Application Layer

Computer Networks

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CS4054 - 2025I
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SRC: KUROSE – COMPUTER NETWORKS BOOK
PETERSON AND DAVIE – COMPUTER NETWORKS BOOK

Executive Summary

- **Motivation: Network conceptual and implementation aspects can lead to complex applications.**
- **Problem: We need details of the layered network abstraction and its relationship with applications.**
- **Overview:**

 - Layered network review.

 - Application layer and transport relationship

 - Review of two important applications: HTTP and STMP

- **Conclusion: We introduced fundamental aspects of well-known applications such as web HTTP and mail.**

Outline

Introduction

Processes and sockets

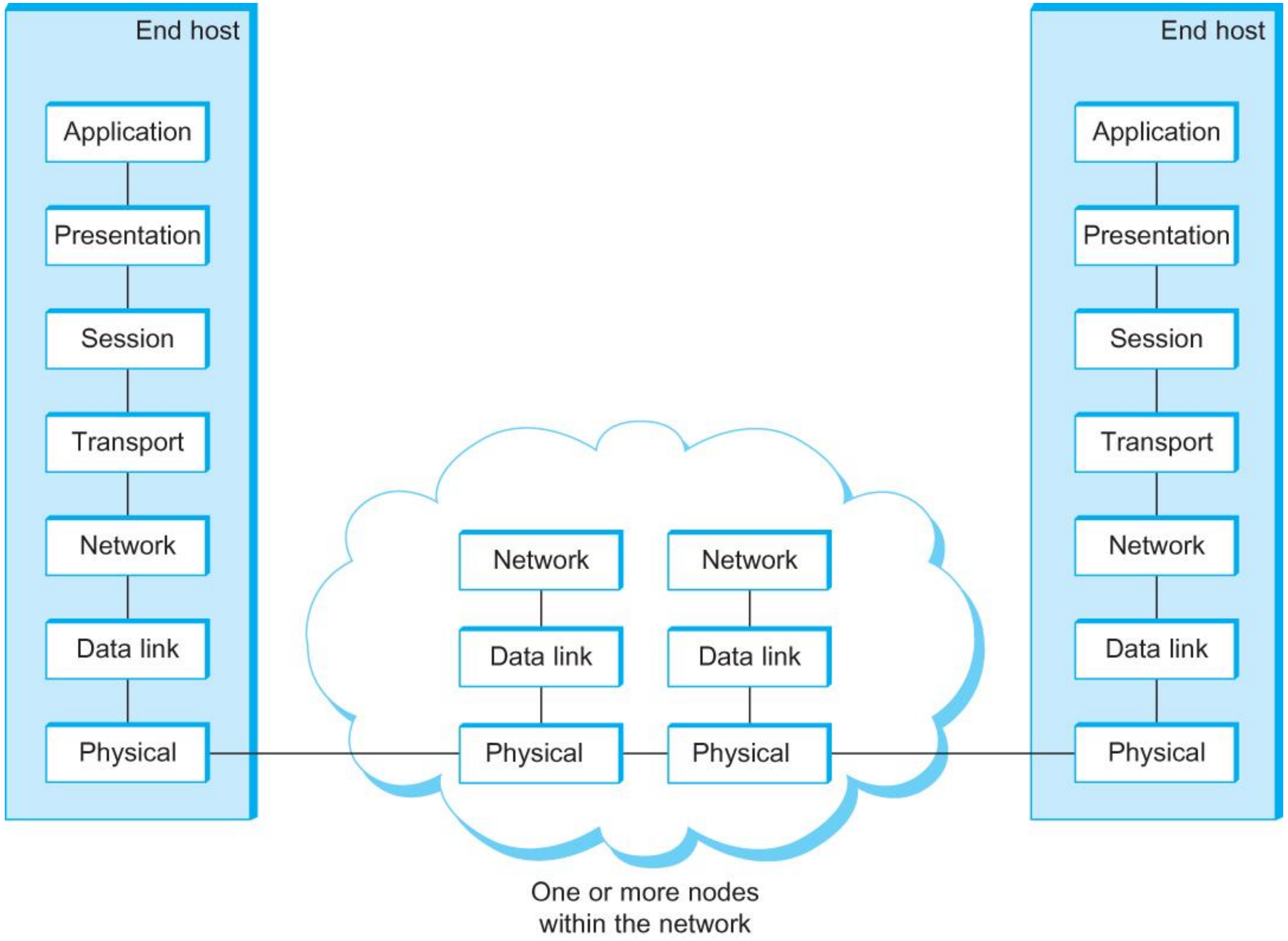
Application layer and protocols

HTTP

SMTP

Conclusions

Recall: OSI Architecture



One or more nodes
within the network

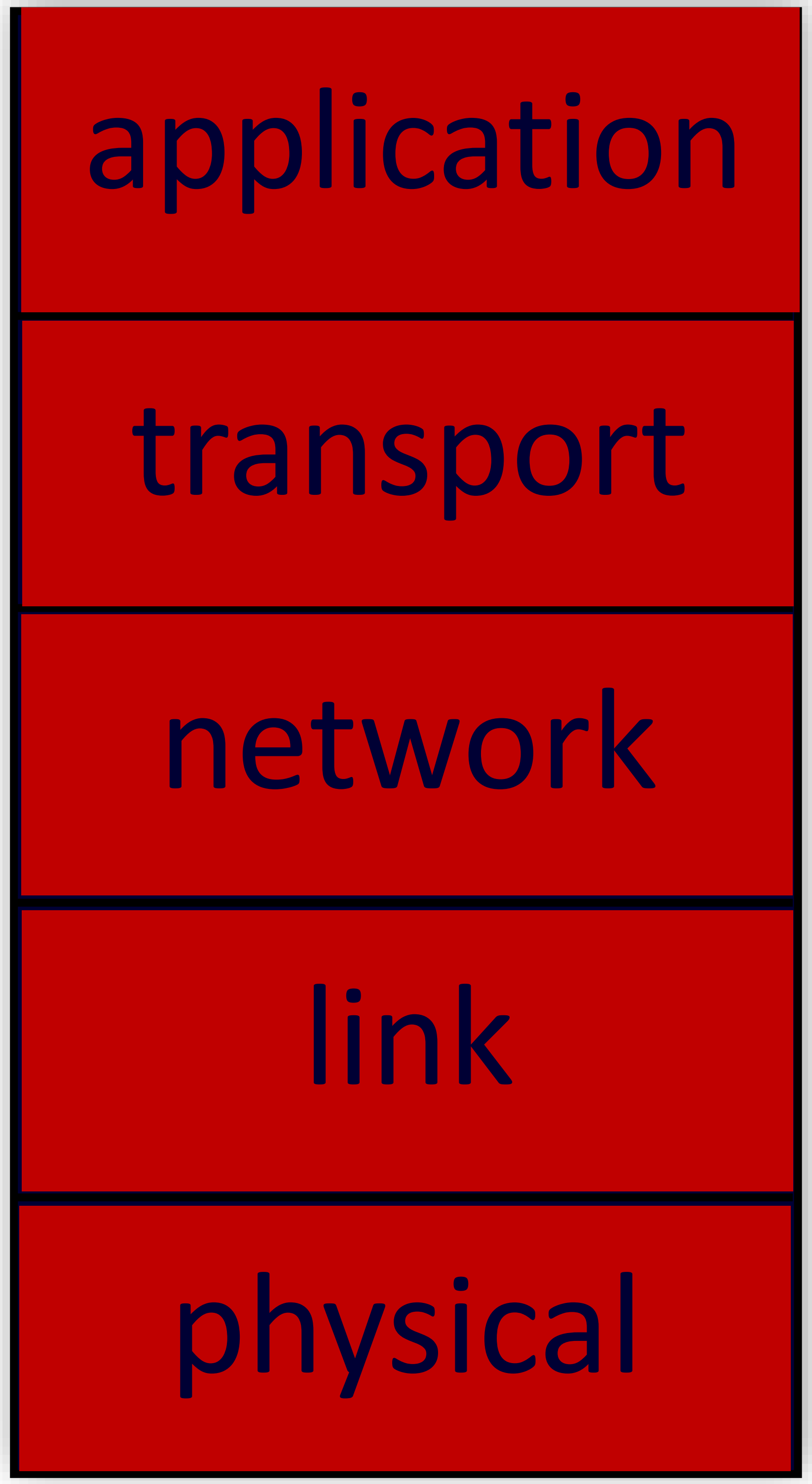
OSI 7-layer Model

OSI – Open Systems Interconnection

- **As a layer standard for network architecture.**

Recall: Layered Internet protocol stack

- *application:* supporting network applications
