Network Applications: HTTP/1.0/1.1/2; High-Performance Server Design (Per Thread)

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https://qiaoxiang.me/courses/cnns-xmuf21/index.shtml

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This deck of slides are heavily based on CPSC 433/533 at Yale University, by courtesy of Dr. Y. Richard Yang.

Outline

- Admin and recap
- HTTP/1.0
  - Basic design
  - Dynamic content
- HTTP "acceleration"
- Network server design

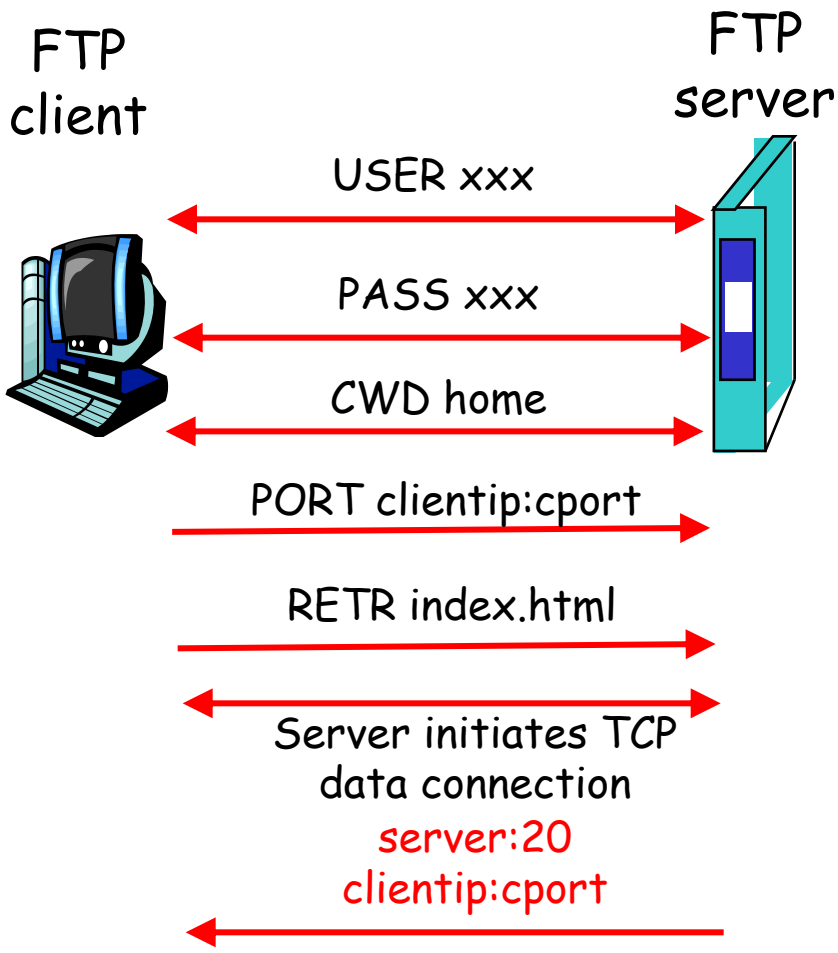
Admin

- HTTP server assignment (part 1) to be posted later today

- Plagiarism is NOT allowed in any assignment
  - Discussion and reading are encouraged, but copying is NOT!
  - If you reuse others' (e.g., classmates, friends, Stackoverflow, CSDN) code as part of your solution, please mark it in comments.

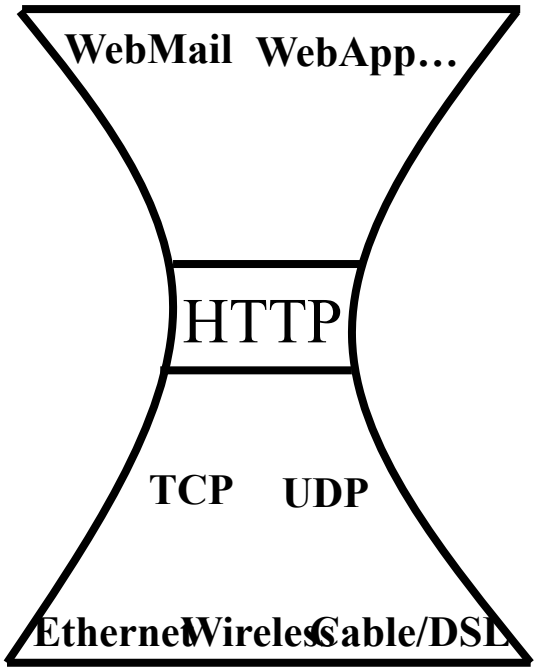
Recap: FTP

- A stateful protocol
  - state established by commands such as
    - USER/PASS, CWD, TYPE
- Multiple TCP connections
  - A control connection
  - Data connections
    - Two approaches: PORT vs PASV
    - GridFTP: concurrent data connections; block data transfer mode



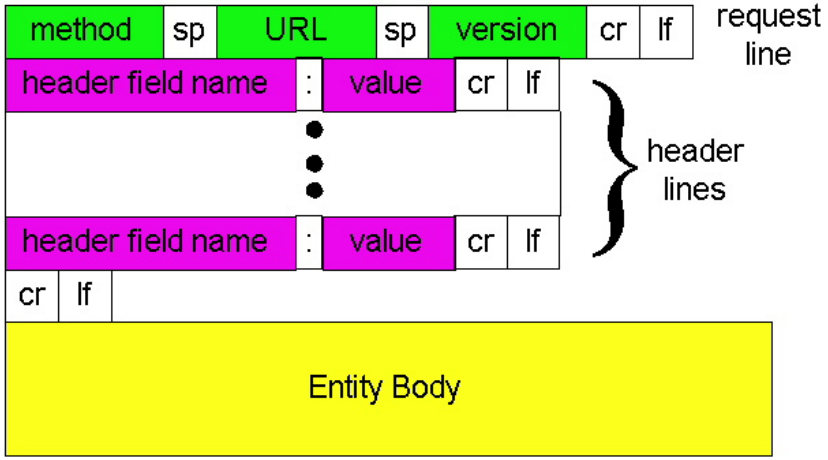
Recap: HTTP

- Wide use of HTTP for Web applications
- Example: RESTful API
  - RESTful design
    - http://www.ics.uci.edu/~fielding/pubs/dissertation/rest_arch_style.htm
    - http://docs.oracle.com/javaee/6/tutorial/doc/giepu.html

