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Load Balancing of Heterogeneous Workloads in Memcached Clusters

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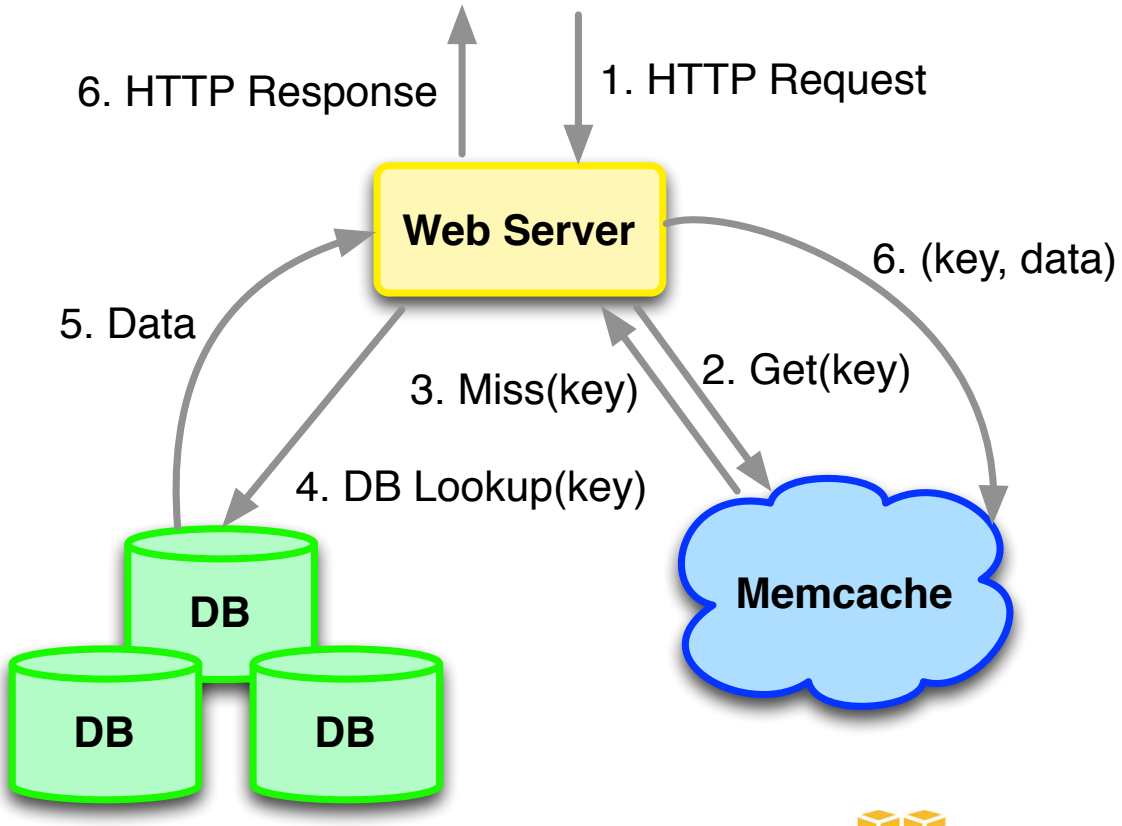
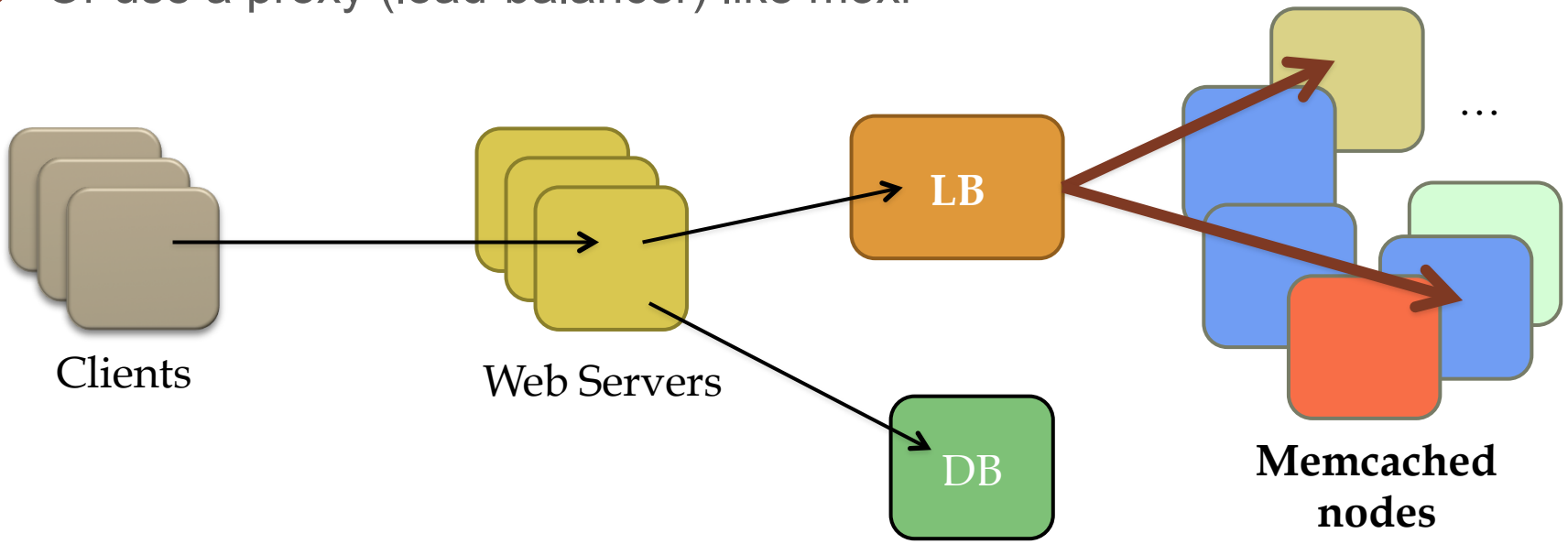
Background: Memory Caching

