15-441: Computer Networking

Lecture 23: HTTP

Overview

- HTTP Basics
- HTTP Fixes
- Web Caches
- Content Distribution Networks

HTTP Basics

- HTTP layered over bidirectional byte stream
  - Almost always TCP
- Interaction
  - Client sends request to server, followed by response from server to client
  - Requests/responses are encoded in text
- How to mark end of message?
  - Size of message → Content-Length
    - Must know size of transfer in advance
  - Delimiter → MIME style Content-Type
    - Server must "byte-stuff"
  - Close connection
    - Only server can do this

HTTP Request

- Request line
  - Method
    - GET – return URI
    - HEAD – return headers only of GET response
    - POST – send data to the server (forms, etc.)
  - URI
    - E.g. http://www.seshan.org/index.html with a proxy
    - E.g. /index.html if no proxy
  - HTTP version

HTTP Request

- Request headers
  - Authorization – authentication info
  - Acceptable document types/encodings
  - From – user email
  - If-Modified-Since
  - Referrer – what caused this page to be requested
  - User-Agent – client software
- Blank-line
- Body

HTTP Request Example

GET / HTTP/1.1
Accept: */*
Accept-Language: en-us
Accept-Encoding: gzip, deflate
User-Agent: Mozilla/4.0 (compatible; MSIE 5.5; Windows NT 5.0)
Host: www.seshan.org
Connection: Keep-Alive

HTTP Response

- Status-line
  - HTTP version
  - 3 digit response code
    - 1XX – informational
    - 2XX – success
    - 3XX – redirection
    - 4XX – client error
    - 5XX – server error
  - Reason phrase

HTTP Response

- Headers
  - Location – for redirection
  - Server – server software
  - WWW-Authenticate – request for authentication
  - Allow – list of methods supported (get, head, etc)
  - Content-Encoding – E.g x-gzip
  - Content-Length
  - Content-Type
  - Expires
  - Last-Modified
- Blank-line
- Body

HTTP Response Example

HTTP/1.1 200 OK
Date: Tue, 27 Mar 2001 03:49:38 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
Last-Modified: Mon, 29 Jan 2001 17:54:18 GMT
ETag: "7a11f-10ed-3a75ae4a"
Accept-Ranges: bytes
Content-Length: 4333
Keep-Alive: timeout=15, max=100
Connection: Keep-Alive
Content-Type: text/html
…..

Typical Workload

- Multiple (typically small) objects per page
- Request sizes
  - In one measurement paper → median 1946 bytes, mean 13767 bytes
  - Why such a difference? Heavy-tailed distribution
    - Pareto – $p(x) = ak^a x^{-(a+1)}$
- File sizes
  - Why different than request sizes?
  - Also heavy-tailed
    - Pareto distribution for tail
    - Lognormal for body of distribution

Typical Workload

- Popularity
  - Zipf distribution ($P = kr^{-1}$)
  - Surprisingly common
- Embedded references
  - Number of embedded objects = pareto
- Temporal locality
  - Modeled as distance into push-down stack
  - Lognormal distribution of stack distances
- Request interarrival
  - Bursty request patterns

HTTP 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 file signature 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

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.seshan.org
Connection: Keep-Alive

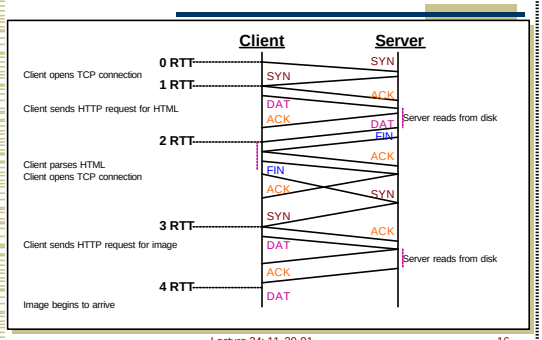
Example Cache Check Response

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"

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

Single Transfer Example



More Problems

- Short transfers are hard on TCP
  - Stuck in slow start
  - 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
  - Why must server keep these?
  - Tends to be an order of magnitude greater than # of active connections, why?

