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Computer Networks (CS F303)

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innovate achieve lead

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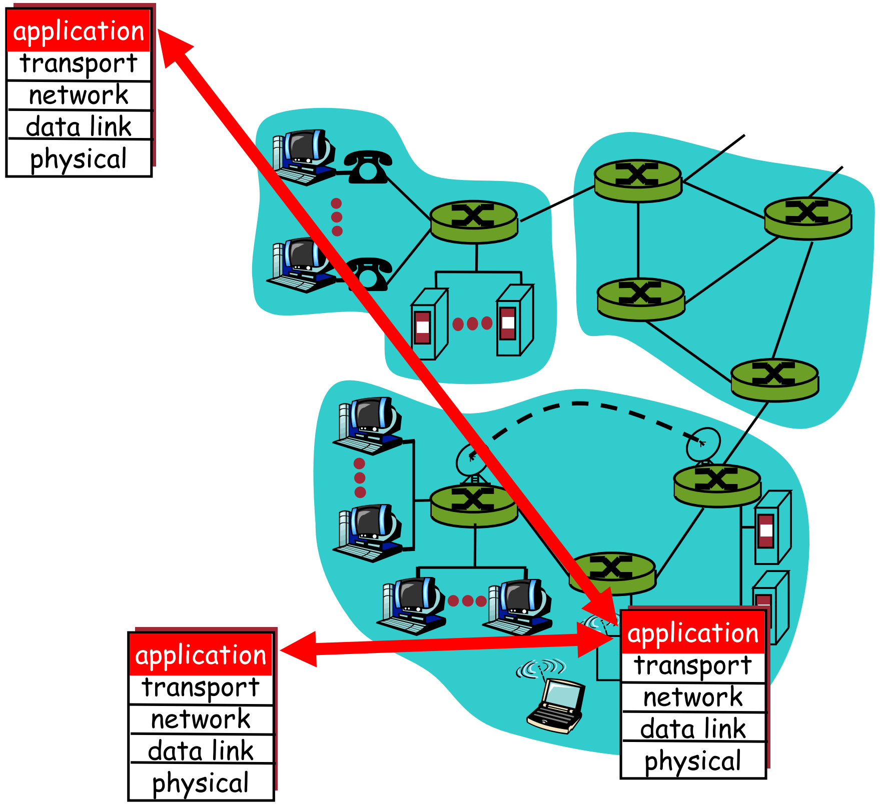
Second Semester 2020-2021
Module-2 Application Layer

What is a Network Application?

- Programs that run on different end systems and communicate over a network
  - e.g., Web: Web server software communicates with browser software

- Network core devices do not run user application code

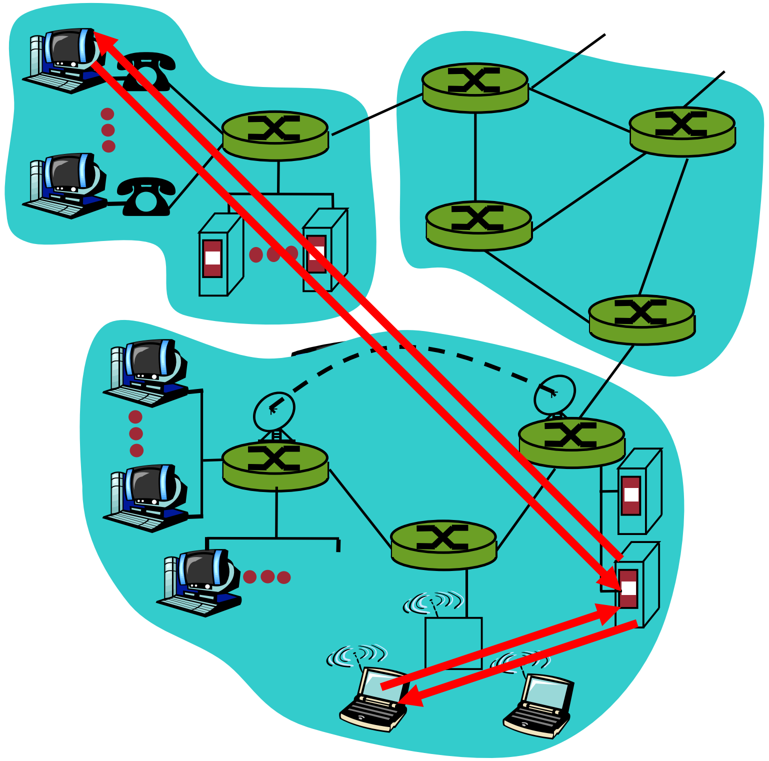
- Application on end systems allows for rapid application development



Application architectures

- Client-server
- Peer-to-Peer (P2P)
- Hybrid of client-server and P2P

Client-Server Architecture



Server:

- "always-on" host
- Permanent IP address
- For scaling, data center is used to create large powerful virtual server