- Two orders of magnitude more reads than writes
- Solution: Deploy memcached hosts to handle the read capacity



Memcached at Scale

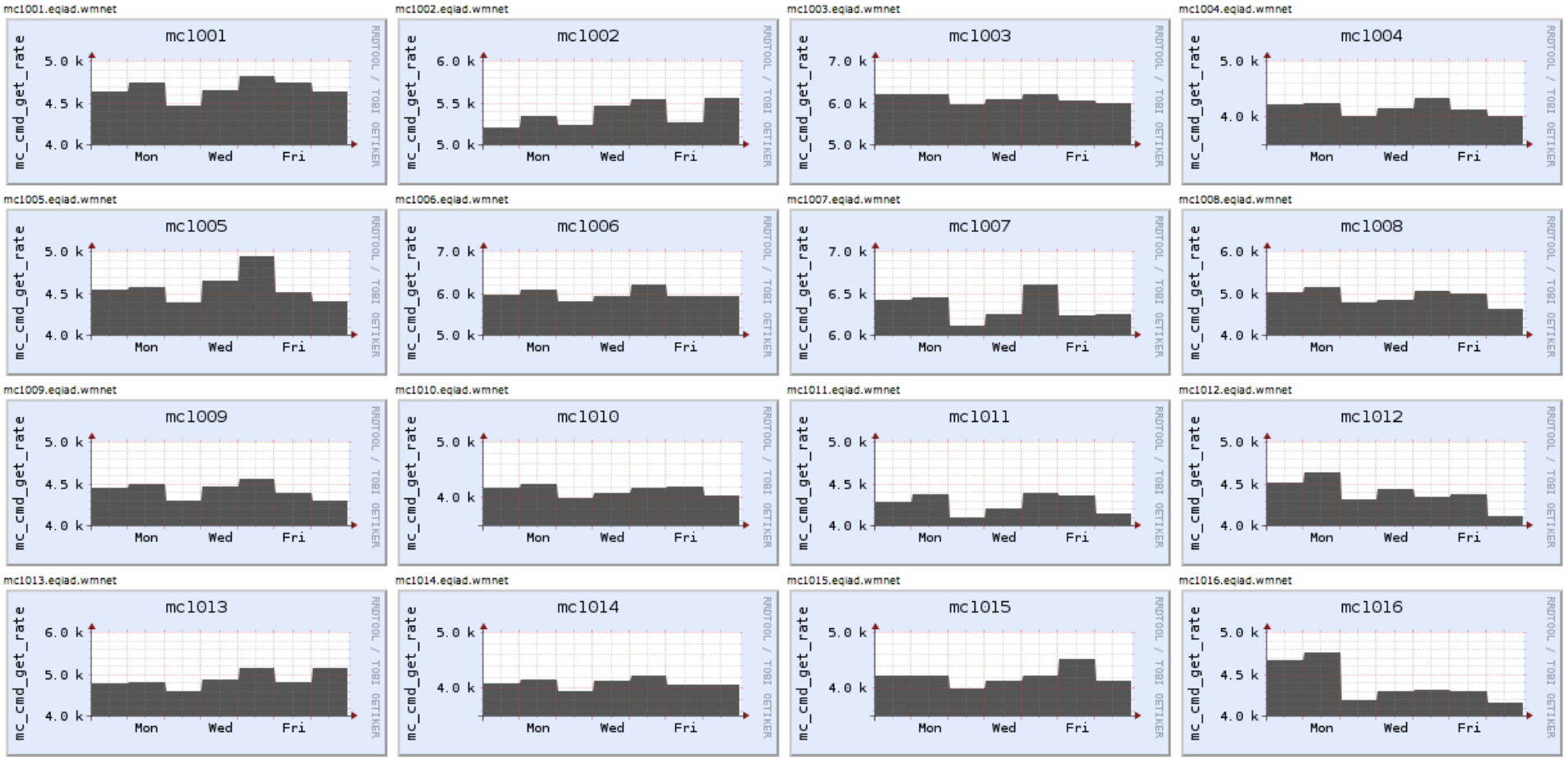
- Databases are hard to scale… Memcached is easy
  - Facebook has 10,000+ memcached servers
- Partition data and divide key space among all nodes
  - Simple data model. Stupid nodes.
- Web application must track where each object is stored
  - Or use a proxy (load-balancer) like moxi



