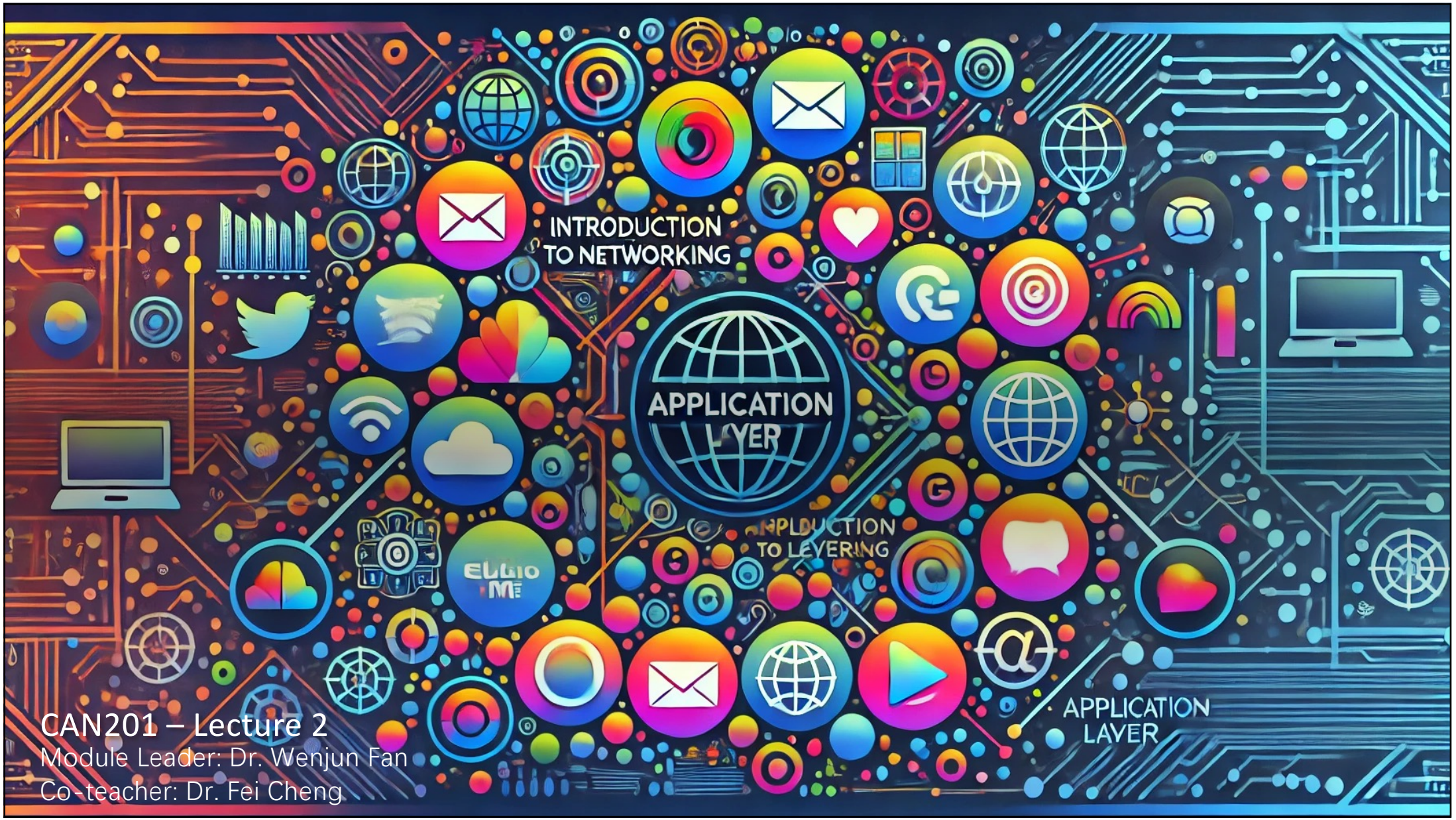


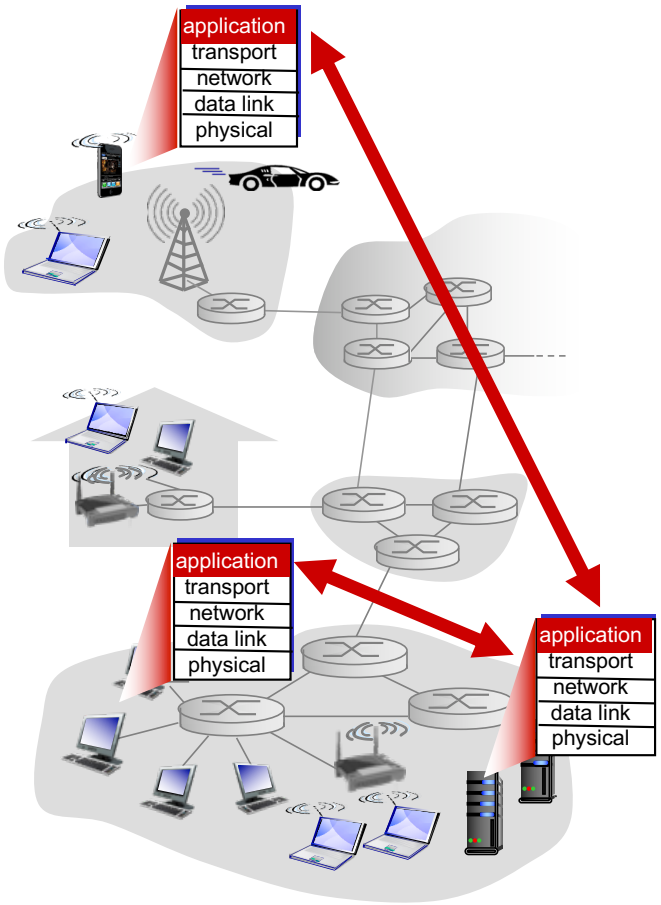
CAN201 – Lecture 2