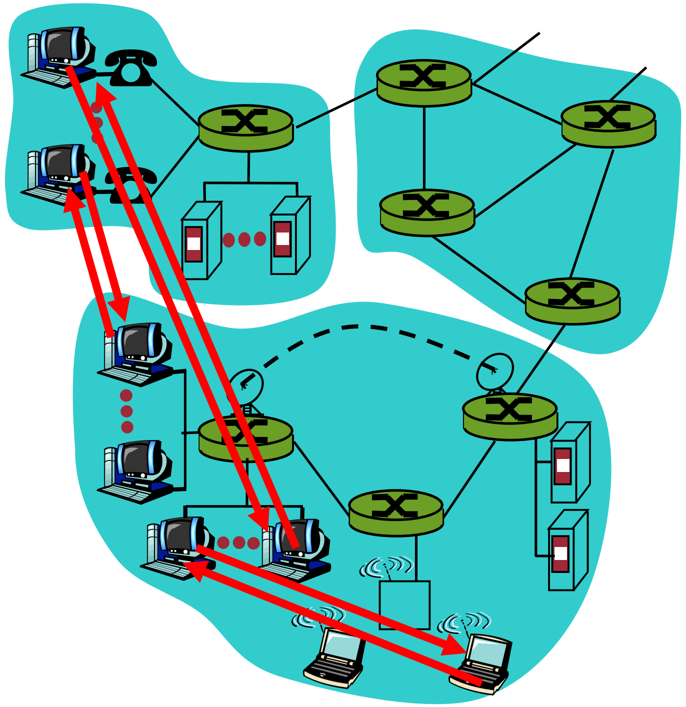
Clients:

- Communicate with server
- May be intermittently connected
- May have dynamic IP addresses
- Clients do not communicate directly with each other

Pure P2P Architecture

- No “always-on” server
- Arbitrary end systems directly communicate
- Peers are connected and change IP addresses
  - example: Freenet and BitTorrent (File Sharing Apps)

Highly scalable but difficult to manage!!!



Hybrid of client-server and P2P

Skype

- Internet telephony application
- Finding address of remote party: centralized server (s)
- Client-client connection is direct (not through server)

Instant messaging

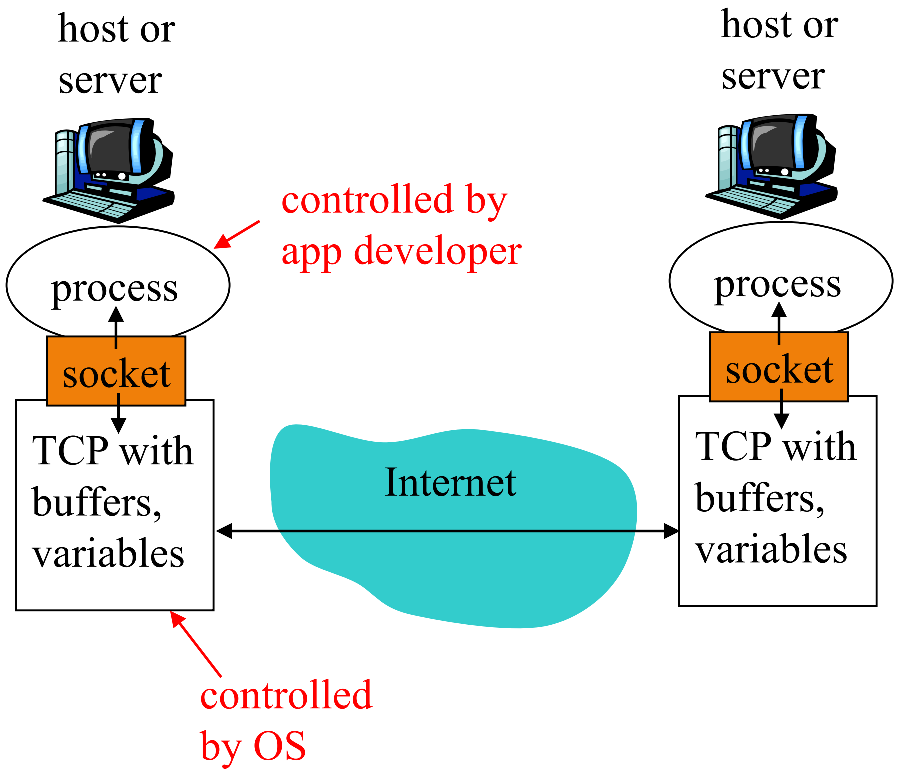
- Chatting between two users is P2P
- Presence detection/location centralized:
  - User registers its IP address with central server when it comes online
  - User contacts central server to find IP addresses of buddies

How Network Applications Communicate?

