Korea University

Computer Networks
컴퓨터네트워크

(Ch. 2: Layer 7 - Application Layer & Network Programming)

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Application layer: overview

- Principles of network applications
- Web and HTTP
- E-mail, SMTP, IMAP
- The Domain Name System DNS
- P2P applications
- video streaming and content distribution networks
- socket programming with UDP and TCP

Web and HTTP

First, a quick review…

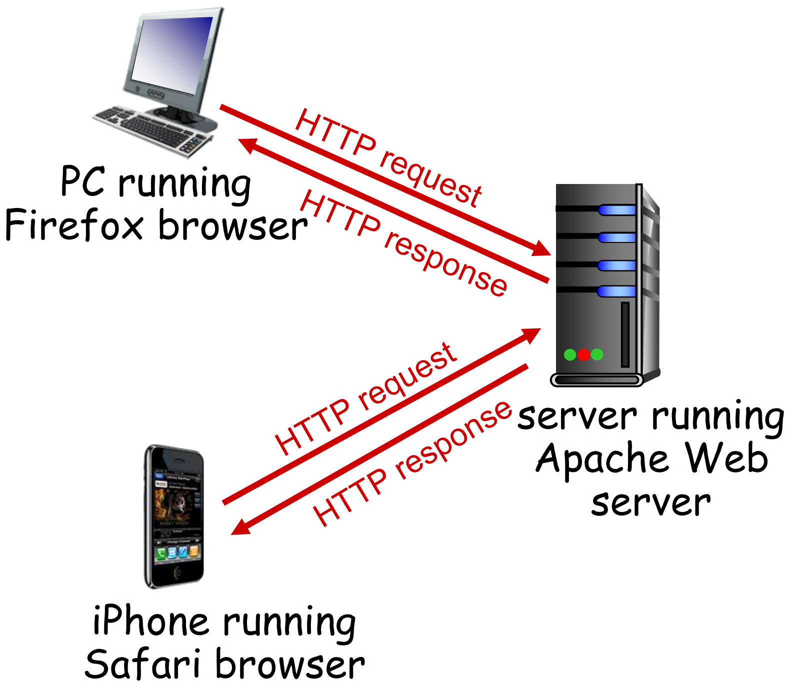
- web page consists of ***objects***, each of which can be stored on different Web servers
- ***object*** can be *HTML file, JPEG image, Java applet, audio file*,…
- web page consists of *base HTML-file* which includes *several referenced objects, each* addressable by a *URL,* e.g.,

$$\underbrace{\texttt{www.someschool.edu}}_{\text{host name}}\underbrace{\texttt{/someDept/pic.gif}}_{\text{path name}}$$

HTTP overview

HTTP: hypertext transfer protocol

- Web's application layer protocol
- client/server model:
  - *client:* browser that requests, receives, (using HTTP protocol) and "displays" Web objects
  - *server:* Web server sends (using HTTP protocol) objects in response to requests



HTTP overview (continued)

HTTP uses TCP:

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

HTTP is "stateless"

- server maintains *no* information about past client requests

aside

protocols that maintain "state" are complex!

- past history (state) must be maintained
- if server/client crashes, their views of "state" may be inconsistent, must be reconciled

HTTP connections: two types

Non-persistent HTTP

1. TCP connection opened
2. at most one object sent over TCP connection
3. TCP connection closed

downloading multiple objects required multiple connections

Persistent HTTP

- TCP connection opened to a server
- multiple objects can be sent over *single* TCP connection between client, and that server
- TCP connection closed

Non-persistent HTTP: example

User enters URL: **`www.someSchool.edu/someDepartment/home.index`**

(containing text, references to 10 jpeg images)

time

1a. HTTP client initiates TCP connection to HTTP server (process) at www.someSchool.edu on port 80

1b. HTTP server at host www.someSchool.edu waiting for TCP connection at port 80 "accepts" connection, notifying client

2. HTTP client sends HTTP *request message* (containing URL) into TCP connection socket. Message indicates that client wants object someDepartment/home.index

3. HTTP server receives request message, forms *response message* containing requested object, and sends message into its socket

Non-persistent HTTP: example (cont.)