Module Leader: Dr. Wenjun Fan
Co-teacher: Dr. Fei Cheng

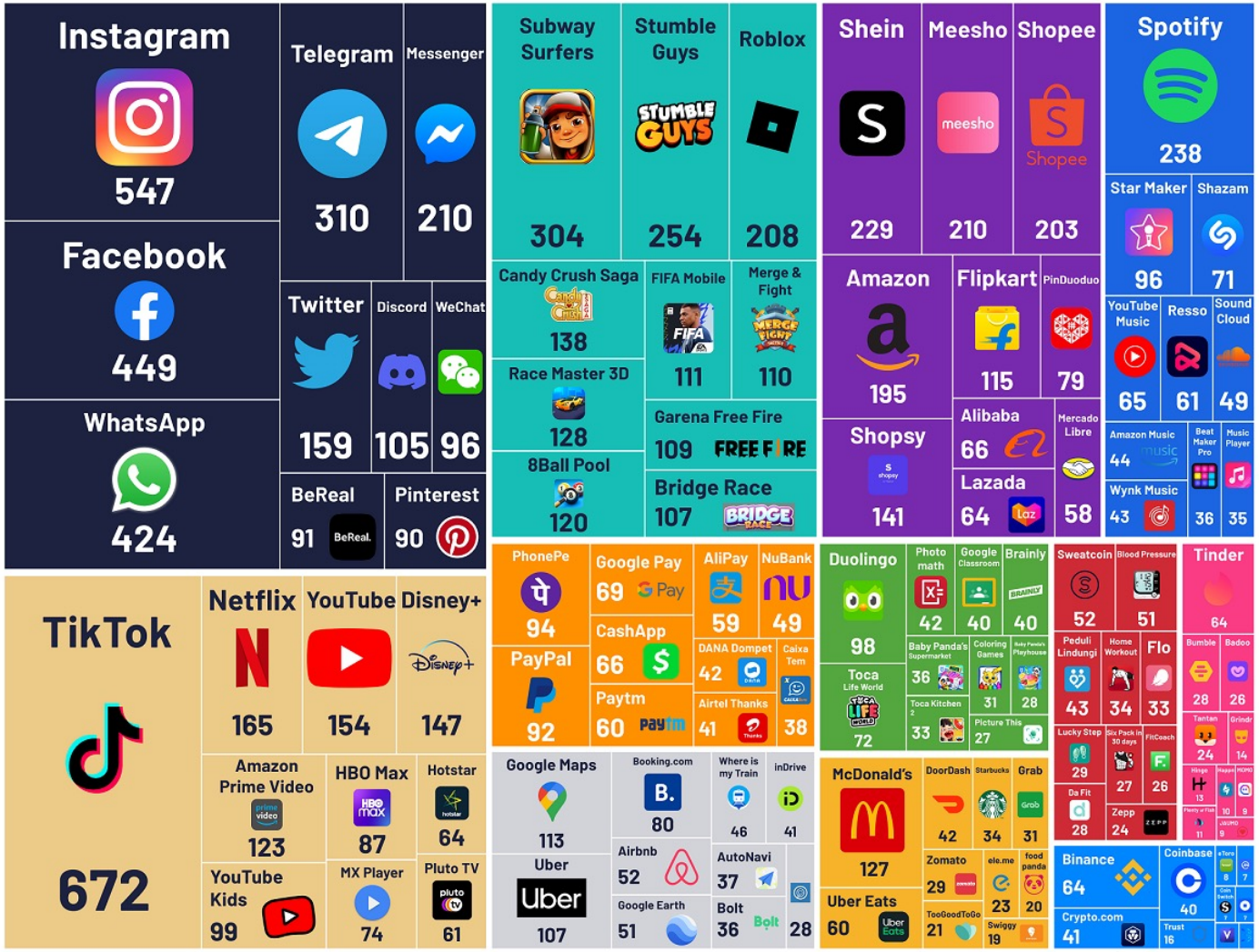
Lecture 2 – Application Layer (1)