  - HTTP, IMAP, SMTP, DNS
- *transport:* process-process data transfer
  - TCP, UDP
- *network:* routing of datagrams from source to destination
  - IP, routing protocols
- *link:* data transfer between neighboring network elements
  - Ethernet, 802.11 (WiFi), PPP
- *physical:* bits “on the wire”



application

transport

network

link

physical

Some network apps

- e-mail
- web
- text messaging
- remote login
- P2P file sharing
- multi-user network games
- streaming stored video (YouTube, Hulu, Netflix)

possible structure of applications:

- client-server: usual architecture
- peer-to-peer (P2P): we will cover this in detail next week

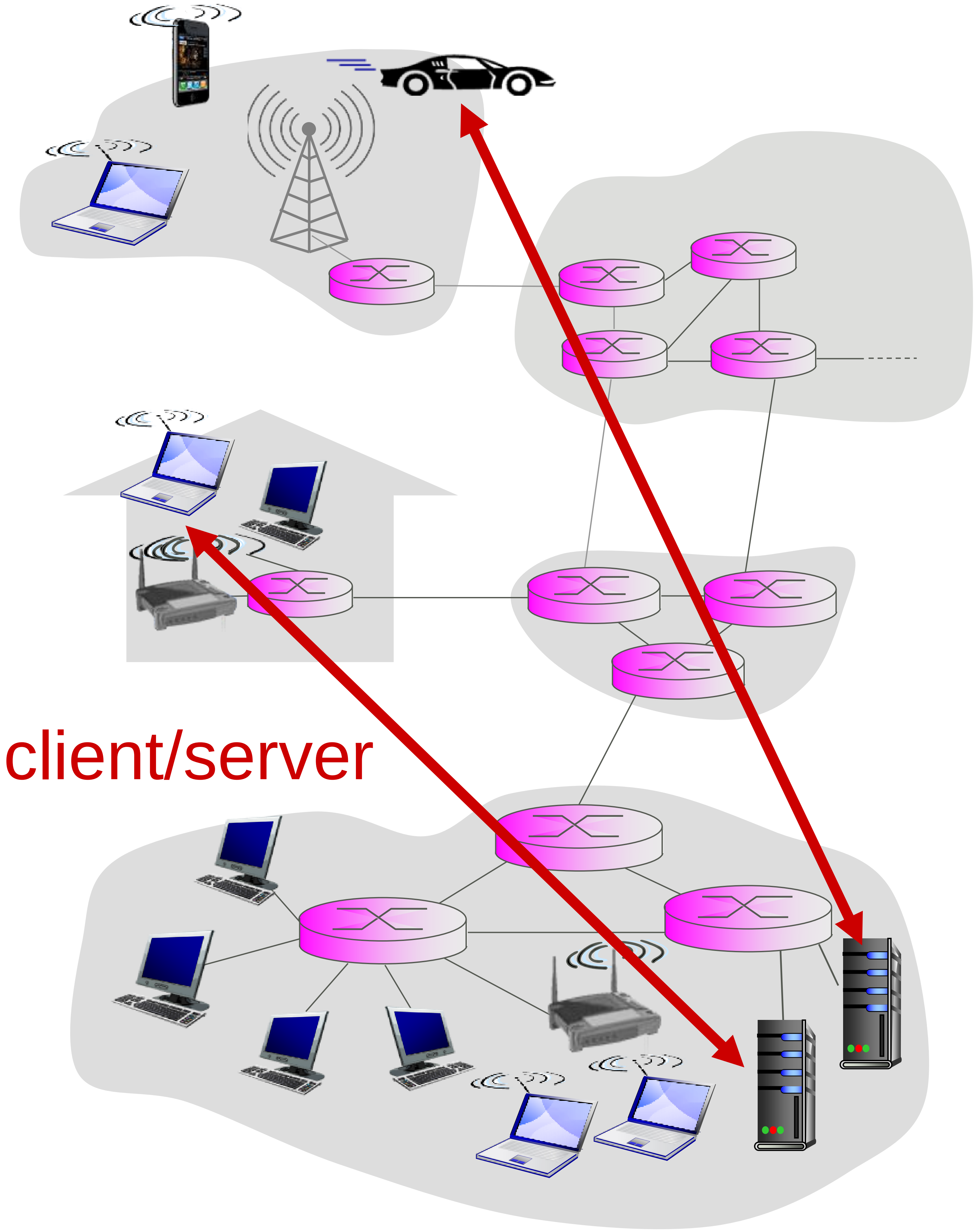
Client-server architecture

server:

- always-on host
- permanent IP address
- data centers for scaling

clients:

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



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Processes communicating

process: program running within a host

- within same host, two processes communicate using inter-process communication (defined by OS)
- processes in different hosts communicate by exchanging messages

