CS 330: Network Applications & Protocols

Application Layer: HTTP

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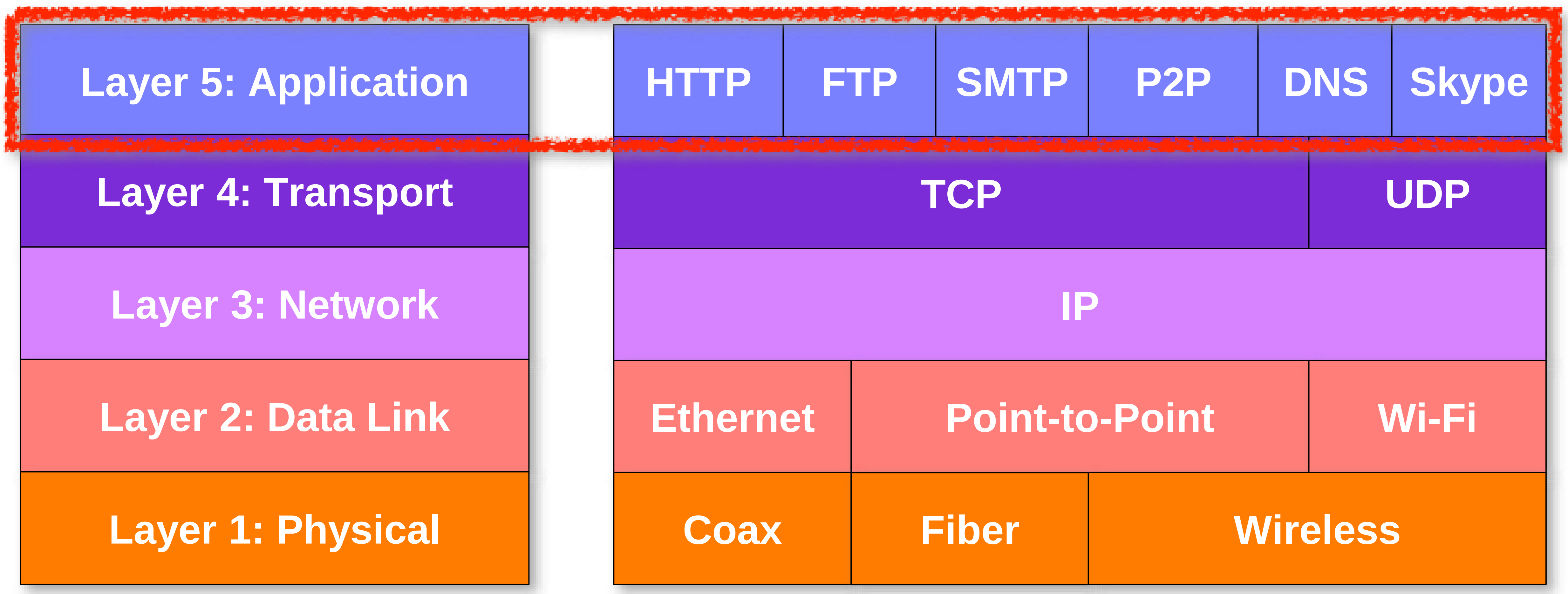
Based on Computer Networking: A Top-Down Approach, 7th Edition by Kurose and Ross

Overview of Application Layer

- **Network Application Architectures**
  - Protocol Layers
  - Client-Server vs. Peer-to-Peer
  - Process Communication
  - Transport Services
- **HyperText Transfer Protocol (HTTP)**
- **File Transfer and Email protocols (FTP, SMTP)**
- **Domain Name System (DNS)**
- **Peer-to-Peer Applications (P2P)**

Protocol Layers

- **Top-Down Approach**



Example Applications

- E-mail
- Web
- Text messaging
- Remote login
- P2P file sharing
- Multi-user network games
- Streaming stored video (YouTube, Hulu, Netflix)
- Voice over IP (e.g. Skype)
- Real-time video conferencing
- Social networking
- Search
- ...

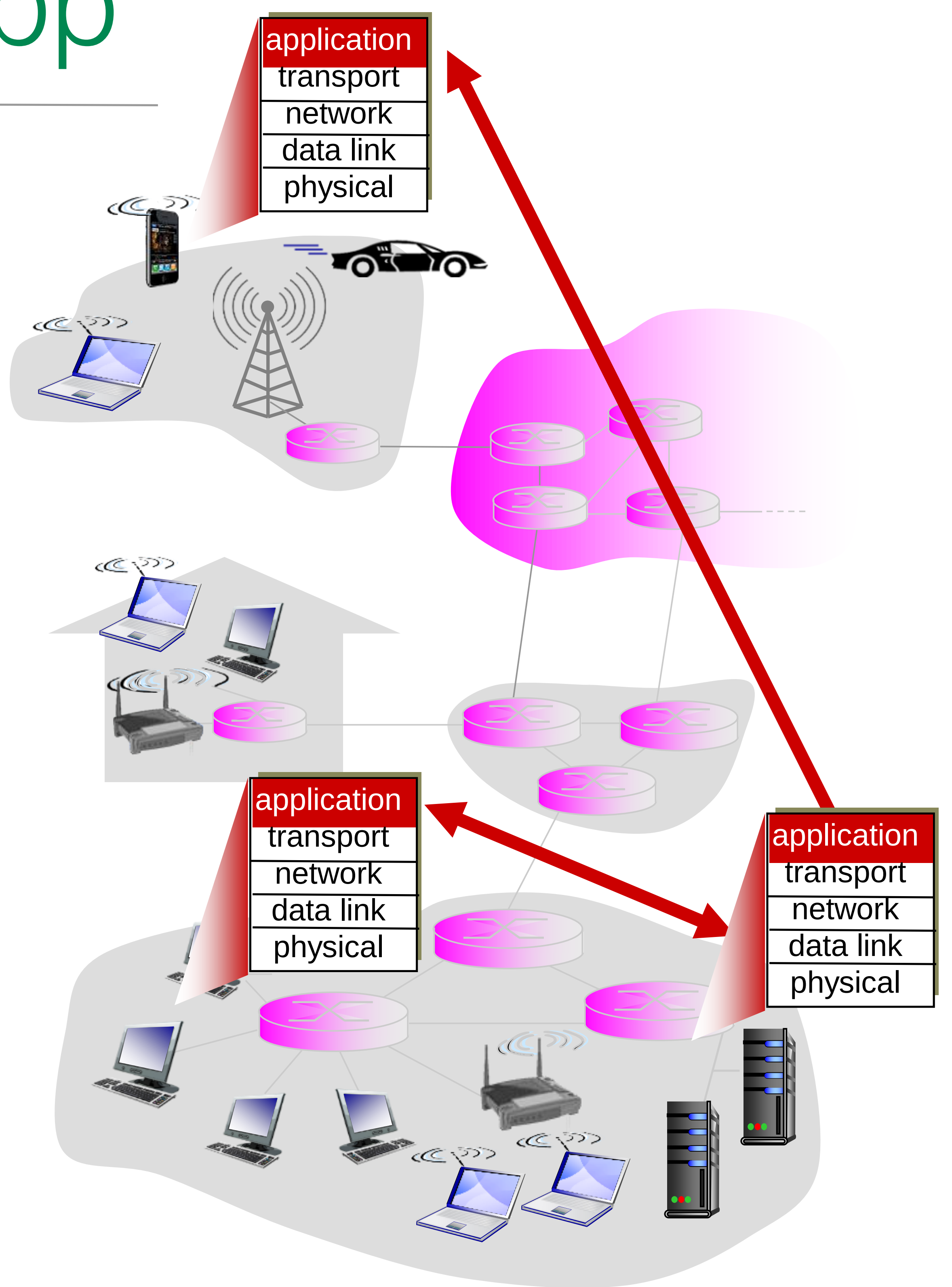
Creating a network app

write programs that:

- **run on (different) *end systems***
- **communicate over network**
- **e.g., web server software communicates with browser software**

no need to write software for network-core devices

- **network-core devices do not run user applications**
- **applications on end systems allows for rapid app development, propagation**

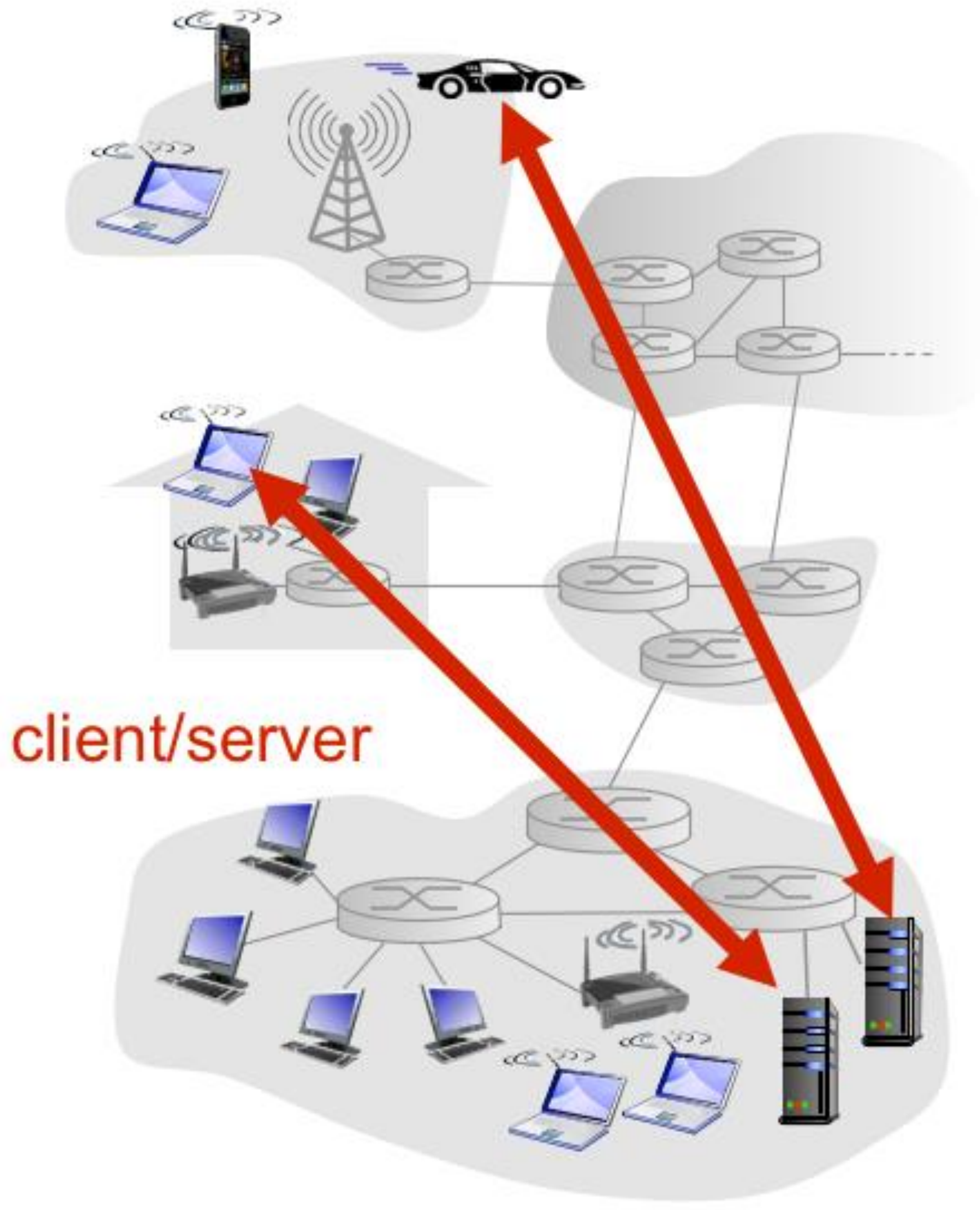


Network Application Architectures

- **Client-Server**
- **Peer-to-Peer**

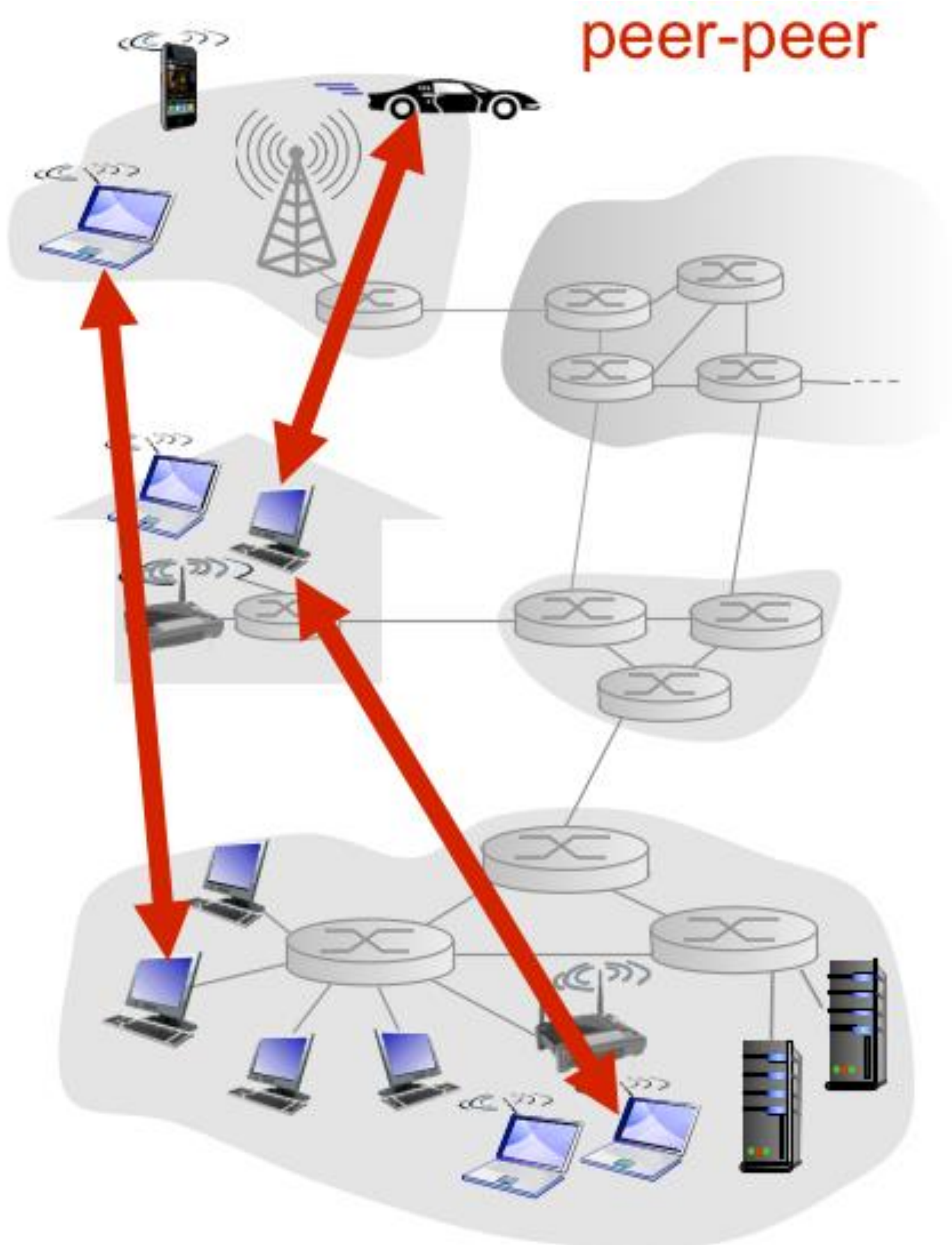
Client-Server Architecture

- **Clients:**
  - Request service from server
  - May be intermittently connected
  - May have dynamic IP addresses
  - Do not communicate directly with each other
- **Server:**
  - Provides a service to clients
  - Always-on host
  - Permanent IP address
  - Data centers for scaling