1. Introduction to Application Layer
2. Principles of Network Applications
3. Web Application - HTTP

APP layer in TCP/IP stack

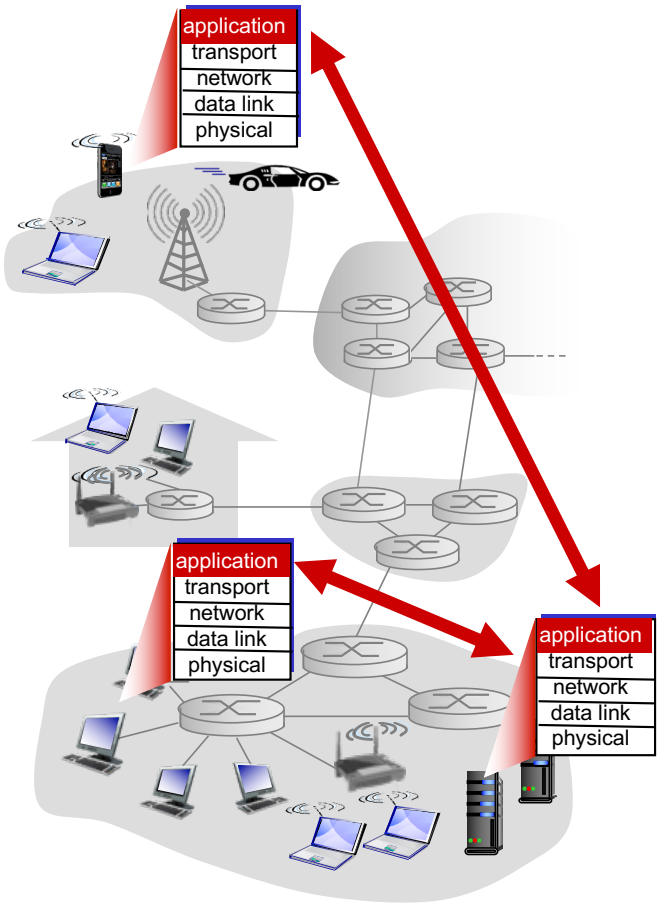


- Top of the TCP/IP stack
- Closest to the end-user
- Provides protocols for TX/RX over the network
- Rich network applications