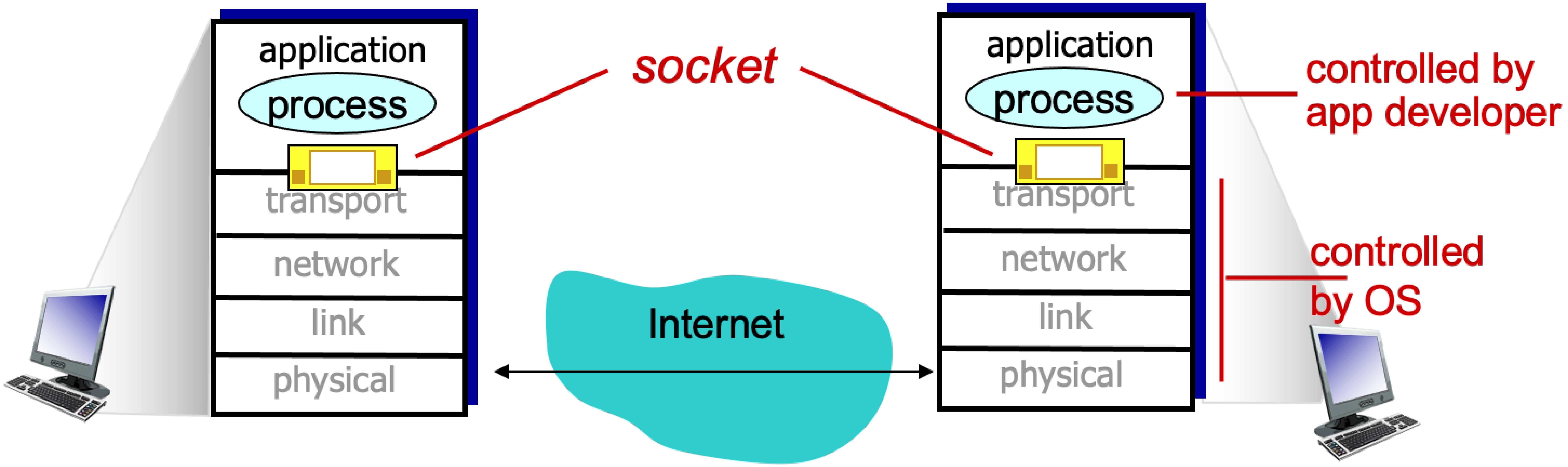
clients, servers

client process: process that initiates communication

server process: process that waits to be contacted

Sockets

- process sends/receives messages to/from its socket
- socket analogous to door
  - sending process shoves message out door
  - sending process relies on transport infrastructure on other side of door to deliver message to socket at receiving process



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App-layer protocol defines

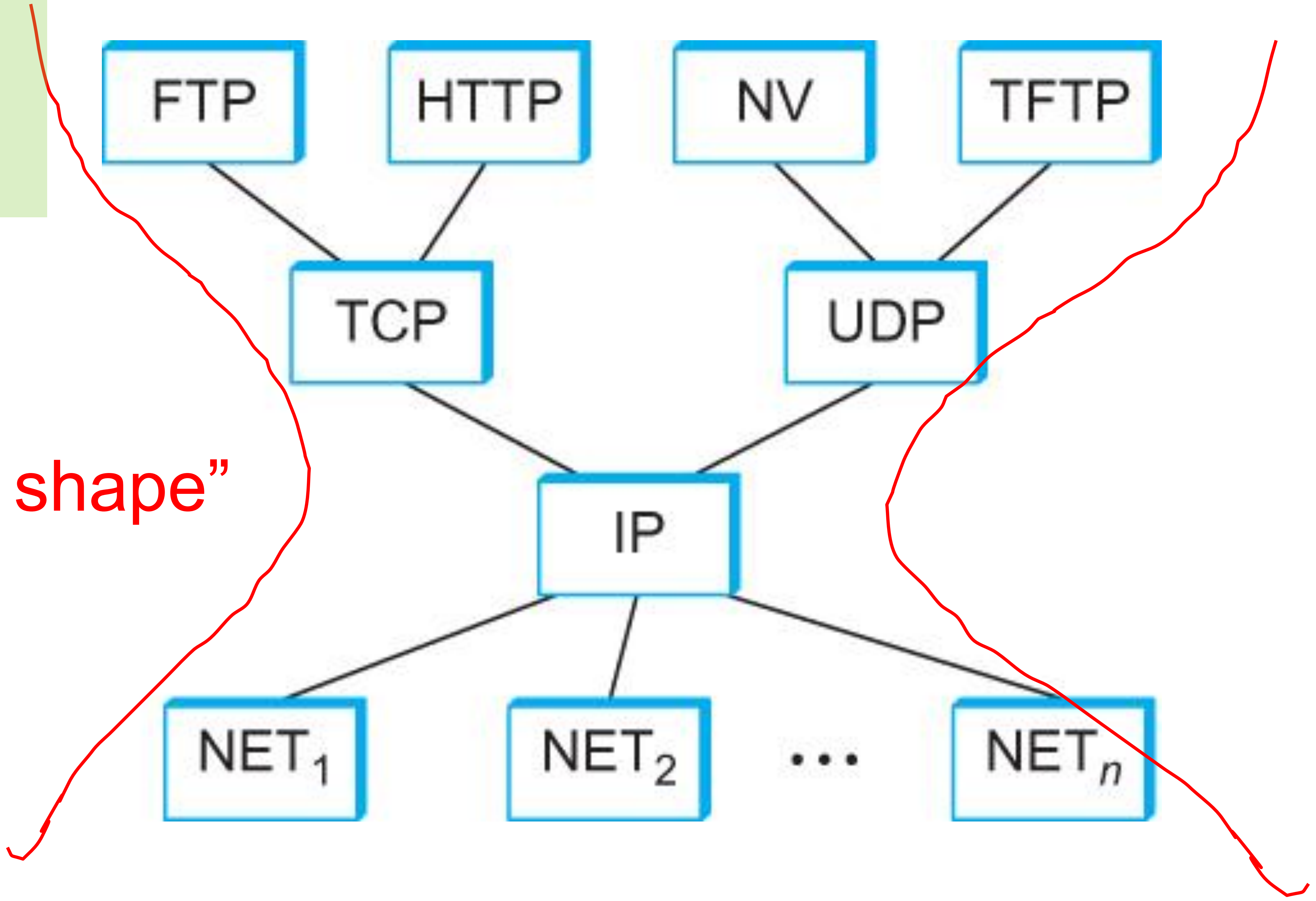
- types of messages exchanged,
  - e.g., request, response
- message syntax:
  - what fields in messages & how fields are delineated
- message semantics
  - meaning of information in fields
- rules for when and how processes send & respond to messages

open protocols:
defined in RFCs
allows for interoperability
e.g., HTTP, SMTP
proprietary protocols:
e.g., Skype

