CS640: Introduction to Computer Networks

Aditya Akella

Lecture 18 -
The Web, Caching and CDNs

Announcements

- PA 3 out today
- HW 4 will be out some time next week
- HW 3 due today
- Sign up for PA 2 demo slot soon!

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The Road Ahead

- HTTP and TCP
- HTTP caching
- Content distribution networks

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HTTP 0.9/1.0

- One request/response per TCP connection
  - Simple to implement
- Disadvantages
  - Multiple connection setups → three-way handshake each time
    - Several extra round trips added to transfer
  - Multiple slow starts
    - Why is this bad?

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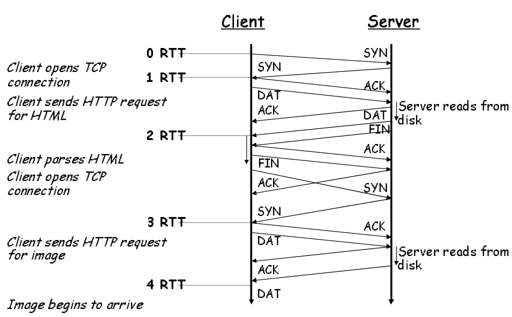
Single Transfer Example



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More Problems

- Short transfers are hard on TCP
  - Stuck in slow start
  - Also, loss recovery is poor when windows are small
- Lots of extra connections
  - Increases server state/processing
- Server also forced to keep TIME_WAIT connection state
  - Tends to be an order of magnitude greater than # of active connections

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Persistent Connection Solution

- Multiplex multiple transfers onto one TCP connection
- How to identify requests/responses
  - Delimiter → Server must examine response for delimiter string
  - Content-length and delimiter → Must know size of transfer in advance
  - Block-based transmission → send in multiple length-delimited blocks
  - Store-and-forward → wait for entire response and then use content-length
  - Solution → use existing methods and close connection otherwise

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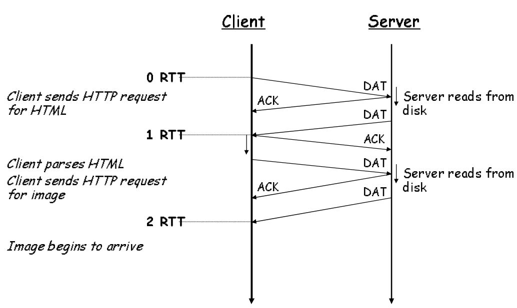
Persistent Connection Example



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Persistent HTTP

Nonpersistent HTTP issues:
- Requires 2 RTTs per object
- OS must work and allocate host resources for each TCP connection
- But browsers often open parallel TCP connections to fetch referenced objects

Persistent HTTP
- Server leaves connection open after sending response
- Subsequent HTTP messages between same client/server are sent over connection

Persistent without pipelining:
- Client issues new request only when previous response has been received
- One RTT for each referenced object

Persistent with pipelining:
- Default in HTTP/1.1
- Client sends requests as soon as it encounters a referenced object
- As little as one RTT for all the referenced objects

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HTTP Caching

- Why caching?
- Clients often cache documents
  - Challenge: update of documents
  - If-Modified-Since requests to check
    - HTTP 0.9/1.0 used just date
    - HTTP 1.1 has an opaque "entity tag" (could be a file signature, etc.) as well
- When/how often should the original be checked for changes?
  - Check every time?
  - Check each session? Day? Etc?
  - Use "Expires" header
    - If no Expires, often use Last-Modified as estimate

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Example Cache Check Request

GET / HTTP/1.1
Accept: */*
Accept-Language: en-us
Accept-Encoding: gzip, deflate
If-Modified-Since: Mon, 29 Jan 2001 17:54:18 GMT
If-None-Match: "7a11f-10ed-3a75ae4a"
User-Agent: Mozilla/4.0 (compatible; MSIE 5.5; Windows NT 5.0)
Host: www.intel-iris.net
Connection: Keep-Alive

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Example Cache Check Response