https://www.businessofapps.com/data/app-reports/

APP layer in TCP/IP stack



- Top of the TCP/IP stack
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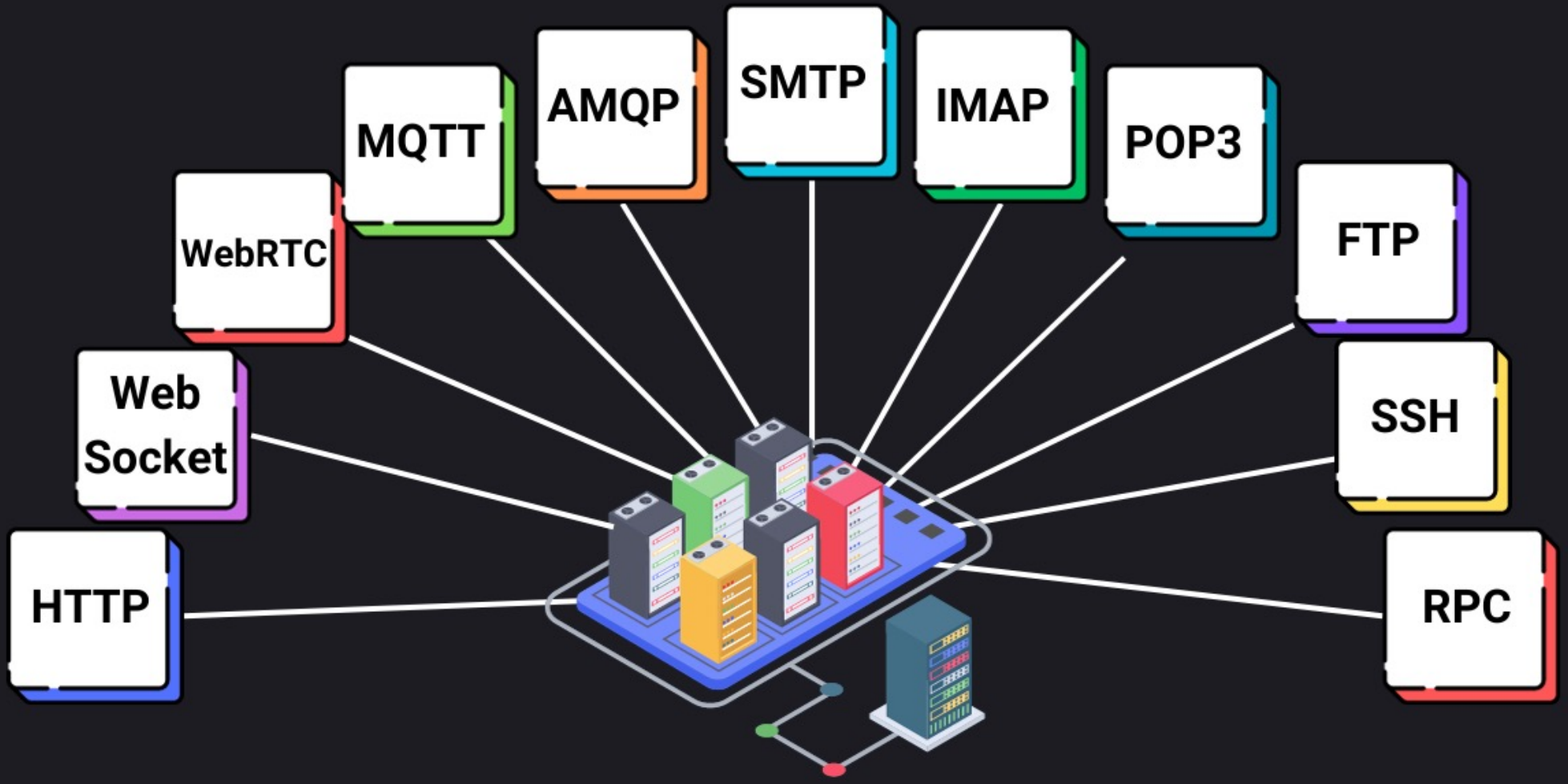
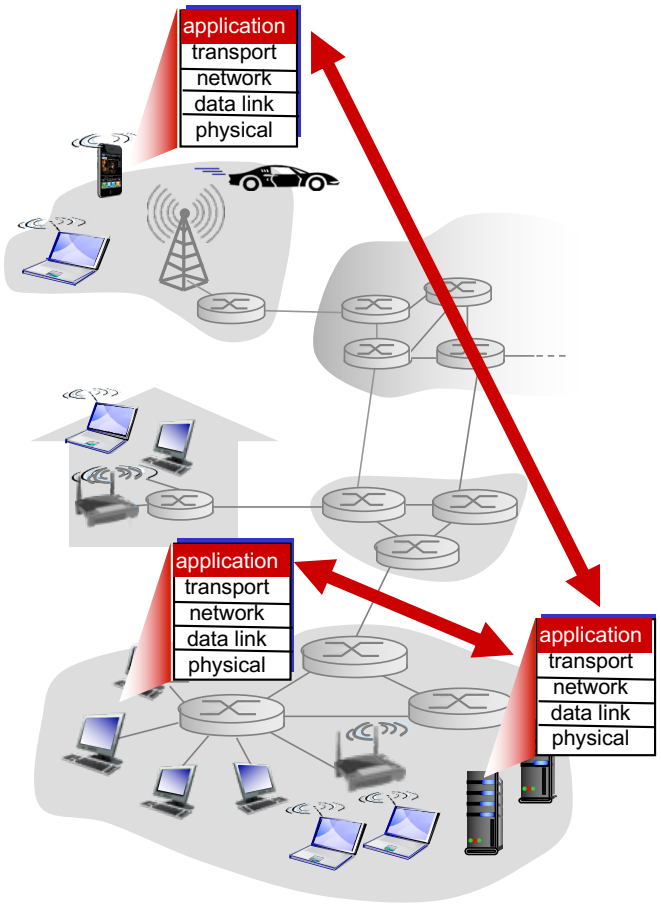
- Rich network applications
- Many protocols for application layers

