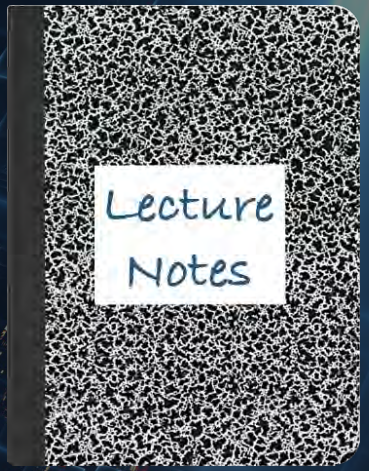
CS 417 – DISTRIBUTED SYSTEMS

Week 11: Content Delivery

Part 3: Memory Caching



Paul Krzyzanowski

Caching

Purpose of a cache

- Temporary storage to increase data access speeds
- Increase effective bandwidth by caching most frequently used data

Store raw data from slow devices

- Memory cache on CPUs
- Buffer cache in operating system
- Chubby file data and metadata
- GFS master caches all metadata in memory

Store computed data

- Avoid the need to look the same thing up again
  - Results of database queries or file searches
  - Spark RDDs in memory

What would you use a caching service for?

Cache user session state on web application servers

No need to have user come back to the same computer

Cache user preferences, shopping carts, etc.

Avoid repeated database lookups (e.g., key-value data)

Cache rendered web pages

Avoid re-processing server-side includes, JSP/ASP/PHP code

Cache precomputed results

Avoid re-computing data that gets reused
(Spark RDDs, news posts, inventory status, …)

Distributed In-Memory Caching as a Service

A network memory-based caching service

Shared by many – typically used by front-end services

Stores frequently-used (key, value) data

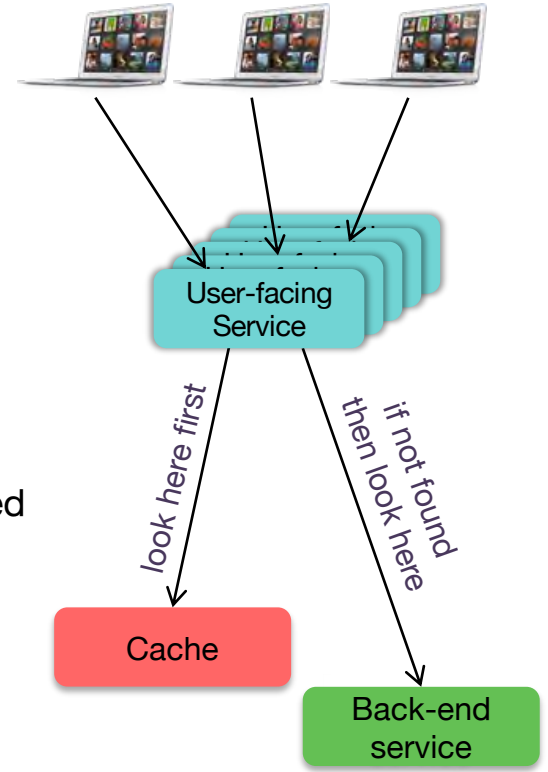
Old data gets evicted

General purpose

Not tied to a specific back-end service

Not transparent (usually)

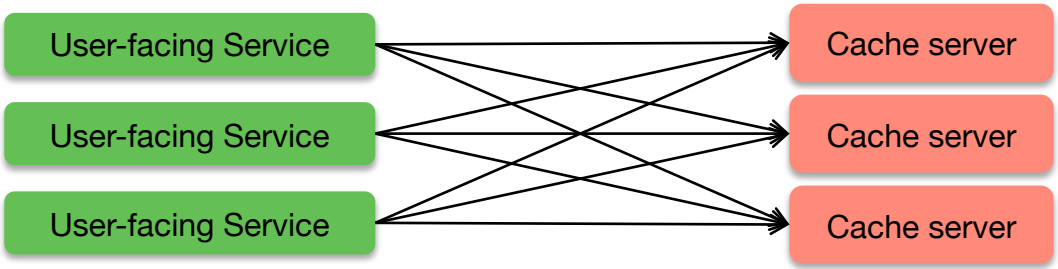
Because it's a general-purpose service, the programmer gets involved