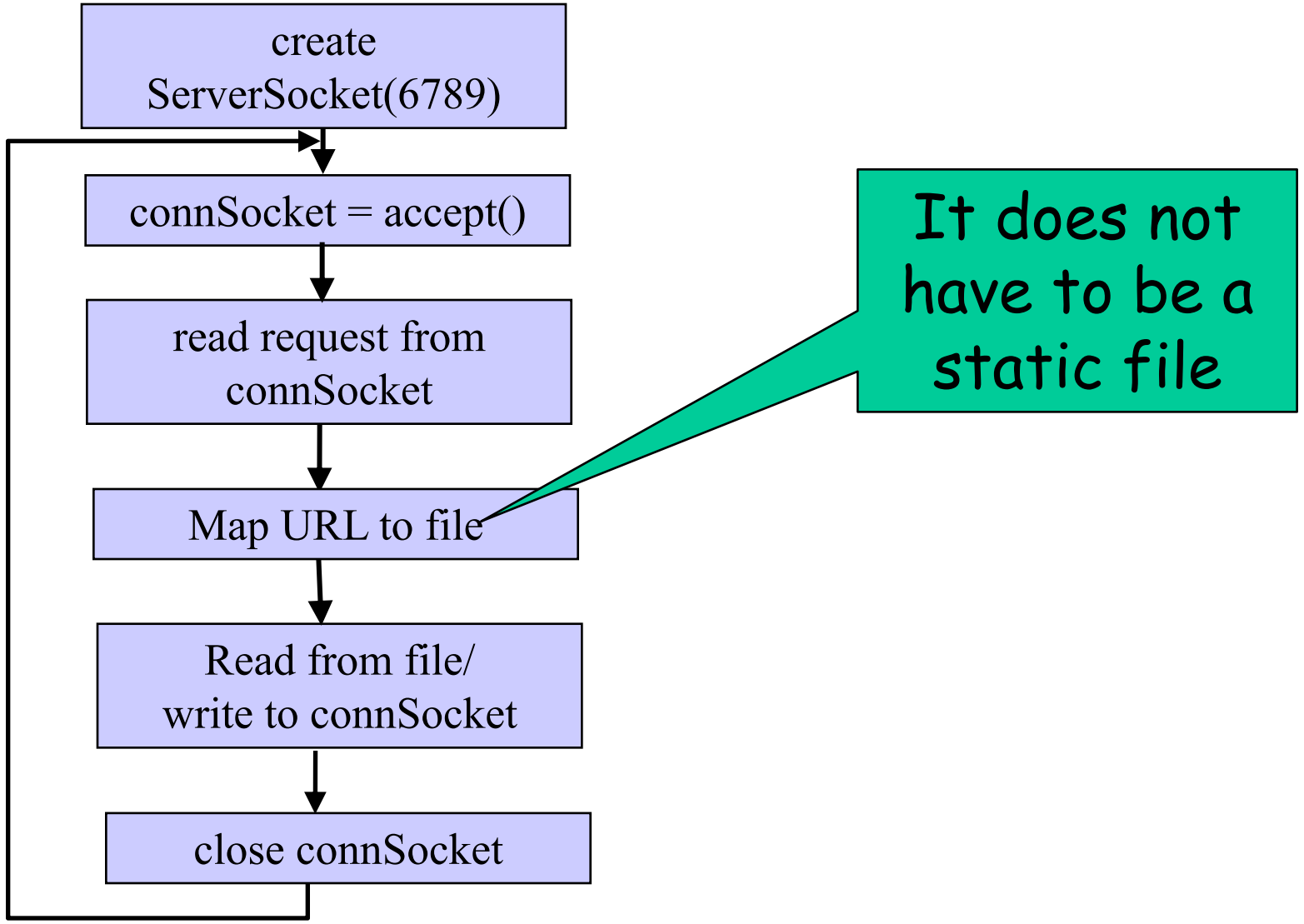


Recap: HTTP

- C-S app serving Web pages
  - message format
    - request/response line, header lines, entity body
    - simple methods, rich headers
  - message flow
    - stateless server, thus states such as cookie and authentication are needed in each message



Recap: Basic HTTP/1.0 Server



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  - Basic design
  - *Dynamic content*

Dynamic Content Pages

- There are multiple approaches to make dynamic web pages:
  - Embed code into pages (server side include)
    - http server includes an interpreter for the type of pages
  - Invoke external programs (http server is agnostic to the external program execution)
    - E.g., Common Gateway Interface (CGI)

```
http://www.cs.yale.edu/index.shtml
http://www.cs.yale.edu/cgi-bin/ureserve.pl
http://www.google.com/search?q=Yale&sourceid=chrome
```

Example SSI

- See programming/examples-java-socket/BasicWebServer/ssi/index.shtml, header.shtml, …

Example SSI

- See programming/examples-java-socket/BasicWebServer/ssi/index.shtml, header.shtml, …

- To enable ssi, need configuration to tell the web server (see conf/apache-htaccess)
  - https://httpd.apache.org/docs/2.2/howto/htaccess.html (Server Side Includes example)

CGI: Invoking External Programs

- Two issues
  - Input: Pass HTTP request parameters to the external program
  - Output: Redirect external program output to socket

Example: Typical CGI Implementation

- Starts the executable as a child process
  - Passes HTTP request as environment variables
    - `http://httpd.apache.org/docs/2.2/env.html`
    - CGI standard: http://www.ietf.org/rfc/rfc3875
  - Redirects input/output of the child process to the socket

Example: CGI

- Example:
  - `GET /search?q=Yale&sourceid=chrome HTTP/1.0`
  - setup environment variables, in particular $QUERY_STRING=`q=Yale&sourceid=chrome`
  - start `search` and redirect its input/output

https://docs.oracle.com/javase/7/docs/api/java/lang/ProcessBuilder.html

https://httpd.apache.org/docs/2.2/howto/htaccess.html
(CGI Example)

Example

- http://172.28.229.215/BasicWebServer/cgi/price.cgi?appl

```
#!/usr/bin/perl -w

$company = $ENV{'QUERY_STRING'};
print "Content-Type: text/html\r\n";
print "\r\n";

print "<html>";
print "<h1>Hello! The price is ";

if ($company =~ /appl/) {
  my $var_rand = rand();
  print 450 + 10 * $var_rand;
} else {
  print "150";
}

print "</h1>";
print "</html>";
```

Client Using Dynamic Pages

- See ajax.html and wireshark for client code example

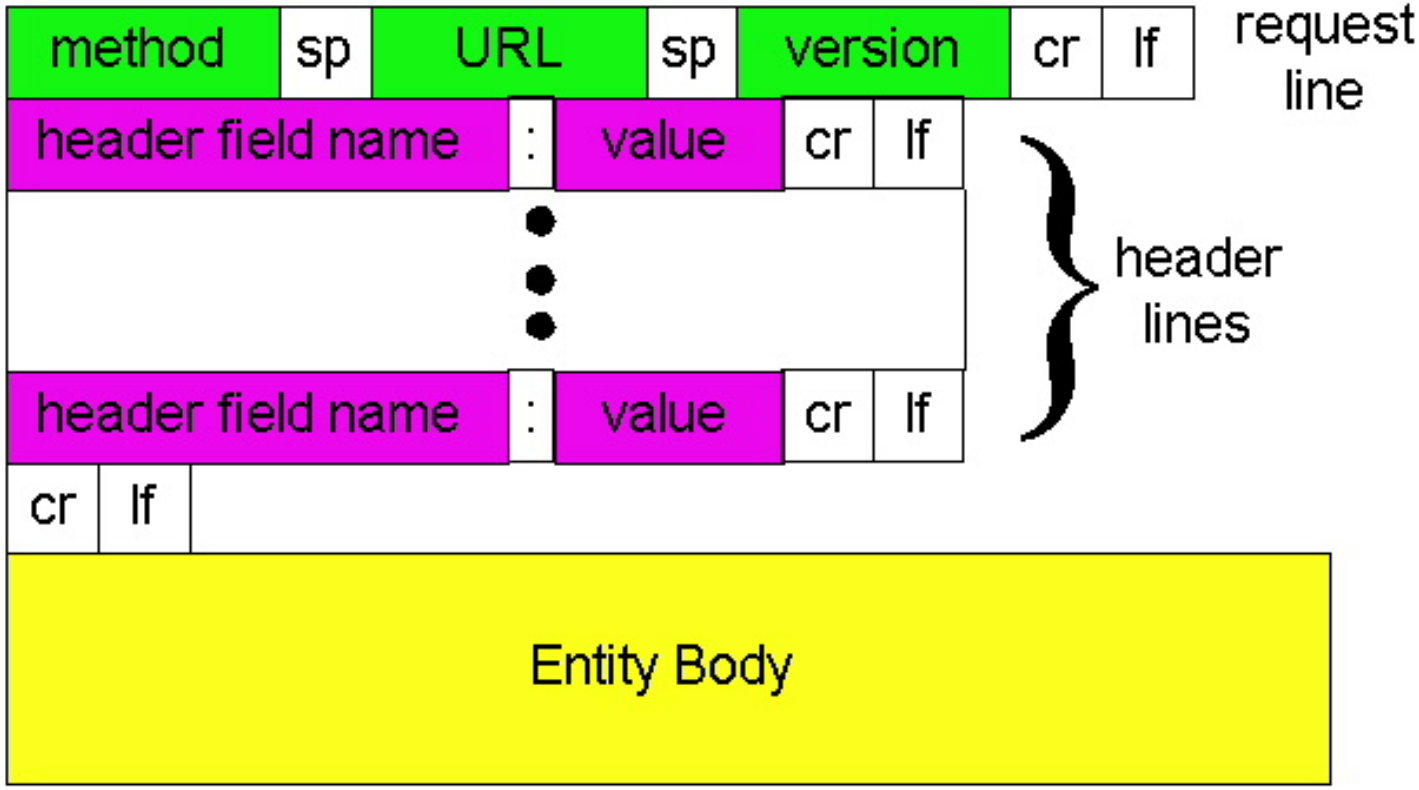
  http://172.28.229.215/BasicWebServer/cgi/ajax.html

Discussions

- What features are missing in HTTP that we have covered so far?

HTTP: POST

- If an HTML page contains forms or parameter too large, they are sent using POST and encoded in message body