Peer-to-Peer Architecture

- Does not require always-on servers
- Hosts communicate directly with each other
- Peers request service from other peers, and provide service in return to other peers
- Highly scalable
- Self scalability – new peers bring new service capacity, as well as new service demands
- Hosts are intermittently connected and may change IP addresses
- Difficult to authenticate - possibly insecure
- Hosts need incentive to share data



Process Communications

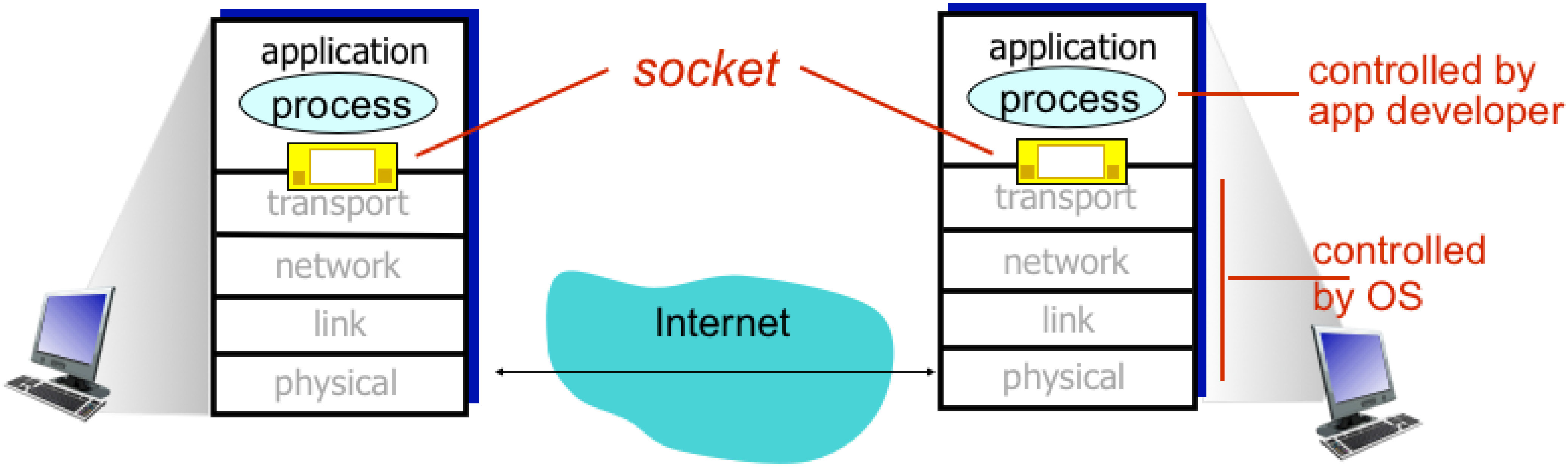
- **A process is program running on a host**
  - Client process - process that initiates communication
  - Server process - process that waits to be contacted

Note: Applications with P2P architectures have both client processes & server processes

- **Sockets provide a mechanism for inter-process communication (IPC)**
  - Inter-process communication on the same host
    - Operating system provides message passing
  - Inter-process communication on different hosts
    - Network provides message passing

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



Addressing Processes

- **To receive messages, process must have some identifier**
- **Host device has unique 32-bit IP address (IPv4)**
  - IP address alone is insufficient to address a process on a system
  - Many processes may be running on the same system
- **Identifier includes both IP address and port numbers associated with process on host**
  - Example port numbers:
    - HTTP server: port 80
    - SMTP Mail server: port 25
- **To send an HTTP message to cs.ycp.edu web server:**
  - IP address: 192.245.87.64
  - Port number: 80

Application Layer Protocol Defines

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

What Transport Service Does an Application Need?

- **Data integrity**
  - Some applications require 100% reliable data transfer (e.g. file transfer, web transactions)
  - Other applications can tolerate some loss (e.g. audio)
- **Timing**
  - Some applications require low delay to be “effective” (e.g. Internet telephony, interactive games)
- **Throughput**
  - Some applications require minimum amount of throughput to be “effective” (e.g., multimedia)
  - Other “elastic” applications make use of whatever throughput they get
- **Security**
  - Encryption, data integrity, etc.

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 Transport Protocol Services

TCP (Transmission Control Protocol)	UDP (User-Datagram Protocol)
Reliable data transfer	Unreliable data transfer
Packet sequence # required	Sequence # is optional
Every packet is acked	Not acked
Lost packets are retransmitted	No retransmission
May cause long delay	Quick and lossy
Connection-oriented service	Connection-less service
Good for reliable and delay-insensitive applications	Good for loss-tolerant and delay sensitive applications
Application examples: email, HTTP, FTP, remote terminal access	Application examples: Telephony, streaming multimedia

Securing TCP

TCP & UDP

- no encryption
- cleartext passwds sent into socket traverse Internet in cleartext

SSL

- provides encrypted TCP connection
- data integrity
- end-point authentication

SSL is at app layer

- apps use SSL libraries, that "talk" to TCP

SSL socket API

- cleartext passwords sent into socket traverse Internet encrypted

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

Overview of Application Layer

- **Network Application Architectures**
- **HyperText Transfer Protocol (HTTP)**
  - HTTP Overview
  - HTTP Communication
  - HTTP Request Message
  - HTTP Response Message
  - Cookies
  - Web Caching
- **File Transfer and Email protocols (FTP, SMTP)**
- **Domain Name System (DNS)**
- **Peer-to-Peer Applications (P2P)**

