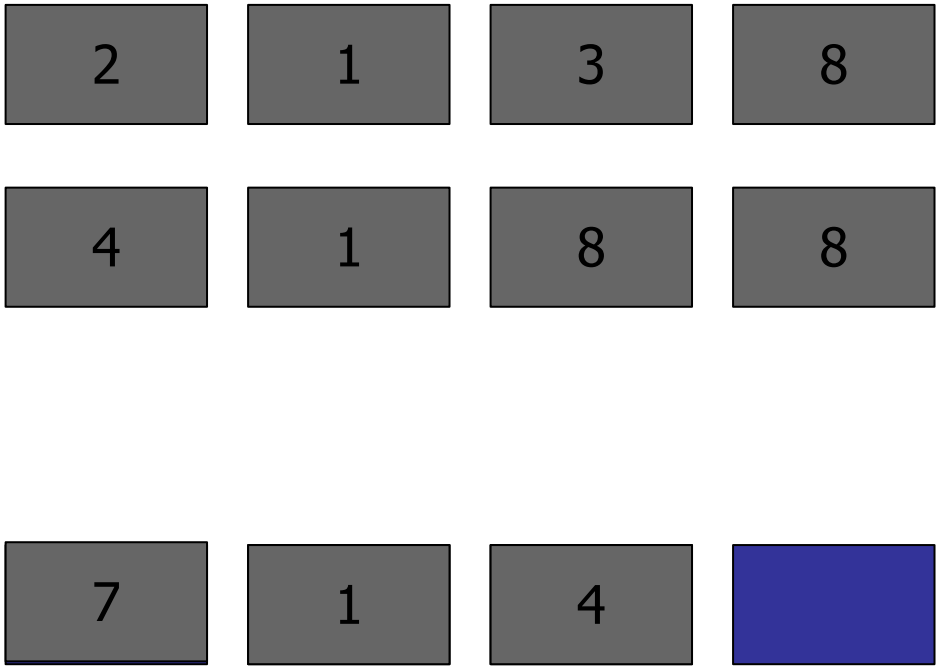
Miss: 4
Hit: 0

LRU Example



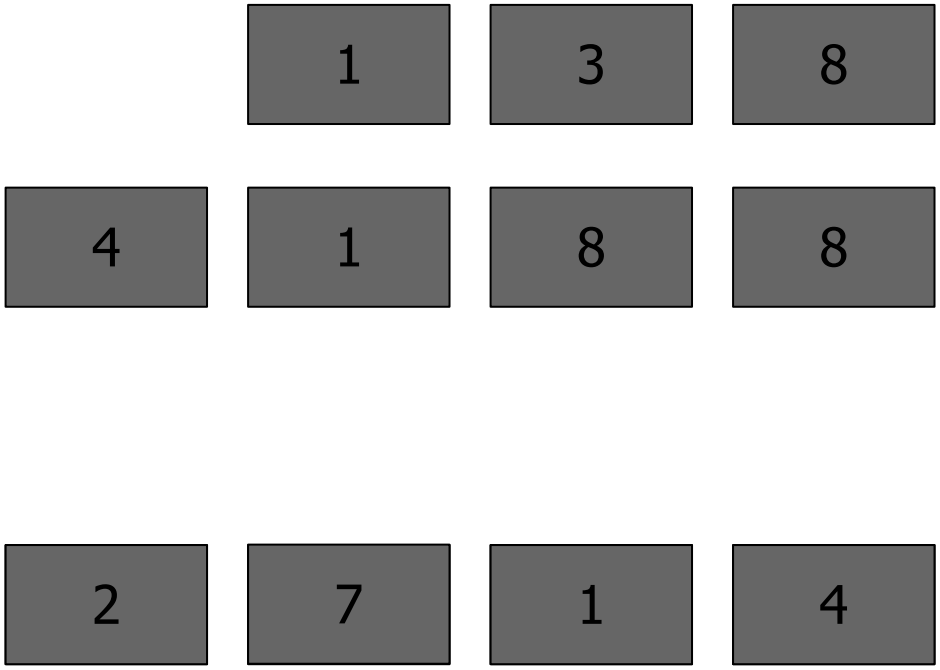
Miss: 4
Hit: 1

LRU Example



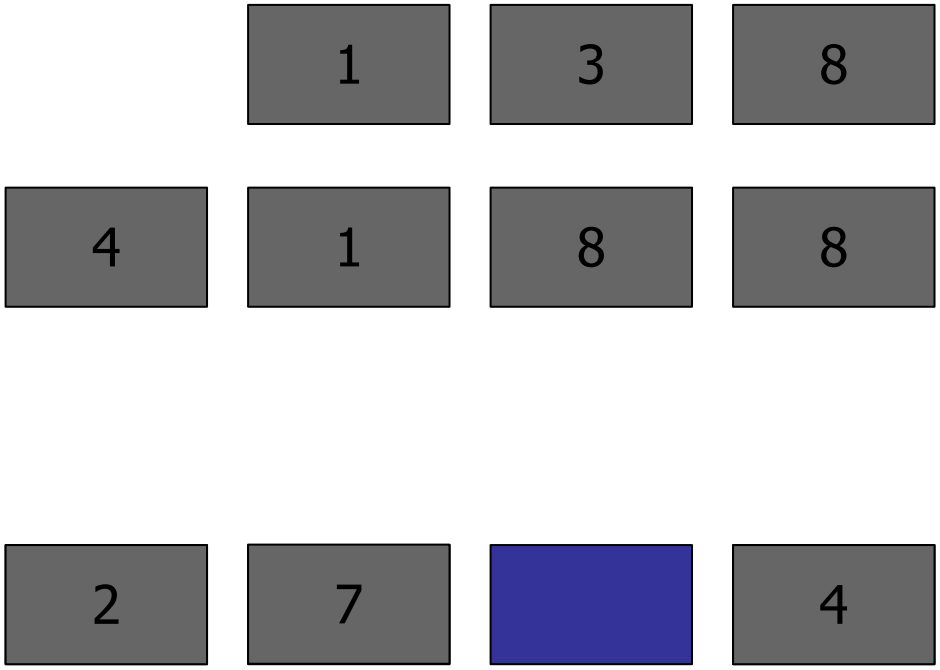