HTTP: POST Example

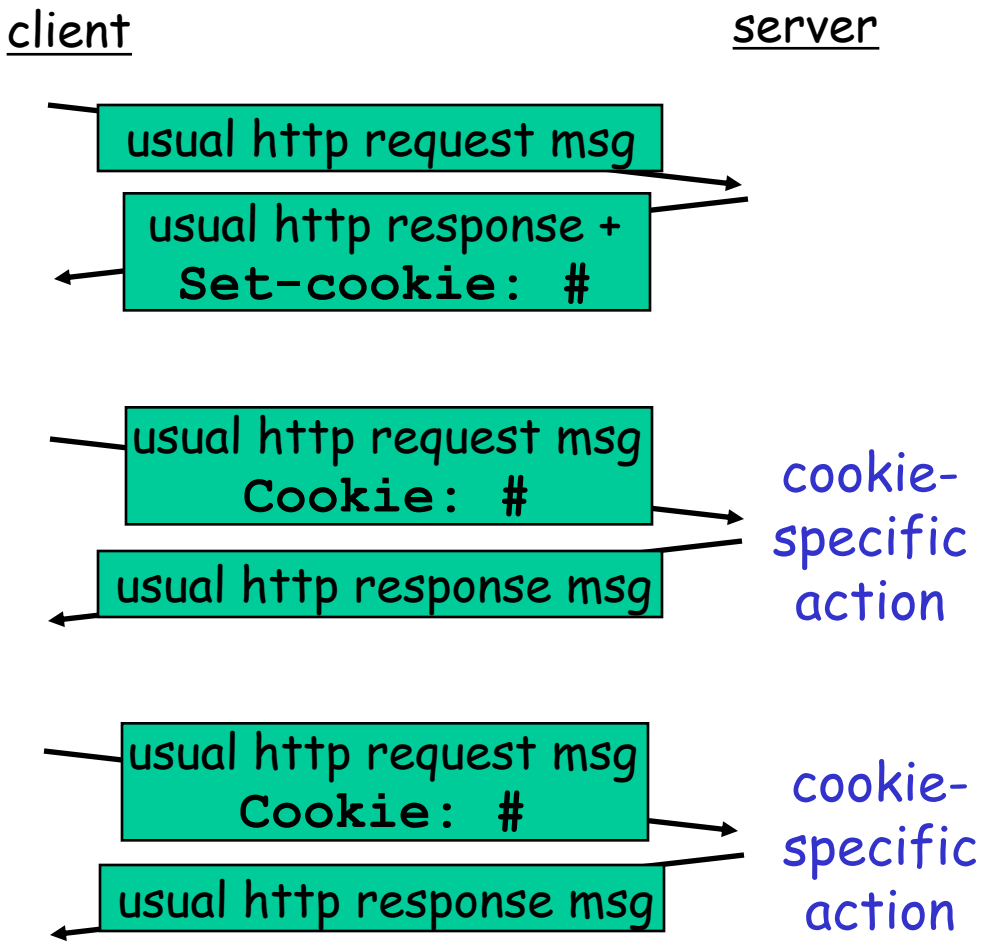
```
POST /path/script.cgi HTTP/1.0
User-Agent: MyAgent
Content-Type: application/x-www-form-urlencoded
Content-Length: 15

item1=A&item2=B
```

Example using nc:
programming/examples-java-socket/BasicWebServer/nc/

Stateful User-server Interaction: Cookies

Goal: no explicit application level session

- Server sends "cookie" to client in response msg
  - `Set-cookie: 1678453`
- Client presents cookie in later requests
  - `Cookie: 1678453`
- Server matches presented-cookie with server-stored info
  - authentication
  - remembering user preferences, previous choices



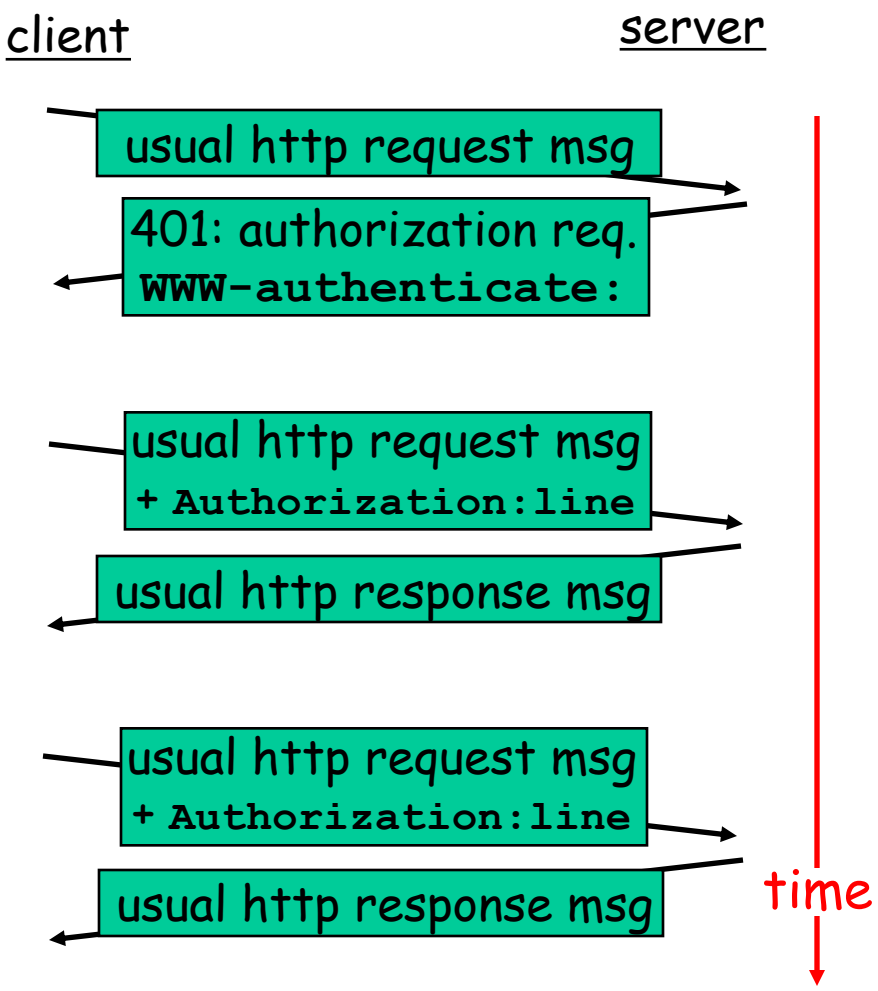
Authentication of Client Request

Authentication goal: control access to server documents

- stateless: client must present authorization in each request
- authorization: typically name, password
  - `Authorization:` header line in request
  - if no authorization presented, server refuses access, sends

    `WWW-authenticate:`

    header line in response

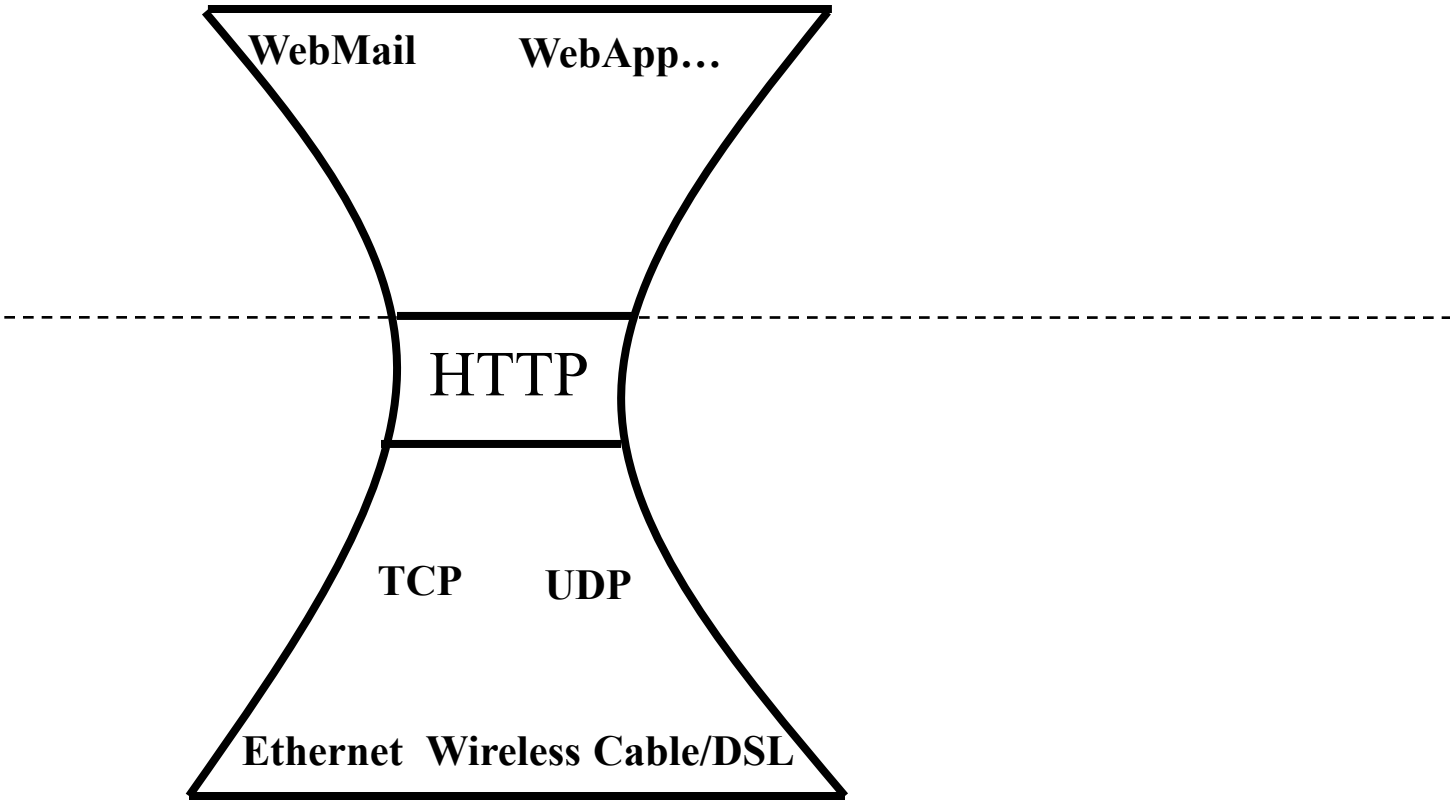


Browser caches name & password so that user does not have to repeatedly enter it.