Scales easily, but loads are imbalanced

- Random placement…
- Skewed popularity distributions…

Load on Wikipedia's memcached servers



Motivation

- Cache clusters are typically provisioned to support peak load, in terms of request processing capabilities and cache storage size
  - This worst-case provisioning can be very expensive
  - This does not take advantage of dynamic resource allocation and VM provisioning capabilities
- There can be great diversity in both the workloads and types of nodes
  - This makes cluster management difficult
- Solution: large-scale self-managing caches

Contributions

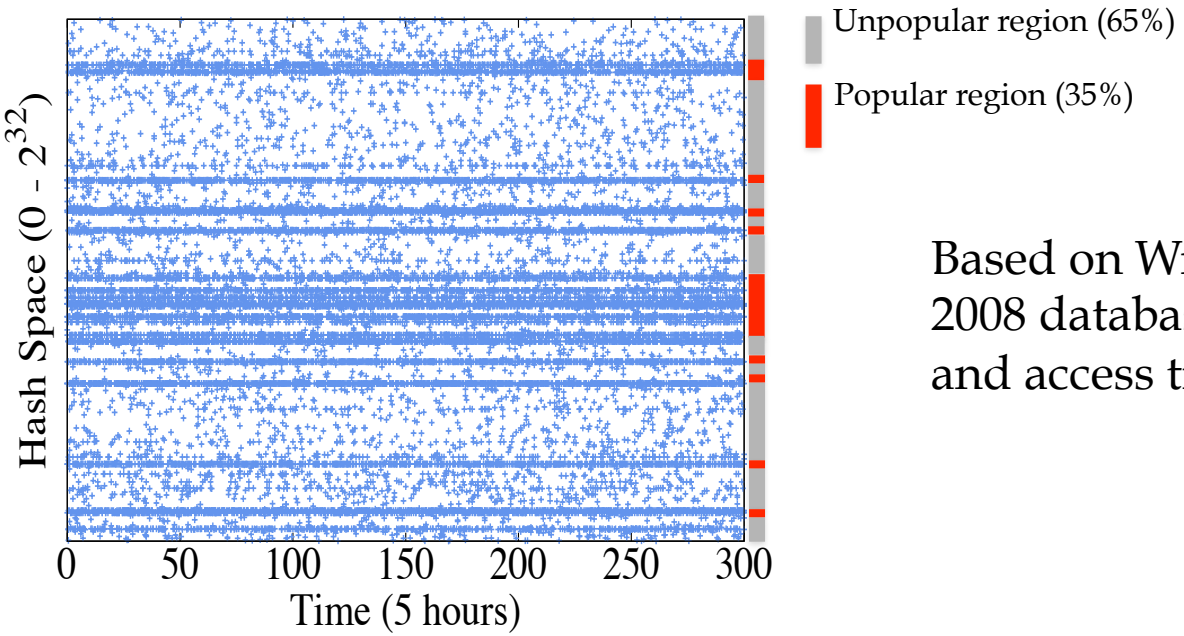
- A high speed memcached load balancer
  - can forward millions of requests per second
- A hot spot detection algorithm
  - uses stream data mining techniques to efficiently determine the hottest keys
- A two-level key mapping system
  - combines consistent hashing with a lookup table to flexibly control the placement and replication level of hot keys
- An automated server management system
  - determines the number of (types of) servers in the caching cluster

