EN.601.414/614 Computer Networks

HTTP and the Web

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Spring 2019 (MW 3:00-4:15pm in Shaffer 301)

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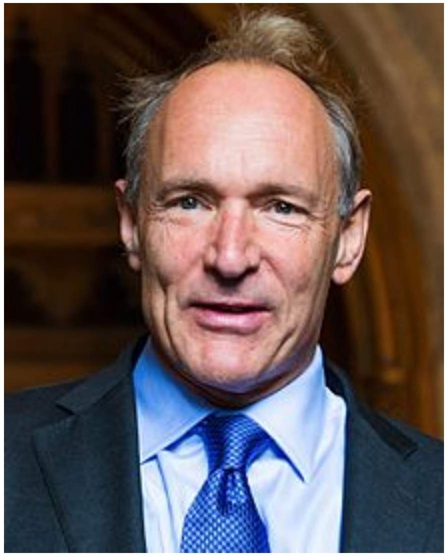
https://github.com/xinjin/course-net

Agenda

- **HTTP and the Web**
- **Improving HTTP Performance**

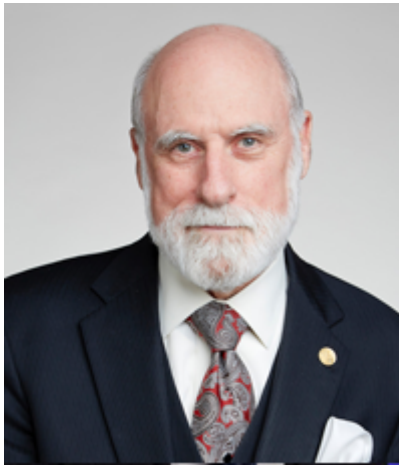
The Web: History

- **World Wide Web (WWW): a distributed database of "pages" linked through Hypertext Transport Protocol (HTTP)**
  - ➢First HTTP implementation – 1990
    - Tim Berners-Lee at CERN
    - Turing award at 2016: for inventing the World Wide Web, the first web browser, and the fundamental protocols and algorithms allowing the Web to scale



WWW != Internet

- **Vint Cerf, Robert Kahn**
- **Turing award at 2004:** for pioneering work on internetworking, including the design and implementation of the Internet's basic communications protocols, TCP/IP, and for inspired leadership in networking.



The Web: History (cont’d)

- **World Wide Web (WWW): a distributed database of “pages” linked through Hypertext Transport Protocol (HTTP)**
  - HTTP/0.9 – 1991
    - Simple GET command for the Web
  - HTTP/1.0 – 1992
    - Client/server information, simple caching
  - HTTP/1.1 – 1996
    - Performance and security optimizations
  - HTTP/2 – 2015
    - Latency optimizations via request multiplexing over single TCP connection
    - Binary protocol instead of text

Web components

- **Infrastructure:**
  - Clients
  - Servers (DNS, CDN, Datacenters)

- **Content:**
  - URL: naming content
  - HTML: formatting content

- **Protocol for exchanging information: HTTP**

URL: Uniform Record Locator

- `protocol://host-name[:port]/directory-path/resource`

- **Extend the idea of hierarchical hostnames to include anything in a file system**
  - https://github.com/xinjin/course-net/blob/master/slides/lec01_introduction.pptx
- **Extend to program executions as well…**
  - http://us.f413.mail.yahoo.com/ym/ShowLetter?box=%40B%40Bulk&MsgId=2604_1744106_29699_1123_1261_0_28917_3552_1289957100&Search=&Nhead=f&YY=31454&order=down&sort=date&pos=0&view=a&head=b
  - Server side processing can be included in the name