Example: Amazon S3

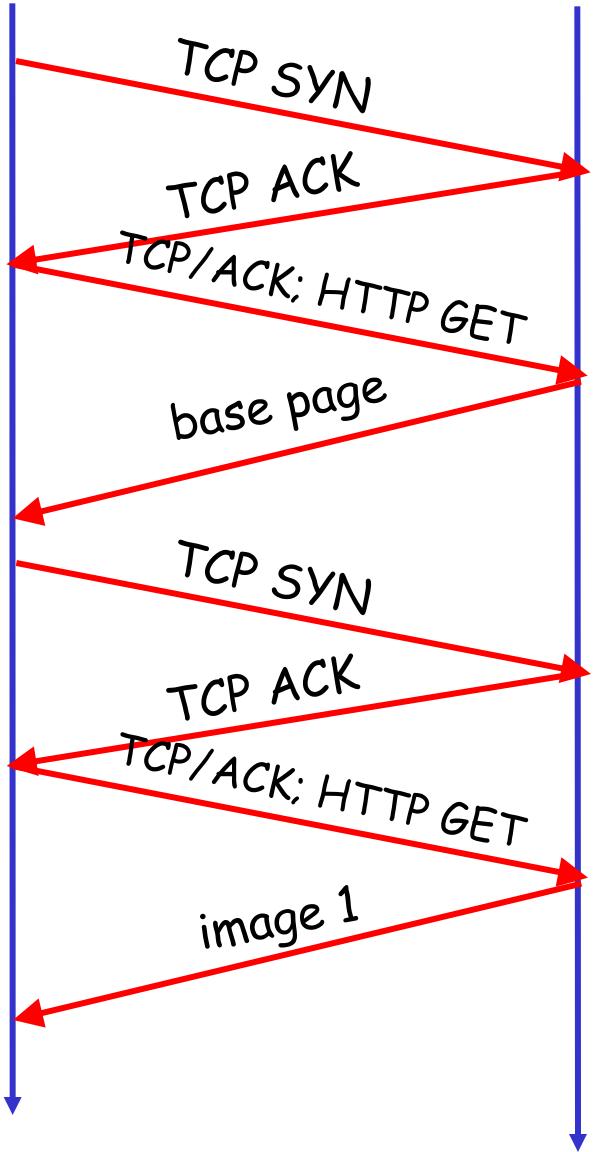
- Amazon S3 API
  - http://docs.aws.amazon.com/AmazonS3/latest/API/APIRest.html

HTTP as the Thin Waist



Protocol Flow of Basic HTTP/1.0

- >= 2 RTTs per object:
  - TCP handshake --- 1 RTT
  - client request and server responds --- at least 1 RTT (if object can be contained in one packet)



Outline

- Admin and recap
- HTTP/1.0
- *HTTP "acceleration"*

Substantial Efforts to Speedup Basic HTTP/1.0

- Reduce the number of objects fetched [Browser cache]

- Reduce data volume [Compression of data]
- Header compression [HTTP/2]

- Reduce the latency to the server to fetch the content [Proxy cache]
- Remove the extra RTTs to fetch an object [Persistent HTTP, aka HTTP/1.1]

- Increase concurrency [Multiple TCP connections]
- Asynchronous fetch (multiple streams) using a single TCP [HTTP/2]

- Server push [HTTP/2]

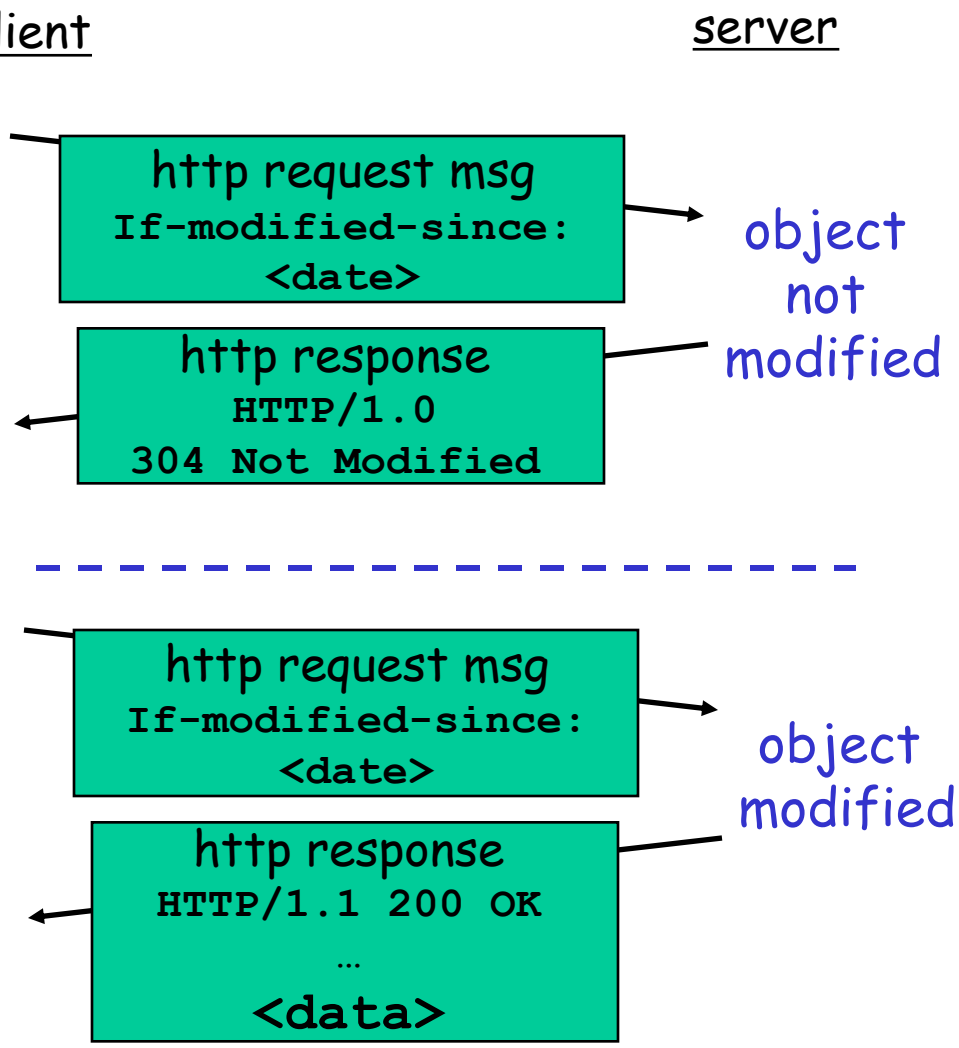
Browser Cache and Conditional GET

- Goal: don't send object if client has up-to-date stored (cached) version
- client: specify date of cached copy in http request

```
If-modified-since:
   <date>
```

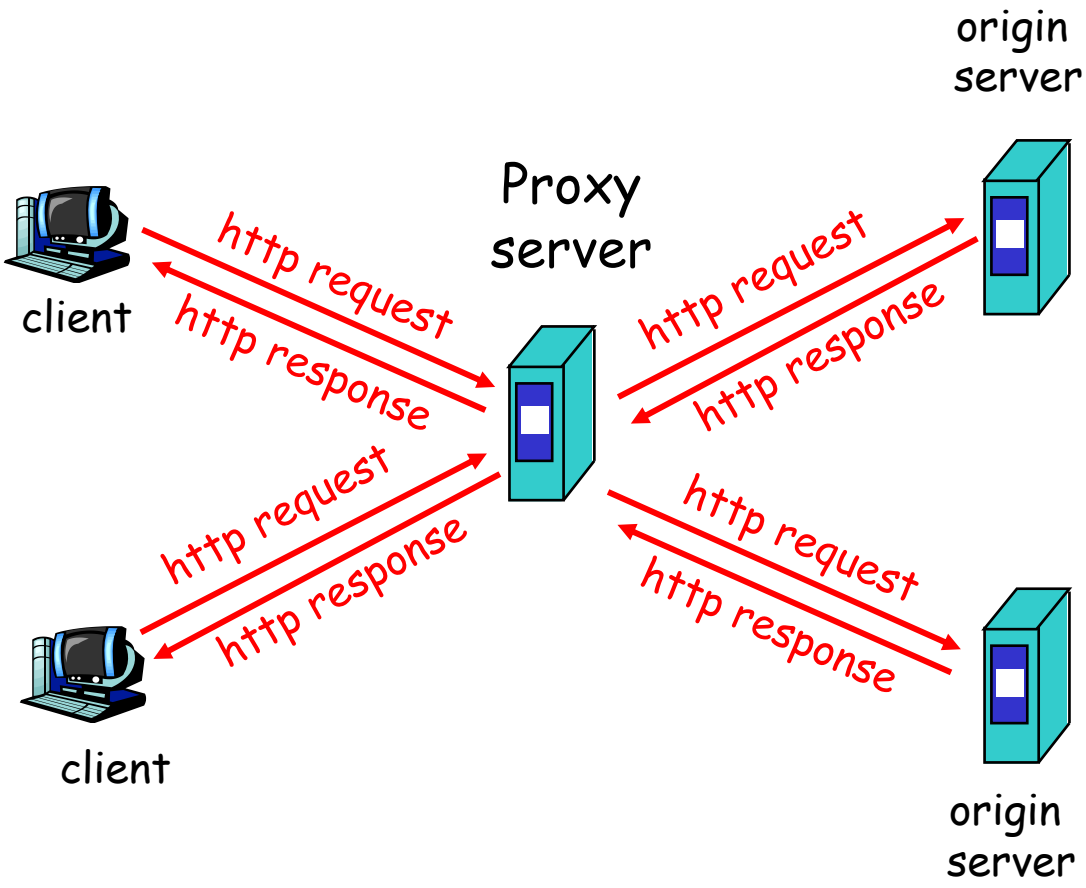
- server: response contains no object if cached copy up-to-date:

```
HTTP/1.0 304 Not
   Modified
```