Overview

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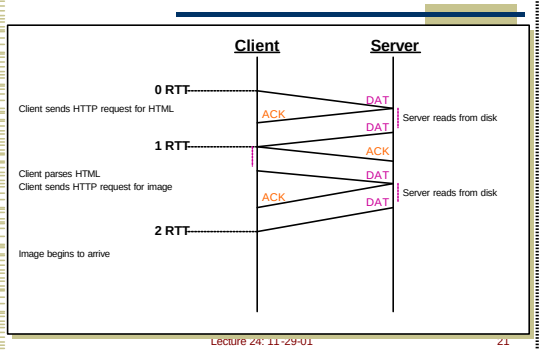
Netscape Solution

- Use multiple concurrent connections to improve response time
  - Different parts of Web page arrive independently
  - Can grab more of the network bandwidth than other users
- Doesn't necessarily improve response time
  - TCP loss recovery ends up being timeout dominated because windows are small

Persistent Connection Solution

- Multiplex multiple transfers onto one TCP connection
  - Serialize transfers → client makes next request only after previous response
- How to demultiplex requests/responses
  - Content-length and delimiter → same problems as before
  - Block-based transmission – send in multiple length delimited blocks
  - Store-and-forward – wait for entire response and then use content-length
  - PM95 solution – use existing methods and close connection otherwise

Persistent Connection Example



Persistent Connection Solution

- Serialized requests do not improve interactive response
- Pipelining requests
  - Getall – request HTML document and all embeds
    - Requires server to parse HTML files
    - Doesn't consider client cached documents
  - Getlist – request a set of documents
    - Implemented as a simple set of GETs
- Prefetching
  - Must carefully balance impact of unused data transfers
  - Not widely used due to poor hit rates

Persistent Connection Performance

- Benefits greatest for small objects
  - Up to 2x improvement in response time
- Server resource utilization reduce due to fewer connection establishments and fewer active connections
- TCP behavior improved
  - Longer connections help adaptation to available bandwidth
  - Larger congestion window improves loss recovery

Remaining Problems

- Application specific solution to transport protocol problems
- Stall in transfer of one object prevents delivery of others
- Serialized transmission
  - Much of the useful information in first few bytes
  - Can "packetize" transfer over TCP
    - HTTP 1.1 recommends using range requests
    - MUX protocol provides similar generic solution
- Solve the problem at the transport layer
  - Fix TCP so it works well with multiple simultaneous connections

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Web Caching

- Why cache HTTP objects?
  - Reduce client response time
  - Reduce network bandwidth usage
    - Wide area vs. local area use
  - These two objectives are often in conflict
    - May do exhaustive local search to avoid using wide area bandwidth
    - Prefetching uses extra bandwidth to reduce client response time

Web Proxies

- Also used for security
  - Proxy is only host that can access Internet
  - Administrators makes sure that it is secure
- Performance
  - How many clients can a single proxy handle?
- Caching
  - Provides a centralized coordination point to share information across clients
- How to index
  - Early caches used file system to find file
  - Metadata now kept in memory on most caches

Caching Proxies – Sources for misses

- Capacity
  - How large a cache is necessary or equivalent to infinite
  - On disk vs. in memory → typically on disk
- Compulsory
  - First time access to document
  - Non-cacheable documents
    - CGI-scripts
    - Personalized documents (cookies, etc)
    - Encrypted data (SSL)
- Consistency
  - Document has been updated/expired before reuse
- Conflict → no such issue

Cache Hierarchies

- Use hierarchy to scale a proxy to more than limited population
  - Why?
    - Larger population = higher hit rate
    - Larger effective cache size
  - Why is population for single proxy limited?
    - Performance, administration, policy, etc.
- NLANR cache hierarchy
  - Most popular
  - 9 top level caches
  - Internet Cache Protocol based (ICP)
  - Squid/Harvest proxy