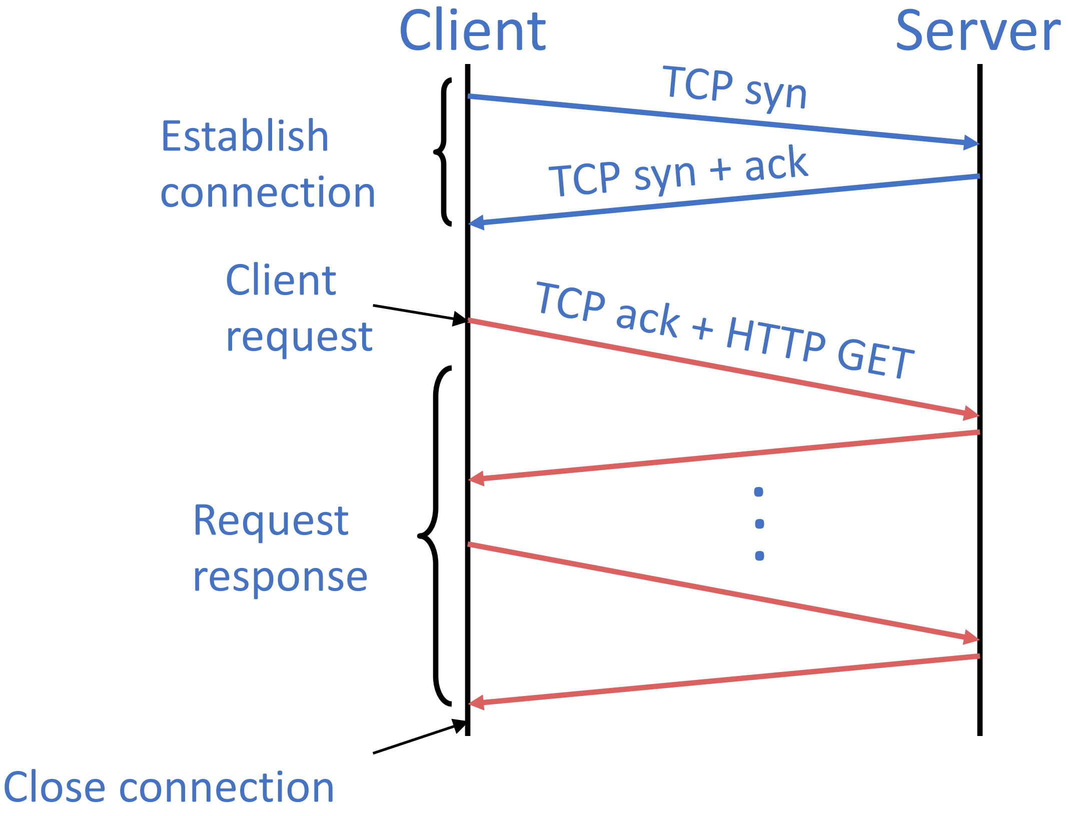
URL: Uniform Record Locator

- **`protocol://host-name[:port]/directory-path/resource`**
  - `protocol`: http, ftp, https, smtp, rtsp, *etc*.
  - `hostname`: DNS name, IP address
  - `port`*:* defaults to protocol's standard port
    - *e.g.,* http: 80, https: 443
  - `directory path`: hierarchical, reflecting file system
  - `resource`: Identifies the desired resource

Hyper Text Transfer Protocol (HTTP)

- **Client-server architecture**
  - Server is “always on” and “well known”
  - Clients initiate contact to server
- **Synchronous request/reply protocol**
  - Runs over TCP, Port 80
- **Stateless**
- **ASCII format**
  - Before HTTP/2

