CSCE 463/612
Networks and Distributed Processing
Fall 2024

Application Layer

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Updates

```
http://x.com/path:900
http://x.com?script:900/
http://x.com?script/
http://x.com:8800?script:/
```

- URLs to try the parser on →
- Quiz next time (entire class), variation on problems 5-33 at the end of chapter 1
  - More questions based on my programming tutorial (pointers, bits ops, debugging, Windows datatypes)
- Examine this fragment:
- Issues include
  - Inefficient recv
  - Buffer overflow when page exceeds 10 MB
  - Deadlock on errors
  - Probably stack overflow if buf declared in a function

```
#define HUGE 10000000          // 10 MB
char buf [HUGE], *ptr = buf;
while((bytes = recv (sock, ptr, 100, 0)) != 0)
          ptr += bytes;

*ptr = NULL;
len = ptr – buf;
```

Robots.txt

- Websites are crawled by many automated programs
  - This potentially consumes large volumes of traffic
- Besides bandwidth, concerns arise about protected or human-only portions of websites
  - Shopping carts, registration pages, posting into forums
- Webmasters need a mechanism to indicate prohibited request prefixes within their sites
  - These are given in /robots.txt

```
User-agent: *
Disallow: /search
Disallow: /sdch
Disallow: /groups
Disallow: /images
Disallow: /catalogs
Allow: /catalogs/about
Allow: /catalogs/p?
Disallow: /catalogues
```

- Directives are parsed in order, until first match
  - Algorithm has become ambiguous in recent years: Google crawlers use the longest-prefix match

Robots.txt 2

- Despite being around since 1994, robots.txt is not a standard, but rather a suggestion on politeness
  - See http://robotstxt.org
- Extensions to robots.txt (even less official)
  - Crawl-delay specifies the # of seconds between visits
  - Sitemap points to an XML file that lists all available documents
  - Wildcards in directory paths (* and $ = ends with)

```
User-agent: *
Disallow: /*.asp$
Disallow: /sdch/*.php
Crawl-delay: 64
Sitemap: http://www.google.com/sitemaps_webmasters.xml
```

- How often should robots.txt be reloaded?
  - Original spec doesn't say; Google uses 1 day by default

Chapter 2: Roadmap

2.1 Principles of network applications

2.2 Web and HTTP

2.3 FTP

2.4 Electronic Mail

- SMTP, POP3, IMAP

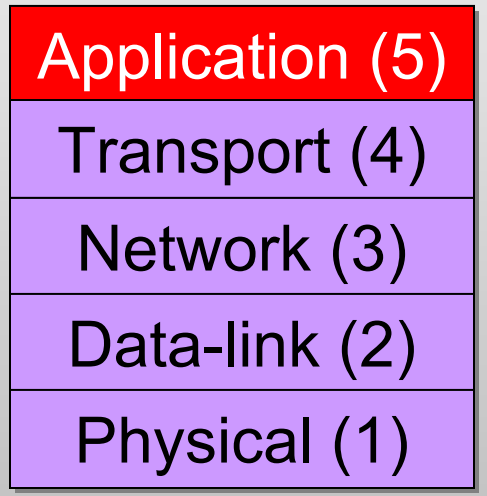
2.5 DNS

2.6 P2P file sharing

2.7 Socket programming with TCP

2.8 Socket programming with UDP

2.9 Building a Web server



Some Network Applications

- E-mail
- Remote login
- Web
- Instant messaging
- P2P file sharing
- Multi-user network games
- Streaming video
- Internet telephone
- Thermostat
- House alarm
- Real-time video conferencing
- Massively parallel computing
- Phones, tablets
- Internet fridge, TV