Miss: 5
Hit: 1

LRU Example



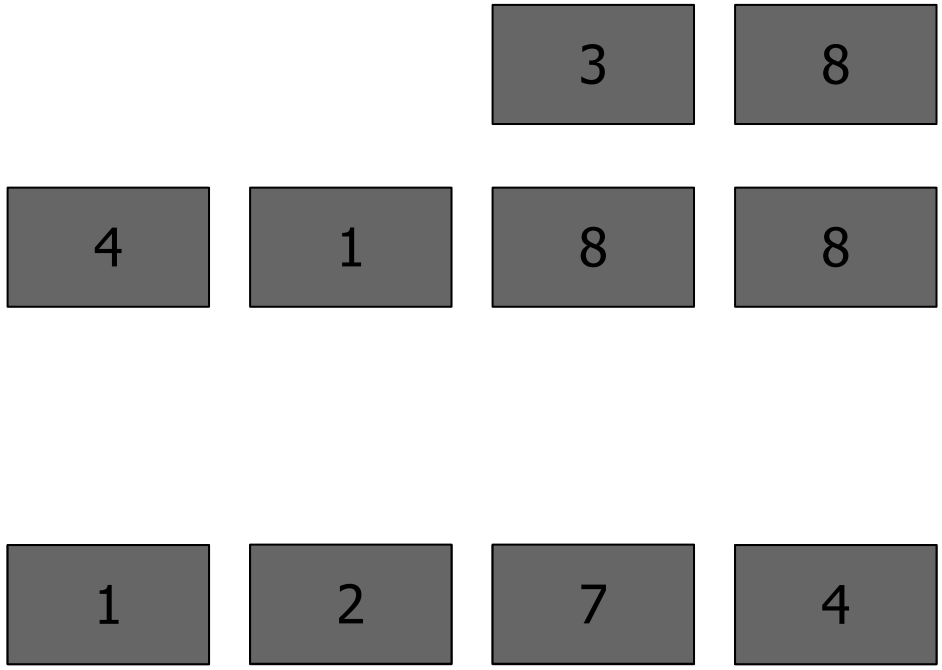
Miss: 5
Hit: 2

LRU Example



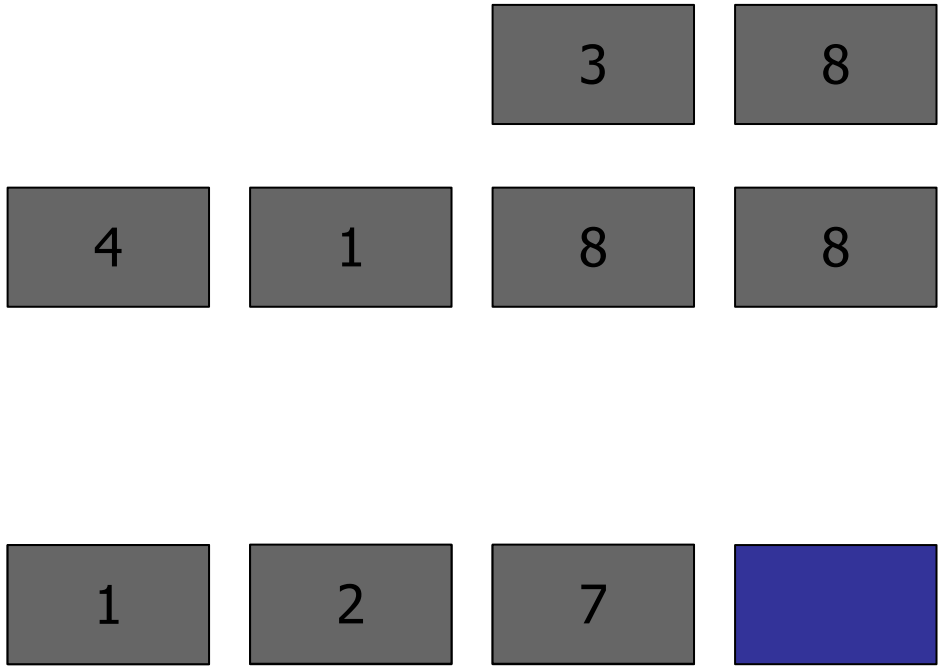
Miss: 5
Hit: 2

LRU Example