Steps in HTTP request/response

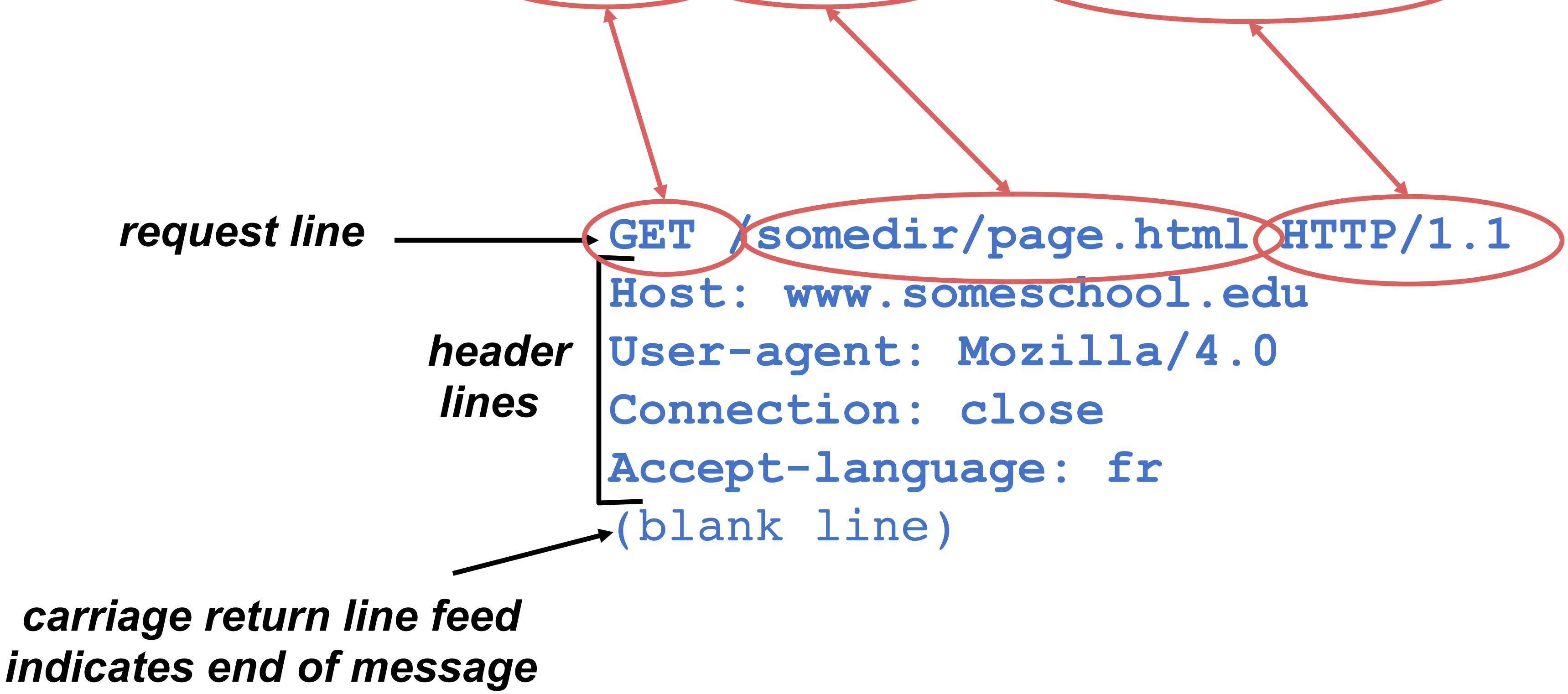


Method types (HTTP 1.1)

- **GET, HEAD**
- **POST**
  - ➢Send information (e.g., web forms)
- **PUT**
  - ➢Upload file in entity body to path specified in URL field
- **DELETE**
  - ➢Delete file specified in the URL field

Client-to-server communication

- **HTTP Request Message**
  - Request line: method, resource, and protocol version