- **Process** sends/receives messages to/from its **Socket**
  - **Socket** is the interface between the application layer and the transport layer within the host

- Within same host, two **processes** communicate using **inter-process communication**

- **Processes** in different hosts communicate by exchanging **messages**

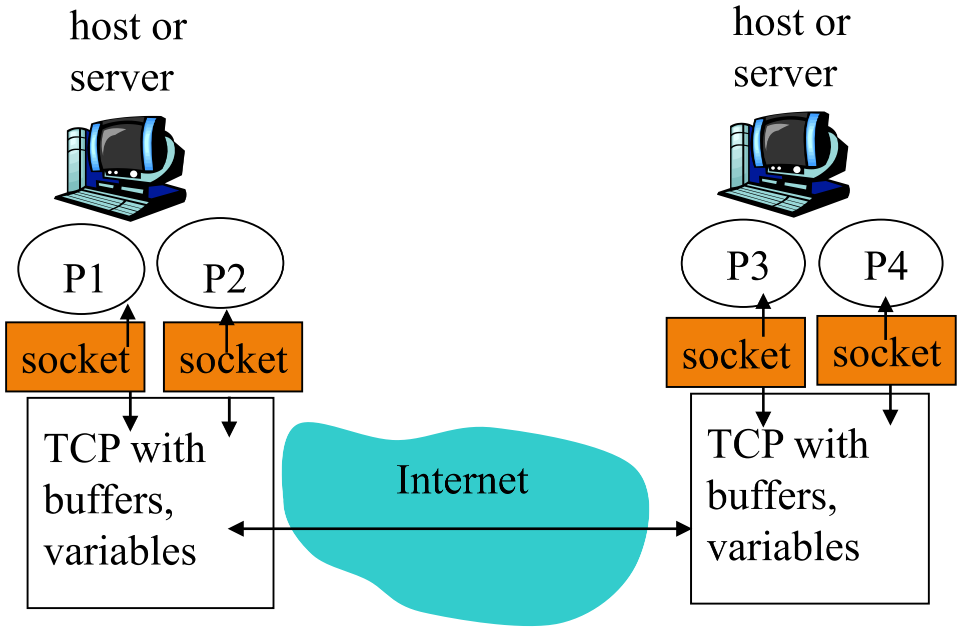

host or server
process
socket
TCP with buffers, variables
controlled by app developer
Internet
controlled by OS
host or server
process
socket
TCP with buffers, variables

How to identify a process running on a machine?

- To receive messages, process must have *identifier*

- IP address of host on which process runs is not sufficient for identifying the process. Why?

- *Process identifier* = IP address + port number
  - e.g., HTTP server: 80, Mail server (SMTP): 25
  - List of well known port numbers is available at **http://www.iana.org**



What transport service does an app need?

- Data loss
  - Some apps (e.g., audio, video) can tolerate some loss
  - Other apps (e.g., file transfer, telnet) require 100% reliable data transfer
- Bandwidth
  - Some apps (e.g., multimedia) require minimum amount of bandwidth to be “effective”
  - Other apps (“elastic apps”) make use of whatever bandwidth they get
  - ex. E-mail, File Transfer
- Timing
  - Some apps (e.g., Internet telephony, interactive games) require low **delay** to be “effective”

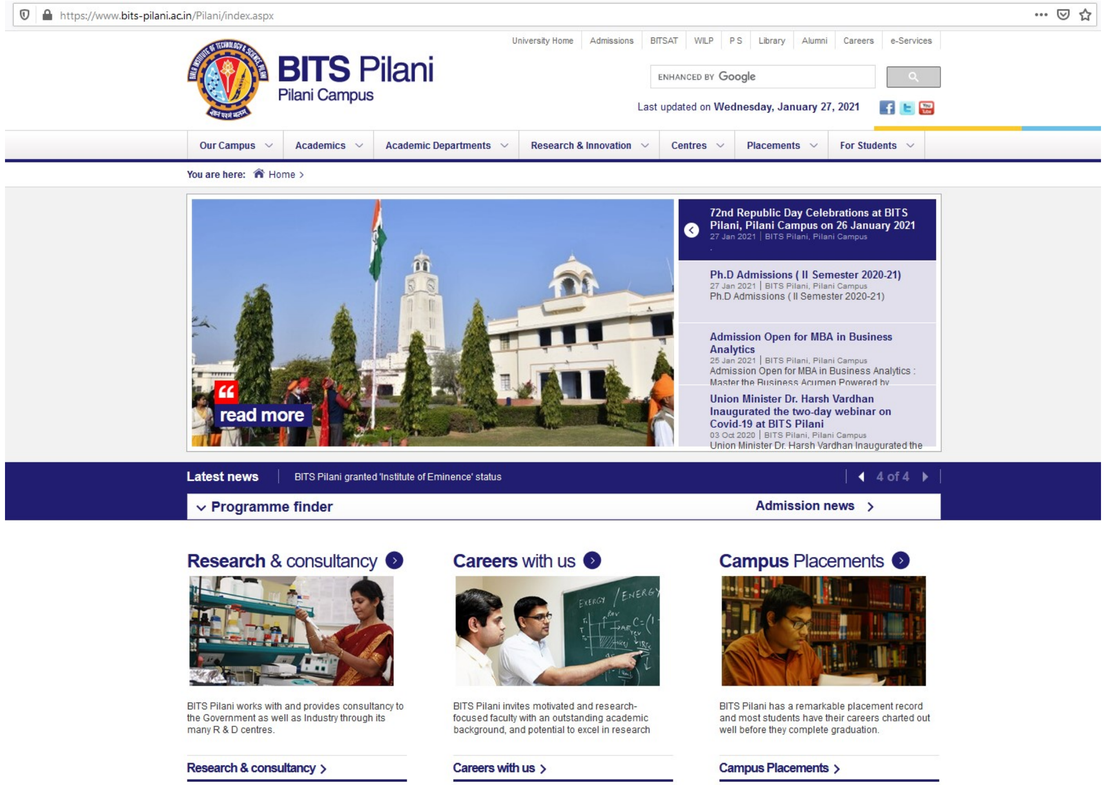
Web and HTTP [1994]

