

CSE 123b

Communications Software

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Lecture 11: HTTP

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Some slides courtesy Srinu Seshan

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 → End-of-Message
 - » Yes, but server must “byte-stuff” binary data
 - ◆ 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
 - » E.g. `http://www.cs.ucsd.edu/index.html`
 - » `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

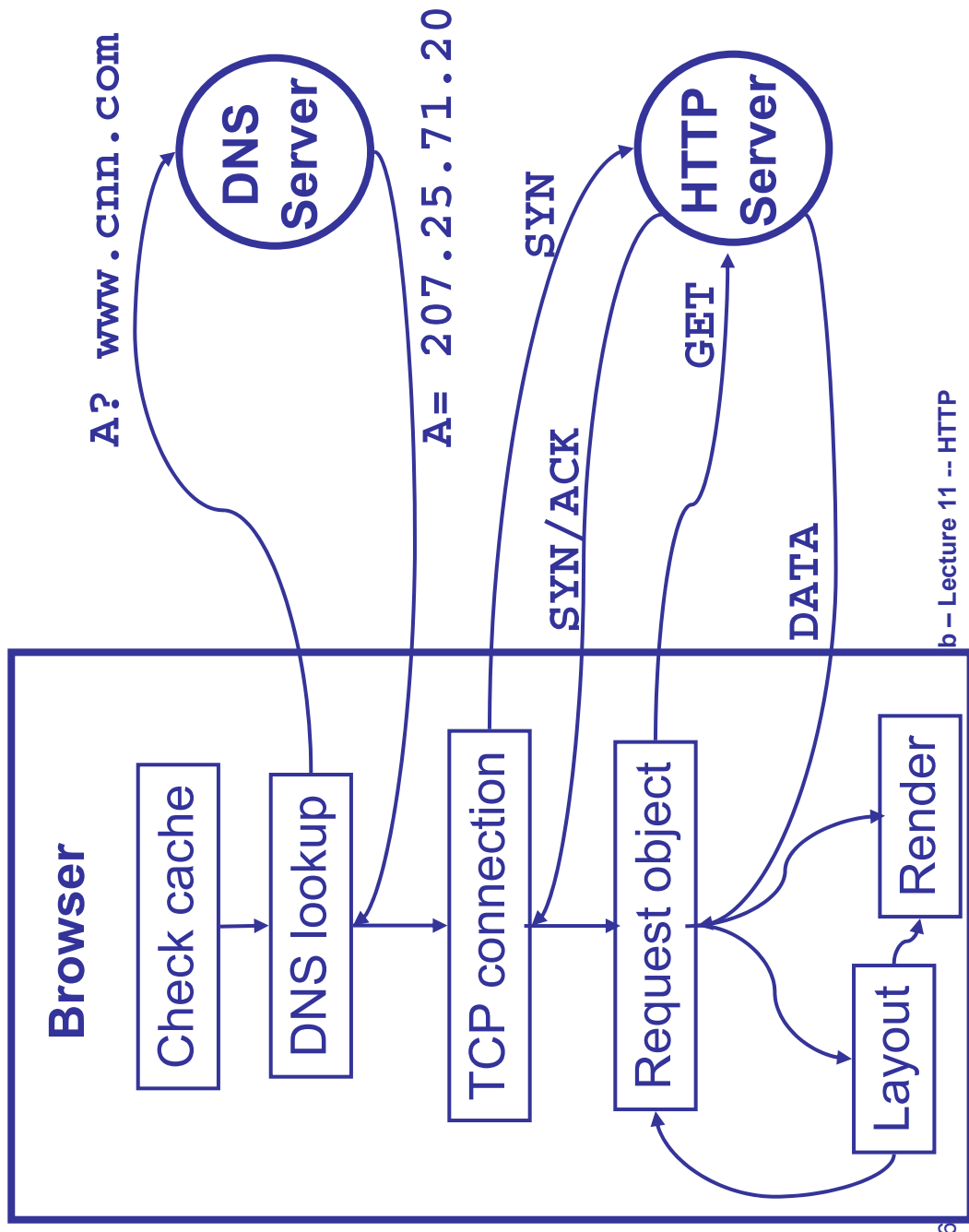
HTTP Response Example

```
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
```