APPLICATION PROTOCOLS



APP layer in TCP/IP stack



- Top of the TCP/IP stack
- Closest to the end-user
- Provides protocols for TX/RX over the network
- Rich network applications
- Many protocols for application layers
- **Can be customized easily!**

OR

openWRT

Lecture 2 – Application Layer (1)

1. Introduction to Application Layer
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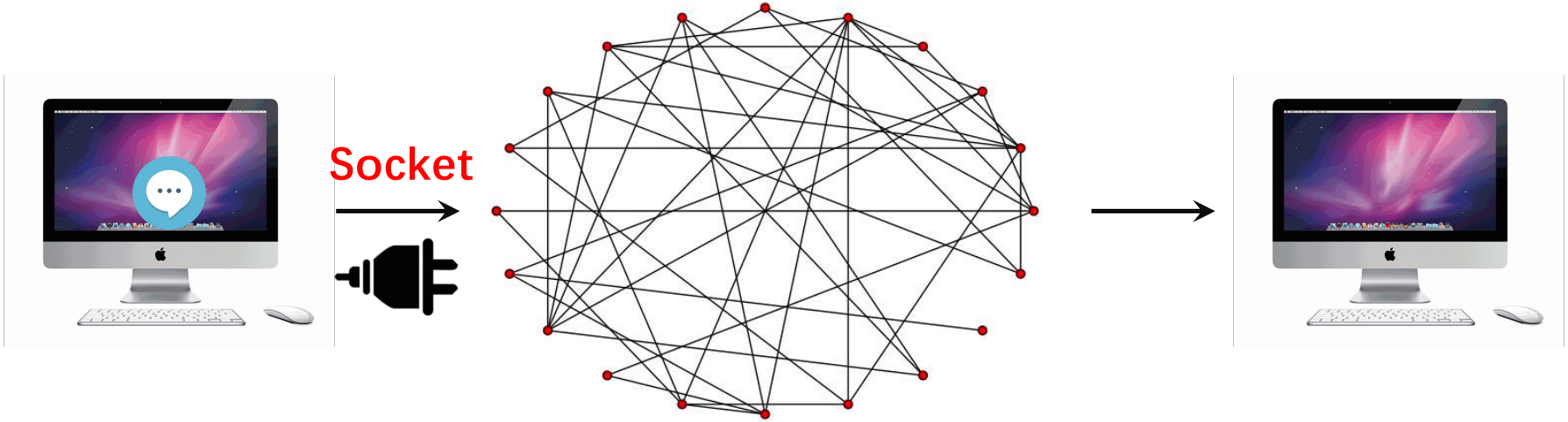
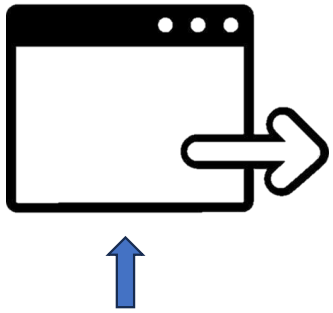
What do we use to deliver messages?



What do we use to deliver messages?

Host

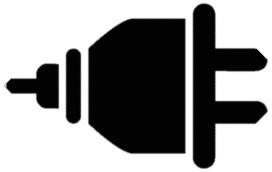


A program(process) with:

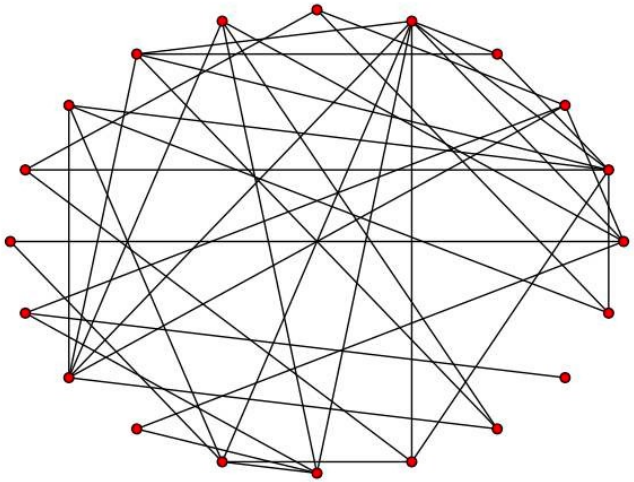
identifier

protocols

Sockets

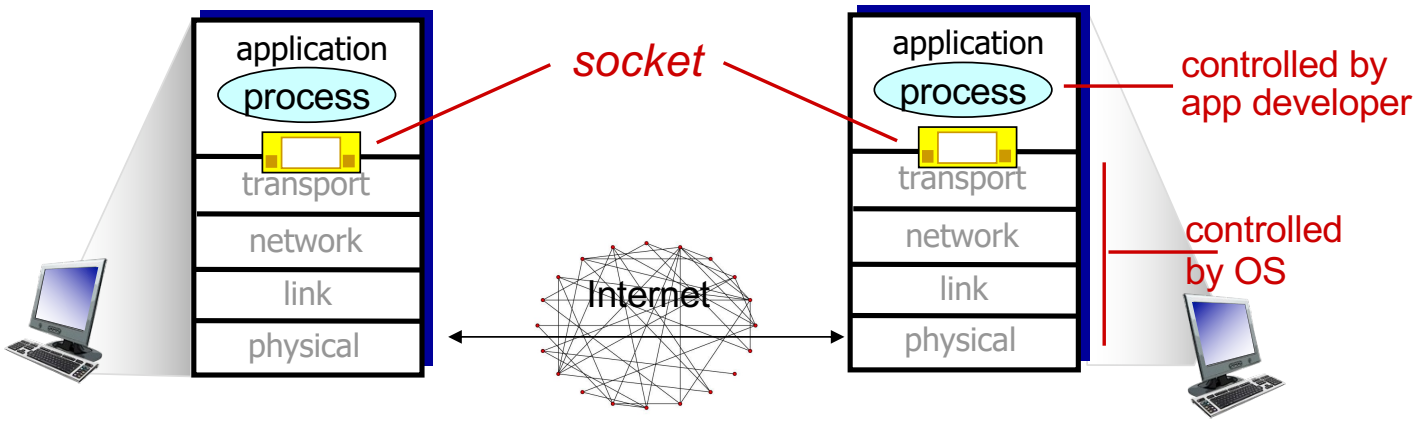


Network



Sockets

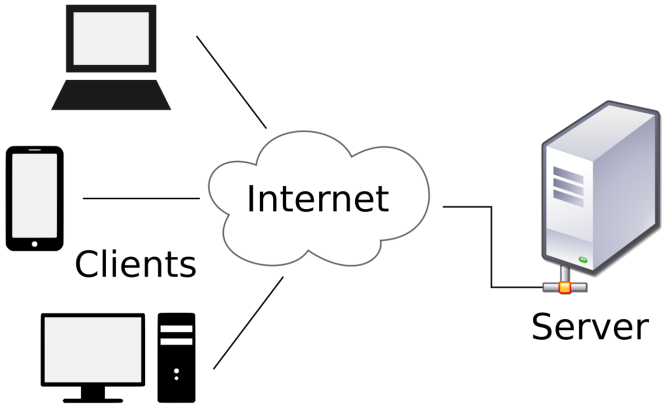
- Process sends/receives messages to/from its socket
- Socket analogous to door
  - Sending process "push" message out of the door
  - Sending process relies on transport infrastructure on other side of door to deliver message to socket at receiving process



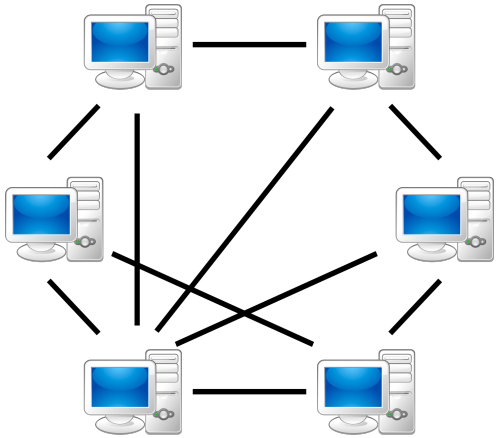
Addressing processes

- To receive messages, process must have ***identifier***
- Host device has **unique** 32-bit IPv4 and/or 128-bit IPv6
- Process network identifier :
  - IPv4:port 192.168.1.100:80
  - [IPv6]:port [240e:3a1:4cb1:69d0:f40c:4269:74a2:7ea3]:80