Outline

- Background and Motivation
- Workload & Server Heterogeneity
- Memcached Load Balancer Design
- Hotspot Detection Algorithm
- Conclusions

Workload Heterogeneity

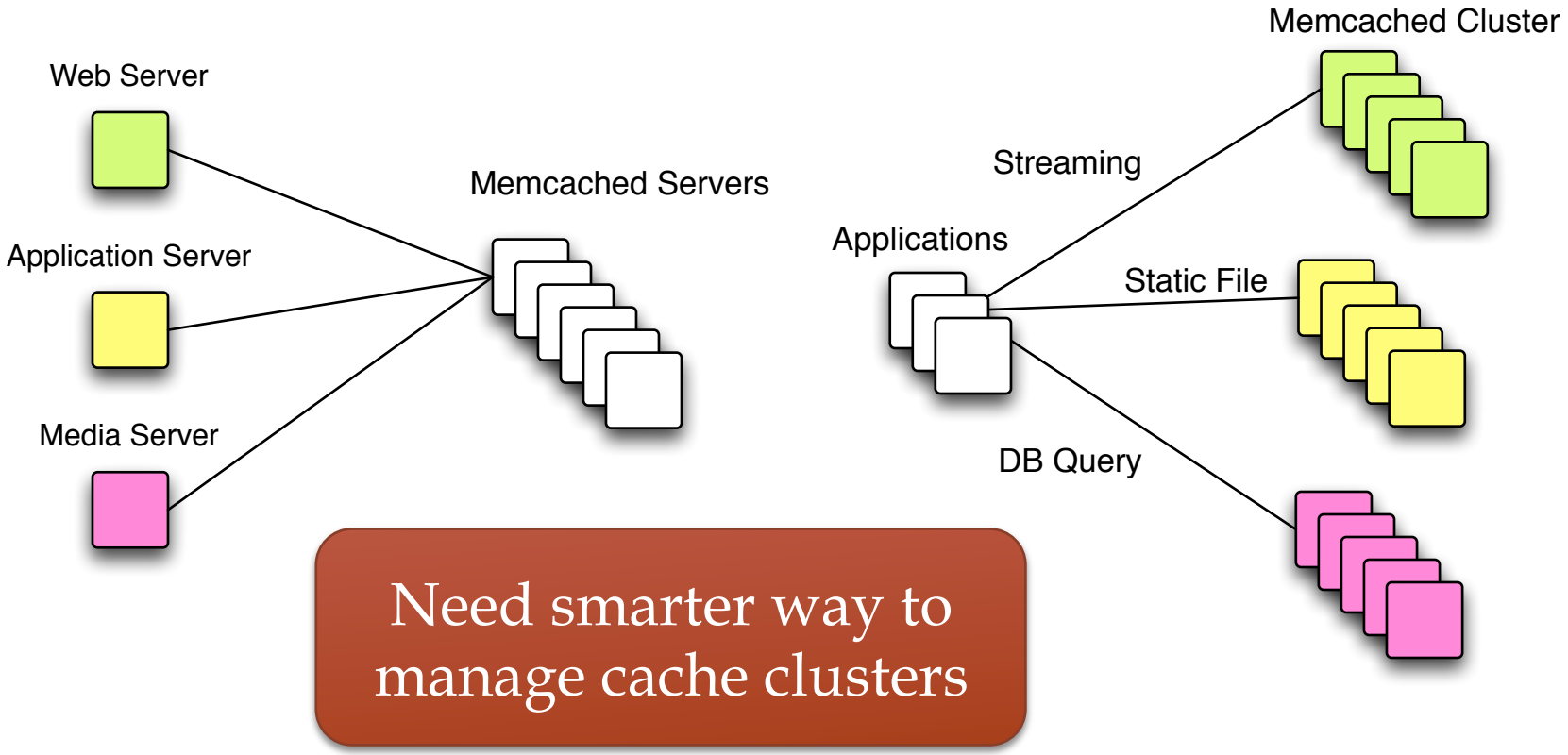
- Varied key popularity depending on applications
- Read/write rates, churn rates, costs for cache misses, quality-of-service demands