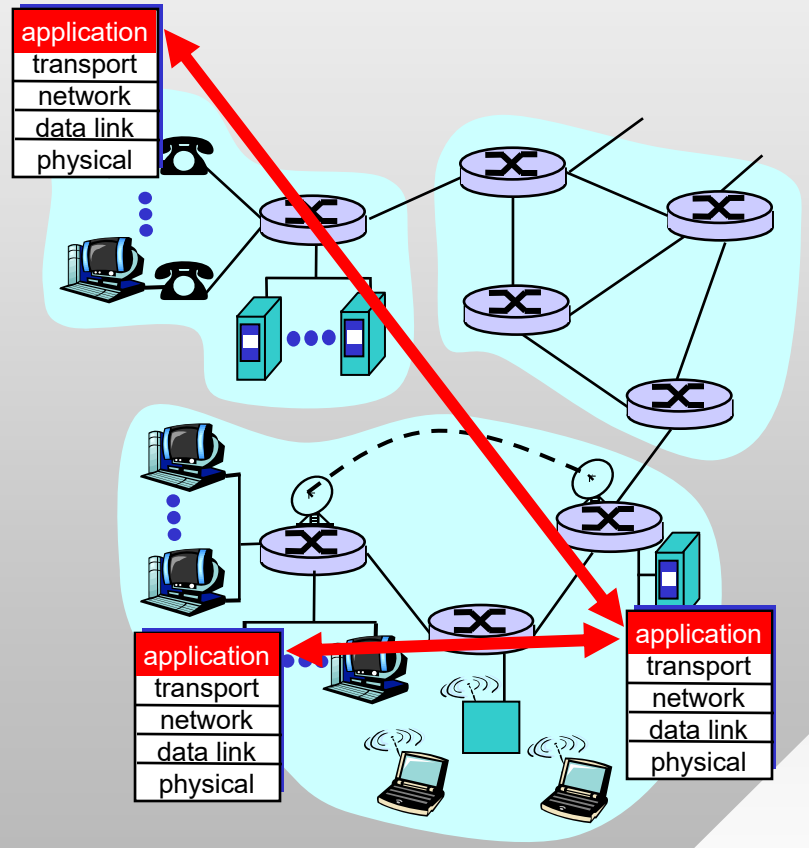
Creating a Network Application

Programs that

- Usually interact with user
- Communicate over a network
- E.g., Web server software communicates with browser software

No software written for devices in network core

- Network core devices do not function at app layer
- This design allows for rapid application development



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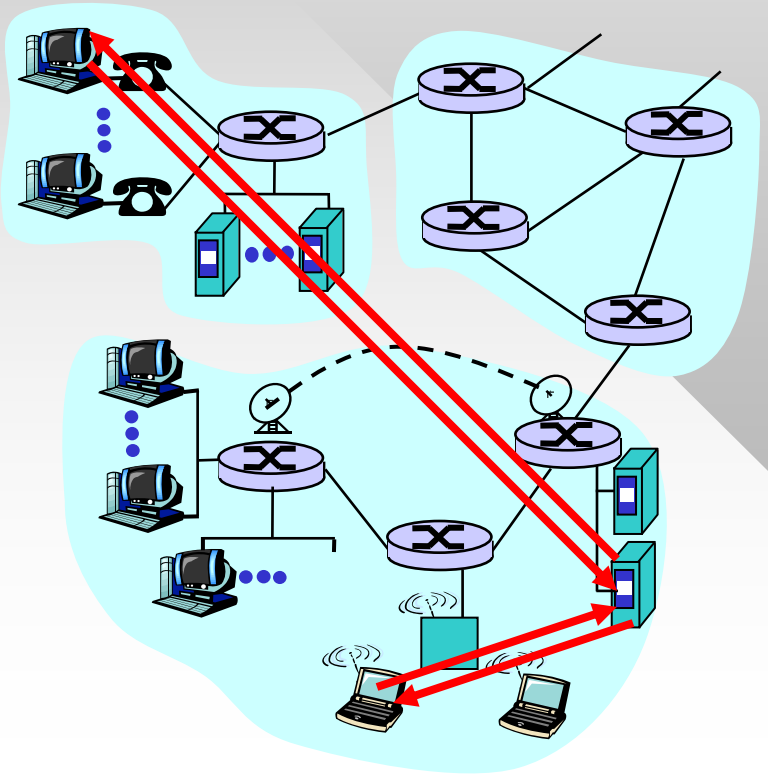
Communication Principles