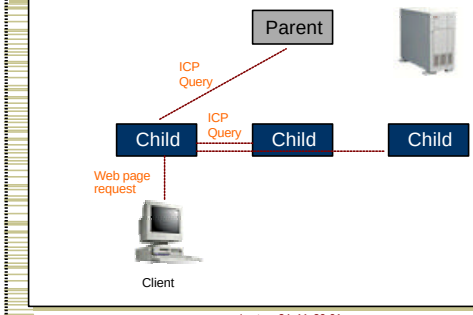
ICP

- Simple protocol to query another cache for content
- Uses UDP – why?
- ICP message contents
  - Type – query, hit, hit_obj, miss
  - Other – identifier, URL, version, sender address (is this needed?)
  - Special message types used with UDP echo port
    - Used to probe server or “dumb cache”
- Transfers between caches still done using HTTP

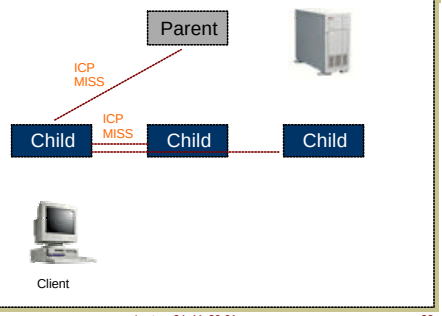
Squid Cache ICP Use

- Upon query that is not in cache
  - Sends ICP_Query to each peer (or ICP_Decho to echo port of peer caches that do not speak ICP)
  - May also send ICP_Secho to origin server's echo port
  - Sets time to short period (default 2 sec)
- Peer caches process queries and return either ICP_Hit or ICP_Miss
- Proxy begins transfer upon reception of ICP_Hit, ICP_Decho or ICP_Secho
- Upon timer expiration, proxy request object from closest (RTT) parent proxy
  - Would be better to direct to parent that is towards origin server

Squid



Squid



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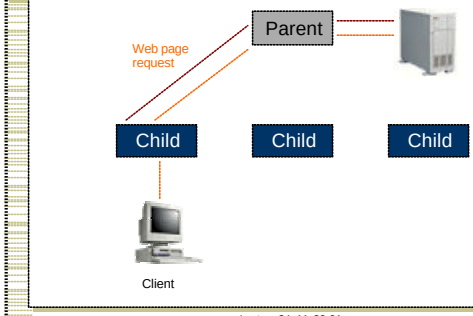

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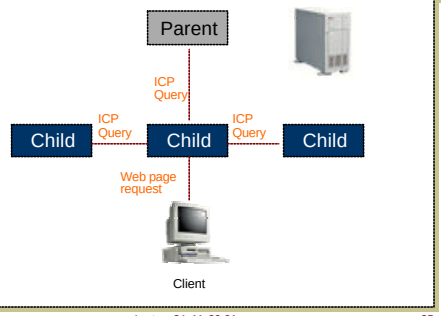

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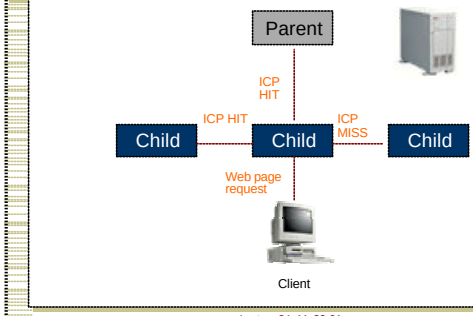

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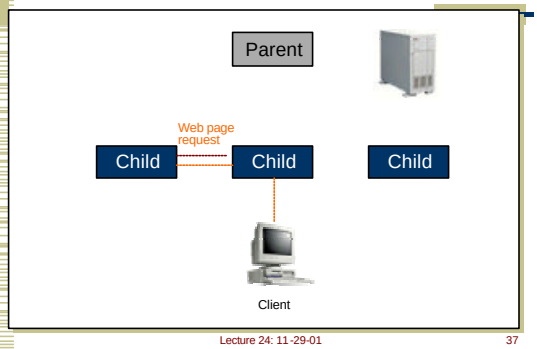