request line

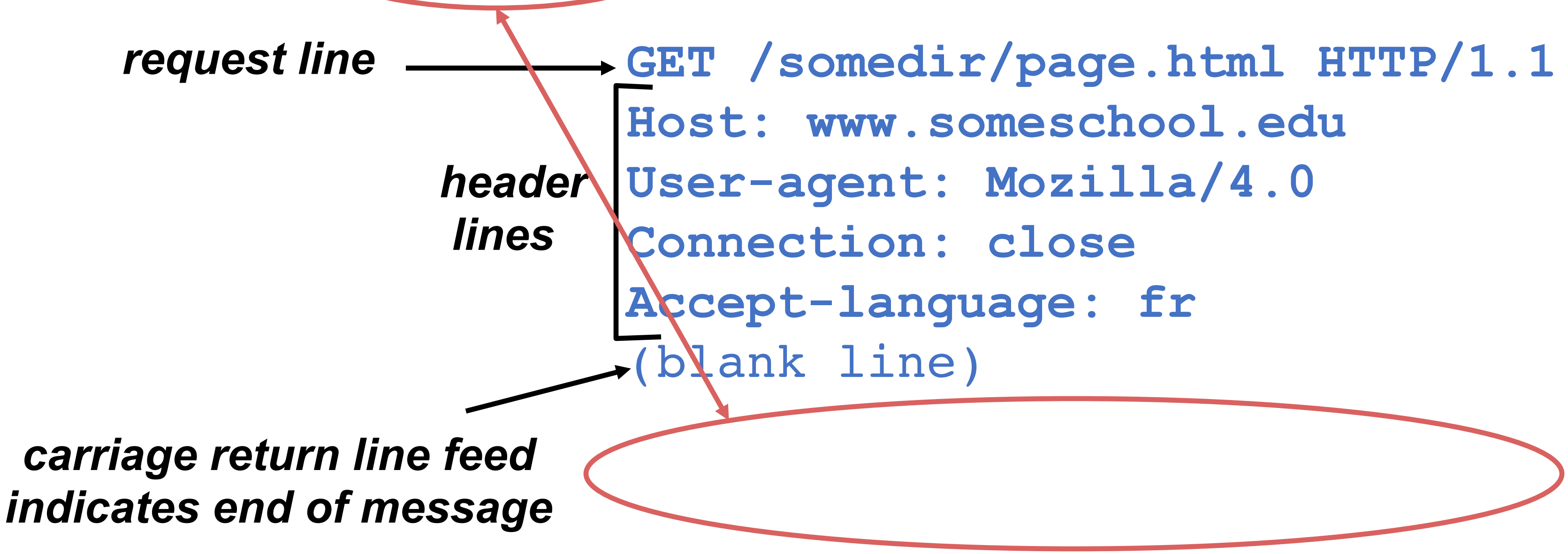
header lines

```
GET /somedir/page.html HTTP/1.1
Host: www.someschool.edu
User-agent: Mozilla/4.0
Connection: close
Accept-language: fr
(blank line)
```

carriage return line feed indicates end of message

Client-to-server communication

- **HTTP Request Message**
  - Request line: method, resource, and protocol version
  - Request headers: provide info or modify request
