

CSCE 463/612

Networks and Distributed Processing
Fall 2025

Application Layer

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Updates

- 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:
- Some of the issues:
 - Inefficient recv
 - Buffer overflow when page exceeds 10 MB
 - Deadlock on errors
 - Probably stack overflow if buf declared in a function

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

```
#define HUGE 100000000          // 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
- Directives are parsed in order, until first match
 - Algorithm has become ambiguous in recent years: Google crawlers use the longest-prefix match

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

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

Application (5)

Transport (4)

Network (3)

Data-link (2)

Physical (1)

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



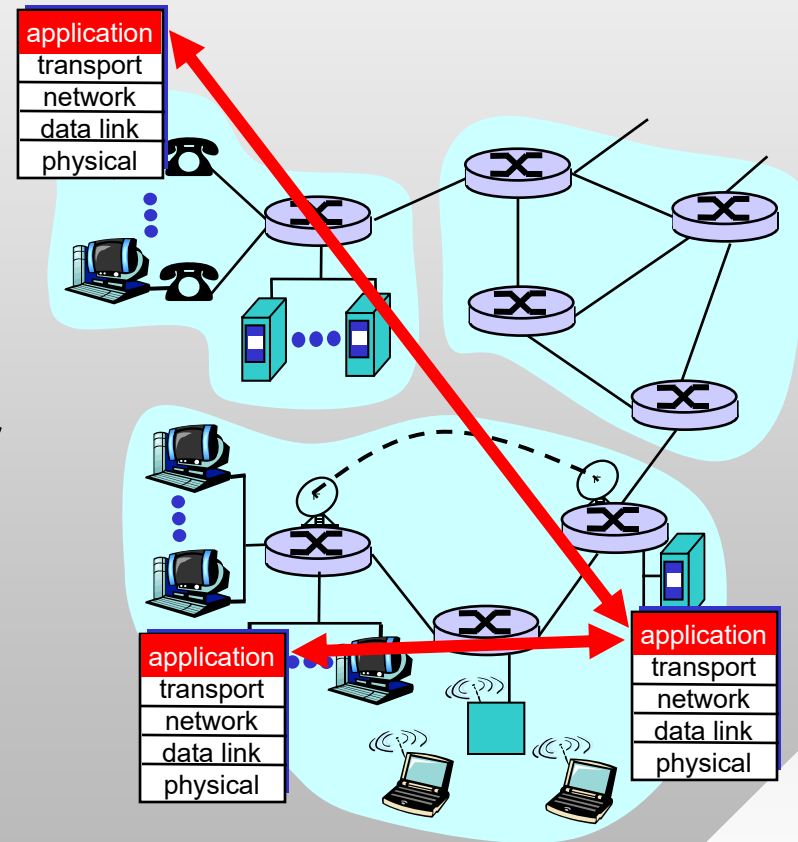
Creating a Network Application

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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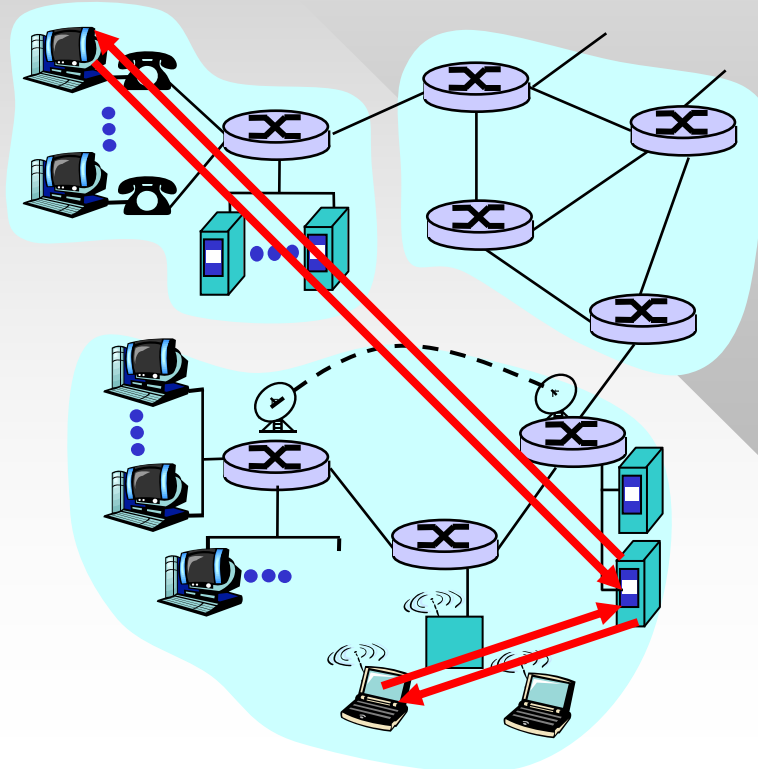
2.7 Socket programming with TCP

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Communication Principles

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



Server:

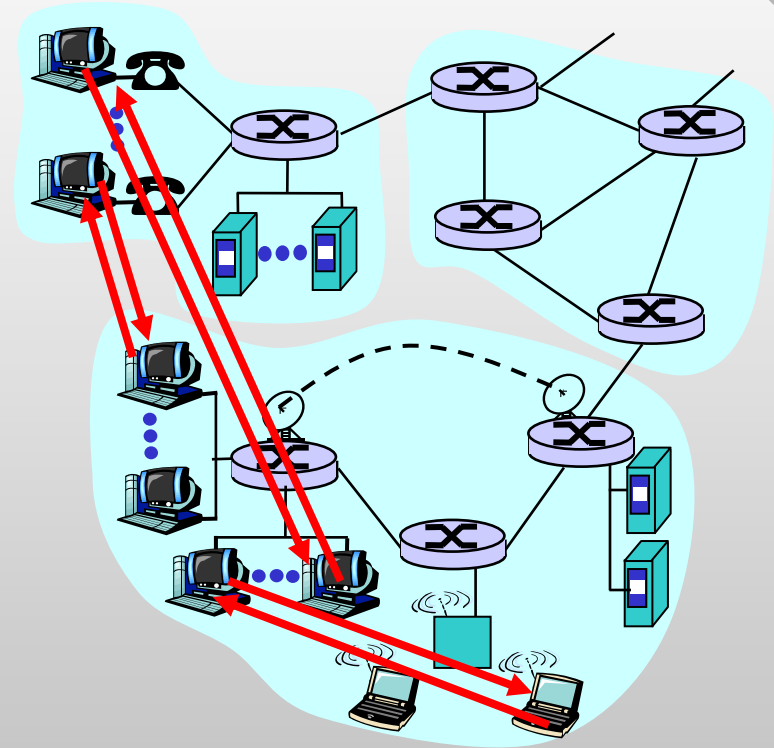
- An **always-on** host
- Permanent IP address or hostname
- Server farms for scaling

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 10 GB of shared data and 20 Mbps upstream bandwidth
 - 60 PB of storage, 120 Tbps bandwidth for free
- Downside – difficult to provide reliable service