ICP vs HTTP

- Why not just use HTTP to query other caches?
- ICP is lightweight – positive and negative
  - Makes it easy to process quickly
  - Caches may process many more ICP requests than HTTP requests
  - HTTP has many functions that are not supported by ICP
  - ICP does not evolve with HTTP changes
  - Adds extra RTT to any proxy-proxy transfer

Optimal Cache Mesh Behavior

- Minimize number of hops through mesh
  - Each hop add significant latency
    - ICP hops can cost a 2 sec timeout each!
    - Strict hierarchies cost disk lookup, etc.
  - Especially painful for misses
- Share across many users and scale to many caches
  - ICP does not scale to a large number of peers
- Cache and fetch data close to clients

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
- Obvious fixes
  - 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?

Proxy Implementation Problems

- Aborted transfers
  - Many proxies transfer entire document even though client has stopped → eliminates saving of bandwidth
- Making objects cacheable
  - Proxy's apply heuristics → cookies don't apply to some objects, guesswork on expiration
  - May not match client behavior/desires
- Client misconfiguration
  - Many clients have either absurdly small caches or no cache
- How much would hit rate drop if clients did the same things as proxies

Questions – Population Size

- How does population size affect hit rate?
- Critical to understand usefulness of hierarchy or placement of caches
- Issues: frequency of access vs. frequency of change (ignore working set size → infinite cache)
- UW/Msoft measurement → hit rate rises quickly to about 5000 people and very slowly beyond that
- Proxies/Hierarchies don't make much sense for populations > 5000
  - Single proxies can easily handle such populations
  - Hierarchies only make sense for policy/administrative reasons

Questions – Common Interests

- Do different communities have different interests?
  - I.e. do CS and English majors access same pages? IBM and Pepsi workers?
- Has some impact → UW departments have about 5% higher hit rate than randomly chosen UW groups
  - Many common interests remain
- Is this true in general? UW students have more in common than IBM & Pepsi workers
- Some related observations
  - Geographic caching – server traces have shown that there is geographic locality to interest
  - UW & MS hierarchy performance is bad – could be due to size or interests?

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CDN

- Replicate content on many servers
- Challenges
  - How to replicate content
  - Where to replicate content
  - How to find replicated content
  - How to choose among know replicas
  - How to direct clients towards replica
    - Discussed in DNS/server selection lecture
    - DNS, HTTP 304 response, anycast, etc.
- Akamai

How Akamai Works

- Clients fetch html document from primary server
  - E.g. fetch index.html from cnn.com
- 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

How Akamai Works

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

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
  - TTL is large
- G.akamaitech.net nameserver choses server in region
  - Should try to chose server that has file in cache - How to choose?
  - Uses aXYZ name and consistent hash
  - TTL is small

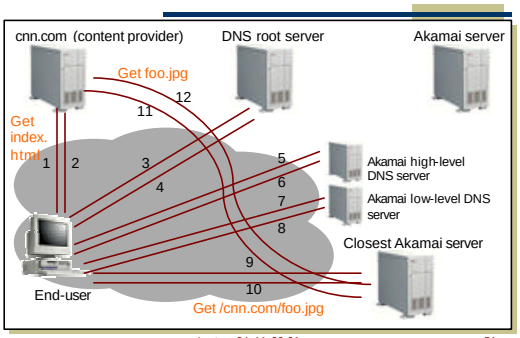
Consistent Hash

- "view" = subset of all hash buckets that are visible
- Desired features
  - Smoothness – little impact on hash bucket contents when buckets are added/removed
  - Spread – small set of hash buckets that may hold an object regardless of views
  - Load – across all views # of objects assigned to hash bucket is small

Consistent Hash – Example

- Construction
  - Assign each of C hash buckets to Klog(C) random points on unit interval
  - Map object to random position on unit interval
  - Hash of object = closest bucket
- Monotone → 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 portion of unit interval

How Akamai Works



Akamai – Subsequent Requests