- Three architectures
  - Client-server
  - Peer-to-peer (P2P)
  - Hybrid



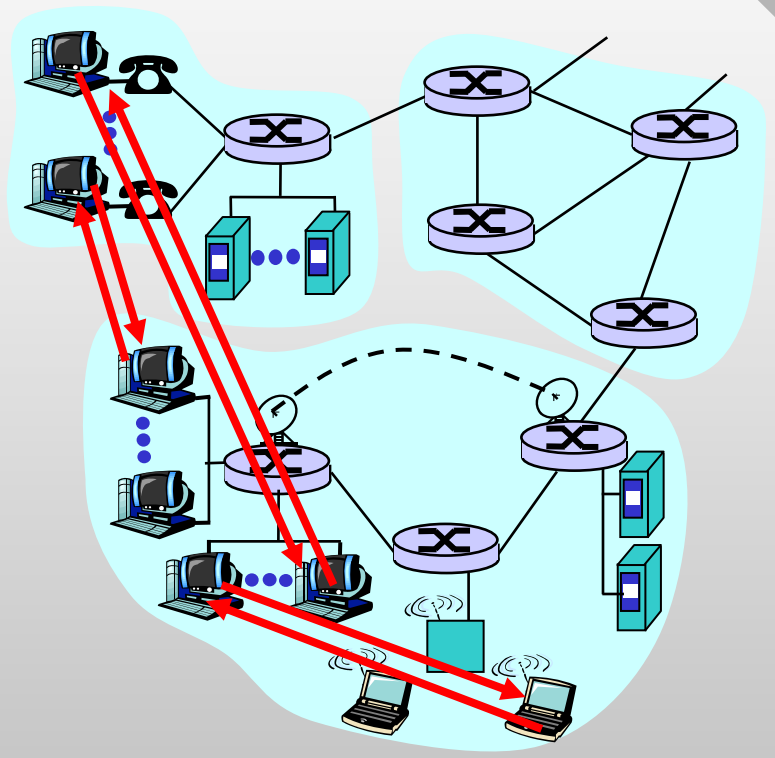
Server:

- An always-on host
- Permanent IP address or hostname
- Server farms for scaling

Clients:

- May be intermittently connected
- May have dynamic IP addresses and hostnames
- Do not communicate directly with each other, only talk to servers

P2P Architecture



- No always-on server
- Arbitrary end systems directly communicate
- Peers are intermittently connected and change IP addresses/hostnames
- Example: Gnutella
  - Distributed graph between users over TCP connections
- Highly scalable: assume 6M users with 1GB of shared data and 500 Kbps upstream bandwidth
  - 6 PB of storage, 3 Tbps bandwidth for free
- Downside – difficult to provide reliable service

Hybrid Architecture

Napster

- File transfer P2P, but search is centralized
  - Peers register content at central server
  - Peers query same central server to locate content

Instant messaging

- Login and chatrooms are centralized
  - User registers its IP address with central server
  - User contacts server to find IP addresses of friends or participate in chatrooms
  - But private chat is P2P (e.g., legacy Skype relayed data through other live peers)

Process Communication

- Process: program running within a host
- Within same host, two processes communicate using inter-process communication (semaphore, mutex, pipe, shared memory)
- Processes in different hosts communicate by exchanging messages

- Client: process that initiates communication
- Server: process that waits to be contacted

- Applications with P2P architecture act as both client & server

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Web and HTTP

Terminology

- Web page consists of a base HTML-file that may include references to external objects
  - Examples of objects: JPEG image, Java applet, audio file, video stream, or flash animation
- Each object is addressable by a URL (Uniform Resource Locator) with the HTTP scheme

```
http://[user:pass@]host[:port][/path][?query][#fragment]
```

  - Username/password not used anymore
  - Fragement specifies portion of HTML for browser to jump to
  - Query provides input arguments to scripts

HTTP Overview

- HTTP: HyperText Transfer Protocol
  - HTTP 1.0: RFC 1945 (1996)
  - HTTP 1.1: RFC 2068 (1997), RFC 2616 (1999)
  - HTTP 2: RFC 7540 (2015), binary protocol over TCP
  - HTTP 3: RFC 9114 (2022), QUIC over UDP
- Nonpersistent HTTP
  - At most one object is sent over a TCP connection
  - HTTP/1.0 must use nonpersistent HTTP
- Persistent HTTP
  - Multiple objects sent over single TCP connection
  - HTTP/1.1 uses persistent connections by default
  - Field “Connection: close” overrides this behavior

Nonpersistent HTTP

(contains text, references to 10 jpeg images)

Suppose user enters URL

`www.tamu.edu/someDepartment/home.html`

1a. Client initiates TCP connection to server process at www.tamu.edu using port 80

1b. Server at host www.tamu.edu waiting for TCP connection on port 80 accepts connection, notifies client

2. Client sends HTTP *request message* (containing URL) into TCP socket. Message indicates object /someDepartment/home.html

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

time

Nonpersistent HTTP (Cont.)