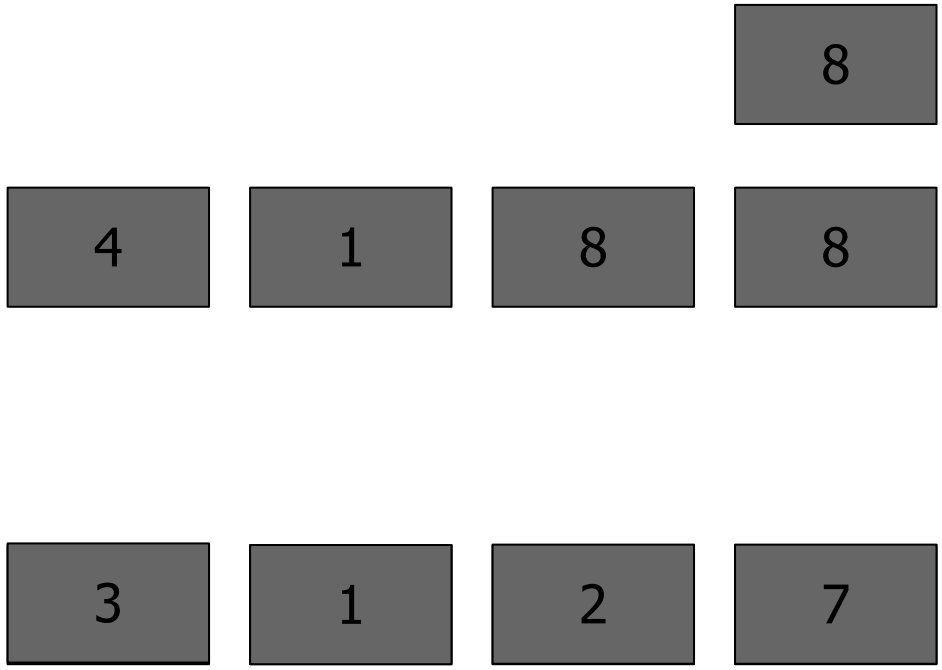
Miss: 6
Hit: 2

LRU Example



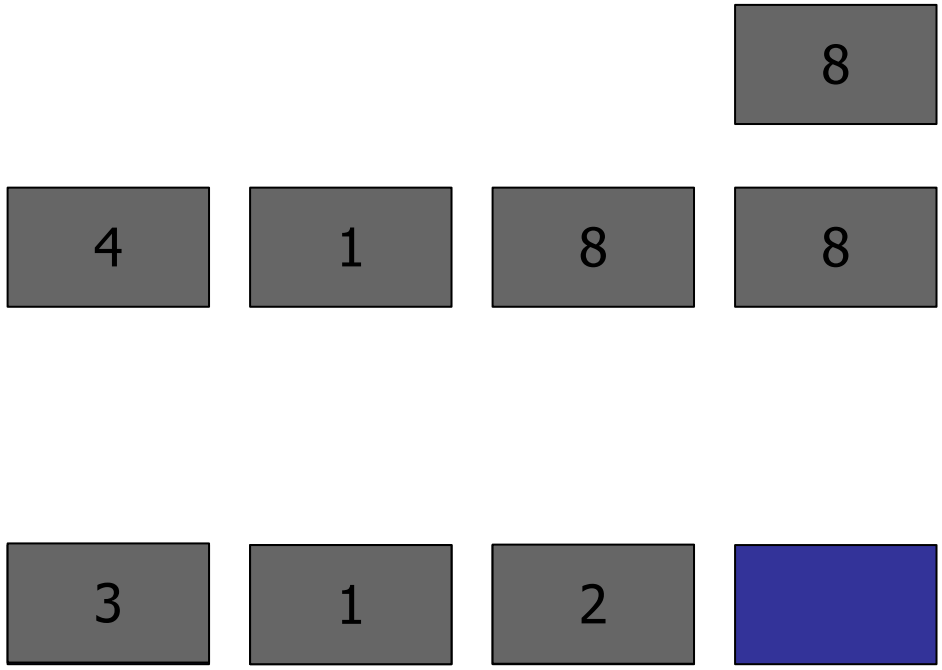
Miss: 6
Hit: 2

LRU Example



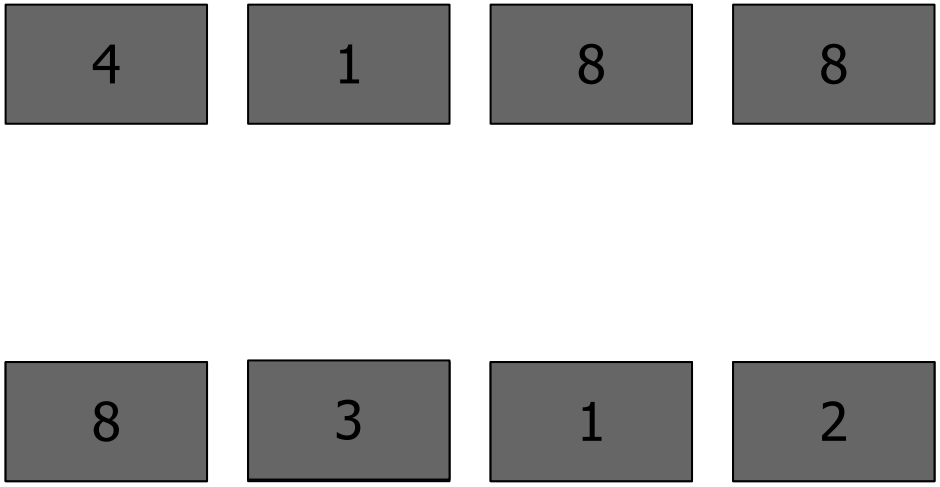