Based on Wikipedia 2008 database dump and access trace

Memcached Cluster Grouping

- Traditionally, many applications share memcached servers
- Today, to handle different applications, memcacheds are clustered ***manually***



Server Heterogeneity

- Software and hardware can be diverse
- Different memory cache softwares out there
- Many researches prototyped memcached on different HW architectures
  - GP-GPU [Hetherington:ISPASS12]
  - RDMA (remote direct memory access) [Stuedi:ATC12]
  - FPGA [Maysam:Computer_Architecture_Letter13]
  - Intel DPDK [Lim:NSDI14]

Dynamically adapt to workload heterogeneity and server heterogeneity

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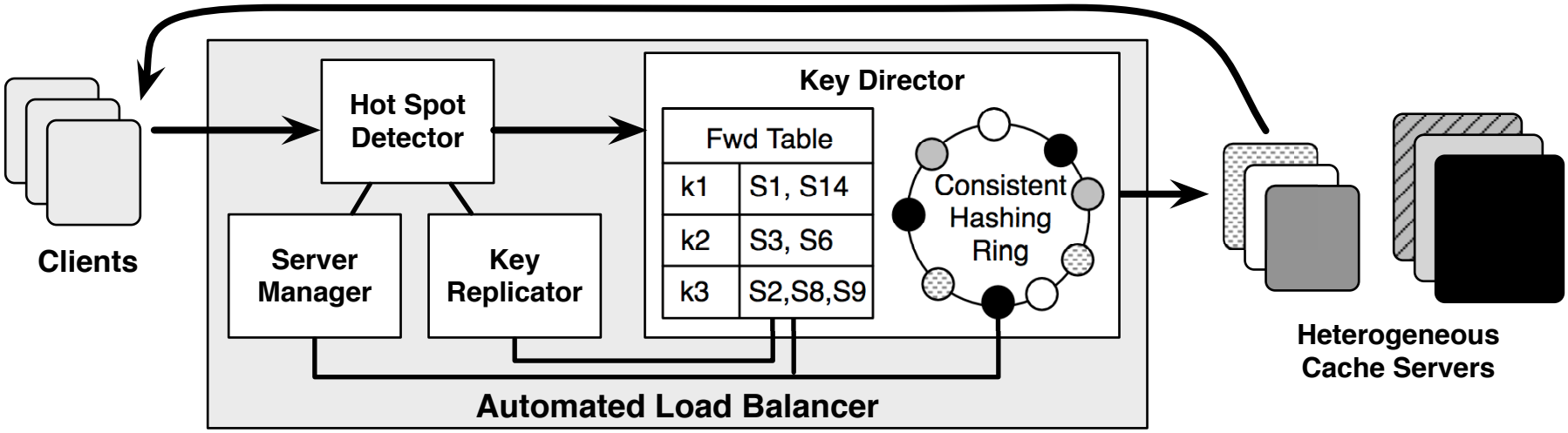
Self-Managing Cache Clustering System

- Cache clustering system considers heterogeneous workloads and servers
  - Identifies server capabilities to adjust key space
  - Finds hot items based on the item frequency to handle them differently
- Dynamically increase/decrease the number of memcached servers
- Uses two-level key mapping system
  - Consistent hashing: ***applies to warm/cold items (LRU)***
  - Forward table: ***applies to hot items***

Automated Load-Balancer Architecture



- Use UDP protocol to redirect the packets directly from memcached servers to clients (lower load in load-balancer)
- ***Hot Spot Detector*** runs a streaming algorithm to find hot items
- ***Server Manager*** manages the memcached servers
- ***Key Replicator*** manages the key replication
- ***Key Director*** manages forwarding table and consistent hashing ring