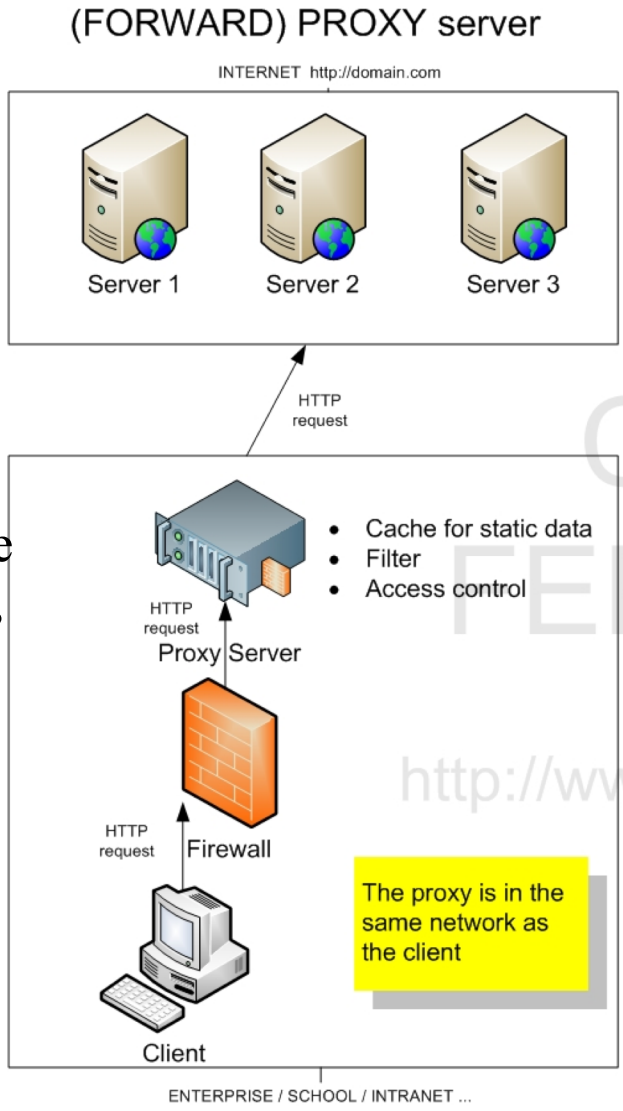
Web Caches (Proxy)

Goal: satisfy client request without involving origin server

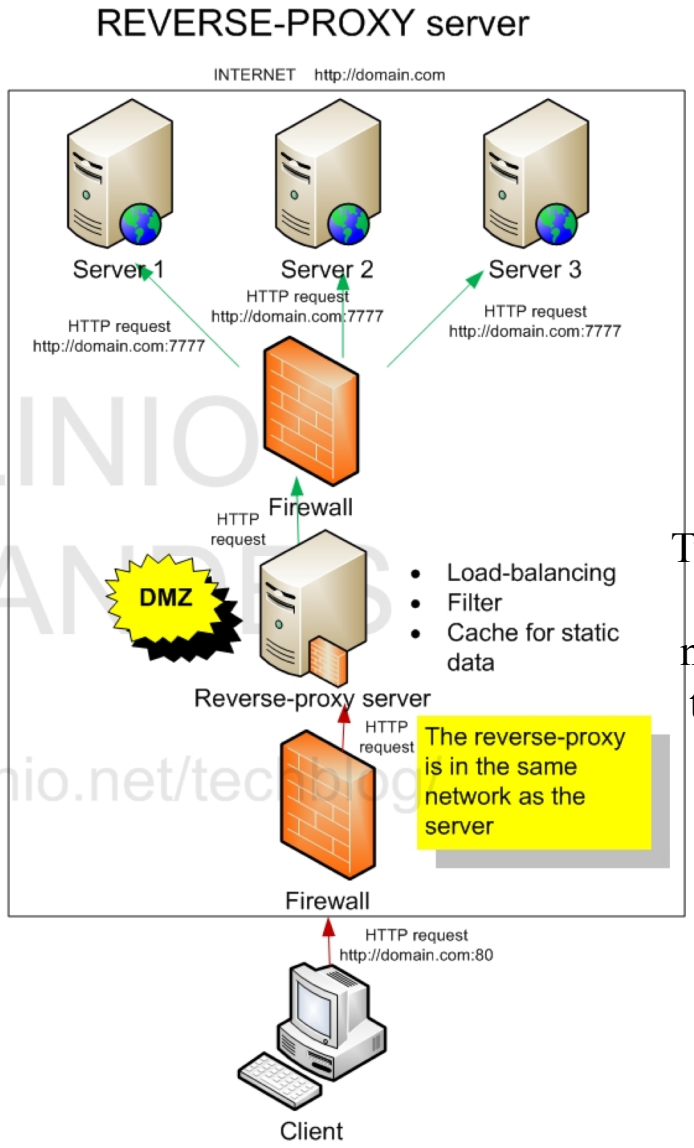


http://www.celinio.net/techblog/?p=1027

Two Types of Proxies



Typically in the same network as the client

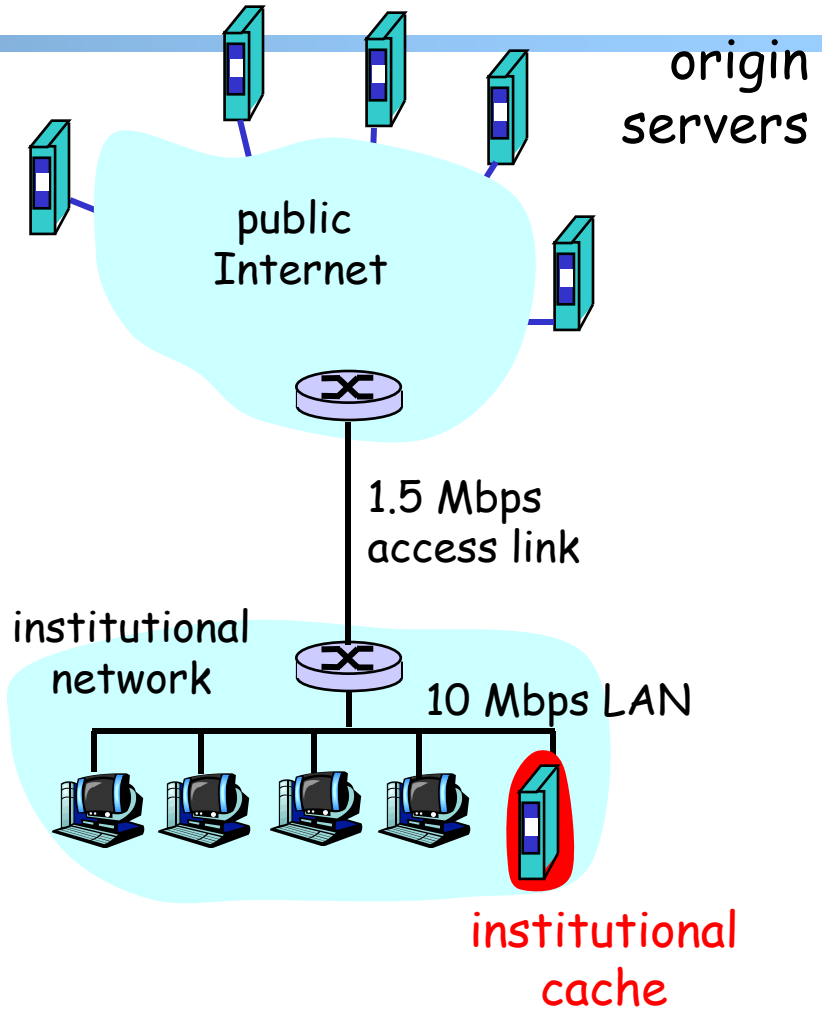


Typically in the same network as the server

Benefits of Forward Proxy

Assume: cache is "close" to client (e.g., in same network)