User enters URL: **`www.someSchool.edu/someDepartment/home.index`**
(containing text, references to 10 jpeg images)

4. HTTP server closes TCP connection.

5. HTTP client receives response message containing html file, displays html. Parsing html file, finds 10 referenced jpeg objects

6. Steps 1-5 repeated for each of 10 jpeg objects

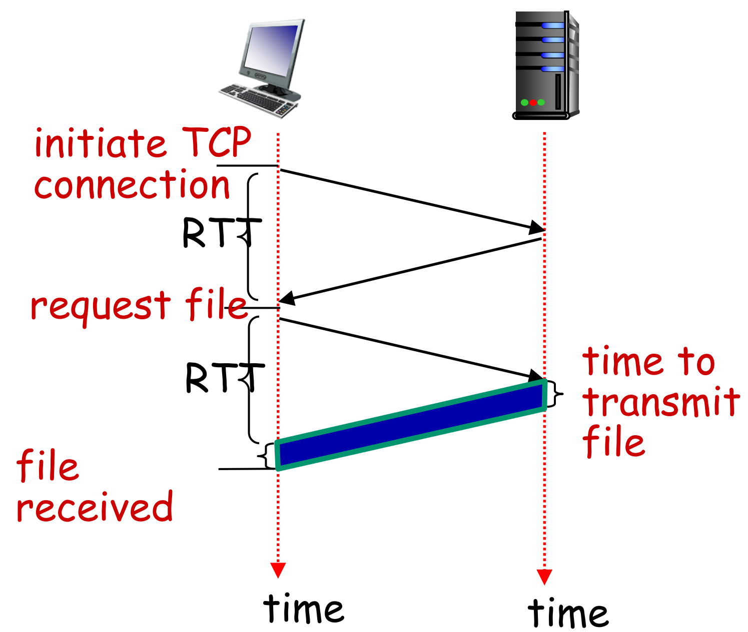
time

Non-persistent HTTP: response time

RTT (definition): time for a small packet to travel from client to server and back

HTTP response time (per object):

- one RTT to initiate TCP connection
- one RTT for HTTP request and first few bytes of HTTP response to return
- obect/file transmission time



Non-persistent HTTP response time = 2RTT+ file transmission time

Persistent HTTP (HTTP 1.1)

Non-persistent HTTP issues:

- requires 2 RTTs per object
- OS overhead for *each* TCP connection
- browsers often open multiple parallel TCP connections to fetch referenced objects in parallel

Persistent HTTP (HTTP1.1):

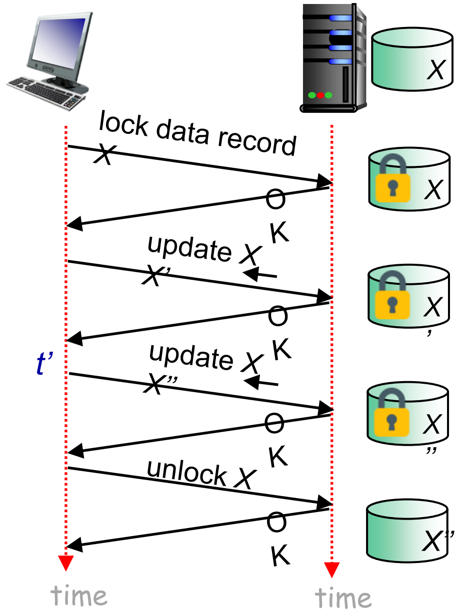
- server leaves connection open after sending response
- subsequent HTTP messages between same client/server sent over open connection
- client sends requests as soon as it encounters a referenced object
- as little as one RTT for all the referenced objects (cutting response time in half)

Maintaining user/server state: cookies

Recall: HTTP GET/response interaction is *stateless*

- no notion of multi-step exchanges of HTTP messages to complete a Web "transaction"
  - no need for client/server to track "state" of multi-step exchange
  - all HTTP requests are independent of each other
  - no need for client/server to "recover" from a partially-completed-but-never-completely-completed transaction

a stateful protocol: client makes two changes to X, or none at all



Q: what happens if network connection or client crashes at *t'* ?