HTTP Overview

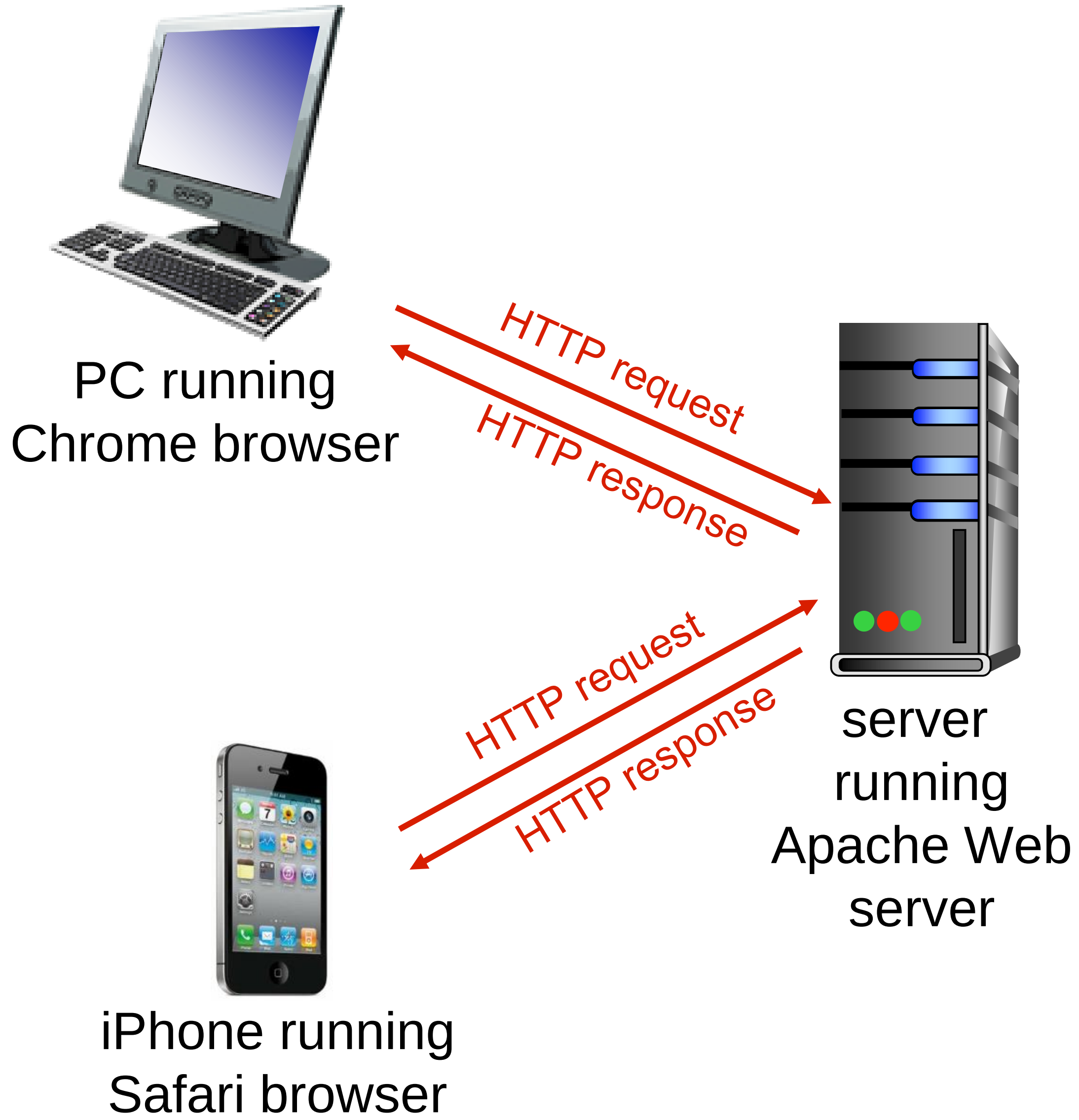
- **HTTP client - web browser (e.g. Chrome, Firefox, Safari)**
- **HTTP server - web server (Apache, Microsoft Internet Information Service (IIS))**
- **Web page consists of:**
  - A group of objects
    - HTML files, images, Java applets, audio files, etc.
  - A base HTML file which references objects
    - Each object is addressable by a URL

`http://faculty.ycp.edu/~alice/classes/cs330/docs/cs330_syllabus.pdf`

Protocol   Host name   Path name

HTTP Overview (Cont.)

- **HTTP: hypertext transfer protocol**
- **Web's application layer protocol**
- **Uses 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 Communication

- **Uses TCP**
  - Client initiates TCP connection (creates socket) to server, port 80
  - Server accepts TCP connection from client
  - HTTP messages exchanged between web browser (HTTP client) and web server (HTTP server)
  - TCP connection closed
- **HTTP is "stateless"**
  - Server maintains no information about past client requests

HTTP Connections

- **Non-persistent HTTP**
  - At most one object is sent over a TCP connection
    - Open connection, get one object, close connection
  - Downloading multiple objects requires multiple connections
- **Persistent HTTP**
  - Multiple objects can be sent over single TCP connection between client and server
    - Server leaves the connection open after sending an object and closes on timeout

HTTP Request Message

- **Two types of HTTP messages: request, response**
- **HTTP Request Message**
  - ASCII (human-readable format)

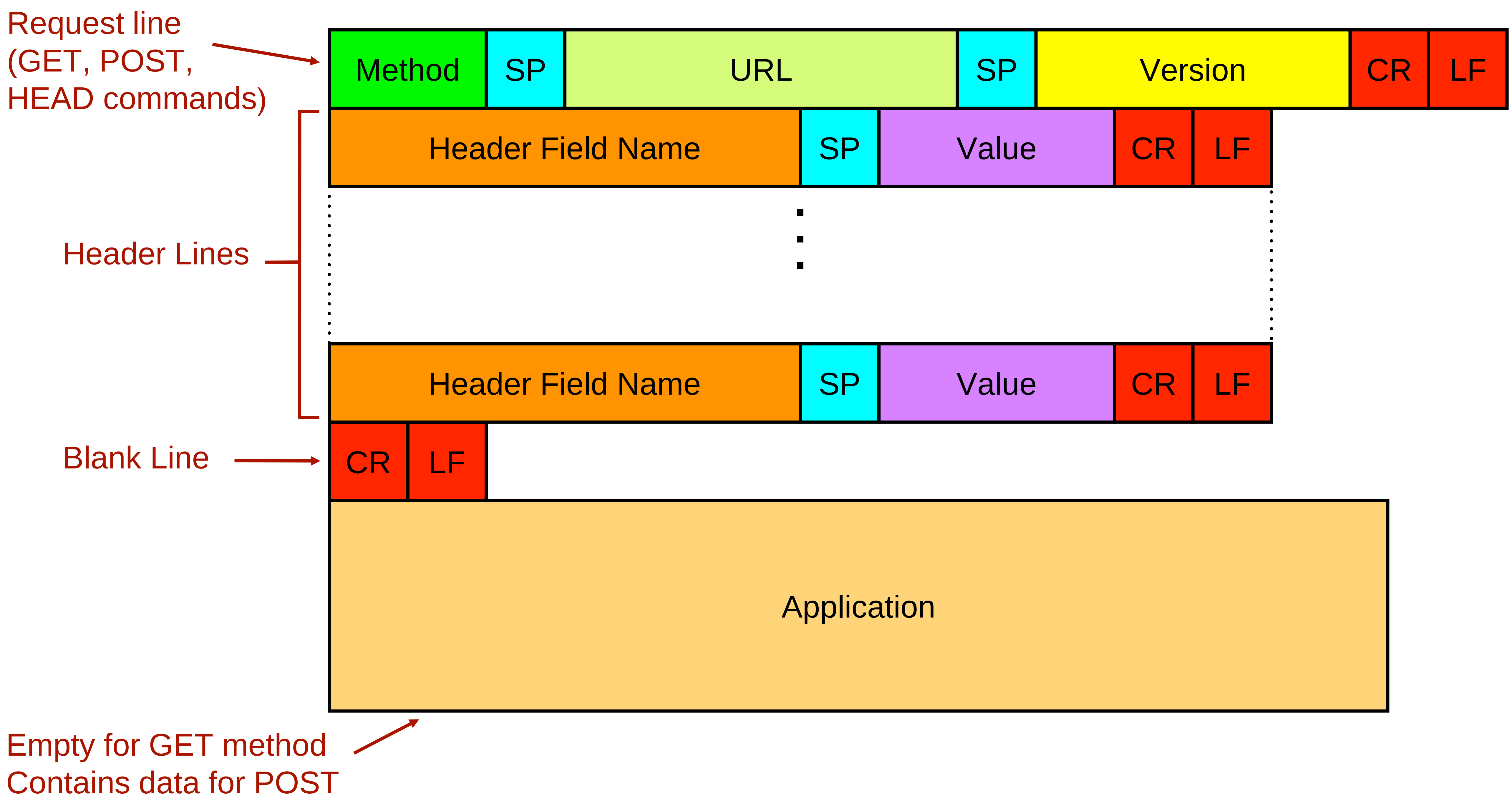
Request line (GET, POST, HEAD commands)