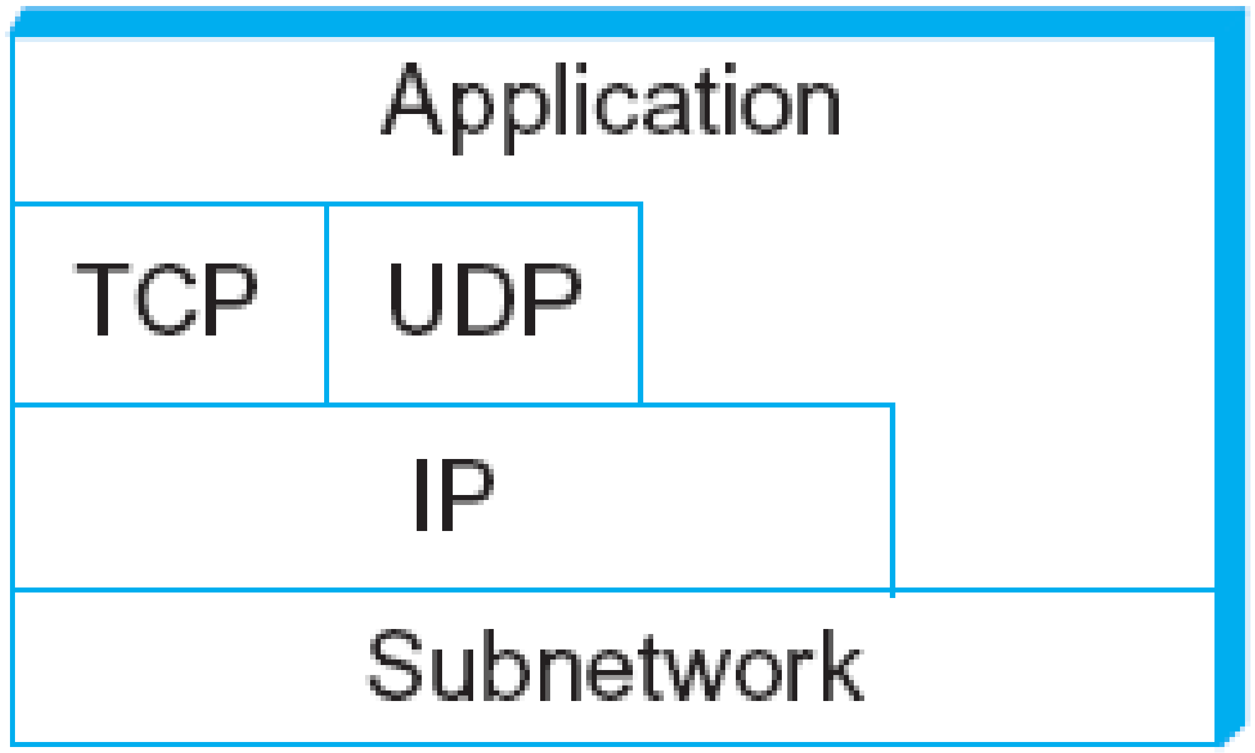
Recall: Internet Architecture Protocol Graph

We are here

“Hourglass shape”



Internet Protocol Graph

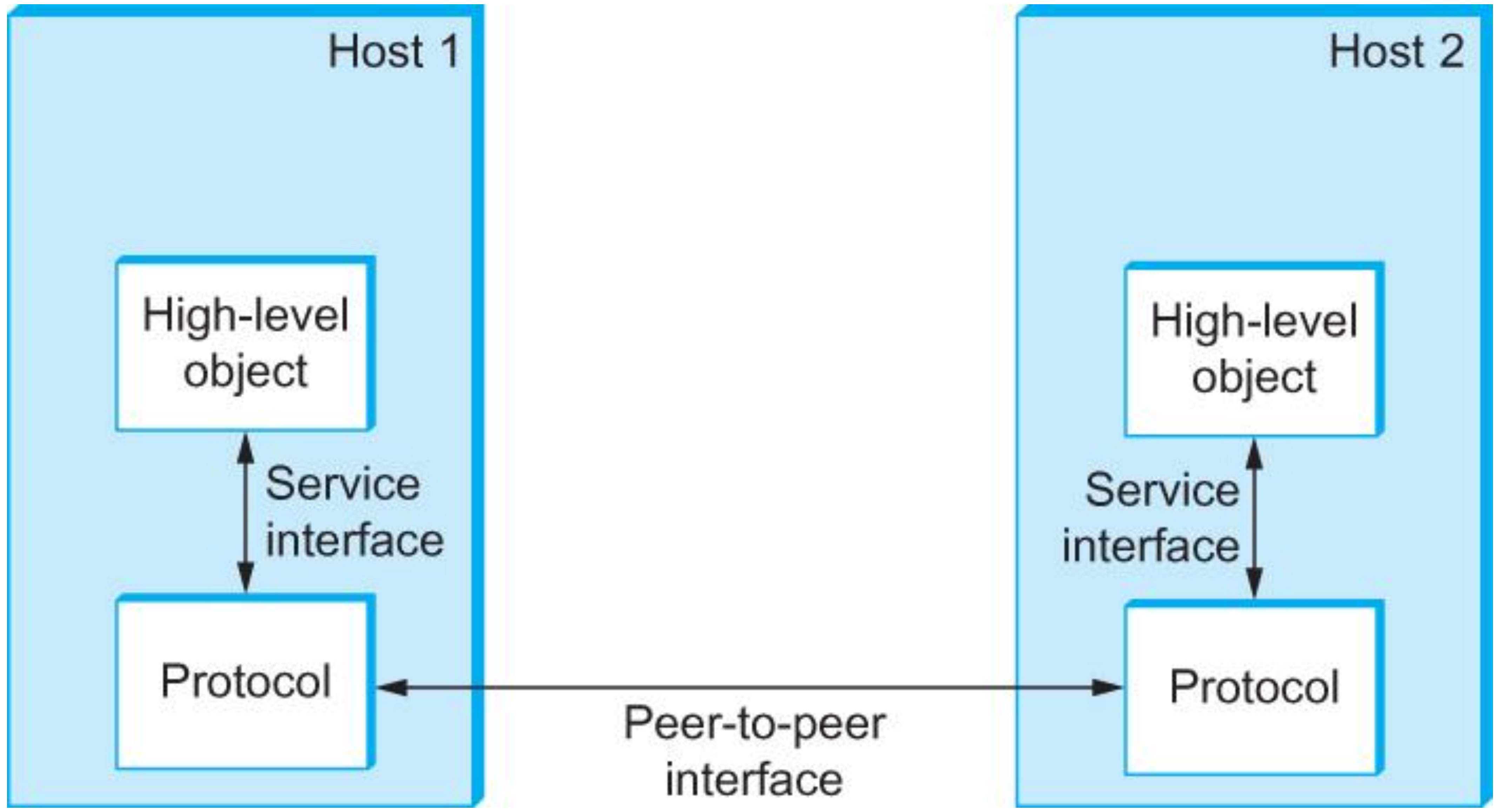


Alternative view of the Internet architecture. The “Network” layer shown here is sometimes referred to as the “sub-network” or “link” layer.

