Quick admin issues

- Project
  - Walter will be having extended office hours today (12:30-2:30) in EBU1 6307
  - Other times?

- Midterm
  - Covers up to and including Mobile IP
  - Closed book/notes (you can have one 8.5x11 sheet)
  - No formal review session
  - I will be available for office hours on Monday 1-3pm
HTTP Basics

- HTTP layered over 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 Messages

- Four parts
  - START LINE <CRLF>
    » Request or response
  - MESSAGE HEADER <CRLF> <CRLF>
    » 0 or more of these; meta data
  - MESSAGE BODY <CRLF>
    » Actual content
HTTP Request

- Request line
  - Method
    » GET – return URL
    » HEAD – return headers only of GET response
    » POST – send data to the server (forms, etc.)
  - URL
    » index.html by default
  - HTTP version

- Example
  GET http://www.cs.ucsd.edu/index.html HTTP/1.1
HTTP Request

- Request headers
  - Authorization – authentication info
  - Acceptable document types/encodings
  - From – user email
  - If-Modified-Since
  - Host
  - Referrer – what caused this page to be requested
  - User-Agent – client software
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.cs.ucsd.edu
Connection: Keep-Alive
HTTP Response

- Status-line (response)
  - 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
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
How HTTP is used

- Browser requests main page
- Browser parses main page for inline images and content (e.g. `<img src=http://k.com/pics/bullet>`)  
  - Typically 4-5 of these  
  - Issues additional requests to server (or other server) for additional data items
- Browser computes location of objects on page (layout)
- Browser draws each object on the screen (rendering)
- If user clicks on a link (href) then restart process
The Way Web Surfing Works...

Browser

Check cache

DNS lookup

TCP connection

Request object

Layout

Render

A? www.cnn.com

A= 207.25.71.20

DNS Server

HTTP Server

SYN/ACK

SYN

DATA

GET
Single Transfer Example

- **0 RTT**
  - Client opens TCP connection

- **1 RTT**
  - Client sends HTTP request for HTML

- **2 RTT**
  - Client parses HTML
  - Client opens TCP connection
  - Server reads from disk

- **3 RTT**
  - Client sends HTTP request for image

- **4 RTT**
  - Image begins to arrive
Problems

- Short transfers are hard on TCP
  - Stuck in slow start
  - Loss recovery is poor when windows are small. Why?
- 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
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 can be timeout dominated because windows are small
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
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
  - Block-based transmission – send in multiple length delimited blocks
  - Store-and-forward – wait for entire response and then use content-length
Persistent Connection Example

Client sends HTTP request for HTML

Client parses HTML
Client sends HTTP request for image

Image begins to arrive

Server reads from disk

0 RTT

1 RTT

2 RTT
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

- How long to keep connection open?
Pipelining

- However, serialized requests do not necessarily improve interactive response
  - Still need to issue requests for each object (one RTT each)

- Proposal
  - 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

- In practice
  - Multiple outstanding GET’s in same message (must be serviced in order)
Remaining 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
- Other solution: solve the problem at the transport layer
  - Fix TCP so it works well with multiple simultaneous connections
TCP modifications for HTTP

- **Key idea:**
  - Have different connections share congestion window information
  - Only do slow start once, recover from congestion losses together

- **Tricky issues**
  - How aggressive should it be vs using multiple connections
  - What is the difference between
    - One packet lost among four separate small TCP connections
    - One packet lost in one larger TCP connection
Typical Workload

- Multiple (typically small) objects per page
- Object sizes vary significantly
  - One measurement 1946 byte median, 13767 byte mean
  - Why so different?
  - Heavy-tailed distribution (Pareto)
  - Also true for number of embedded objects
- Popularity
  - Also heavy-tailed (Zipf)
  - Small number of very popular objects; increasingly large number of less popular objects
- Bursty interarrival pattern
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? 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.cs.ucsd.edu
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"
Web caching in general

- Caching in client
  - Keep unchanging portion of a page

- Caching in server
  - Keep popular content in memory so disk access not needed

- Caching in proxy
  - Between client and server
  - Responsible for sharing content between all users of proxy
  - Example: once one person at UCSD downloads CNN page, then everyone else can simply fetch it from proxy cache
  - Hit rates < 50%
So what makes the Web slow?

- Client delay (parsing, layout, rendering)
- Server delay (page generation)
- DNS Lookup/loss (local, domain, root lookup, loss)
- Propagation delay (client to server, RTT/MSS)
- Queuing delay (sum per message + impact of variability)
- Connection setup & failure (server load, client timeout)
- Congestion + TCP congestion response \((1/\sqrt{p})\)
- Impact of fragmentation/packet size (RTT/MSS)
- Receiver buffering (flow control)
- Sender buffering (sender resource allocation)
- Application serialization (waiting for gif?)

- Will the real culprit please stand up?
Answer is still unclear...

- Browser delay (layout/rendering) can be significant for some host/browser combinations...
- For highly loaded servers, server delay is an important component
- For high capacity networks, slow start is the limiting factor
- For networks with loss TCP congestion control can be the limiter
- For pages with many objects, the # of connections can be a factor
Summary

- HTTP built on top of TCP
  - Request response
  - Negotiates capabilities

- Connection per request is a limitation
  - Persistent connections
  - Pipelining, MUX

- Web caching
  - Check timestamp on cached copy against host/proxy
  - Caching at all levels

- Web is still slow
Next time

- Midterm!
Best case TCP transfer time

TCP Slow start time

\[
RTT \cdot \left\lfloor \log_{1.5} \left( \frac{B}{2W \cdot MSS} + 1 \right) \right\rfloor
\]

- \( RTT \): round-trip time
- \( B \): bytes to be transferred
- \( W \): initial window
- \( MSS \): bytes in a packet
Impact of Congestion control

- Very simple model for steady state TCP transfer time

\[ RTT \cdot \left( \frac{B \cdot \sqrt{p}}{MSS} \right) \]

- The models get more complicated
  - Limited receiver windows, timeouts, loss patterns, when first loss occurs, etc...

\( RTT \): round-trip time
\( B \): bytes to be transferred
\( MSS \): bytes in a packet
\( p \): packet loss rate