Miss: 7
Hit: 2

LRU Example



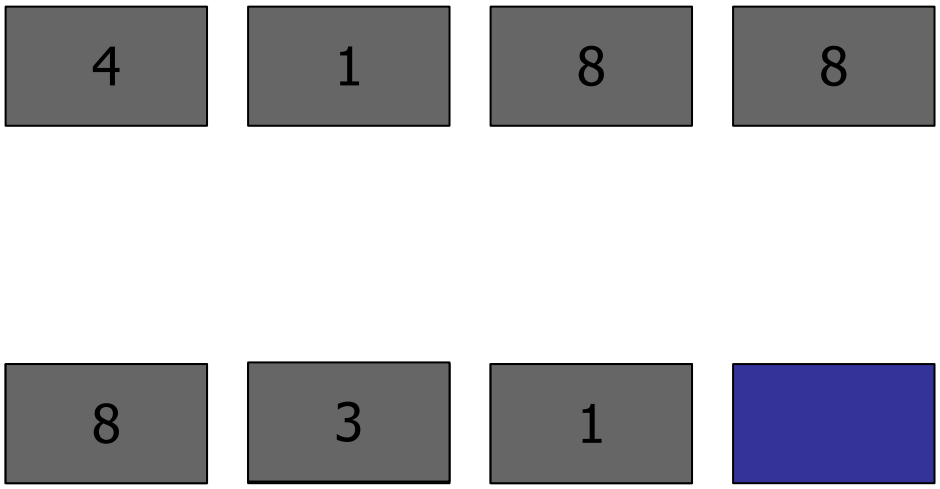
Miss: 7
Hit: 2

LRU Example



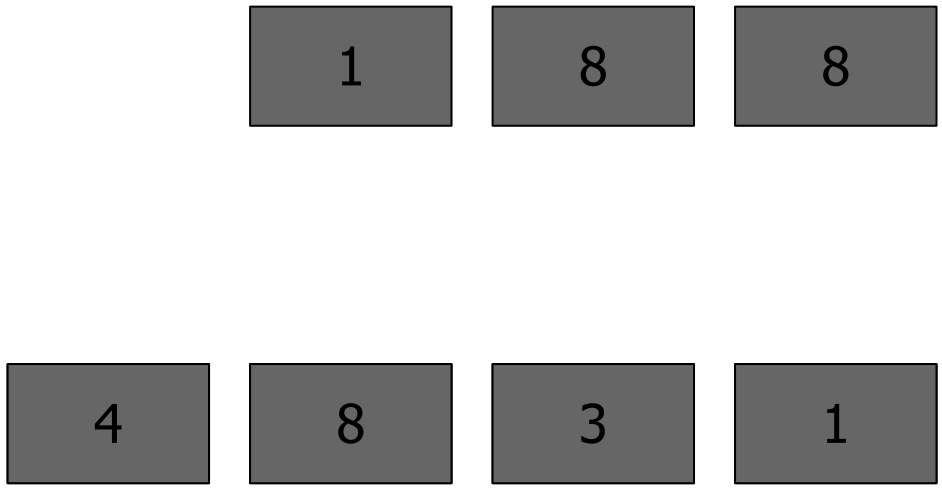
Miss: 8
Hit: 2