HTTP/1.1 304 Not Modified
Date: Tue, 27 Mar 2001 03:50:51 GMT
Server: Apache/1.3.14 (Unix) (Red-Hat/Linux) mod_ssl/2.7.1 OpenSSL/0.9.5a DAV/1.0.2 PHP/4.0.1pl2 mod_perl/1.24
Connection: Keep-Alive
Keep-Alive: timeout=15, max=100
ETag: "7a11f-10ed-3a75ae4a"

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Caching Example (1)

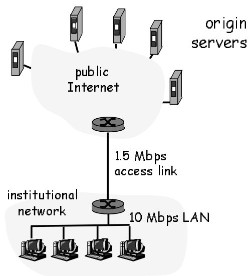
Assumptions

- Average object size = 100,000 bits
- Avg. request rate from institution's browser to origin servers = 15/sec
- Delay from institutional router to any origin server and back to router = 2 sec

Consequences

- Utilization on LAN = 15%
- Utilization on access link = 100%
- Total delay = Internet delay + access delay + LAN delay

= 2 sec + minutes + milliseconds



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Caching Example (2)

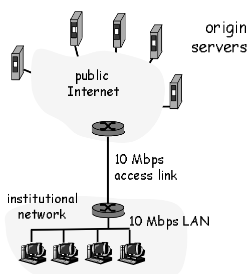
Possible solution

- Increase bandwidth of access link to, say, 10 Mbps
- Often a costly upgrade

Consequences

- Utilization on LAN = 15%
- Utilization on access link = 15%
- Total delay = Internet delay + access delay + LAN delay

= 2 sec + msecs + msecs



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Caching Example (3)

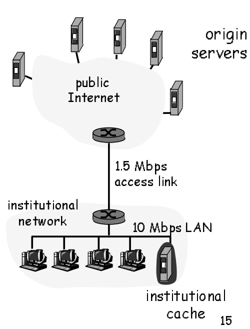
Install cache

- Suppose hit rate is .4

Consequence

- 40% requests will be satisfied almost immediately (say 10 msec)
- 60% requests satisfied by origin server
- Utilization of access link reduced to 60%, resulting in negligible delays
- Weighted average of delays

= .6*2 sec + .4*10msecs < 1.3 secs



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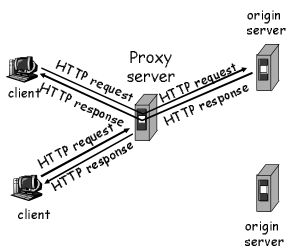
Web Proxy Caches

- User configures browser: Web accesses via cache
- Browser sends all HTTP requests to cache
  - Object in cache: cache returns object
  - Else cache requests object from origin server, then returns object to client



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Problems

- Over 50% of all HTTP objects are uncacheable – why?
- Not easily solvable
  - Dynamic data → stock prices, scores, web cams
  - CGI scripts → results based on passed parameters
  - SSL → encrypted data is not cacheable
    - Most web clients don't handle mixed pages well →many generic objects transferred with SSL
  - Cookies → results may be based on passed data
  - Hit metering → owner wants to measure # of hits for revenue, etc.
- What will be the end result?

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Content Distribution Networks & Server Selection

- Replicate content on many servers
- Challenges
  - Which content to replicate
  - How to replicate content
  - Where to place replicas
  - How to find replicated content
  - How to choose among know replicas
  - How to direct clients towards replica

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Server Selection

- Which server?
  - Lowest load → to balance load on servers
  - Best performance → to improve client performance
    - Based on Geography? RTT? Throughput? Load?
  - Any alive node → to provide fault tolerance
- How to direct clients to a particular server?
  - As part of routing → anycast, cluster load balancing
    - Not covered today…
  - As part of application → HTTP redirect
  - As part of naming → DNS

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Application-Based Redirection

- HTTP supports simple way to indicate that Web page has moved (30X responses)
- Server receives Get request from client
  - Decides which server is best suited for particular client and object
  - Returns HTTP redirect to that server
- Can make informed application specific decision
- May introduce additional overhead → multiple connection setup, name lookups, etc.