Maintaining user/server state: cookies

Web sites and client browser use *cookies* to maintain some state between transactions

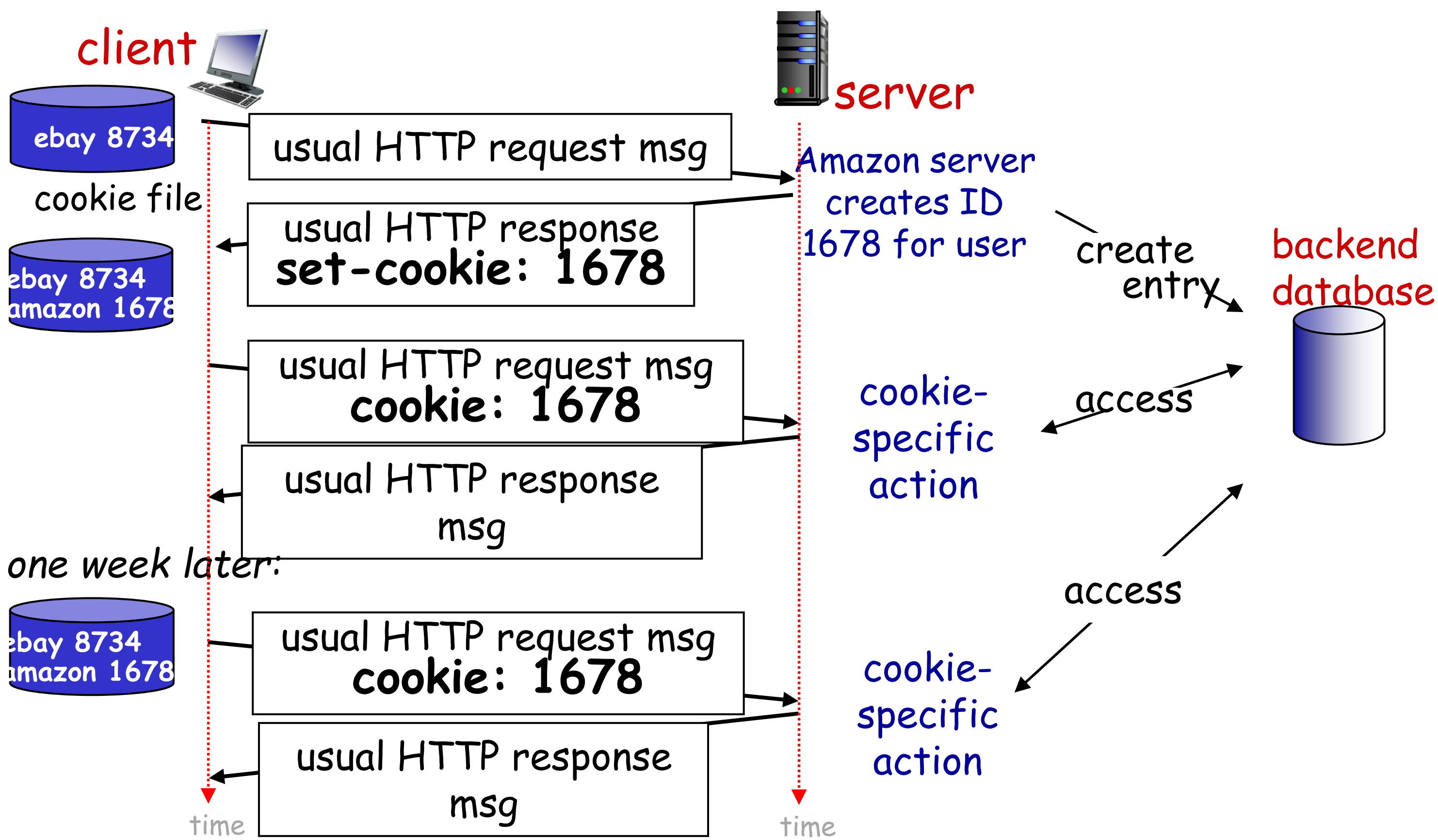
four components:

1) cookie header line of HTTP *response* message
2) cookie header line in next HTTP *request* message
3) cookie file kept on user's host, managed by user's browser
4) back-end database at Web site

Example:

- Susan uses browser on laptop, visits specific e-commerce site for first time
- when initial HTTP requests arrives at site, site creates:
  - unique ID (aka "cookie")
  - entry in backend database for ID
- subsequent HTTP requests from Susan to this site will contain cookie ID value, allowing site to "identify" Susan

Maintaining user/server state: cookies



HTTP cookies: comments

What cookies can be used for:

- authorization
- shopping carts
- recommendations
- user session state (Web e-mail)

Challenge: How to keep state:

- protocol endpoints: maintain state at sender/receiver over multiple transactions
- cookies: HTTP messages carry state

aside

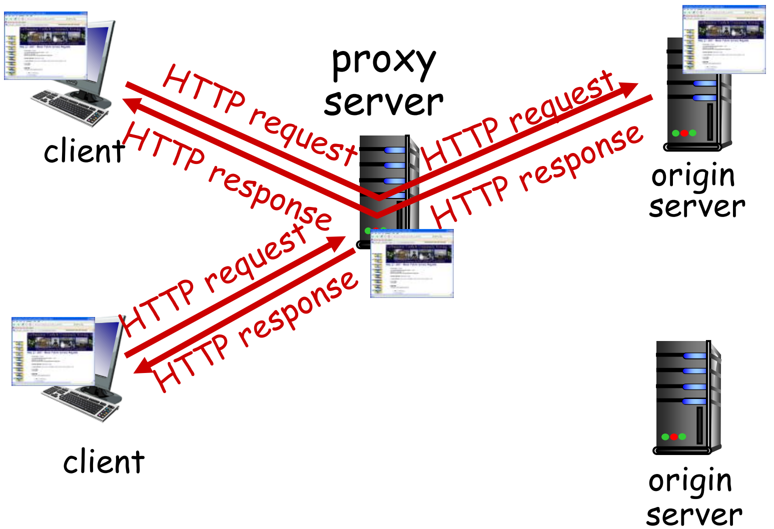
cookies and privacy:

- cookies permit sites to *learn* a lot about you on their site.
- third party persistent cookies (tracking cookies) allow common identity (cookie value) to be tracked across multiple web sites

Web caches (proxy servers)

Goal: satisfy client request without involving origin server

- user configures browser to point to a *Web cache*
- browser sends all HTTP requests to cache
  - *if* object in cache: cache returns object to client
  - *else* cache requests object from origin server, caches received object, then returns object to client



Web caches (proxy servers)

- Web cache acts as both client and server
  - server for original requesting client
  - client to origin server
- typically cache is installed by ISP (university, company, residential ISP)

Why Web caching?

- reduce response time for client request
  - cache is closer to client
- reduce traffic on an institution's access link
- Internet is dense with caches
  - enables "poor" content providers to more effectively deliver content

Caching example

Scenario:

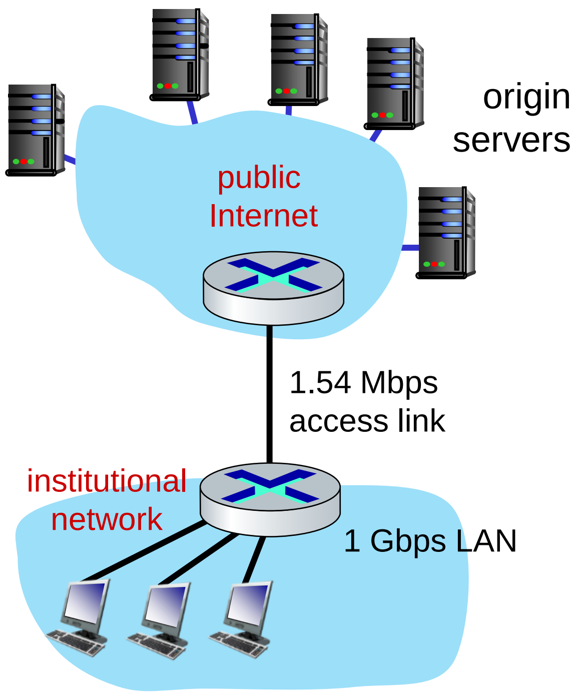
- access link rate: 1.54 Mbps
- RTT from institutional router to server: 2 sec
- Web object size: 100K bits
- Average request rate from browsers to origin servers: 15/sec
  - average data rate to browsers: 1.50 Mbps

Performance:

- LAN utilization: .0015
- access link utilization = .97
- end-end delay = Internet delay + access link delay + LAN delay

  = 2 sec + minutes + usecs

problem: large delays at high utilization!



Caching example: buy a faster access link

Scenario:

- access link rate: ~~1.54~~ 154 Mbps
- RTT from institutional router to server: 2 sec
- Web object size: 100K bits
- Average request rate from browsers to origin servers: 15/sec
  - average data rate to browsers: 1.50 Mbps