- smaller response time: cache "closer" to client
- decrease traffic to distant servers
  - link out of institutional/local ISP network often is bottleneck



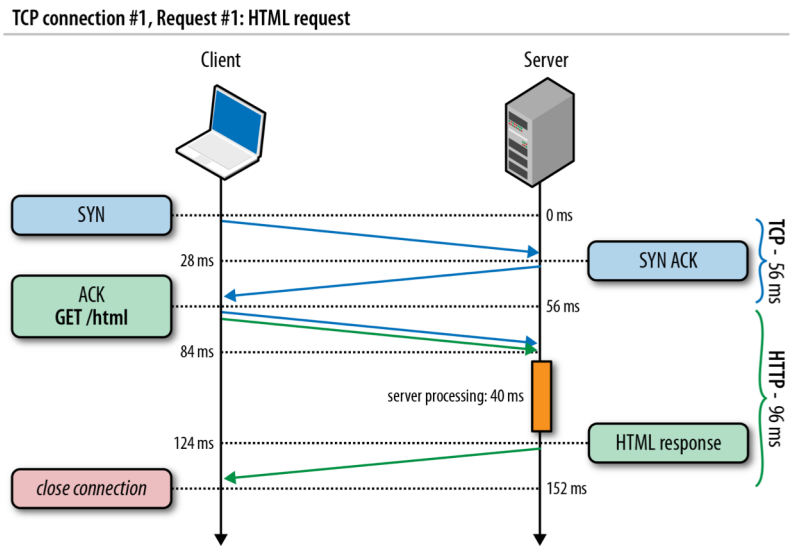
No Free Lunch: Problems of Web Caching

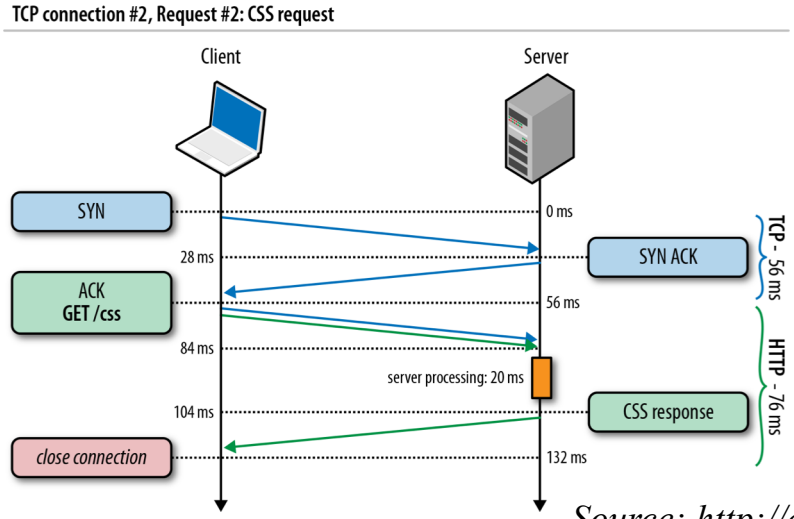
- The major issue of web caching is how to maintain consistency
- Two ways
  - pull
    - Web caches periodically pull the web server to see if a document is modified
  - push
    - whenever a server gives a copy of a web page to a web cache, they sign a lease with an expiration time; if the web page is modified before the lease, the server notifies the cache

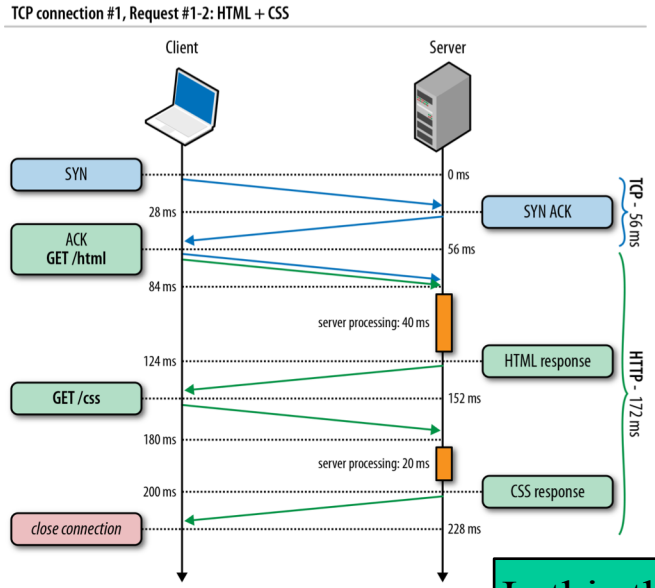
HTTP/1.1: Persistent (keepalive/pipelining) HTTP

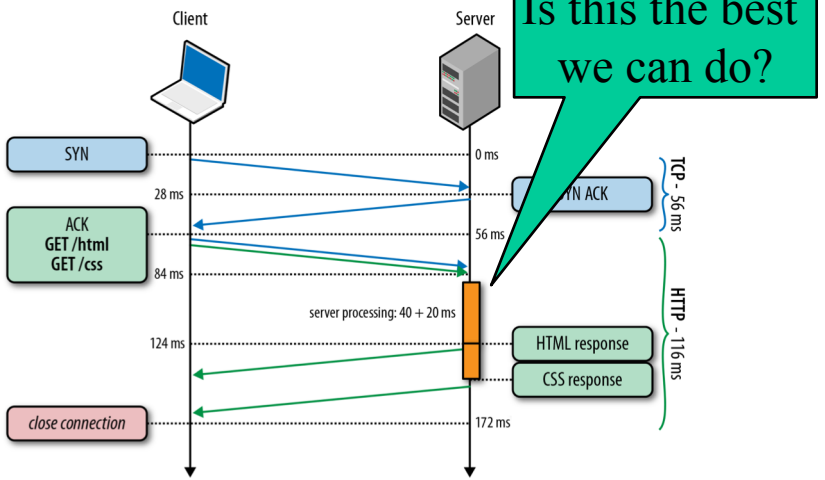
- HTTP/1.0 allows a single request outstanding, while HTTP/1.1 allows request pipelining
  - On same TCP connection: server parses request, responds, parses new request, …
  - Client sends requests for all referenced objects as soon as it receives base HTML
- Benefit
  - Fewer RTTs
  - See Joshua Graessley WWDC 2012 talk: 3x within iTunes