Recall: Protocols and Interfaces

- Defines the interfaces between **the layers (more later)** in the same system and with the layers of peer system
- **Building blocks** of a network architecture

- **Each protocol object has** two different interfaces
  1. **service interface:** operations on this protocol
  2. **peer-to-peer interface:** messages exchanged with peer



Service and Peer Interfaces

Transport layer provides to the App layer

1. data integrity

some apps (e.g., file transfer, web transactions) require 100% reliable data transfer

other apps (e.g., audio) can tolerate some loss

2. security

encryption, data integrity, …

3. throughput

some apps (e.g., multimedia) require minimum amount of throughput to be "effective"

other apps ("elastic apps") make use of whatever throughput they get

Transport service requirements: common apps

application	data loss	throughput	time sensitive
file transfer	no loss	elastic	no
e-mail	no loss	elastic	no
Web documents	no loss	elastic	no
real-time audio/video	loss-tolerant	audio: 5kbps-1Mbps video:10kbps-5Mbps	yes, 100's msec
stored audio/video	loss-tolerant	same as above	yes, few secs
interactive games	loss-tolerant	few kbps up	yes, 100's msec
text messaging	no loss	elastic	yes and no

Internet apps: application, transport protocols

application	application layer protocol	underlying transport protocol
e-mail	SMTP [RFC 2821]	TCP
remote terminal access	Telnet [RFC 854]	TCP
Web	HTTP [RFC 2616]	TCP
file transfer	FTP [RFC 959]	TCP
streaming multimedia	HTTP (e.g., YouTube), RTP [RFC 1889]	TCP or UDP
Internet telephony	SIP, RTP, proprietary (e.g., Skype)	TCP or UDP

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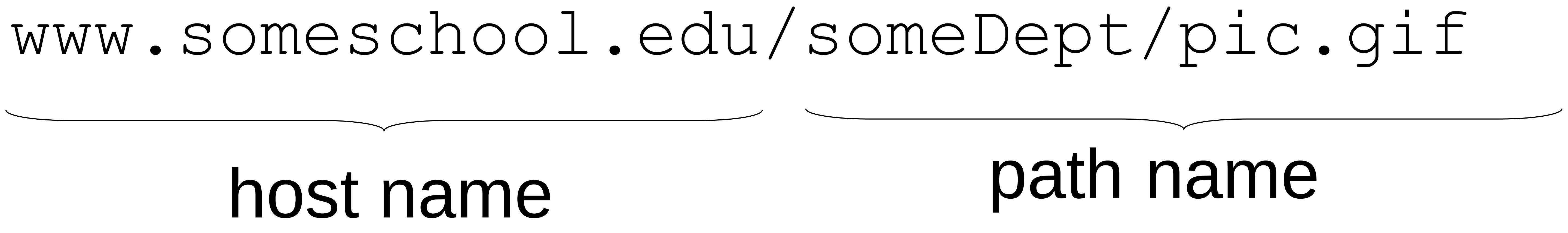
Web and HTTP

First, a review…

- *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,* e.g.,

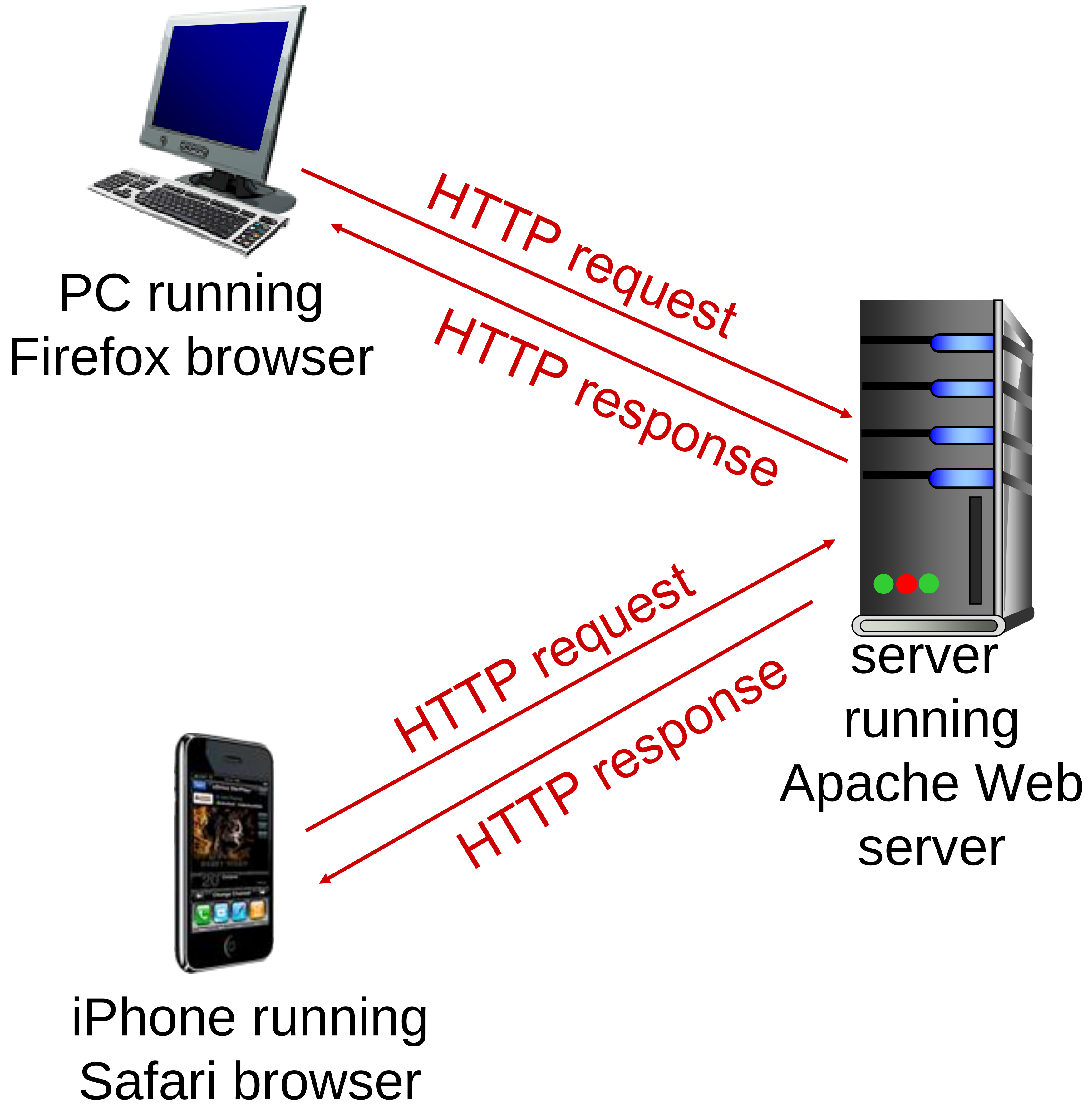


```
www.someschool.edu/someDept/pic.gif
```

