CSCI-1680
Web Performance and Content Distribution

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Based partly on lecture notes by Scott Shenker and John Jannotti
Last time

• HTTP and the WWW
• Some performance issues
  – Persistent Connections, Pipeline, Multiple Connections
  – Caching
• Today
  – More on Caching
  – Content Distribution Networks
Caching

• **Why cache content?**
  – Client (browser): avoid extra network transfers
  – Server: reduce load on the server
  – Service Provider: reduce external traffic
Caching

- Why caching works?
  - Locality of reference:
    - Users tend to request the same object in succession
    - Some objects are popular: requested by many users
How well does caching work?

- Very well, up to a point
  - Large overlap in requested objects
  - Objects with one access place upper bound on hit ratio
  - About 400 servers, 100 are HTTP Caches (Squid)
  - 85% Hit ratio for text, 98% for media
HTTP Cache Control

Cache-Control = "Cache-Control" ":" 1#cache-directive
cache-directive = cache-request-directive
| cache-response-directive
cache-request-directive =
  "no-cache" ; Section 14.9.1
| "no-store" ; Section 14.9.2
| "max-age" "=" delta-seconds ; Section 14.9.3, 14.9.4
| "max-stale" [ "=" delta-seconds ] ; Section 14.9.3
| "min-fresh" "=" delta-seconds ; Section 14.9.3
| "no-transform" ; Section 14.9.5
| "only-if-cached" ; Section 14.9.4
| cache-extension ; Section 14.9.6

cache-response-directive =
  "public" ; Section 14.9.1
| "private" [ "=" <"> 1#field-name <"> ] ; Section 14.9.1
| "no-cache" [ "=" <"> 1#field-name <"> ] ; Section 14.9.1
| "no-store" ; Section 14.9.2
| "no-transform"
| "must-revalidate" ; Section 14.9.4
| "proxy-revalidate" ; Section 14.9.4
| "max-age" "=" delta-seconds ; Section 14.9.3
| "s-maxage" "=" delta-seconds ; Section 14.9.3
| cache-extension ; Section 14.9.6

cache-extension = token [ "=" ( token | quoted-string ) ]
Reverse Proxies

- Close to the server
  - Also called Accelerators
  - Only work for static content
Forward Proxies

• Typically done by ISPs or Enterprises
  – Reduce network traffic and decrease latency
  – May be transparent or configured
Content Distribution Networks

• **Integrate forward and reverse caching**
  – One network generally administered by one entity
  – E.g. Akamai

• **Provide document caching**
  – Pull: result from client requests
  – Push: expectation of high access rates to some objects

• **Can also do some processing**
  – Deploy code to handle some dynamic requests
  – Can do other things, such as transcoding
Example CDN
How Akamai works

• **Akamai has cache servers deployed close to clients**
  – Co-located with many ISPs
• **Challenge: make same domain name resolve to a proxy close to the client**
• **Lots of DNS tricks. BestBuy is a customer**
  – Delegate name resolution to Akamai (via a CNAME)
• **From Brown:**
  
  ```
dig www.bestbuy.com

;; ANSWER SECTION:
www.bestbuy.com.edgesuite.net. 21600 IN  CNAME  a1105.b.akamai.net.
a1105.b.akamai.net.  20  IN  A  198.7.236.235
a1105.b.akamai.net.  20  IN  A  198.7.236.240
  – Ping time: 2.53ms
```
• **From Berkeley, CA:**
  
  ```
a1105.b.akamai.net.  20  IN  A  198.189.255.200
a1105.b.akamai.net.  20  IN  A  198.189.255.207
  – Pint time: 3.20ms
```
DNS Resolution

dig www.bestbuy.com

;; ANSWER SECTION:
www.bestbuy.com.edgesuite.net. 21600 IN CNAME a1105.b.akamai.net.
a1105.b.akamai.net. 20 IN A 198.7.236.235
a1105.b.akamai.net. 20 IN A 198.7.236.240

;; AUTHORITY SECTION:
b.akamai.net. 1101 IN NS n1b.akamai.net.
b.akamai.net. 1101 IN NS n0b.akamai.net.

;; ADDITIONAL SECTION:
n0b.akamai.net. 1267 IN A 24.143.194.45
n1b.akamai.net. 2196 IN A 198.7.236.236

- **n1b.akamai.net** finds an edge server close to the client’s local resolver
  - Uses knowledge of network: BGP feeds, traceroutes. *Their secret sauce...*
What about the content?

• Say you are Akamai
  – Clusters of machines close to clients
  – Caching data from many customers
  – Proxy fetches data from *origin* server first time it sees a URL

• Choose cluster based on client network location

• How to choose server within a cluster?

• If you choose based on client
  – Low hit rate: N servers in cluster means N cache misses per URL
Straw man: modulo hashing

• Say you have N servers
• Map requests to proxies as follows:
  – Number servers 0 to N-1
  – Compute hash of URL: \( h = \text{hash (URL)} \)
  – Redirect client to server \( #p = h \mod N \)
• Keep track of load in each proxy
  – If load on proxy \( #p \) is too high, try again with a different hash function (or “salt”)
• Problem: most caches will be useless if you add or remove proxies, change value of N
Consistent Hashing [Karger et al., 99]

- URLs and Caches are mapped to points on a circle using a hash function
- A URL is assigned to the closest cache clockwise
- Minimizes data movement on change!
  - When a cache is added, only the items in the preceding segment are moved
  - When a cache is removed, only the next cache is affected
Consistent Hashing [Karger et al., 99]

- Minimizes data movement
  - If 100 caches, add/remove a proxy invalidates ~1% of objects
  - When proxy overloaded, spill to successor
- Can also handle servers with different capacities. How?
  - Give bigger proxies more random points on the ring

<table>
<thead>
<tr>
<th>Object</th>
<th>Cache</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B</td>
</tr>
<tr>
<td>2</td>
<td>C</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
</tr>
</tbody>
</table>
CoralCDN

• What if a content provider can’t pay a CDN?
  – Slashdotted servers
• CoralCDN is a clever response to that
• Say you want to access
  http://www.cs.brown.edu/courses/cs168
• Instead, try to access
  http://www.cs.brown.edu.nyud.net/courses/cs168
• What does this accomplish?
CoralCDN

http://www.cs.brown.edu.nyud.net/courses/cs168
– Resolution controlled by the owner of nyud.net
– CoralCDN runs a set of DNS servers and a set of HTTP proxies
– DNS servers return an HTTP proxy close to the client

• The HTTP proxies form a Distributed Hash Table, mapping (url -> {proxies})
  – The mapping for a URL is stored in the server found by a technique similar to consistent hashing

• The HTTP proxy can:
  1. Return the object if stored locally
  2. Fetch it from another CoralCDN proxy if stored there
  3. Fetch it from the origin server
  4. In case of 3 or 4, store the object locally
Summary

• **HTTP Caching can greatly help performance**
  – Client, ISP, and Server-side caching

• **CDNs make it more effective**
  – Incentives, push/pull, well provisioned
  – DNS and Anycast tricks for finding close servers
  – Consistent Hashing for smartly distributing load
Next time

• Justin DeBrabant will talk about Application Layer Data, or how to write your own application layer protocol...