Web page consists of objects

- Object can be HTML file, JPEG image, Java applet, audio file,…
- Web page consists of base HTML-file which includes several referenced objects
- Each object is addressable by a URL
- Example URLs:

  https://www.bits-pilani.ac.in/pilani/computerscience/ProgrammesOffered

  https://www.bits-pilani.ac.in/pilani/computerscience/Faculty



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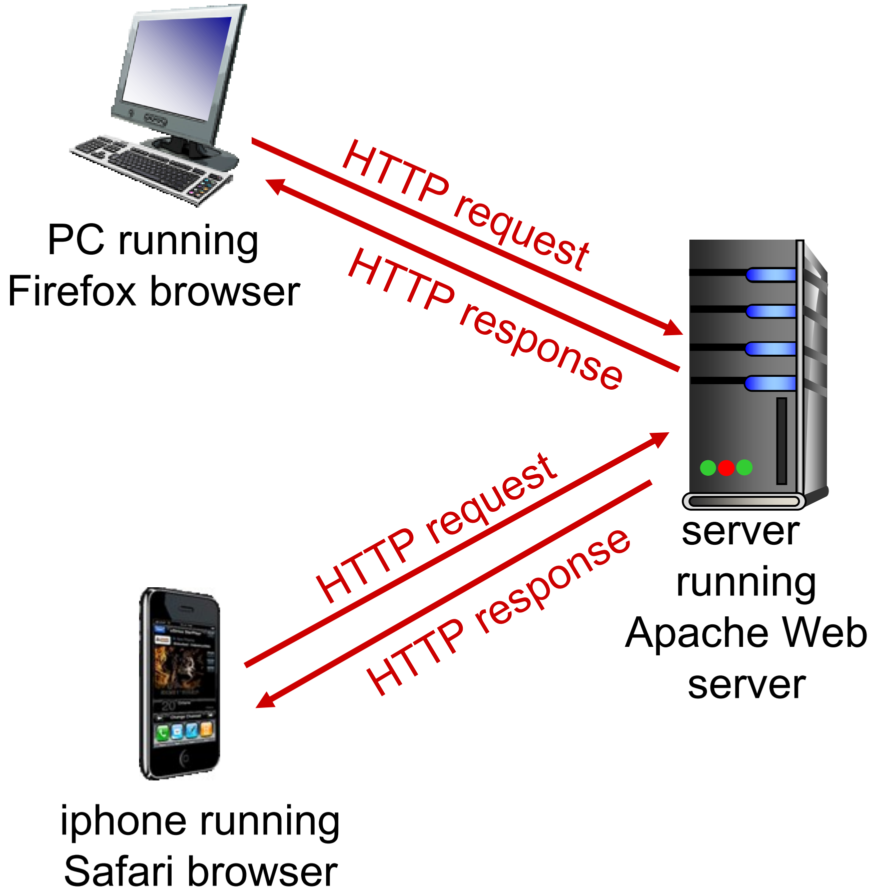
HTTP Overview [.1]

- Types of messages exchanged
  - e.g., request, response
- Message syntax:
  - What fields in messages & how fields are delineated
- Message semantics
  - Meaning of information in fields
- Rules for when and how processes send & respond to messages