  - Body: optional data (e.g., to "POST" data to server)



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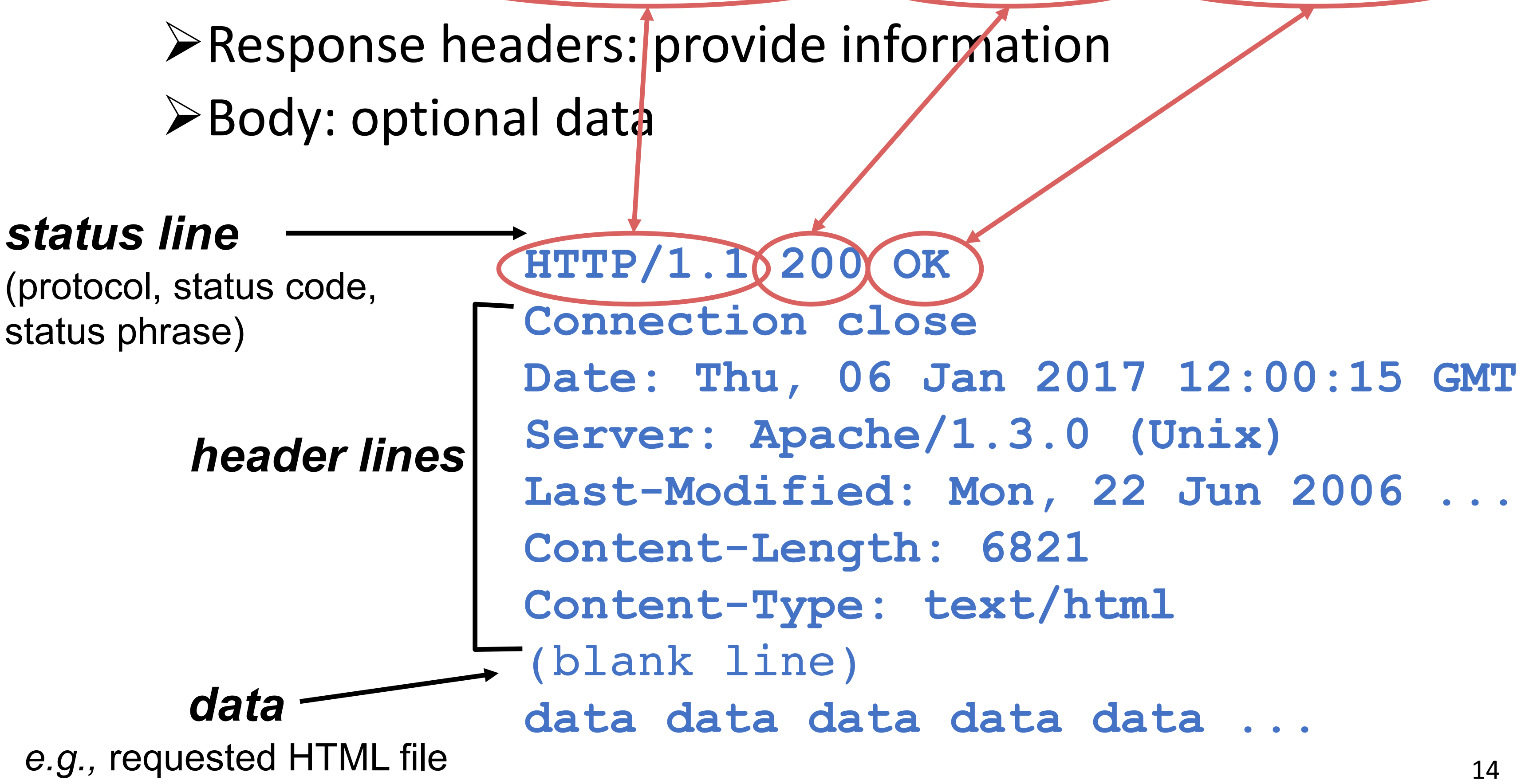
(blank line)
```

Server-to-client communication

- **HTTP Response Message**
  - Status line: protocol version, status code, status phrase
  - Response headers: provide information
  - Body: optional data



status line
(protocol, status code, status phrase)

header lines

data
e.g., requested HTML file