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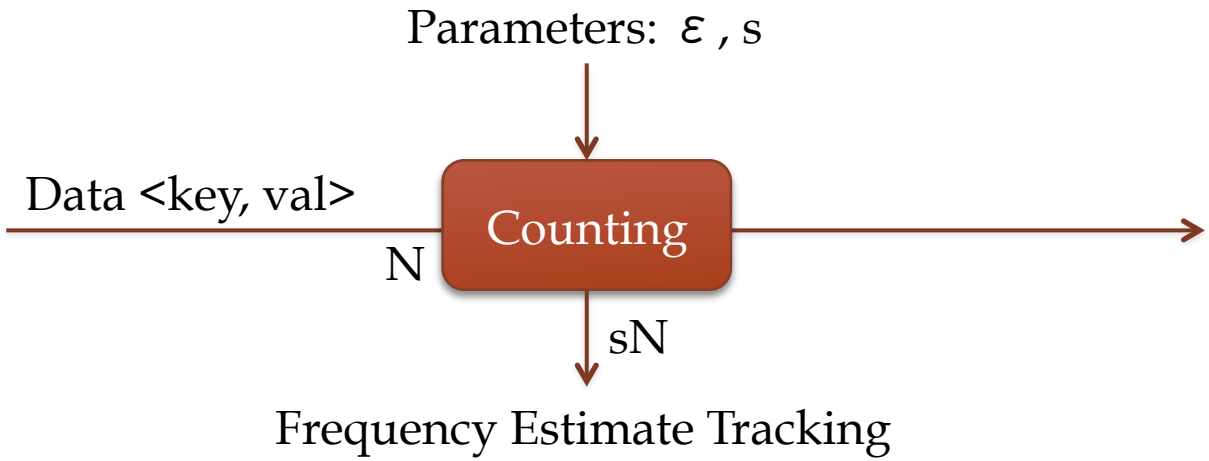
Lossy Counting based Hot Spot Detection

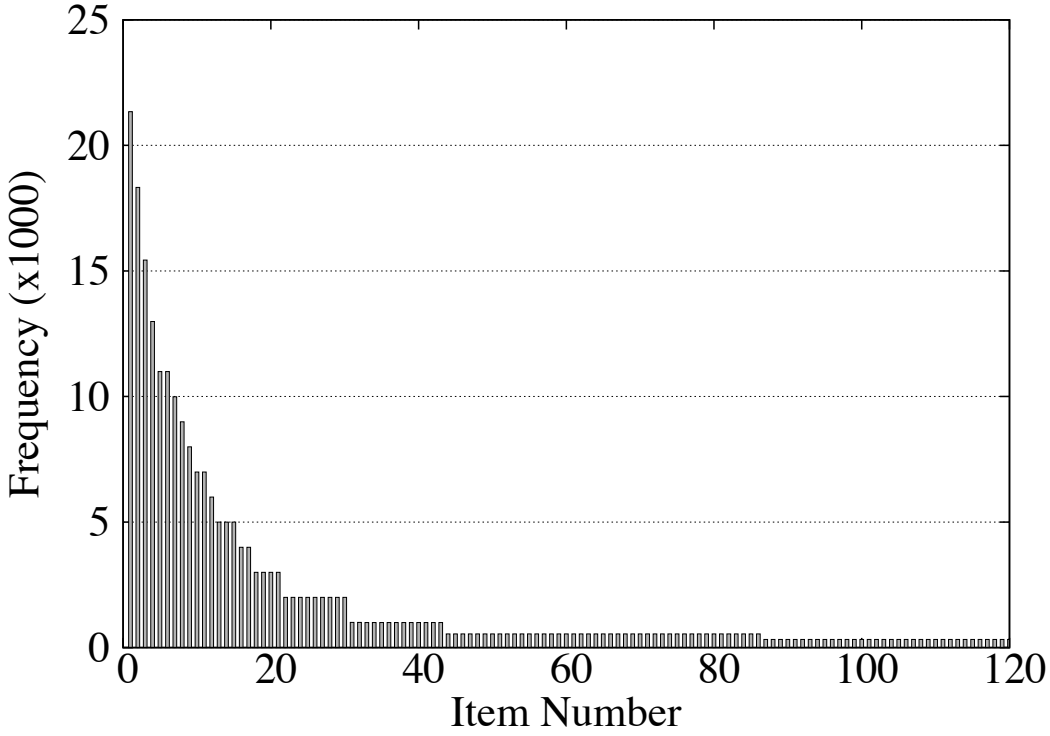
- Lossy counting algorithm is a one-pass deterministic streaming algorithm with user defined parameters
  - Support threshold s