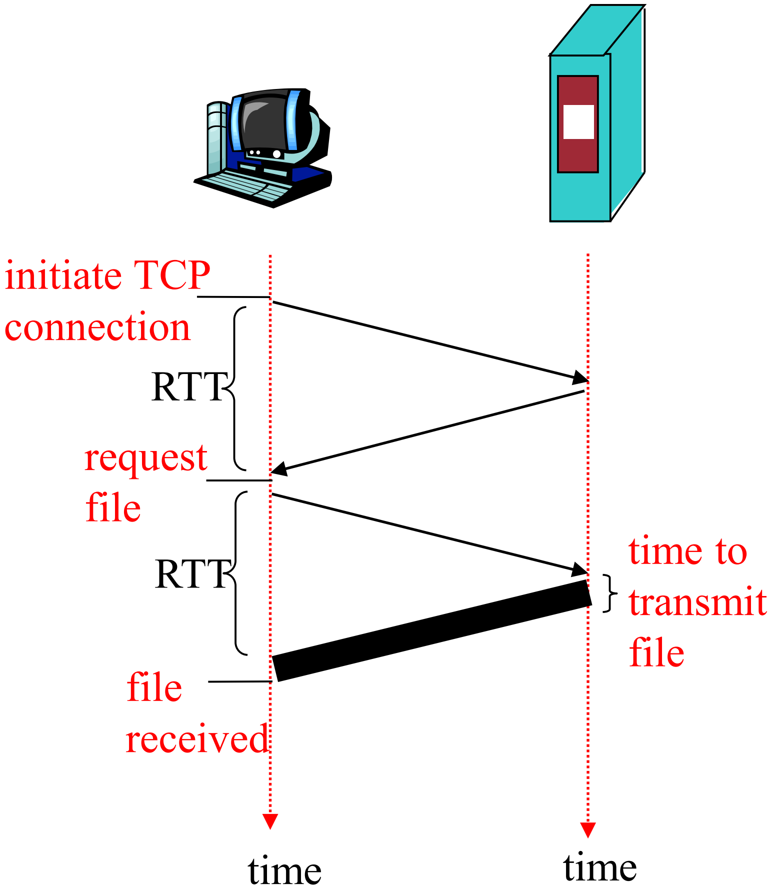


PC running Firefox browser
HTTP request
HTTP response
server running Apache Web server
HTTP request
HTTP response
iphone running Safari browser

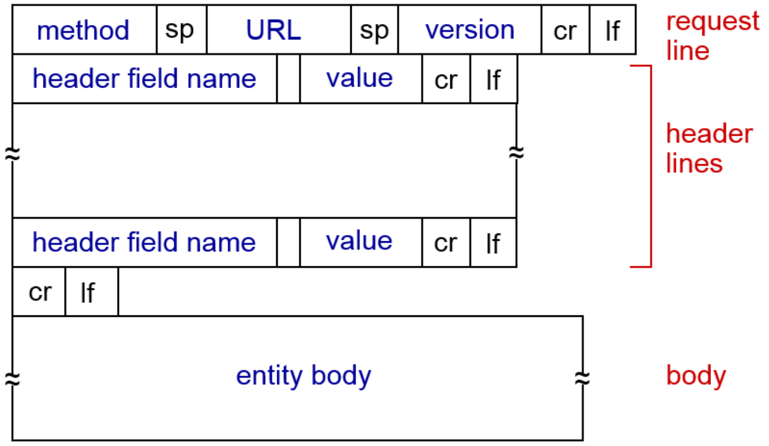
HTTP Overview [..2]

Uses TCP:

- Client initiates TCP connection (creates socket) to server, port 80
- Server accepts TCP connection from client
- HTTP messages exchanged between browser (HTTP client) and Web server (HTTP server)
- TCP connection closed



HTTP Request Message



carriage return character

line-feed character

request line (GET, POST, HEAD commands)

header lines

carriage return, line feed at start of line indicates end of header lines

```
GET /index.html HTTP/1.1\r\n
Host: www-net.cs.umass.edu\r\n
User-Agent: Firefox/3.6.10\r\n
Accept: text/html,application/xhtml+xml\r\n
Accept-Language: en-us,en;q=0.5\r\n
Accept-Encoding: gzip,deflate\r\n
Accept-Charset: ISO-8859-1,utf-8;q=0.7\r\n
Keep-Alive: 115\r\n
Connection: keep-alive\r\n
\r\n
data data data data data ...
```

Response Message

status line
(protocol
status code
status phrase)

```
HTTP/1.1 200 OK\r\n
Date: Sun, 26 Sep 2010 20:09:20 GMT\r\n
Server: Apache/2.0.52 (CentOS)\r\n
Last-Modified: Tue, 30 Oct 2007 17:00:02 GMT\r\n
ETag: "17dc6-a5c-bf716880"\r\n
Accept-Ranges: bytes\r\n
Content-Length: 2652\r\n
Keep-Alive: timeout=10, max=100\r\n
Connection: Keep-Alive\r\n
Content-Type: text/html; charset=ISO-8859-1\r\n
\r\n
data data data data data ...
```

header
lines

data, e.g.,
requested
HTML file

HTTP Response status Codes

200 OK

- request succeeded, requested object later in this msg

301 Moved Permanently

- requested object moved, new location specified later in this msg (Location:)

400 Bad Request

- request msg not understood by server

404 Not Found

- requested document not found on this server

505 HTTP Version Not Supported

- the **HTTP** version used in the request is not supported by the server.

Working of HTTP

- Let’s assume a web page consists of a base HTML file and 10 JPEG images.
  - https://www.bits-pilani.ac.in/Pilani/SustainableEnvironment

HTTP Connections

Non-persistent HTTP

- At most one object is sent over a TCP connection
- HTTP/1.0 uses non-persistent HTTP

Persistent HTTP

- Multiple objects can be sent over single TCP connection between client and server.
- Persistent with Pipeline vs. Persistent without Pipeline
- HTTP/1.1 uses persistent connections in default mode