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Naming Based

- Client does name lookup for service
- Name server chooses appropriate server address
  - A-record returned is "best" one for the client
- What information can name server base decision on?
  - Server load/location → must be collected
  - Information in the name lookup request
    - Name service client → typically the local name server for client

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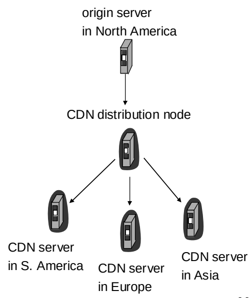
Content Distribution Networks (CDNs)

- The content providers are the CDN customers.

Content replication

- CDN company installs hundreds of CDN servers throughout Internet
  - Close to users
- CDN replicates its customers' content in CDN servers. When provider updates content, CDN updates servers



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How Akamai Works

- Clients fetch html document from primary server
  - E.g. fetch index.html from cnn.com
- "Akamaized" URLs for replicated content are replaced in html
  - E.g. <img src="http://cnn.com/af/x.gif"> replaced with <img src="http://a73.g.akamaitech.net/7/23/cnn.com/af/x.gif">
- Client is forced to resolve aXYZ.g.akamaitech.net hostname

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How Akamai Works

- How is content replicated?
- Akamai only replicates static content (*)
- Modified name contains original file name and content provider ID
- Akamai server is asked for content
  - First checks local cache
  - If not in cache, requests file from primary server; caches file

* (At least, the version we're talking about today. Akamai actually lets sites write code that can run on Akamai's servers, but that's a different beast altogether!)

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How Akamai Works

- Root server gives NS record for akamai.net
- Akamai.net name server returns NS record for g.akamaitech.net
  - Name server chosen to be in region of client's name server
    - Out-of-band measurements to obtain this
- G.akamaitech.net nameserver chooses server in region
  - Which server to choose?
  - Uses aXYZ name and hash

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Simple Hashing

- Given document XYZ, we need to choose a server to use
- Suppose we use modulo
- Number servers from 1…n
  - Place document XYZ on server (XYZ mod n)
  - What happens when a servers fails? n → n-1
  - Why might this be bad?

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Consistent Hash

- Desired features
  - Balanced – load is equal across buckets
  - Smoothness – little impact on hash bucket contents when buckets are added/removed
  - Spread – small set of hash buckets that may hold a set of object
  - Load – # of objects assigned to hash bucket is small

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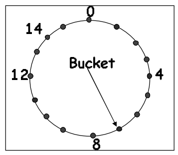
Consistent Hash – Example

- Construction
  - Assign each of C hash buckets to random points on mod 2^n circle, where, hash key size = n.
  - Map object to random position on circle
  - Hash of object = closest clockwise bucket



- Smoothness → addition of bucket does not cause movement between existing buckets
- Spread & Load → small set of buckets that lie near object
- Balance → no bucket is responsible for large number of objects

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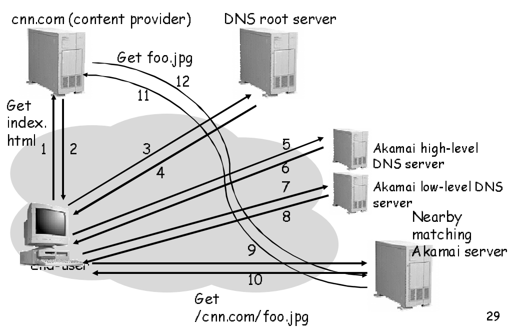
How Akamai Works



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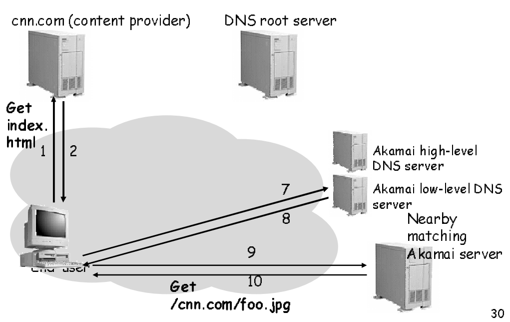
Akamai – Subsequent Requests



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Summary

- HTTP: Simple text-based file exchange protocol
  - Support for status/error responses, authentication, client-side state maintenance, cache maintenance
- Workloads
  - Typical documents structure, popularity
  - Server workload
- Interactions with TCP
  - Connection setup, reliability, state maintenance
  - Persistent connections
- How to improve performance
  - Persistent connections
  - Caching
  - Replication

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