4. Server closes TCP connection

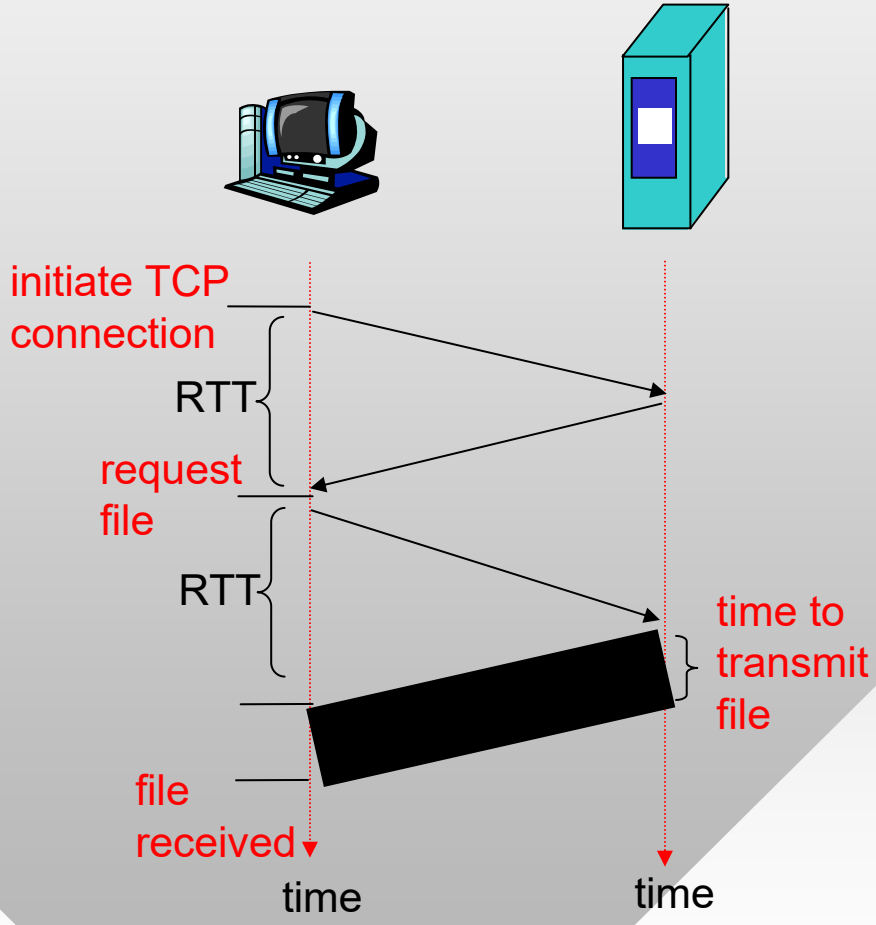
5. Client receives response message containing the html file, displays html. Parsing html file, finds 10 referenced jpeg objects

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

Response Time Modeling

- RTT (Round-Trip Time):
  - Delay for a small packet to travel from client to server and back
- Response time:
  - One RTT to initiate TCP connection
  - One RTT for HTTP request and first few bytes of HTTP response to return
  - File transmission time

total = 2RTT + file load time



Persistent HTTP

HTTP/2 allows out-of-order replies, fragmentation of objects, and prioritization

Nonpersistent HTTP issues:

- Requires two RTTs per object
- Workaround: browsers open parallel TCP connections to fetch referenced objects
- OS must work and allocate host resources for each TCP connection

Persistent HTTP

- Server leaves connection open after sending response
- Subsequent HTTP messages between same client/server are sent over connection

Persistent without pipelining:

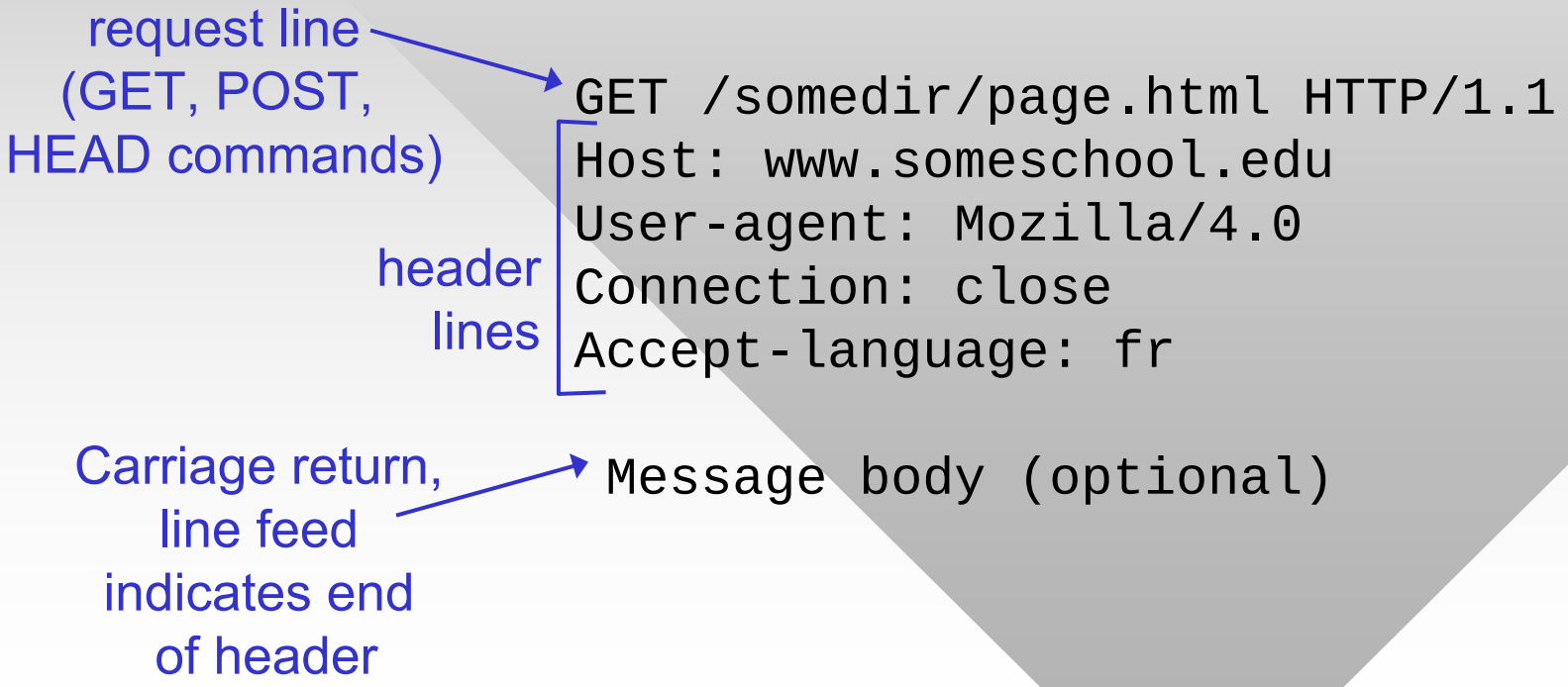
- Client issues new request only when previous response has been received
- One RTT for each referenced object + its transmission time

Persistent with pipelining:

- Default in HTTP/1.1
- Client sends requests as soon as it encounters a referenced object
- One RTT for all referenced objects + their transmission times

HTTP Request Message

- Two types of HTTP messages: *request*, *response*
- HTTP request message:
  - 1.0 and 1.1 use ASCII (human-readable format)



Uploading Form Input

POST method:

- Web page often includes form input
- Input is uploaded to server in entity body
- Used for large amounts of data
  - Data is coded using tuples “field=value”, where + stands for space and & for the field separator

```
POST /map.cgi HTTP/1.0
User-Agent: HTTPTool/1.0
Content-Type: application/x-www-form-urlencoded
Content-Length: 30

city=College+Station&zip=77843
```

Uploading Form Input (Cont'd)

URL method:

- Uses the GET command
- Input is encoded in the URL field of request line
  - Append ? to the script path, followed by the URL-coded data
  - GET /path/script.cgi?field1=value1&field2=value2 HTTP/1.0
- For the previous example
  - GET /map.cgi?city=College+Station&zip=77843 HTTP/1.0
- Google example
  - Javascript forces the URL method:
  - www.google.com/search?hl=en&source=hp&q=computer+science&aq=f&aqi=g10&oq=