HTTP Method Types

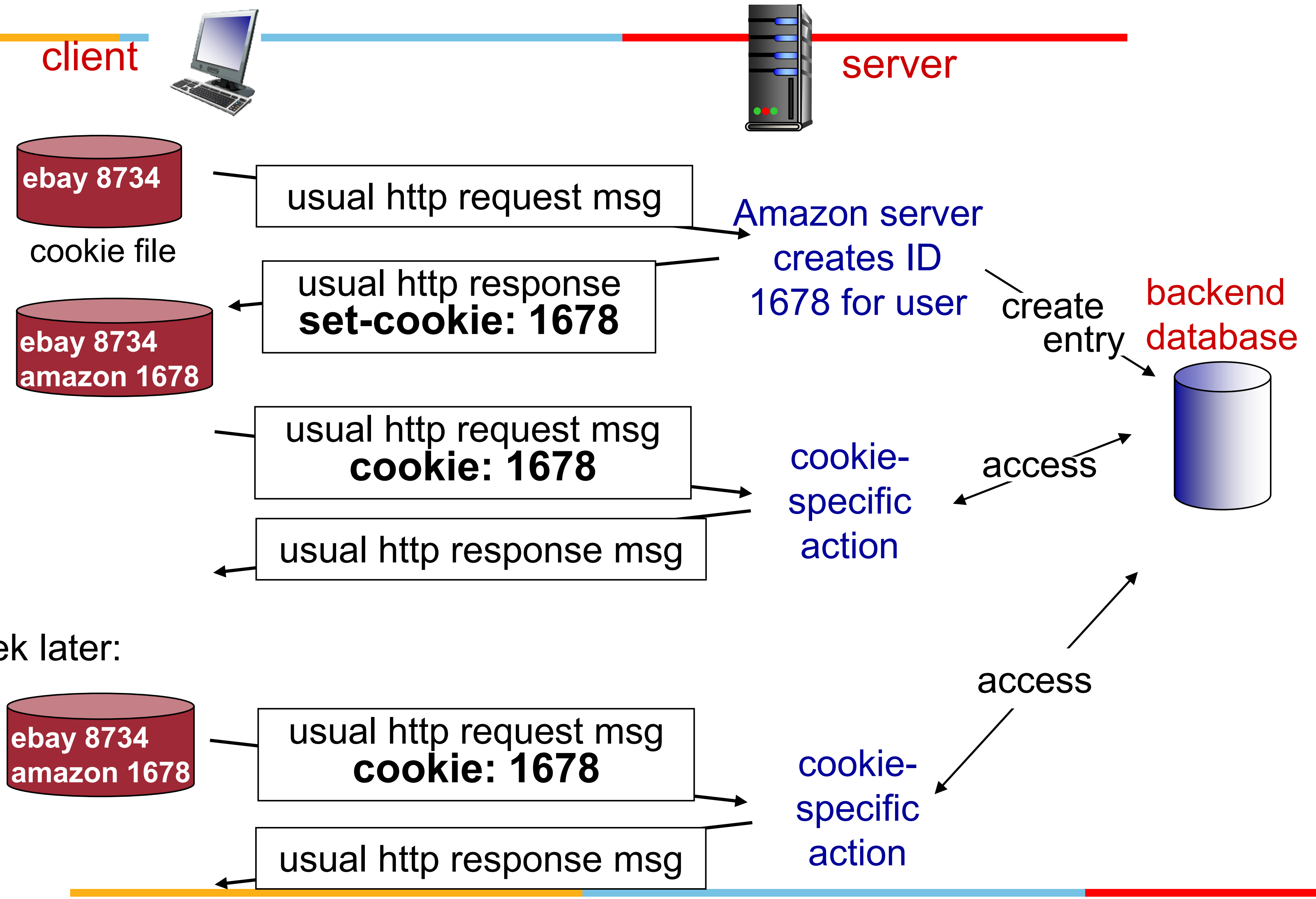
HTTP/1.0:

- GET
- POST
- HEAD
  - asks server to leave requested object out of response

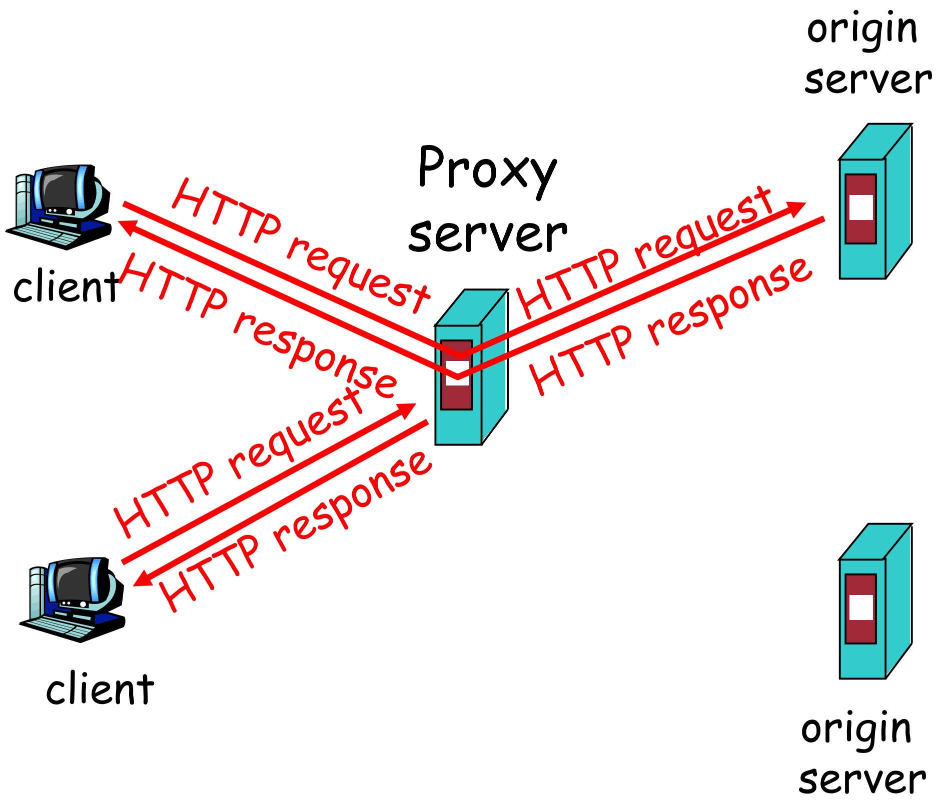
HTTP/1.1:

- GET, POST, HEAD
- PUT
  - uploads file in entity body to path specified in URL field
- DELETE
  - deletes file specified in the URL field

State in HTTP using "Cookies"



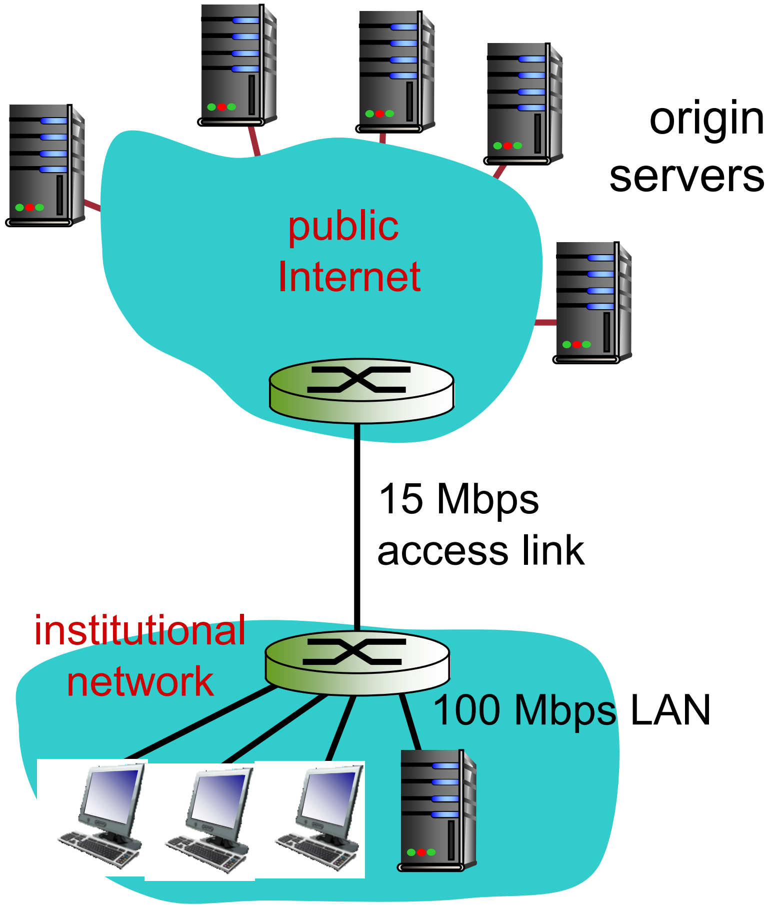
Web Caches (aka Proxy Server)



Proxy Server Example [.1]