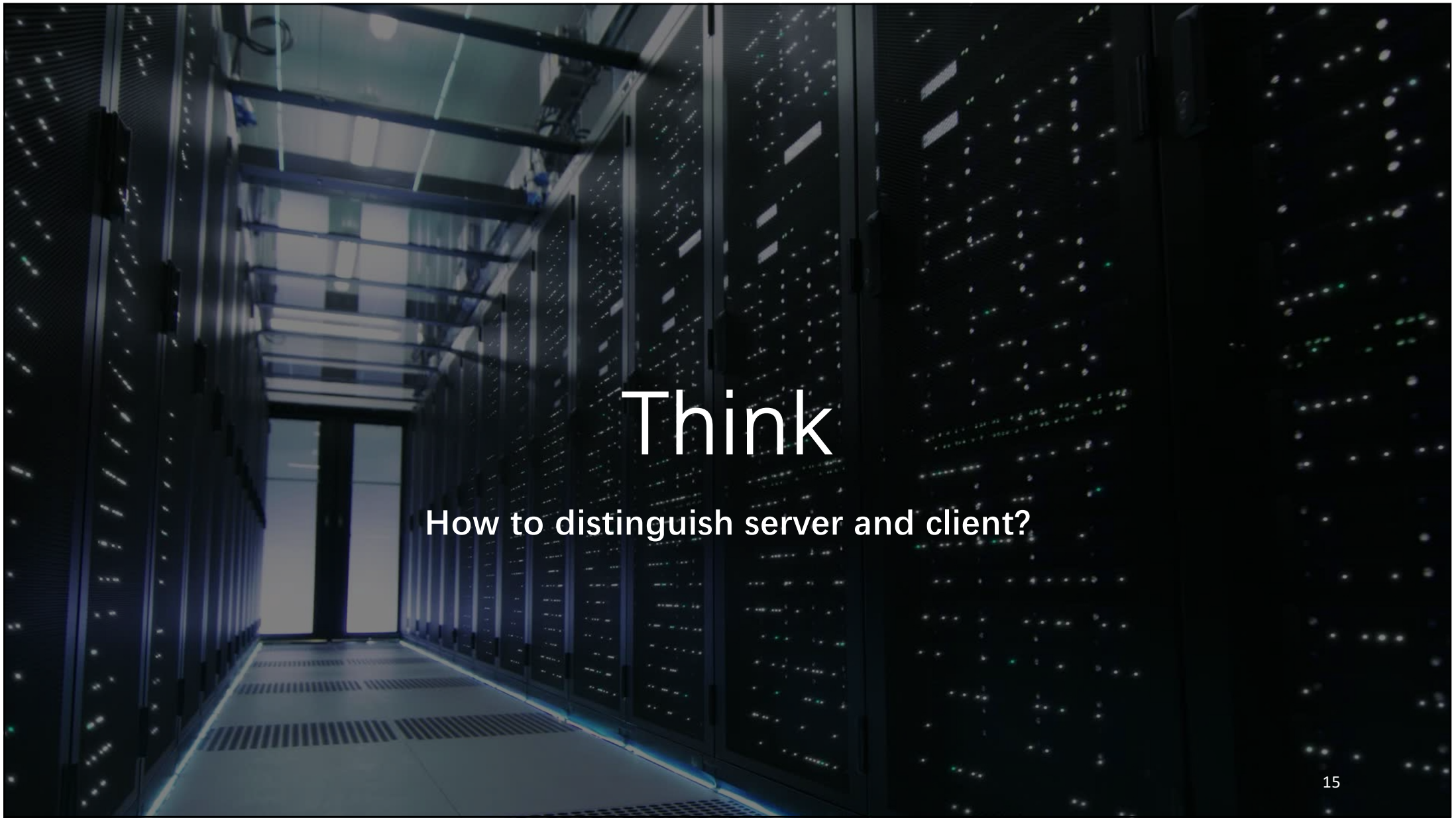
Architectures for applications



Client-server



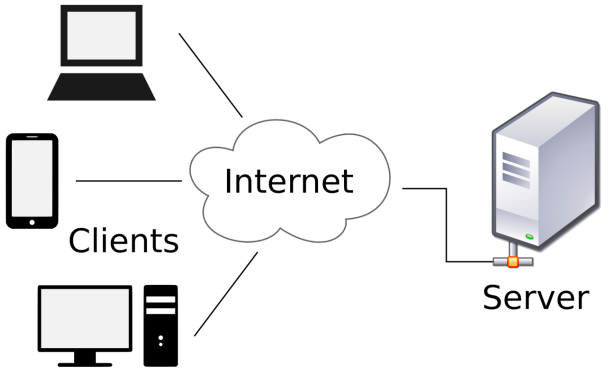
Peer-to-peer



Think

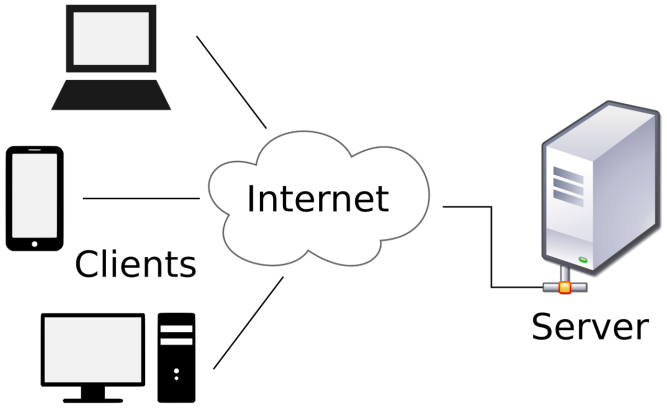
How to distinguish server and client?

Client-server architecture

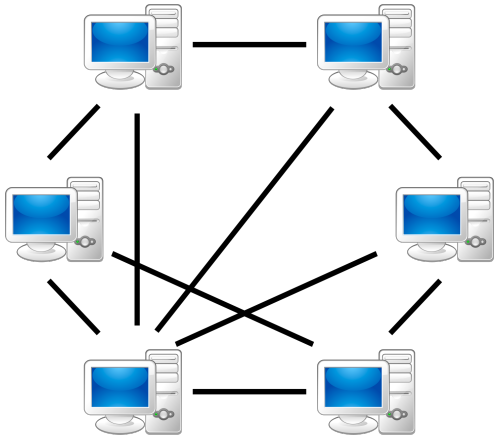


- **Server**
  - Always-on host
  - Permanent IP address
  - High performance / Distributed computing
  - Server process: waits to be contacted (Listen)
- **Clients**
  - Link to the server for service
  - May be intermittently connect to the internet
  - Dynamic IP address
  - Do not communicate directly with each other
  - Client process: initiates communication