LRU Example



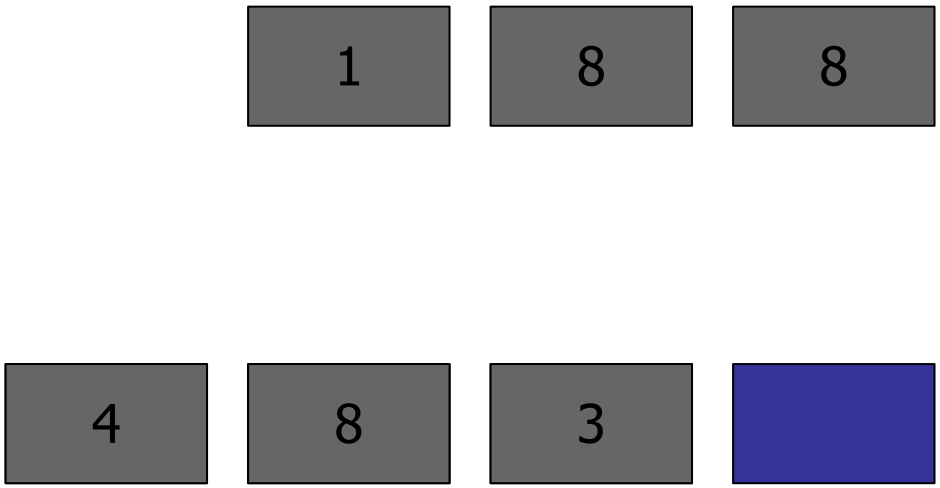
Miss: 8
Hit: 2

LRU Example



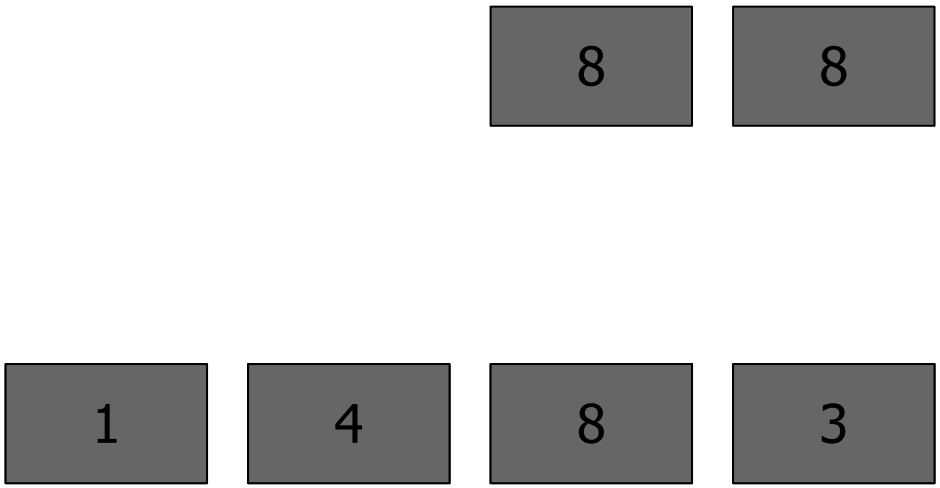
Miss: 8
Hit: 3

LRU Example