    Given the stream length N, return at least sN
  - Error rate ε (ε << s)
  - No item with true frequency < (s - ε)N is returned (no false negative)
  - Memory size is not monotonically increasing



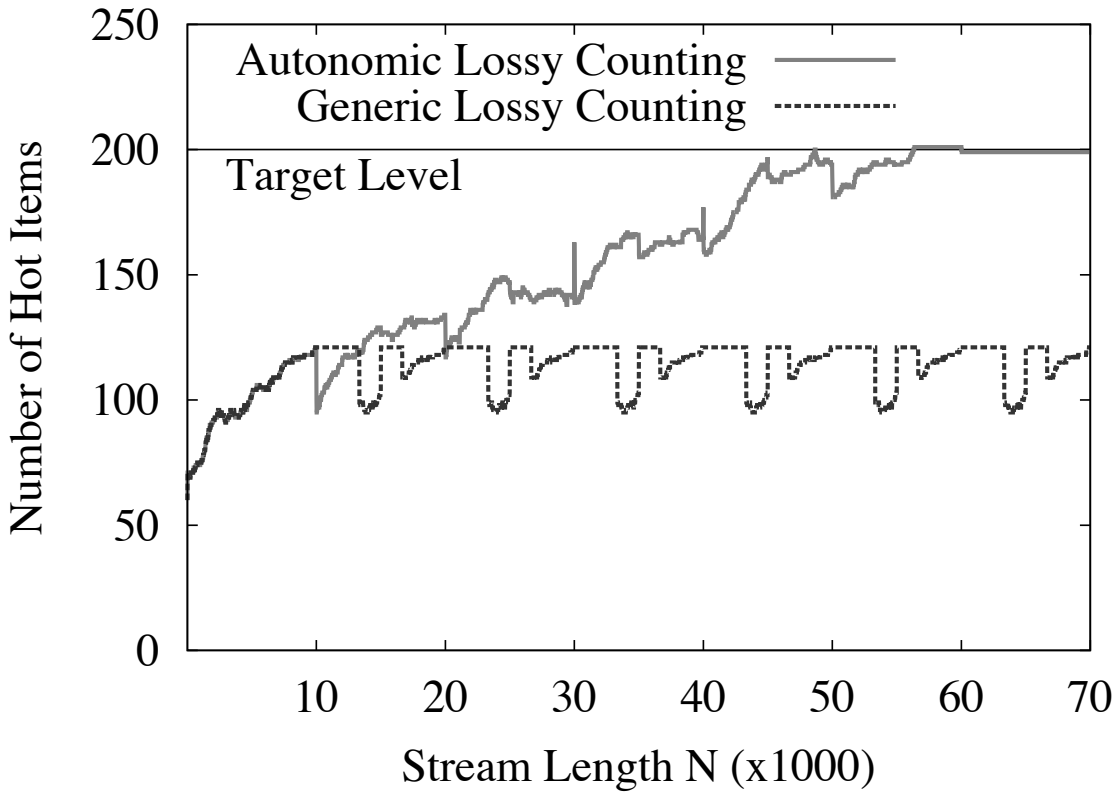
Find Hot Items and Groups of Hot Items

- Estimated frequency (i.e., request rate) seen by the top keys
- The goal is two-fold
  - Find hot items
  - Find groups of items that can balance the loads across servers



Adaptively Sizing Number of Hot Items

- Given the number of servers, and found hot spot groups, the load-balancer decides to increase/decrease the number of keys
- In a scheduling window, we adjust the support parameter *s* to adjust the number of hot items



Conclusion

- Summary
  - Self-managing cache clustering system
    Workload and server heterogeneity
  - Adaptive hot item groups
    Number of keys and groups based on servers
  - High speed load-balancer (~10 million requests per sec / single core)
    Leverage high-performing NICs and processors

- Ongoing work
  - Optimize the number of servers and replicas of hot items (cloud environment)