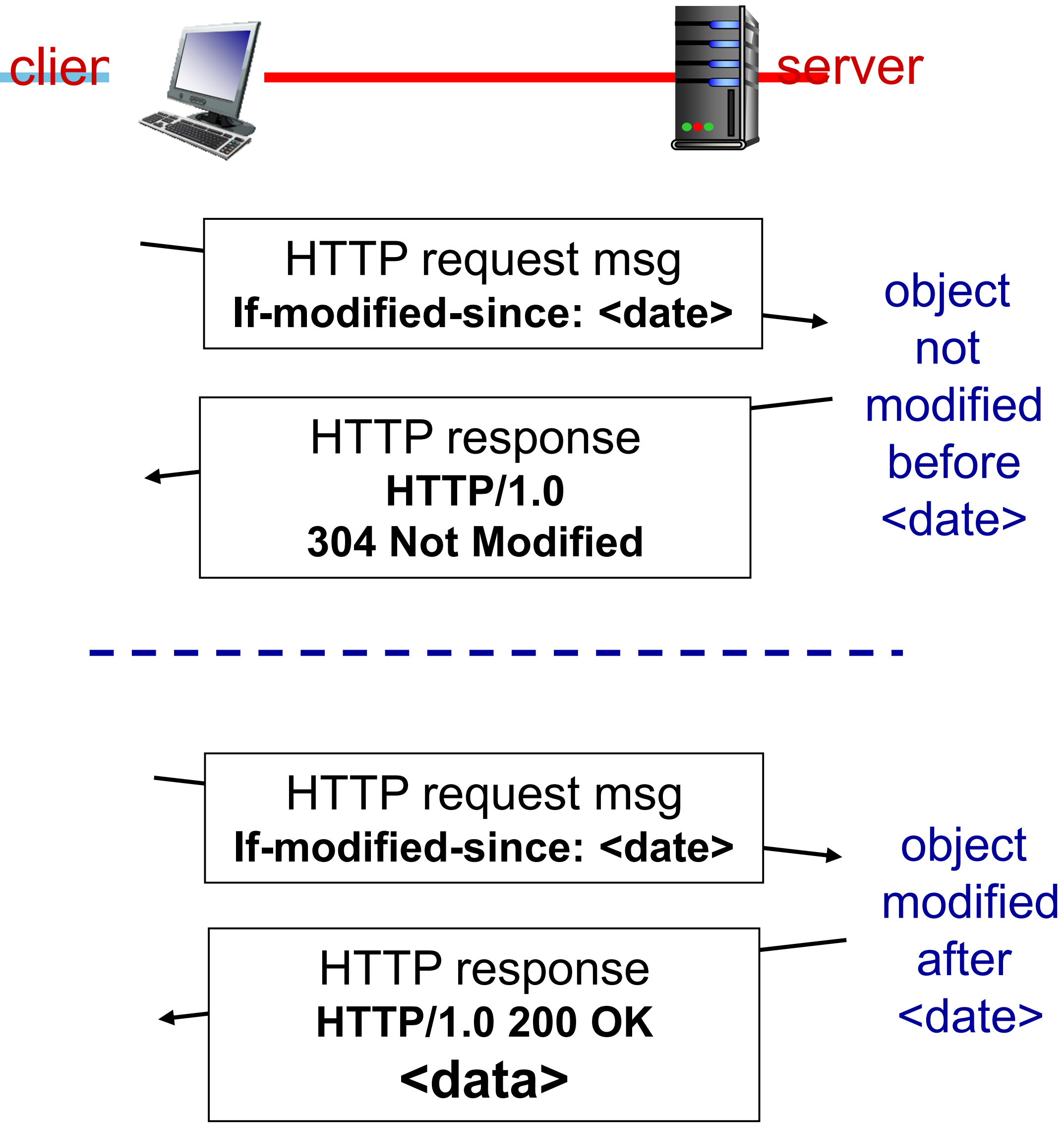
Assumptions:

- avg object size: 100K bits
- avg request rate from browsers to origin servers:15 req/sec
- avg data rate to browsers: 1Mbps
- RTT from institutional router to any origin server: 2 sec
- access link rate: 15 Mbps



Conditional GET

- ***Goal:*** don't send object if cache has up-to-date cached version
- *cache:* specify date of cached copy in HTTP request
  `If-modified-since: <date>`
- *server:* response contains no object if cached copy is up-to-date:
  `HTTP/1.0 304 Not Modified`



HTTP/2 [Proposed in 2015]

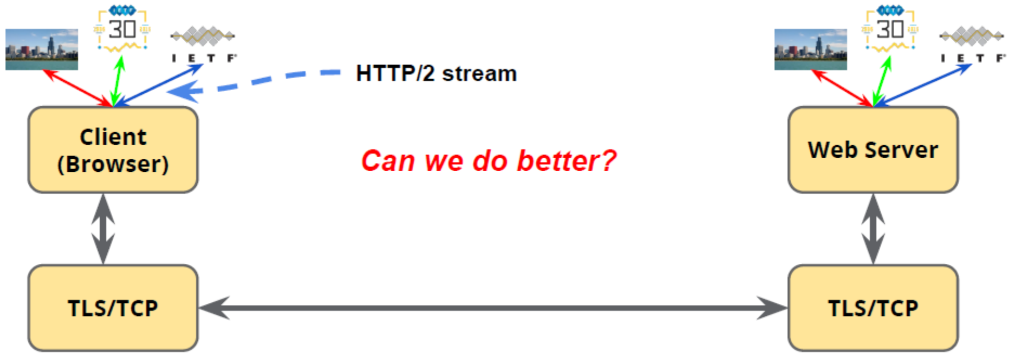
- Motivation
  - To improve internet user experience and effectiveness
  - Webpages comprise resource-intensive multimedia content
  - To make it more secure, reliable with improved performance
- It is an extension to its predecessor not replacing the older one
- Limitations of HTTP1.1
  - It processes only one outstanding request per TCP connection
  - Forcing browsers to use multiple TCP connections to process multiple requests simultaneously
  - HTTP1.x used to process text commands which makes it slower

HTTP/2Feature: Stream Multiplexing

- What is ***stream***?
  - Bi-directional sequence of text format frames sent over the HTTP/2 protocol exchanged between the server and client

- HTTP/1 is capable of transmitting only one stream at a time
  - Receiving large amount of media content via individual streams sent one by one is inefficient and resource consuming

- HTTP/2 allows transmission of parallel multiplexed requests and responses
  - A binary framing layer is created
  - This layer allows client and server to disintegrate the HTTP payload into small, independent and manageable interleaved sequence of frames
  - This information is then reassembled at the other end



HTTP/2 stream

Client (Browser)

Can we do better?

Web Server

TLS/TCP

TLS/TCP

HTTP/2 Feature: Server PUSH

- It allows the server to send additional cacheable information to the client that isn’t requested but is anticipated in future requests.

- This mechanism saves a request-respond round trip and reduces network latency.

Thank You!