Header Lines

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

```
GET /~alice/index.html HTTP/1.1\r\n
Host: faculty.ycp.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 Request Message: General Format



HTTP Methods

- **GET - used to request an object from a server**
  - Requested object is in URL field of HTTP request message
- **HEAD - same as GET, but only sends header**
  - Doesn’t actually send requested object
  - Useful for testing/debugging
- **POST - used to send information to a server when requesting an object**
  - The object returned may depend on the information posted
  - Often used when filling out web forms
- **PUT - uploads file in entity body to path specified in URL field**
- **DELETE - deletes file specified in the URL field**

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

Uploading Form Input

- **Two methods:**
  - POST method:
    - Web page often includes form input
    - Input is uploaded to server in the Entity portion of the HTTP request message
  - URL method:
    - Uses HTTP GET method
    - Input is uploaded in URL field of HTTP request message

      `www.somesite.com/animalsearch?monkeys&banana`

HTTP Response Message

status line (protocol status code status phrase)

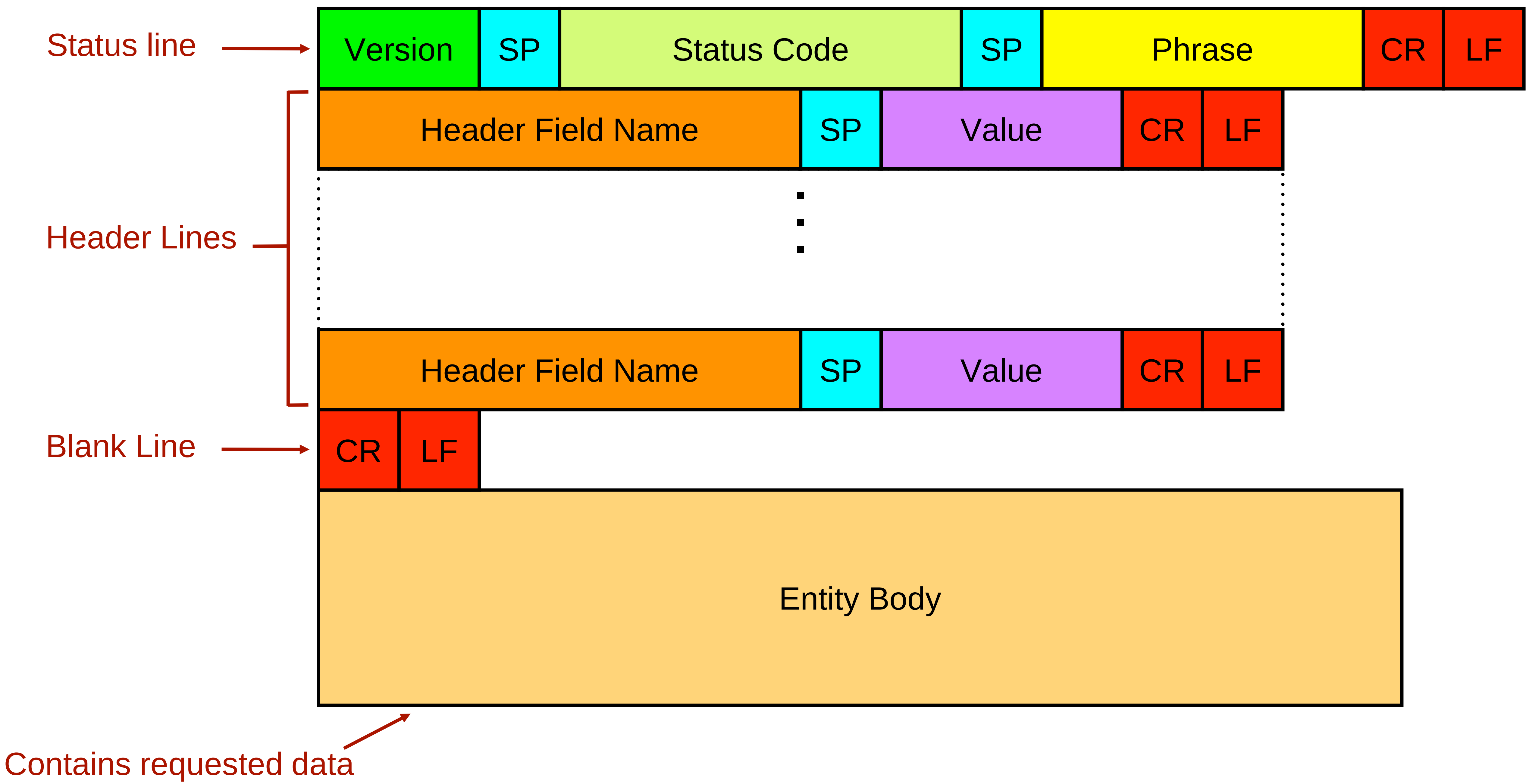
Header Lines

Carriage return, line feed at start of line indicates end of 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 ...
```

HTTP Response Message: General Format



HTTP Response Status Codes

- **Status code appears in first line in server-to-client response message**
- **Some sample codes:**