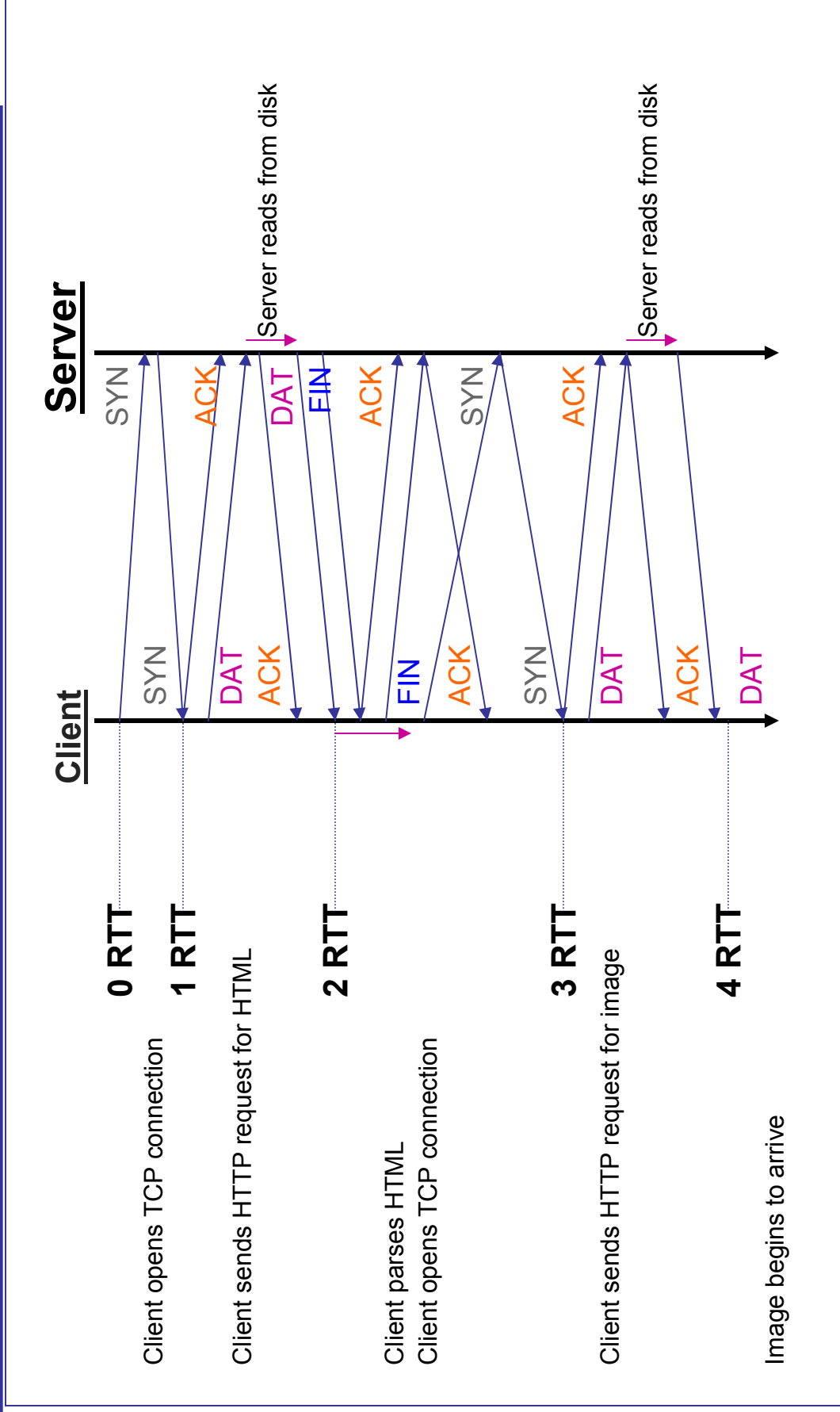
How HTTP is used

- Browser requests main page
- Browser parses main page for inline images and content (e.g. `<imgsrc=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...