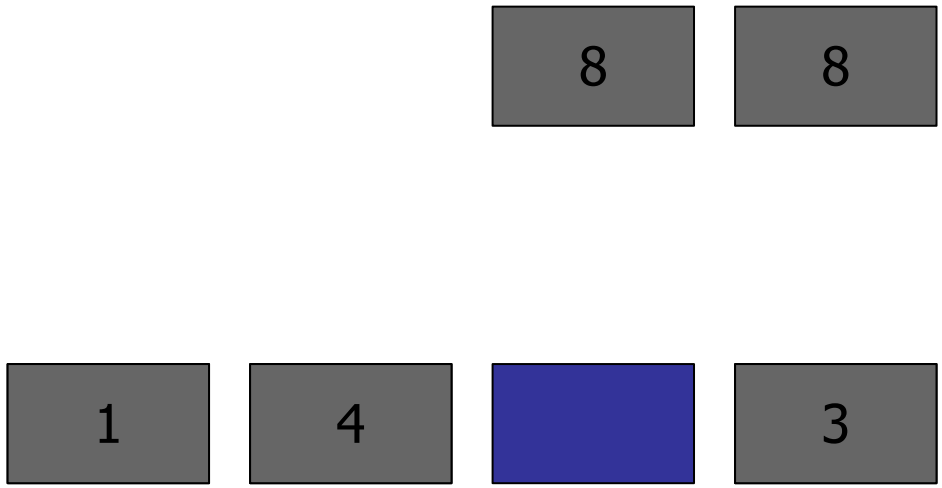
Miss: 8
Hit: 3

LRU Example



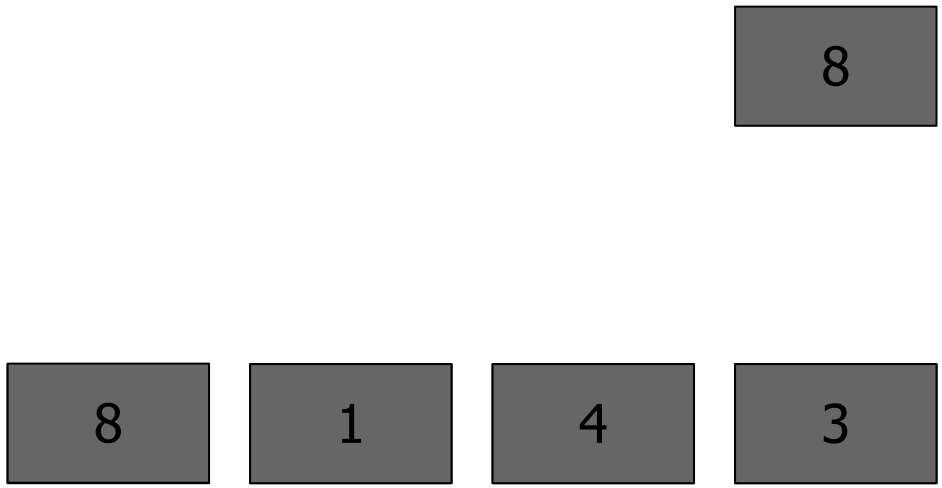
Miss: 8
Hit: 4

LRU Example



Miss: 8
Hit: 4

LRU Example

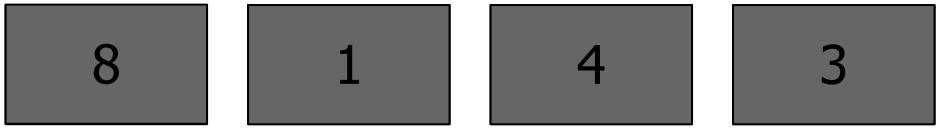