```
HTTP/1.1 200 OK
Connection close
Date: Thu, 06 Jan 2017 12:00:15 GMT
Server: Apache/1.3.0 (Unix)
Last-Modified: Mon, 22 Jun 2006 ...
Content-Length: 6821
Content-Type: text/html
(blank line)
data data data data data ...
```

HTTP is stateless

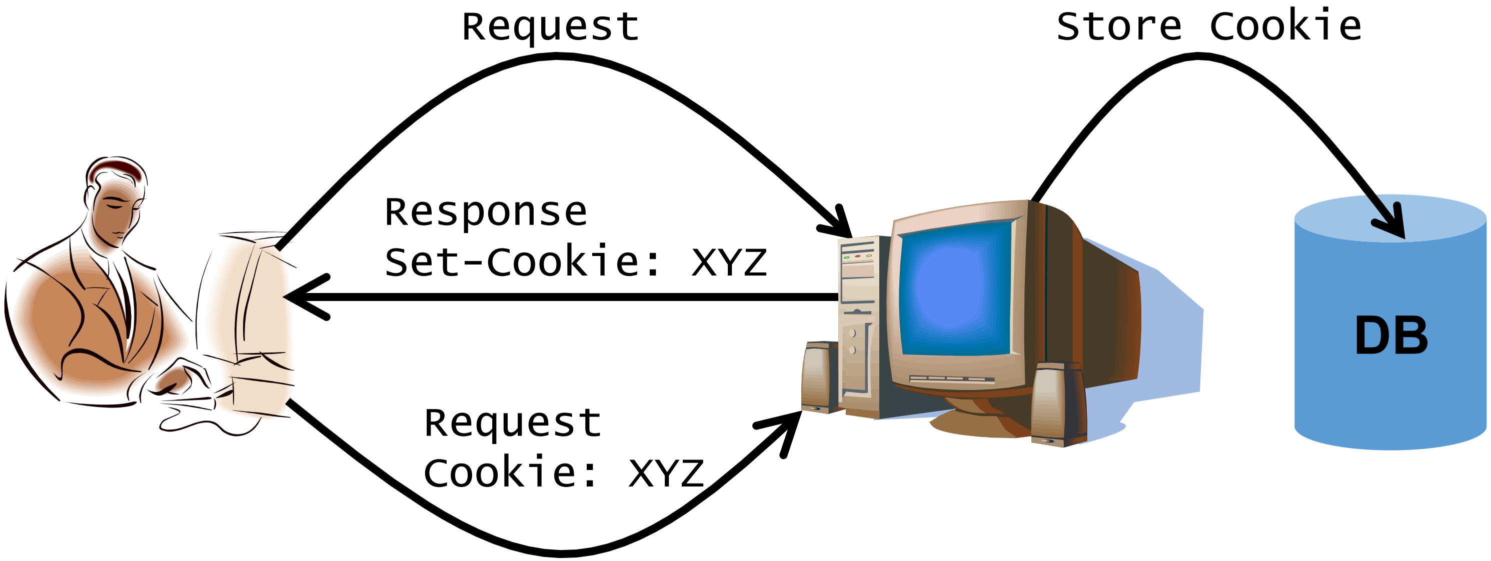
- **Each request-response treated independently**
  - Servers not required to retain state
- **Good: Improves scalability on the server-side**
  - Failure handling is easier
  - Can handle higher rate of requests
  - Order of requests doesn’t matter
- **Bad: Some applications need persistent state**
  - Need to uniquely identify user or store temporary info
  - e.g., Shopping cart, user profiles, usage tracking, …

Question

- **How does a stateless protocol keep state?**

State in a stateless protocol: Cookies

- **Client-side state maintenance**
  - Client stores small state on behalf of server
  - Client sends state in future requests to the server
- **Can provide authentication**



“Abuse” of cookies

- **Excellent marketing opportunities and concerns for privacy**
    - ➢Cookies permit sites to learn a lot about you
    - ➢You may unknowingly supply personal info to sites
    - ➢Advertising companies tracks your preferences and viewing history across sites

Performance goals

- **User**
  - ➢Fast downloads (not identical to low-latency communication!)
  - ➢High availability
- **Content provider**
  - ➢Happy users (hence, above)
  - ➢Cost-effective infrastructure
- **Network (secondary)**
  - ➢Avoid overload

Solutions?