Single Transfer Example



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 Approach

- 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 (instead of using fast-retransmit/recovery) because windows are small

HTTP 0.9/1.0

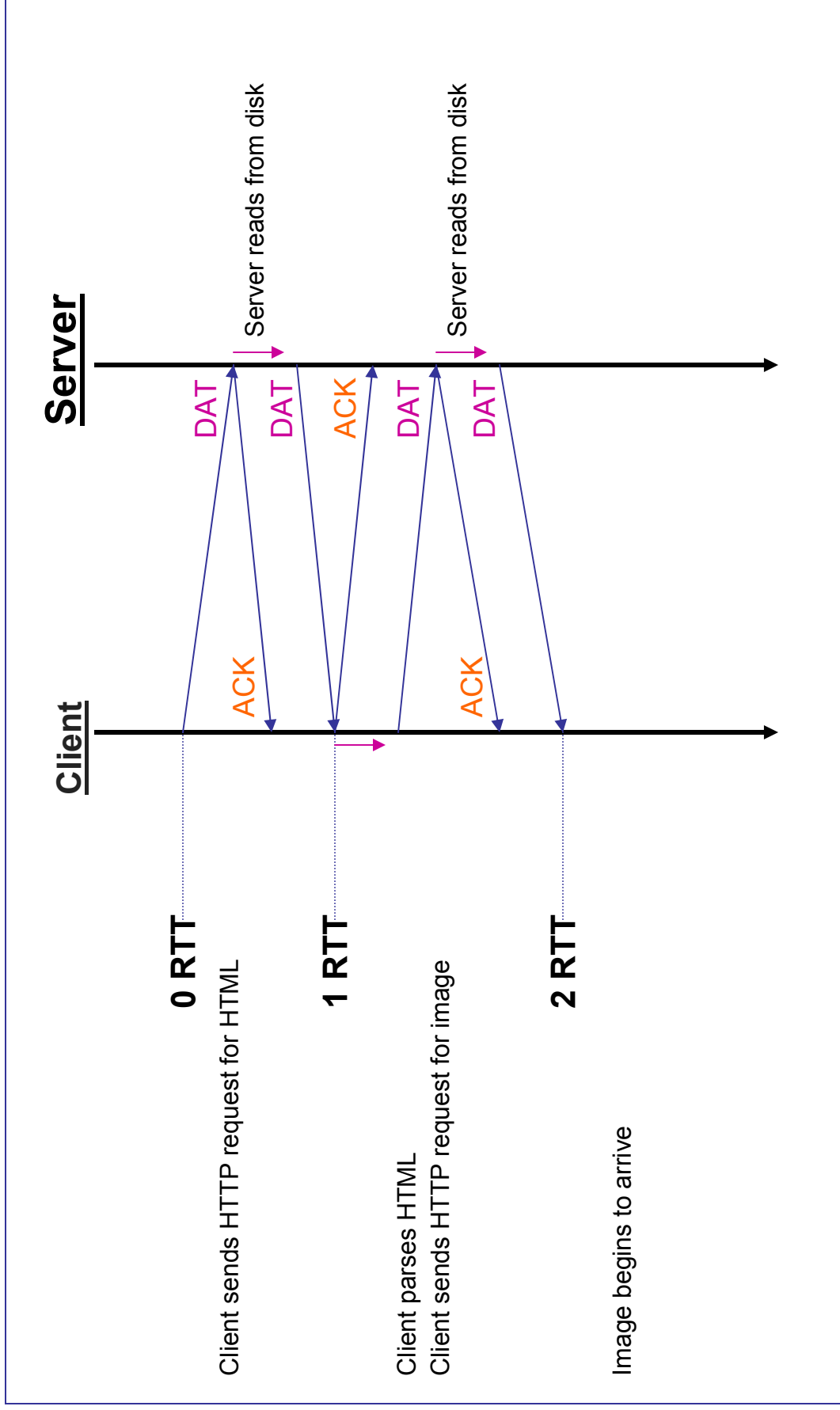
- One request/response per TCP connection
 - ♦ Simple to implement
- Disadvantages
 - ♦ Multiple connection setups → three-way handshake each time
 - » Several extra round trips added to transfer
 - ♦ Multiple slow starts

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



Persistent connection

Solution

- However, 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

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?

Remaining Problems

- Application specific solution
- 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

Best case TCP transfer time

TCP Slow start time

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

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

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

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

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

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...

- We'll cover content distribution networks
- No reading