Hybrid Architecture

Napster (1999)

- 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 that 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** and possibly multiple 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
- Fragment 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

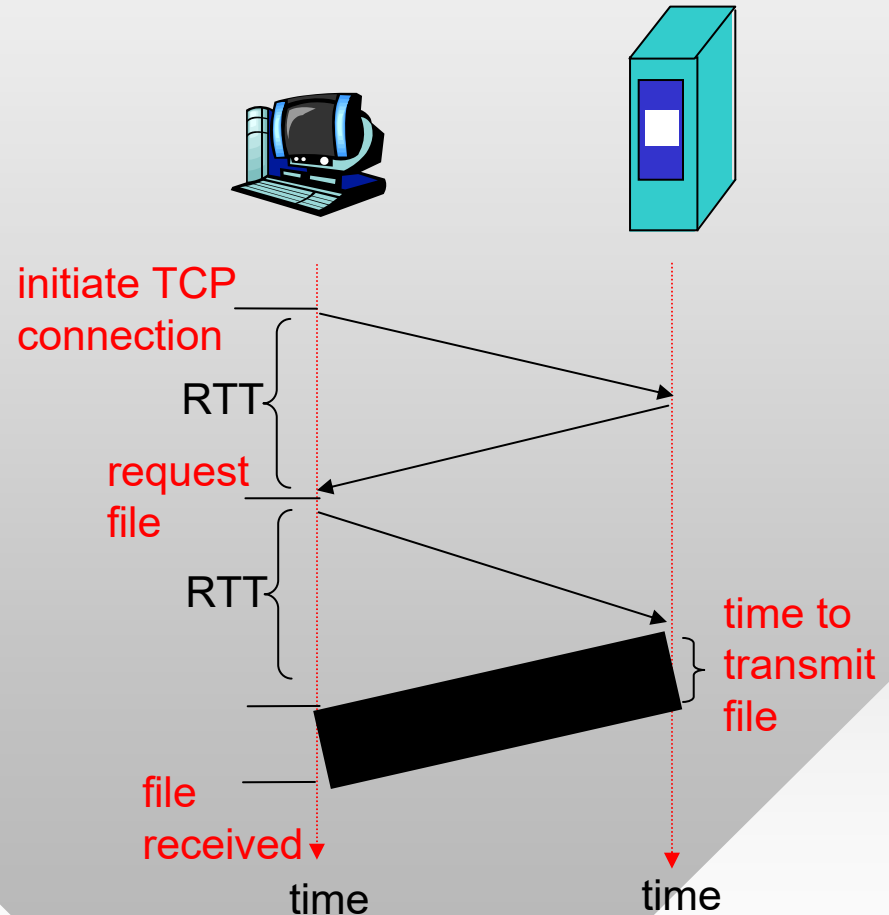


6. Steps 1-5 repeated for each of 10 jpeg objects

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

$\text{total} = 2\text{RTT} + \text{file load time}$



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)

The diagram illustrates the structure of an HTTP request message. It shows a sample request with annotations identifying its parts:

- request line** (GET, POST, HEAD commands) points to the first line: `GET /somedir/page.html HTTP/1.1`
- header lines** points to the subsequent lines: `Host: www.someschool.edu`, `User-agent: Mozilla/4.0`, `Connection: close`, and `Accept-language: fr`
- Carriage return, line feed indicates end of header** points to the space before the message body, indicating the end of the header section.
- Message body (optional)** is the final part of the message.

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

Message body (optional)
```

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

status line
(protocol
status code
status phrase)

header
lines

HTTP/1.1 200 OK

Connection: close

Date: Thu, 06 Aug 1998 12:00:15 GMT

Server: Apache/1.3.0 (Unix)

Last-Modified: Mon, 22 Jun 1998 ...

Content-Length: 6821

Content-Type: text/html

data, e.g.,
requested
HTML file

Message body (optional)

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