Deployment Models

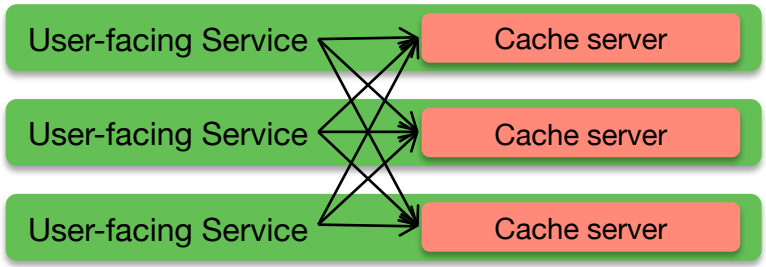
Separate caching server

One or more computers whose sole purpose is to provide a caching service



Or share cache memory among servers

Take advantage of free memory from lightly-loaded nodes



Example: memcached

Free & open source distributed memory caching

memcached.org

Used by

Dropbox, Facebook, Wikipedia, Flickr, Twitter,
YouTube, Instagram, Digg, Bebo, WordPress, Craigslist, …

Protocol

Binary & ASCII versions

Client APIs for

Command line, C/C++, C#, Go, PHP, Java, Python, Ruby, Perl, Erlang, Lua, LISP,
Windows/.NET, mySQL, PostgreSQL, ColdFusion, …

Memcached structure

Key-Value store

- Cache is made up of { key, value, expiration time, flags }
- All access is *O(1)*

Client software

- Provided with a list of *memcached* servers
- Hash(key) chooses a server based on the *key*

Server software

- Stores keys and values in an in-memory hash table
- Throw out old data when necessary
  - LRU cache and time-based expiration
  - Objects expire after a minute to ensure stale data is not returned
- Servers are unaware of each other

Memcached API

Commands sent over TCP (UDP also available)

Connection may be kept open indefinitely

Commands

Storage

- Storage commands take an expiration time in seconds from current time or 0 = forever (but may be deleted)
- set – store data
- add – store data only if the server *does not* have data for the key
- replace – store data if the server *does* have data for the key
- append – add data after existing data
- prepend – add data before existing data
- cas – check & set: *store data only if no one else updated it since I fetched it* (cas = unique, 64-bit value associated with the item)

Retrieval

- get – retrieve one or more keys: returns *key, flags, bytes,* and *cas unique*

Memcached API

Commands

Deletion

- delete *key*

Increment/decrement

- Treat data as a 64-bit unsigned integer and add/subtract value
- incr *key value* – increment *key* by *value*
- decr *key value* – decrement *key* by *value*

Update expiration

- touch *key exptime* – Update the expiration time

Get Statistics

- stats – various options for reporting statistics

Flush

- flush_all – clear the cache

Redis

Memory cache + in-memory database + message broker

Open source: see redis.io

Text-based command interface

Features

- Key-value store
- Transactions
- Publish/subscribe messaging
- Expiration of data
- Built-in replication
- Optional disk persistence
- Lua scripting (via EVAL command)
- Automatic partitioning with Redis Cluster

Used by: Twitter, GitHub, Weibo, Pinterest, Snapchat, Craigslist, Digg, StackOverflow, Flickr, Shopify, Hulu, Trello, Uber, Coinbase, …

Redis Data Types

Strings

- Simplest type; only type supported in memcached)

Lists

- Collections of strings sorted by order of insertion

Sets

- Collections of unique, unsorted strings

Sorted sets

- Every element is associated with a **score** (floating point number)
- Elements sorted by score
- Operations to retrieve ranges (e.g., top 10, bottom 10)

Hashes

- Maps of fields associated with values (fields & values are strings)

Bitmaps

- Commands to treat strings as bits (set/clear bits)

HyperLogLogs

- Probabilistic data structure to estimate the cardinality of a set
  - Count # of unique items without storing the entire set of items
- Use a fixed amount of memory

Redis as a memory cache: Timeouts & Evictions

Set expiration for specific keys

- Associate a timeout with a key
- Key deleted after the timeout

```
SET mykey "hello"
EXPIRE mykey 10          expire key in 10 seconds
```

Tell the cache to automatically evict (delete) old data

Methods of eviction

- LRU (least recently used)
- LRU only for keys that have an expiration time
- Random
- Random only for keys that have an expiration time

Redis as an in-memory database

MULTI

- Mark the start of a transaction (operations queued until EXEC)

EXEC

- Execute queued commands in a transaction

DISCARD

- Abort transaction & revert to previous values

WATCH

- Test-and-set behavior to ensure mutual exclusion
- Monitor keys to detect changes
- Abort if change takes place

Redis as a message broker

Publish/subscribe model

- Senders (publishers) do not send messages to specific receivers
- Messages go to channels
- Subscribers listen to one or more channels, receiving messages of interest

Allows for scalability and dynamic topology

- Publishers do not know subscribers
- Subscribers do not know publishers

Support for pattern-based channels

- Subscribe to all channel names matching a pattern

Redis partitioning

Data can be partitioned across multiple computers

Types of partitions

- Range partitioning
  - Use table that maps ranges to instances
- Hash partitioning
  - Based on hash(key): works with any key

Who does the partitioning?

- Client-side partitioning
- Proxy-assisted partitioning
- Query forwarding by a Redis server

The End