LRU Example

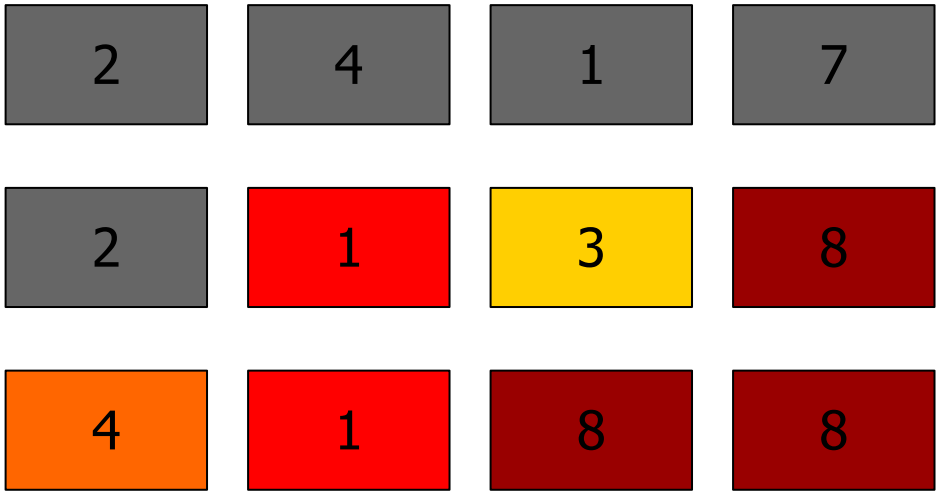
Miss: 7
Hit: 5

MR = 62%
HR = 38%

Final State of the Cache



LRU Example



Final State of the Cache