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)

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

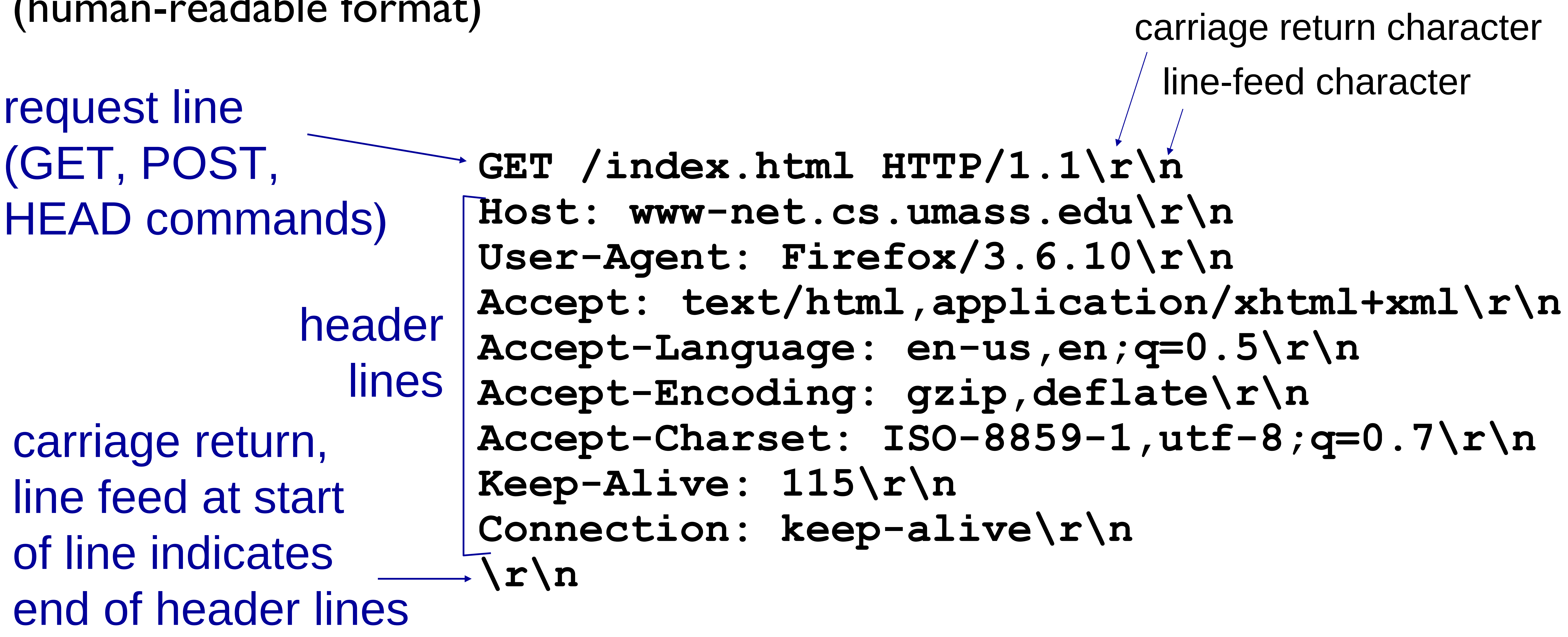
aside

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 request message

- two types of HTTP messages: *request, response*
- HTTP request message:
  - ASCII (human-readable format)



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
```

HTTP response message

status line (protocol status code status phrase)

header lines

data, e.g., requested HTML file