HTTP/1.0, Keep-Alive, Pipelining



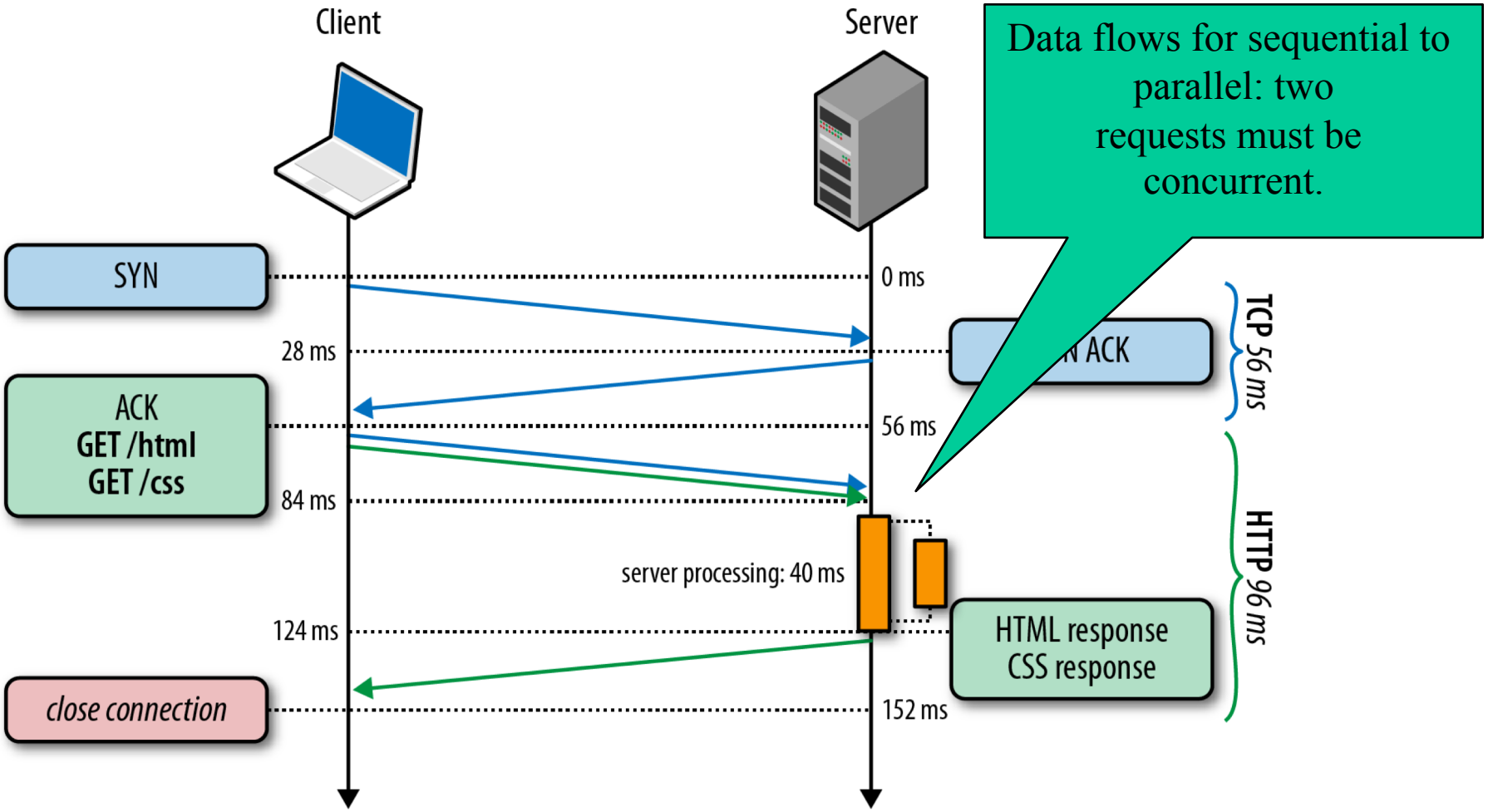






Source: http://chimera.labs.oreilly.com/books/1230000000545/ch11.html

HTTP/2 Basic Idea: Remove Head-of-Line Blocking in HTTP/1.1



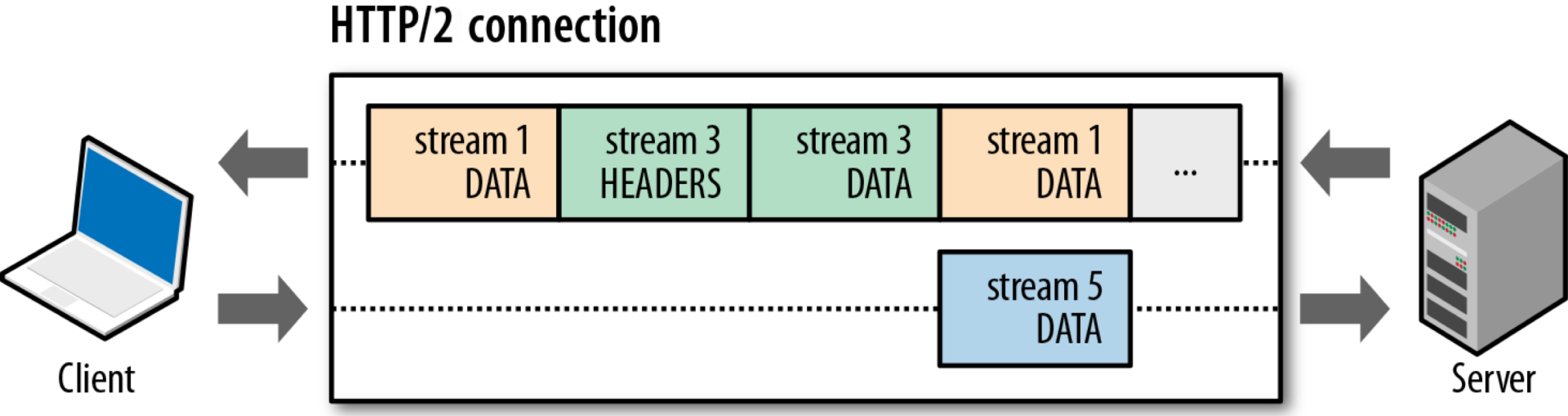
Demo: https://http2.akamai.com/demo

Source: http://chimera.labs.oreilly.com/books/1230000000545/ch11.html

Observing HTTP/2

- export SSLKEYLOGFILE=/tmp/keylog.txt
- Start Chrome, e.g.,
  - Mac: /Applications/Google Chrome.app/Contents/MacOS/Google Chrome
  - Ubuntu: firefox
- Visit HTTP/2 pages, such as https://http2.akamai.com
- Wireshark:
  - Mac: Wireshark -> preferences -> protocol -> TSL
    (pre)-master-secret log file name
  - Ubuntu: edit -> perferences -> protocol -> SSL
    (pre)-master-secret log file name

HTTP/2 Design: Multi-Streams

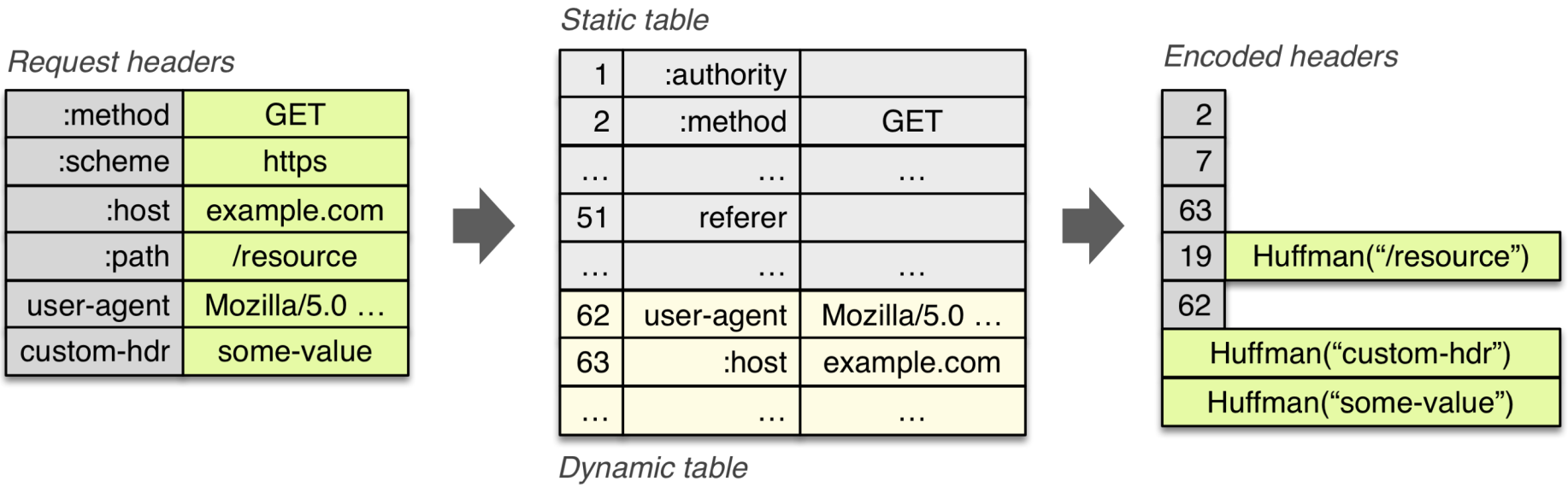


Bit	+0..7	+8..15	+16..23	+24..31
0	Length			Type
32	Flags			
40	R	Stream Identifier		
...	*Frame Payload*			