Improve networking protocols including HTTP, TCP, etc.

- **User**
  - ➢Fast downloads (not identical to low-latency communication!)
  - ➢High availability
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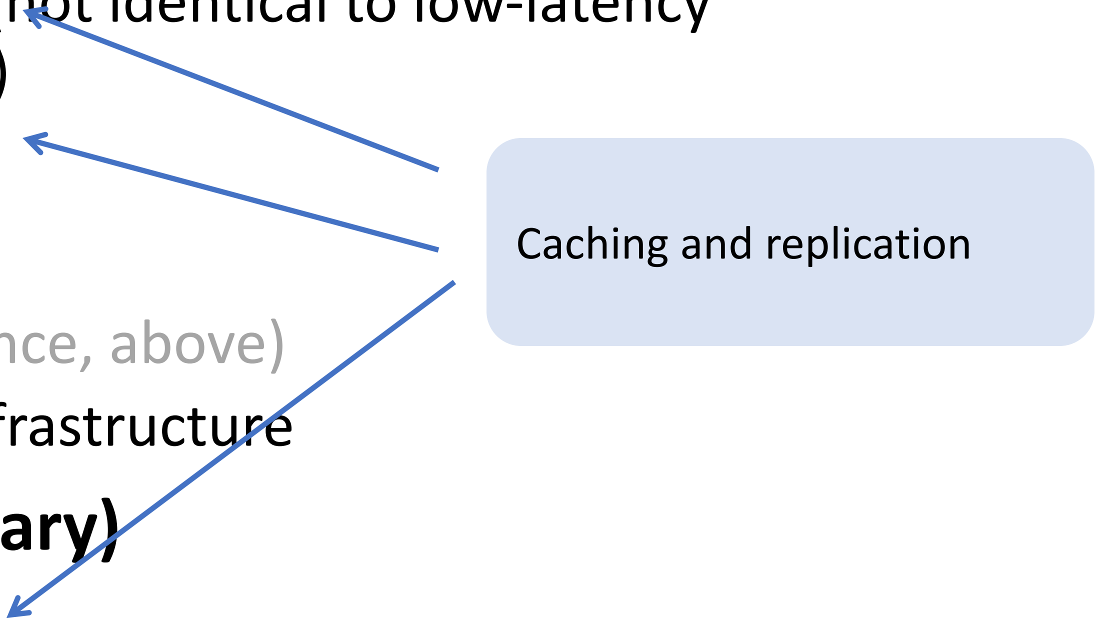
  - Avoid overload



Caching and replication

Solutions?

- **User**
  - Fast downloads (not identical to low-latency communication!)
  - High availability
- **Content provider**
  - Happy users (hence, above)
  - Cost-effective infrastructure
- **Network (secondary)**
  - Avoid overload

Improve networking protocols including HTTP, TCP, etc.

Caching and replication

Exploit economies of scale; e.g., webhosting, CDNs, datacenters

HTTP performance

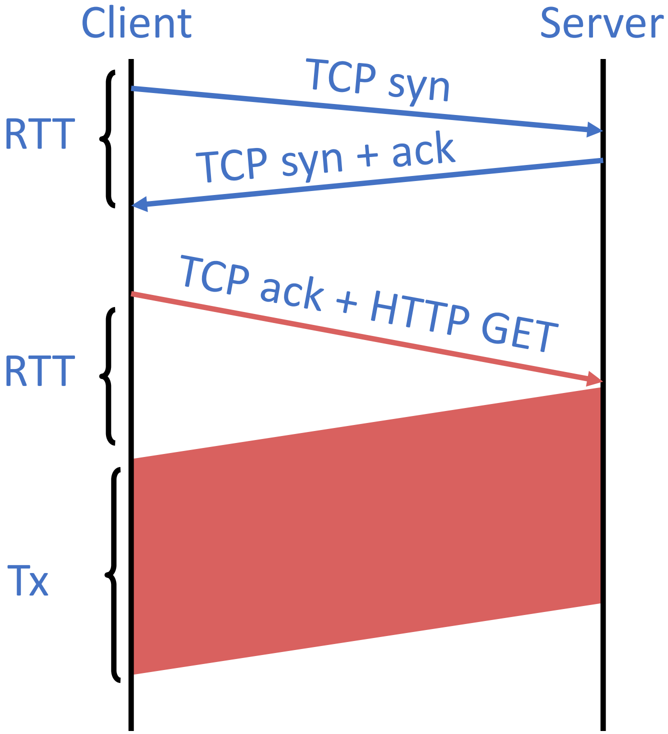
- **Most Web pages have multiple objects**
  - ➢e.g., HTML file and a bunch of embedded images

- **How do you retrieve those objects (naively)?**
  - ➢One item at a time

- **New TCP connection per (small) object!**

Object request response time

- **RTT (round-trip time)**
  - Time for a small packet to travel from client to server and back
- **Response time**
  - 1 RTT for TCP setup
  - 1 RTT for HTTP request and first few bytes
  - Transmission time
  - Total = 2RTT + Transmission Time



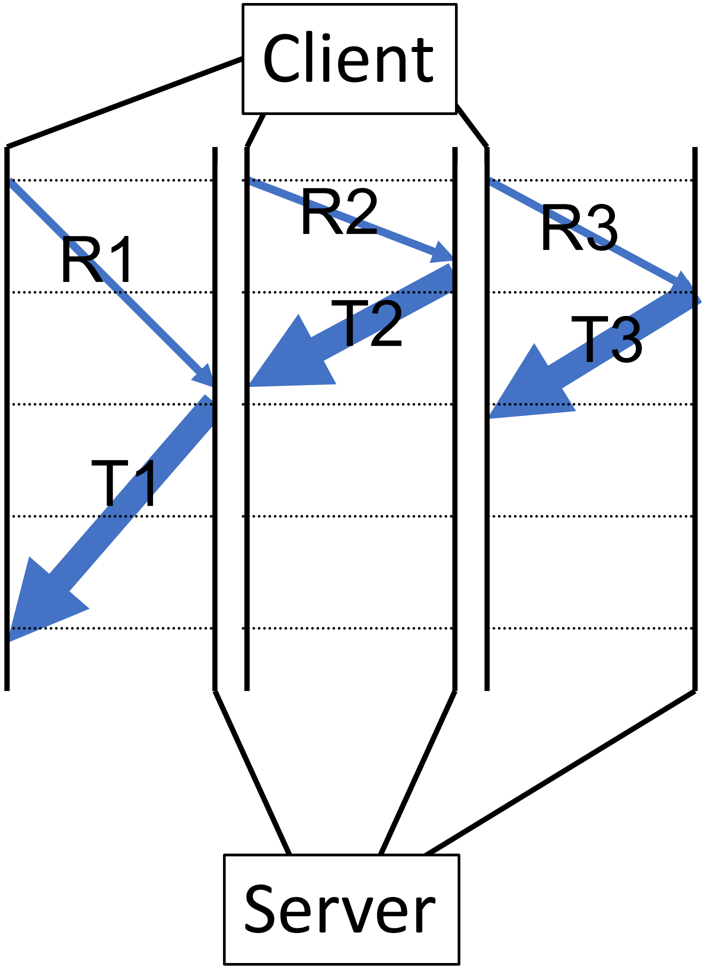
Non-persistent connections

- **Default in HTTP/1.0**
- **2RTT+△ for each object in the HTML file!**
  - ➢One more 2RTT+△ for the HTML file itself
- **Doing the same thing over and over again**
  - ➢Inefficient

Concurrent requests and responses