```
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 ...
```

* Check out the online interactive exercises for more examples: http://gaia.cs.umass.edu/kurose_ross/interactive/

User-server state: cookies

Why?

HTTP is "stateless"
server maintains no information about past client requests

many Web sites use cookies

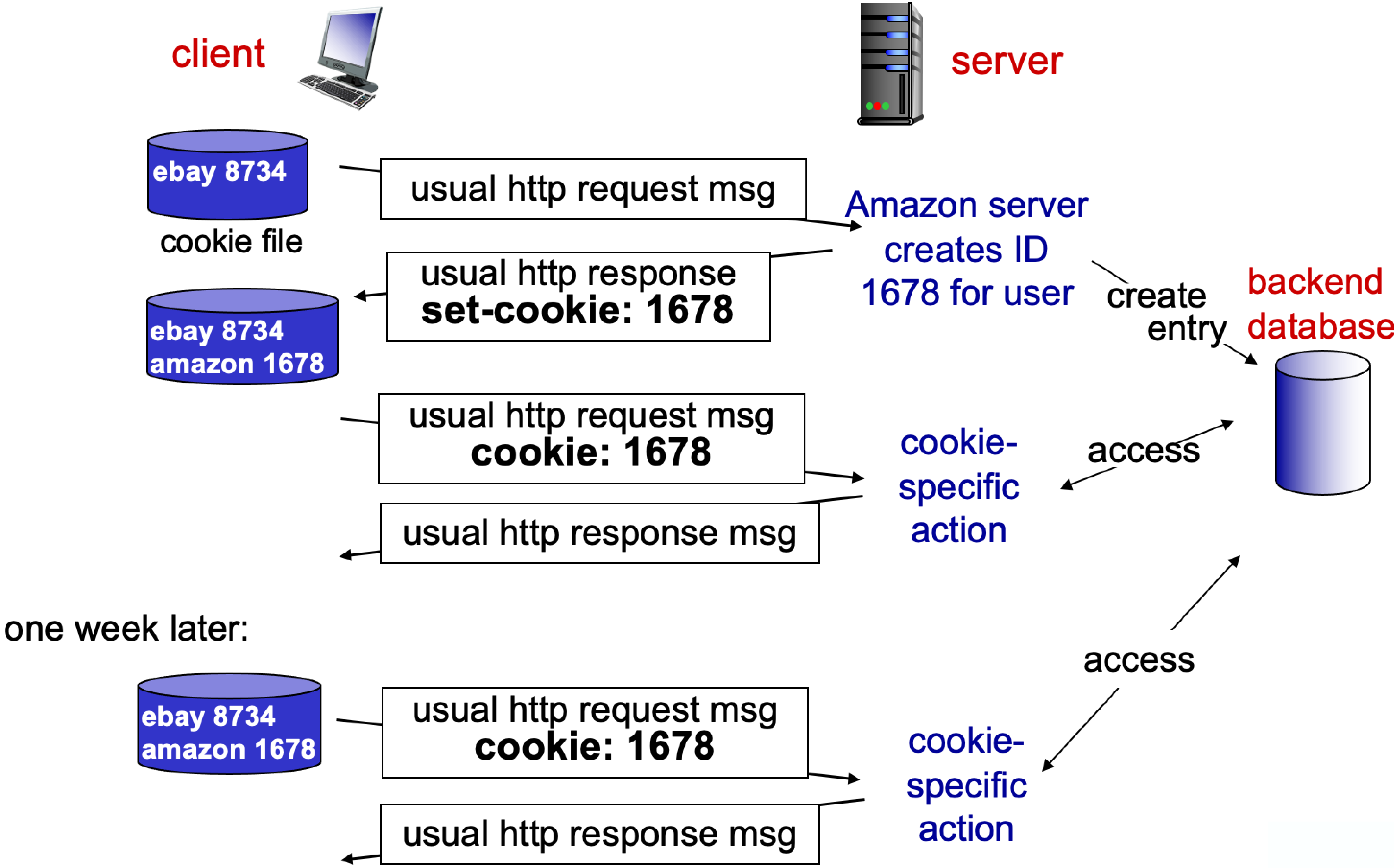
four components:

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 always access Internet from PC**
- **visits specific e-commerce site for first time**
- **when initial HTTP requests arrives at site, site creates**
  - unique ID
  - entry in backend database for ID

Cookies: keeping "state" (cont.)



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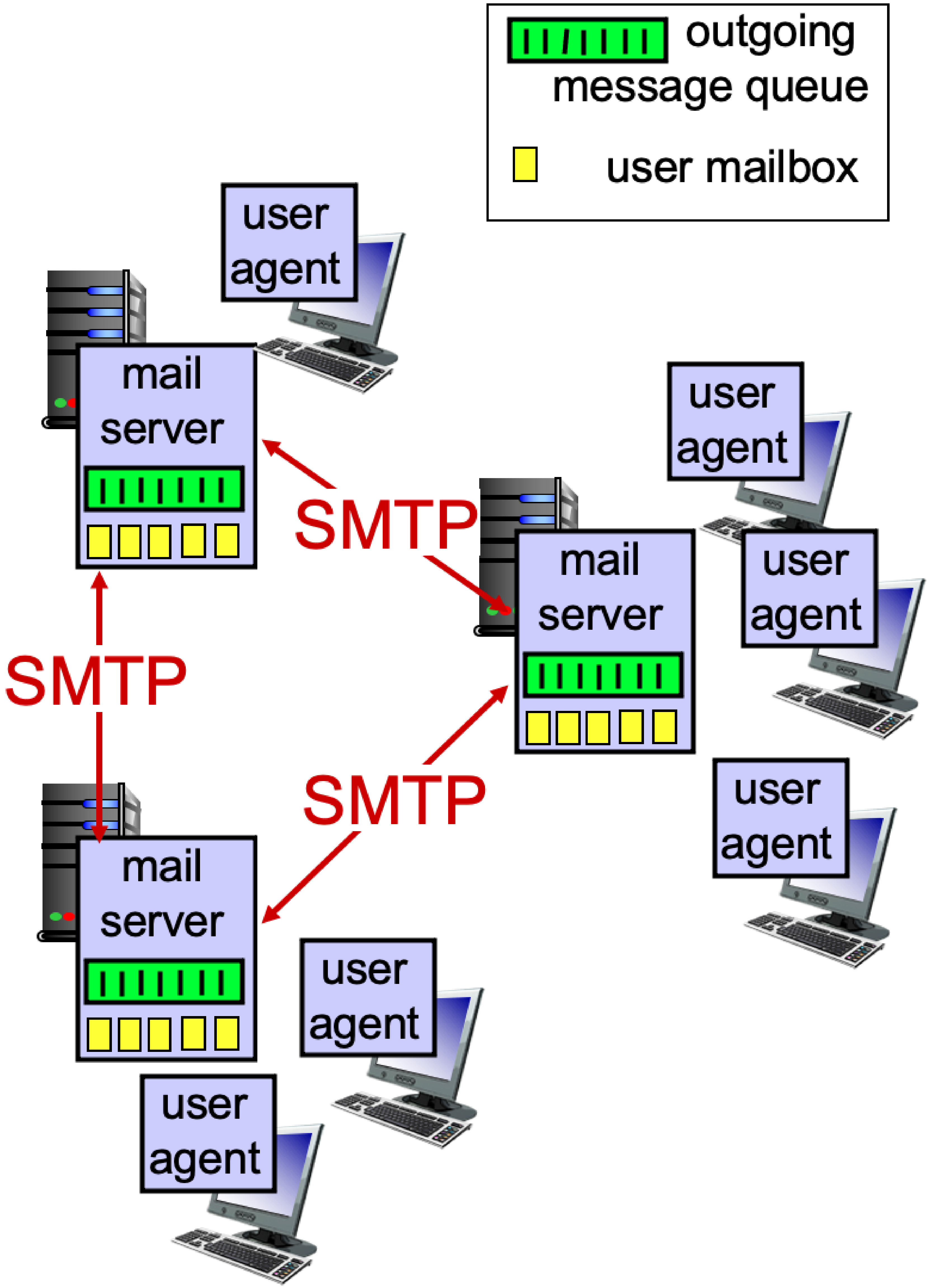
Electronic mail

Three major components:

- user agents
- mail servers
- simple mail transfer protocol: SMTP

User Agent

- a.k.a. "mail reader"
- composing, editing, reading mail messages
- e.g., Outlook, Thunderbird, iPhone mail client
- outgoing, incoming messages stored on server



Electronic Mail: SMTP [RFC 2821]

- uses TCP to reliably transfer email message from client to server, port 25
- direct transfer: sending server to receiving server
- three phases of transfer
  - handshaking (greeting)
  - transfer of messages
  - closure
- command/response interaction (like HTTP)
  - commands: ASCII text
  - response: status code and phrase
- messages must be in 7-bit ASCI

SMTP: final words

- SMTP uses persistent connections