Method Types

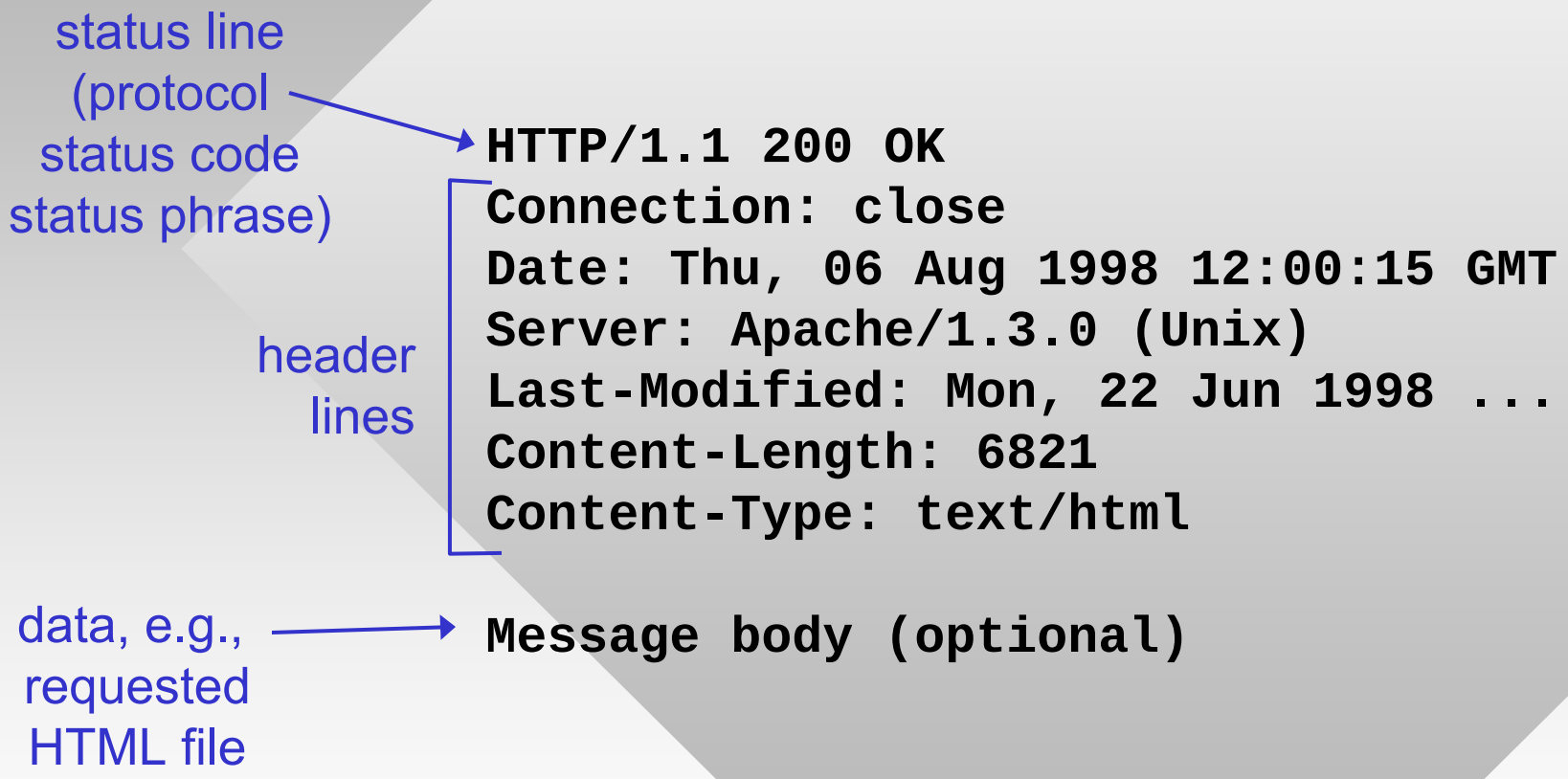
HTTP/1.0

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

HTTP/1.1

- GET, POST, HEAD
- PUT
  - Uploads file to path specified in URL field
- DELETE
  - Deletes file specified in the URL field

HTTP Response Message



HTTP Response Status Codes

- Status code is always in the first line of response
  - Followed by a nice textual explanation
- 200 OK
  - Request succeeded, requested object later in this message
- 301 Moved Permanently
  - Requested object moved, new location specified later in this message (see field Location:)
- 400 Bad Request
  - Request message not understood by server
- 404 Not Found
  - Requested document not found on this server
- 505 HTTP Version Not Supported