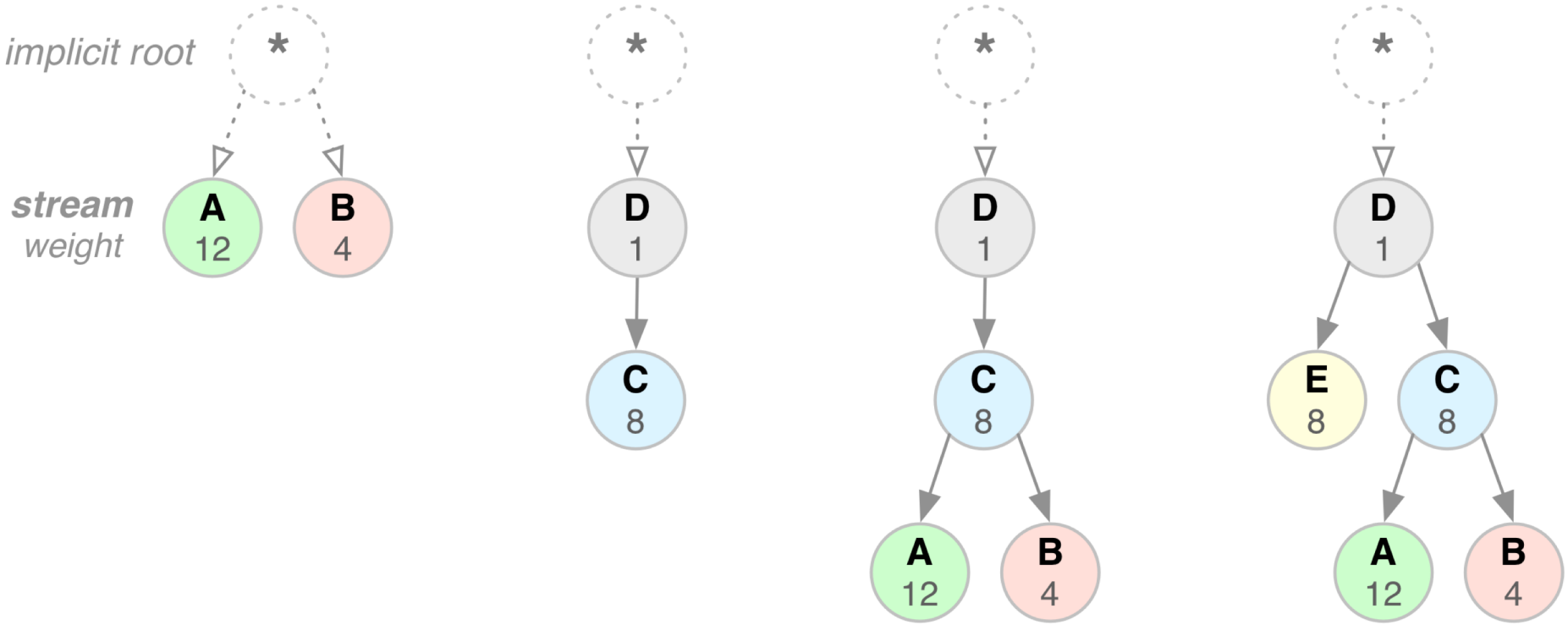
HTTP/2 Binary Framing

https://hpbn.co/http2/ https://tools.ietf.org/html/rfc7540

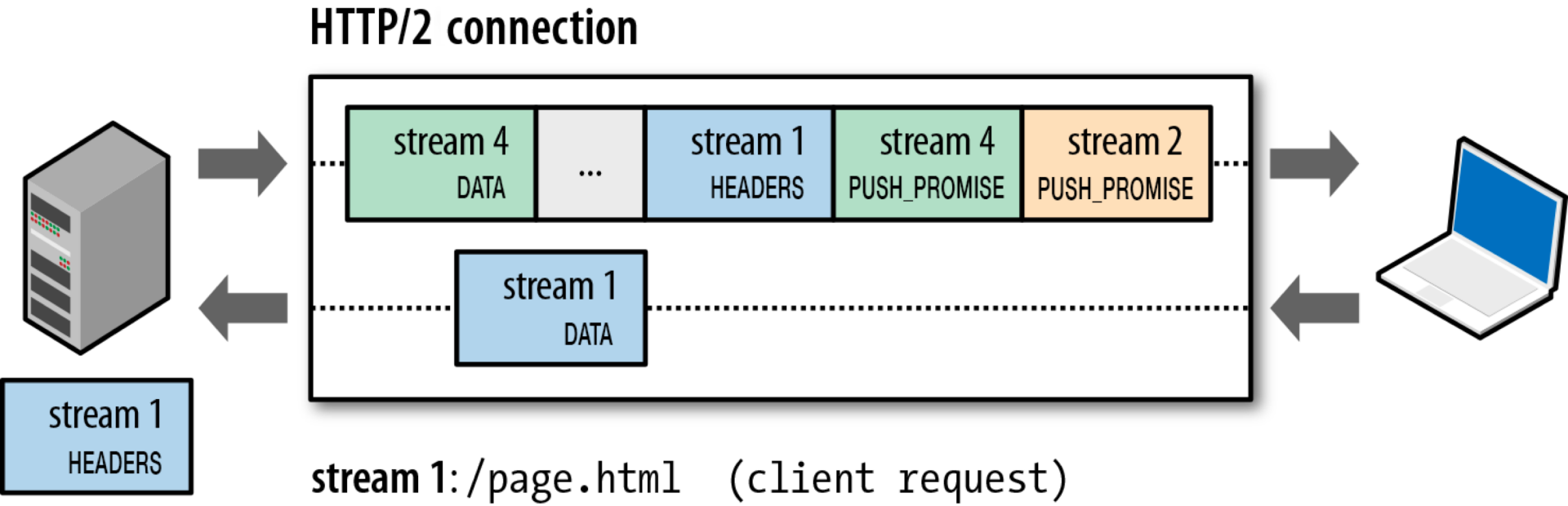
HTTP/2 Header Compression



HTTP/2 Stream Dependency and Weights



HTTP/2 Server Push



stream 1: /page.html (client request)
stream 2: /script.js (push promise)
stream 4: /style.css (push promise)

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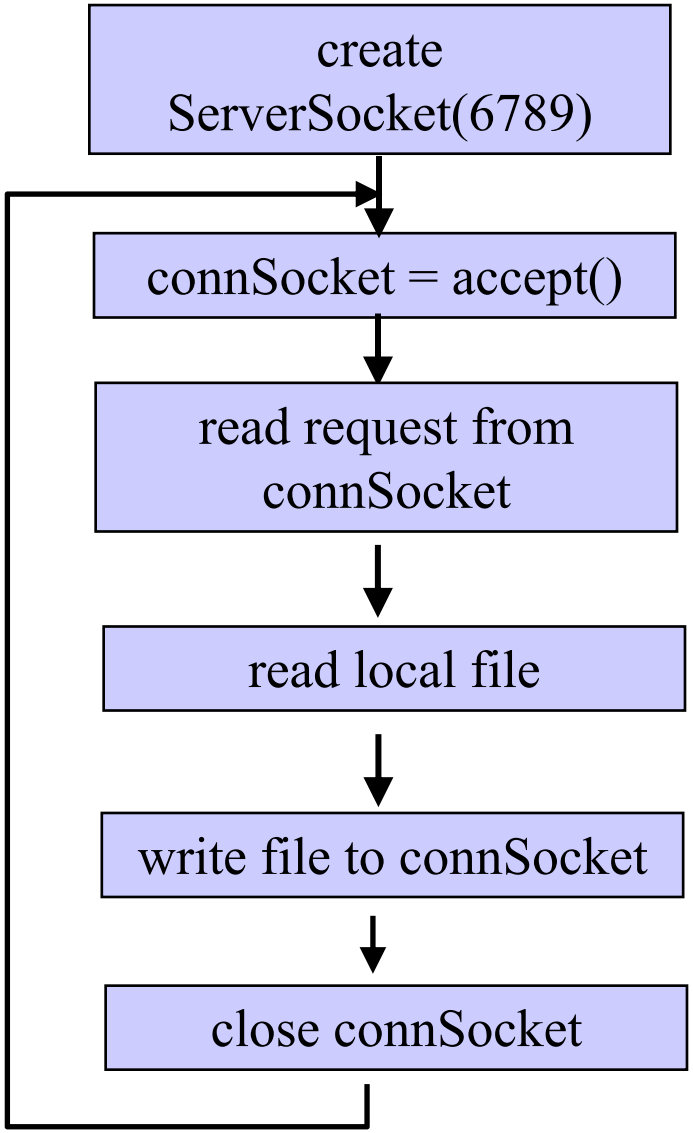
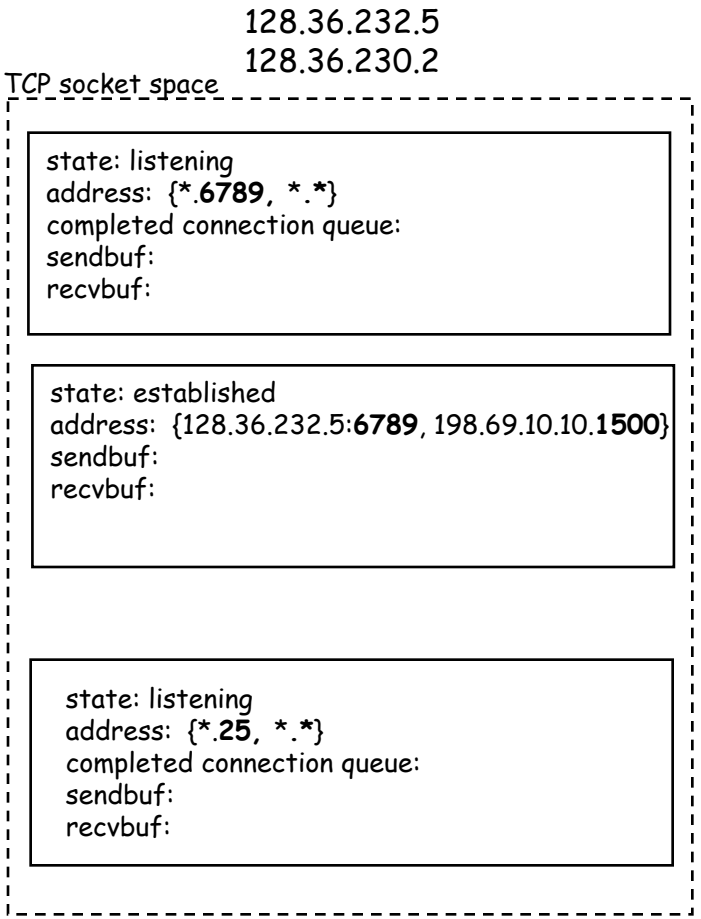
WebServer Implementation





Discussion: what does each step do and how long does it take?

Demo

- Try TCPServer
- Start two TCPClient
  - Client 1 starts early but stops
  - Client 2 starts later but inputs first