- SMTP requires message (header & body) to be in 7-bit ASCII
- SMTP server uses `CRLF.CRLF` to determine end of message

comparison with HTTP:

- **HTTP: pull**
- **SMTP: push**

- **both have ASCII command/response interaction, status codes**

- **HTTP: each object encapsulated in its own response message**
- **SMTP: multiple objects sent in multipart message**

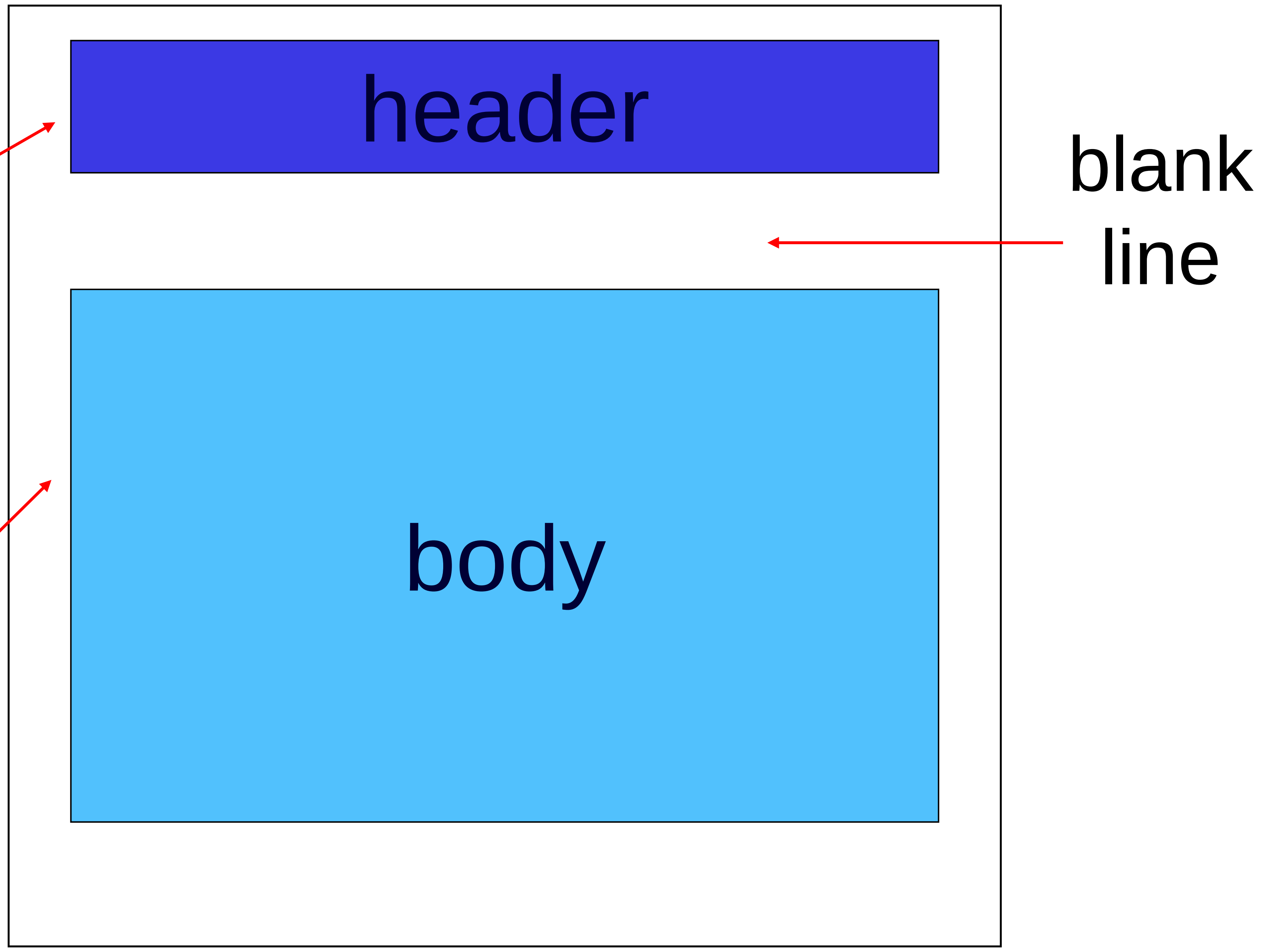
Mail message format

SMTP: protocol for exchanging email messages

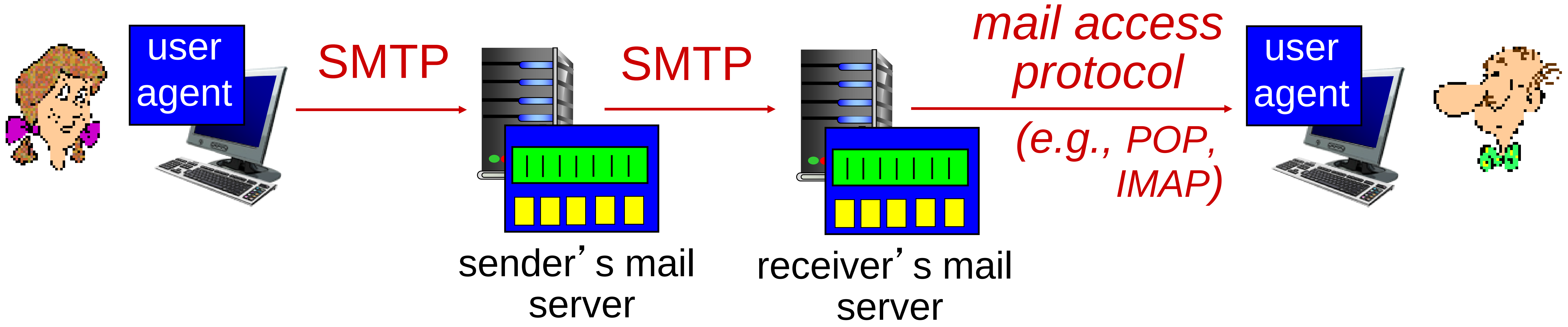
RFC 822: standard for text message format:

- header lines, e.g.,
  - To:
  - From:
  - Subject:

  different from SMTP MAIL FROM, RCPT TO: commands!
- Body: the "message"
  - ASCII characters only



Mail access protocols



- SMTP: delivery/storage to receiver's server
- mail access protocol: retrieval from server
  - POP: Post Office Protocol [RFC 1939]: authorization, download
  - IMAP: Internet Mail Access Protocol [RFC 1730]: more features, including manipulation of stored messages on server
  - HTTP: gmail, Hotmail, Yahoo! Mail, etc.

Outline

Course Logistics

Introduction

Internet Structure

Internet as a Service

Internet Architecture

Conclusions

Summary

We review the Internet, from the:

- Structure perspective
- Application perspective

- **Both perspectives are important,** each one relies on the other for standarization.
- **Internet is a network of computer network,** that follow protocols and it is organized (by astraction) as layers.