`200 OK`

- Request succeeded, requested object later in this message

`301 Moved Permanently`

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

`400 Bad Request`

- Request message not understood by server

`404 Not Found`

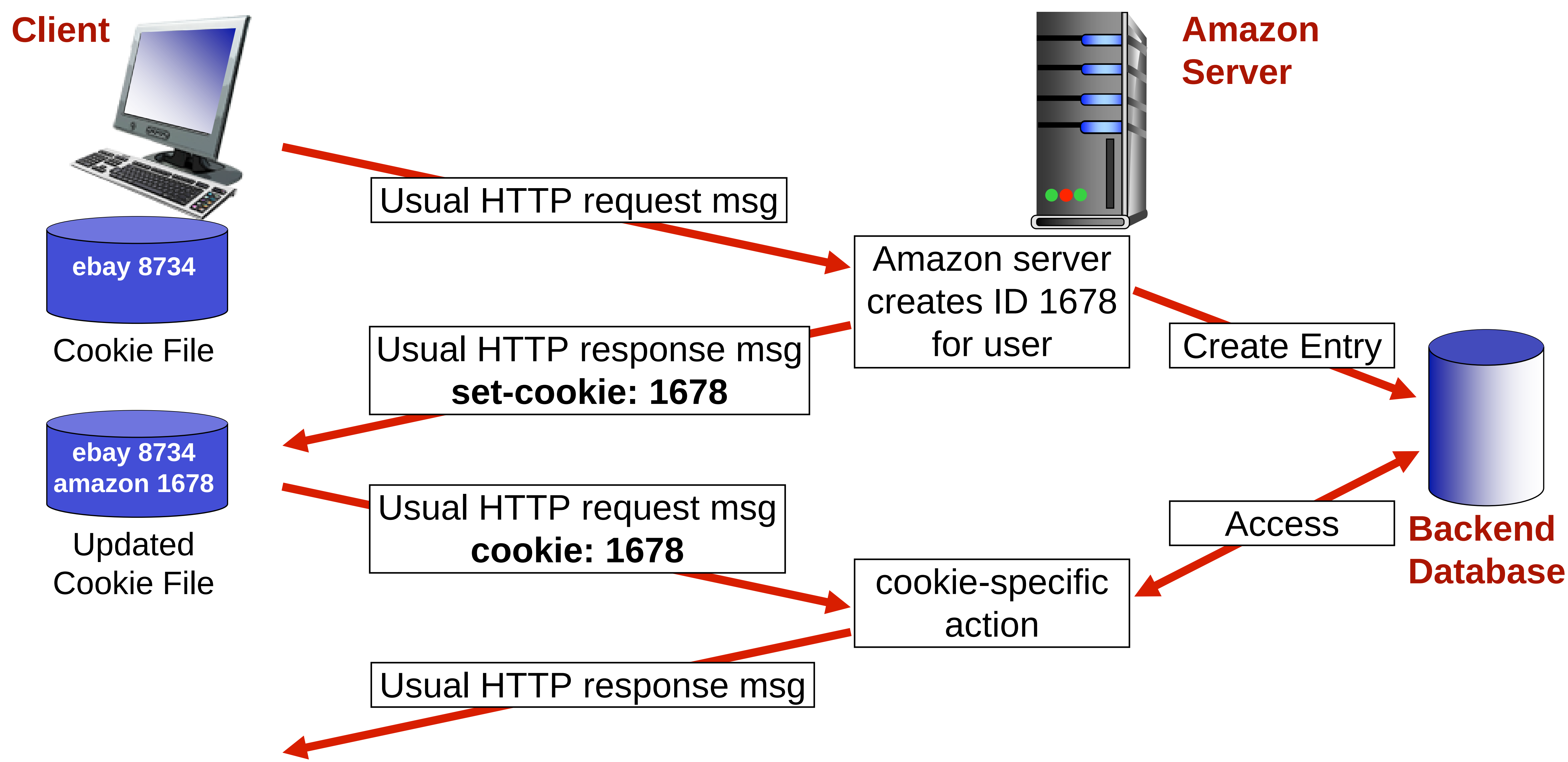
- Requested document not found on this server

`505 HTTP Version Not Supported`

User-Server State: Cookies

- **Cookies allow servers to remember previous information about user**
  - Stored in file on end user system since HTTP server is stateless
  - Many companies use cookies to identify a user
    - Content is dependent on the identity of the user
- **Four components to cookies:**
  - A cookie header line in the HTTP response message
  - A cookie header line in the HTTP request message
  - A cookie file kept on user's end system & managed by user's browser
  - A back-end database at web site

Cookies: Keeping “state”



Cookies

- **What cookies can be used for:**
  - Authorization
  - Shopping carts
  - Recommendations
  - User session state (web-based e-mail)

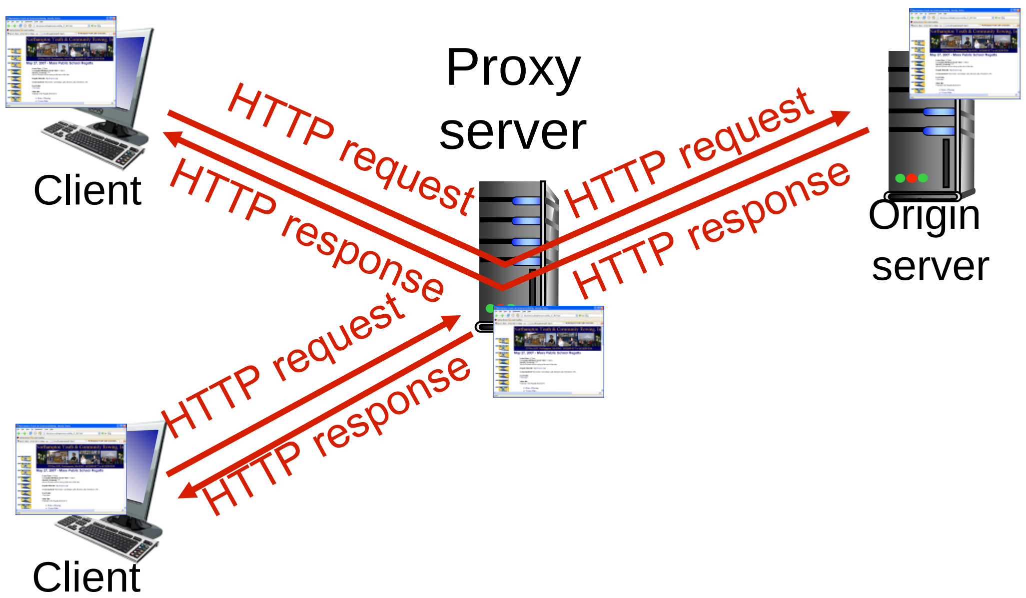
cookies and privacy:

- cookies permit sites to learn a lot about you
- you may supply name and e-mail to sites

- **How to keep "state":**
  - Protocol endpoints: maintain state at sender/receiver over multiple transactions
  - Cookies: http messages carry state

Web Caches (proxy server)

- **A network entity that satisfies requests on behalf of an origin web server**
  - All requests are sent to proxy server
  - Proxy server caches objects
  - Only new objects are requested from origin server



More About Web Caching

- **Cache acts as both client and server**
  - Server for requesting clients
  - Client to the origin server
- **Typically, cache is installed by ISP (university, company, residential ISP)**
- **Why Web caching?**
  - Reduce response time for client request
  - Reduce traffic on an institution’s access link

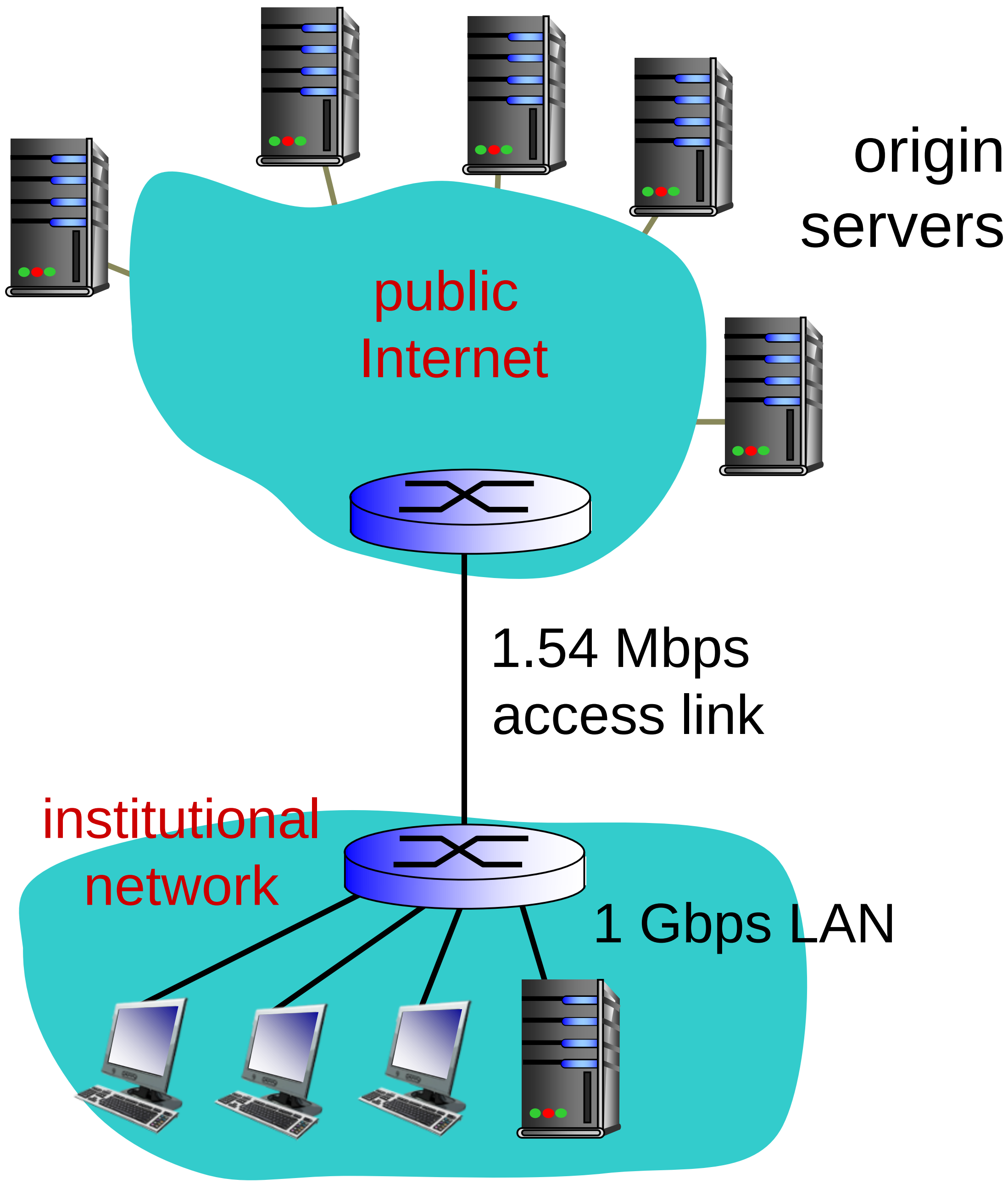
Caching example:

assumptions:

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

consequences:

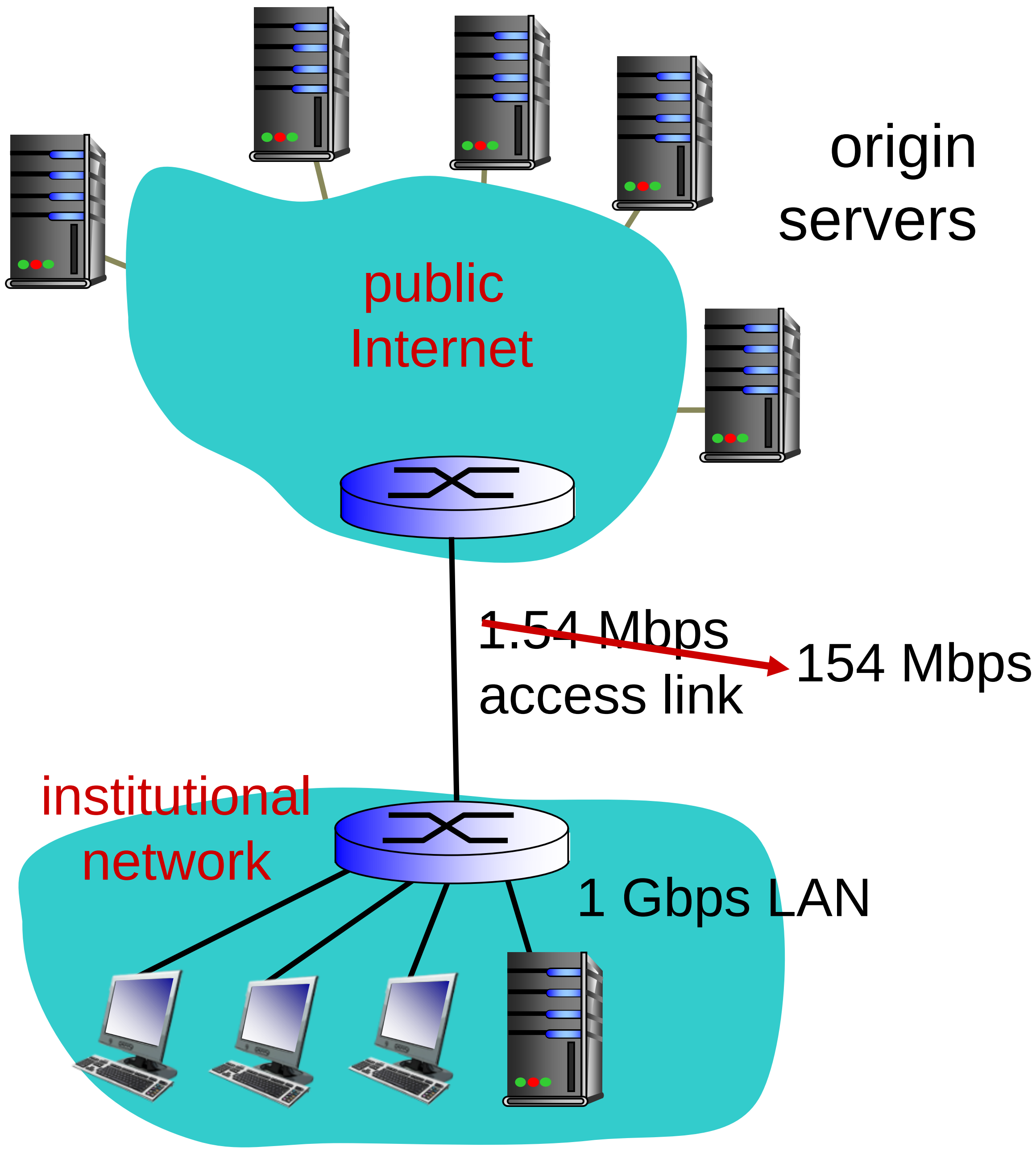
- LAN utilization: 15%
- access link utilization = 99% *problem!*
- total delay = Internet delay + access delay + LAN delay
  = 2 sec + minutes + usecs



Caching example: fatter access link

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

consequences:
- LAN utilization: 15%
- access link utilization = ~~99%~~ → 9.9%
- total delay = Internet delay + access delay + LAN delay
  = 2 sec + ~~minutes~~ → msecs + usecs



Cost: increased access link speed (not cheap!)

Caching example: install local cache

assumptions:

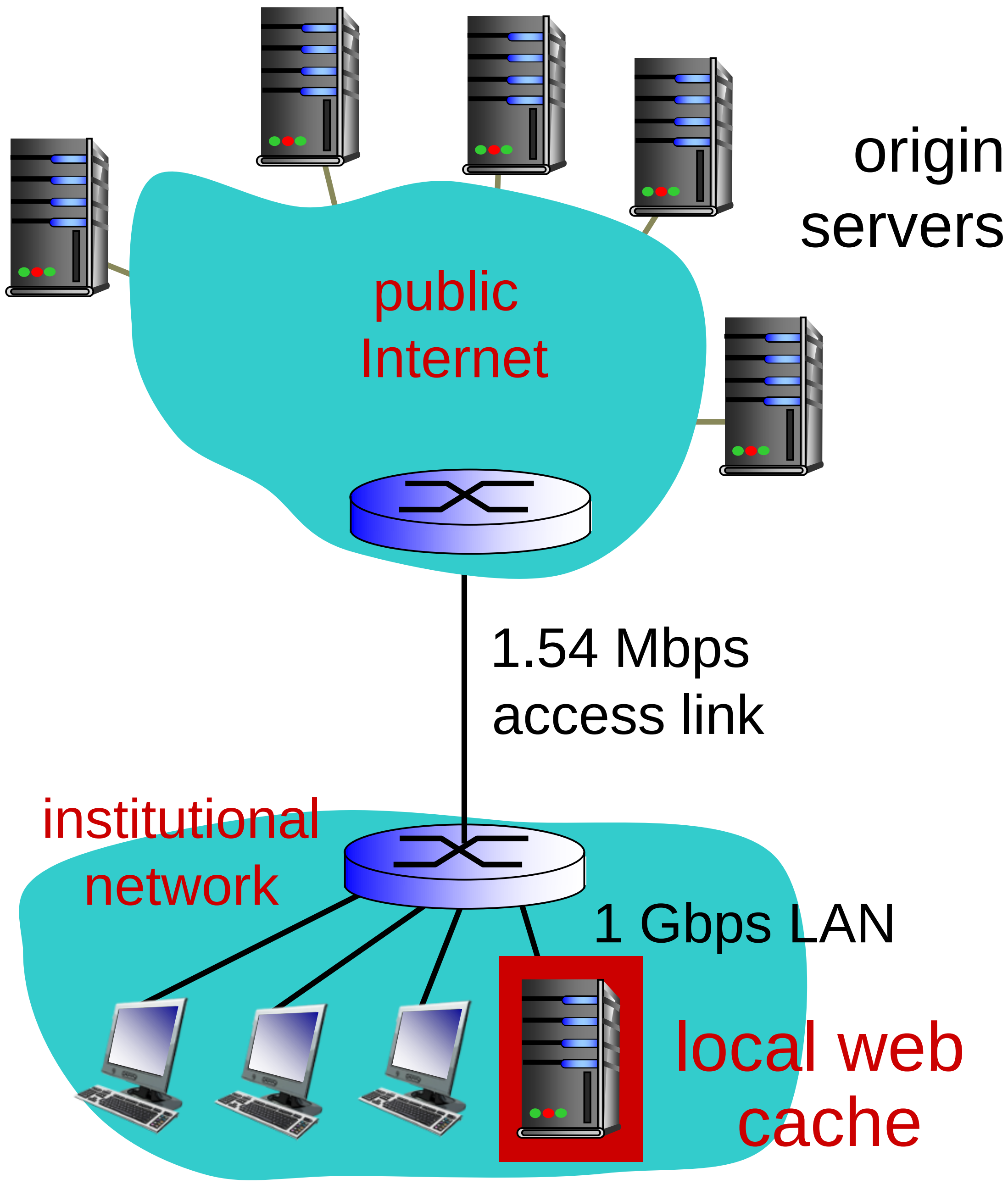
- avg object size: 100K bits
- avg request rate from browsers to origin servers:15/sec
- avg data rate to browsers: 1.50 Mbps
- RTT from institutional router to any origin server: 2 sec
- access link rate: 1.54 Mbps

consequences:

- LAN utilization: 15%
- access link utilization = ?
- total delay = ?

How to compute link utilization, delay?

Cost: web cache (cheap!)



Caching example: install local cache

Calculating access link utilization, delay with cache:

suppose cache hit rate is 0.4

- 40% requests satisfied at cache - --- 60% requests satisfied at origin

access link utilization:

- 60% of requests use access link

data rate to browsers over access link

= 0.6*1.50 Mbps = .9 Mbps

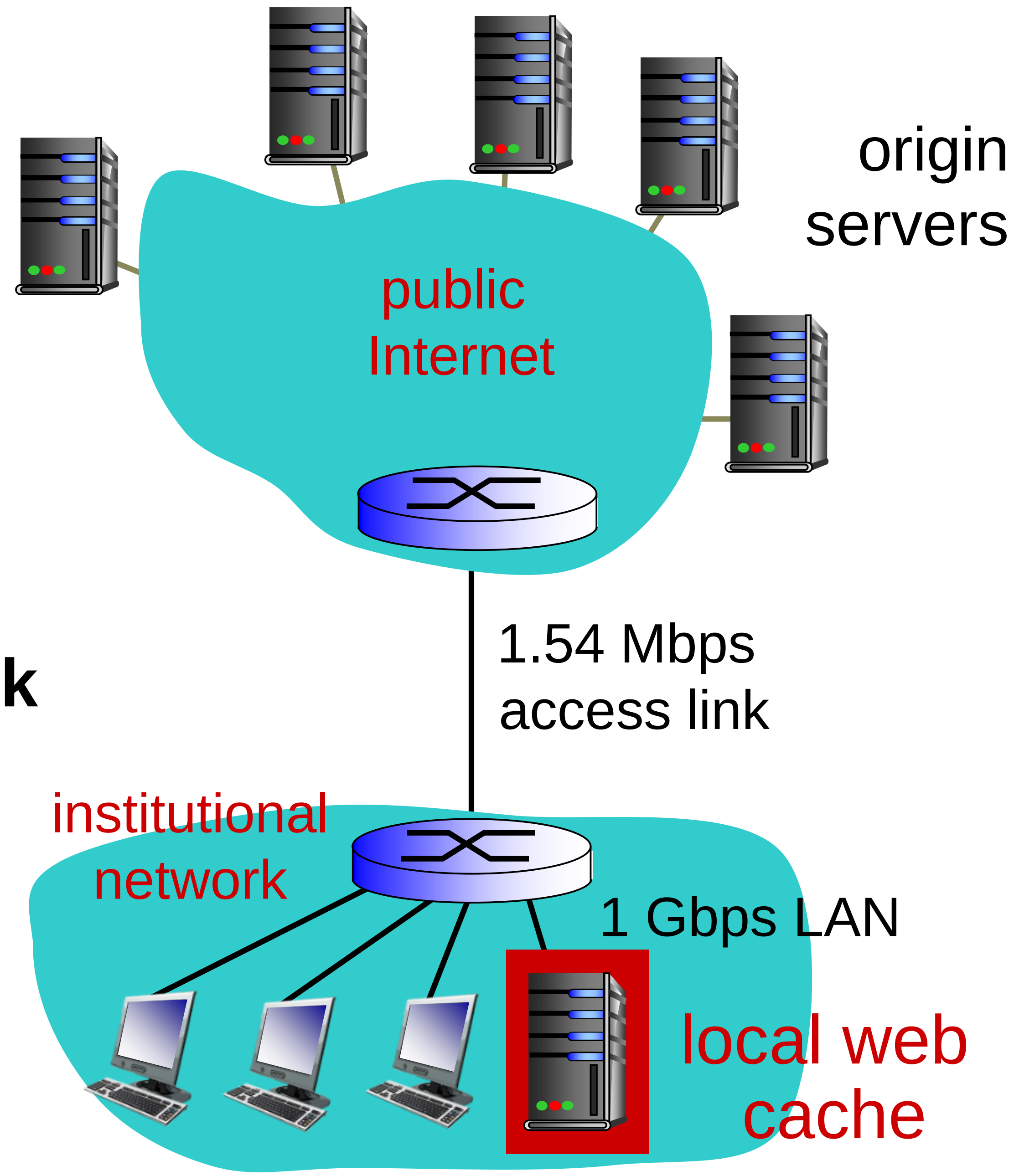
- utilization = 0.9/1.54 = .58

total delay

= 0.6 * (delay from origin servers) + 0.4 * (delay when satisfied at cache)

= 0.6 (2.01) + 0.4 (~msecs) = ~ 1.2 secs

less than with 154 Mbps link (and cheaper too!)



Conditional GET

- **Goal: don’t send object if cache has up-to-date cached version**
  - No object transmission delay
  - lower link utilization
- **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**