- **Use multiple connections in parallel**
- **Does not necessarily maintain order of responses**

- Client = ☺
- Content provider = ☺
- Network = ☹ Why?



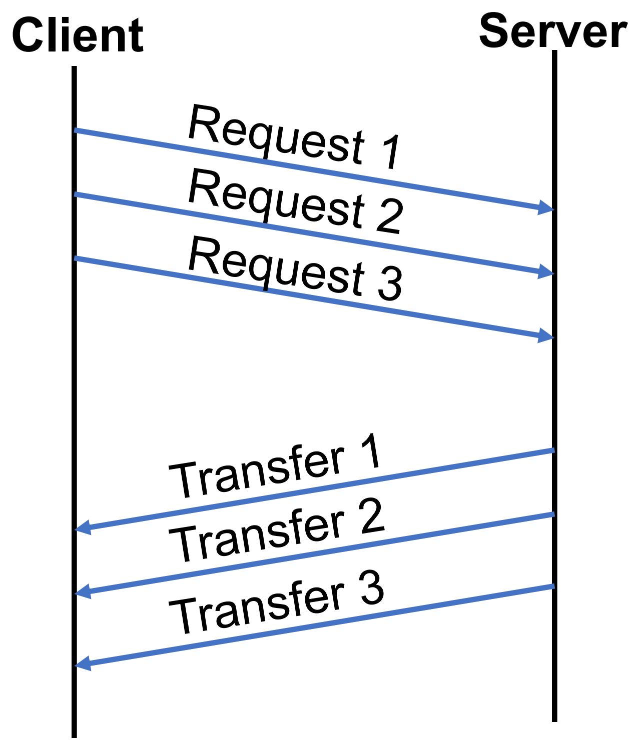
Persistent connections

- **Maintain TCP connection across multiple requests**
  - ➢Including transfers subsequent to current page
  - ➢Client or server can tear down connection
- **Advantages**
  - ➢Avoid overhead of connection set-up and tear-down
  - ➢Allow underlying layers (e.g., TCP) to learn about RTT and bandwidth characteristics
- **Default in HTTP/1.1**

Pipelined requests & responses

- **Batch requests and responses to reduce the number of packets**

- **Multiple requests can be contained in one TCP segment**



Scorecard: Getting n small objects

- **Time dominated by latency**

- **One-at-a-time: ~2n RTT**
- **m concurrent: ~2[n/m] RTT**
- **Persistent: ~ (n+1)RTT**
- **Pipelined: ~2 RTT**
- **Pipelined/Persistent: ~2 RTT first time, RTT later**

Scorecard: Getting n large objects each of size F

- **Time dominated by bandwidth**

- **One-at-a-time: ~ nF/B**
- **m concurrent: ~ [n/m] F/B**
  - Assuming shared with large population of users and each TCP connection gets the same bandwidth
- **Pipelined and/or persistent: ~ nF/B**
  - The only thing that helps is getting more bandwidth

Summary

- **HTTP/1.1**
  - ➢Text-based protocol
  - ➢Being replaced by binary HTTP/2 protocol
- **Many ways to improve performance**
  - ➢Pipelining and batching
- **Assignment 1 is due next Friday**

Thanks!
Q&A