Architectures for applications

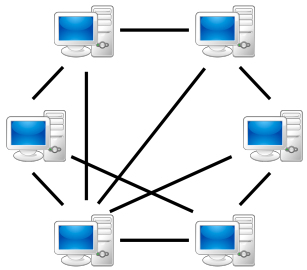


Client-server

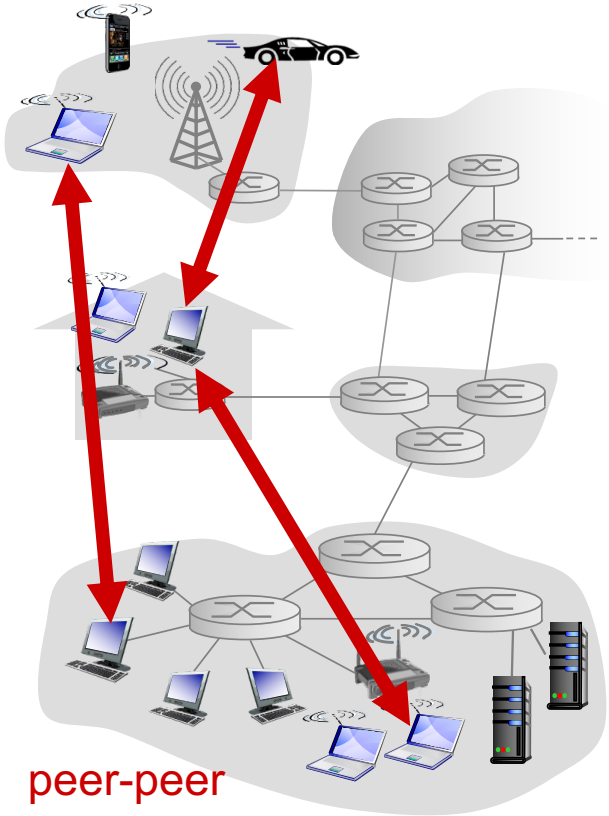


Peer-to-peer

P2P architecture



- No always-on server is needed
- End systems directly exchange data
- Client process / server process on the same host
- Peers request service from other peers, provide service in return to other peers
  - *Self scalability* – new peers bring new service capacity, as well as new service demands
- Peers are intermittently connected
- Dynamic IP addresses
- Q: Did you use Thunder Downloader(迅雷)?
  Why does it download so fast?



Try to have your cloud server (optional)

- Most cloud providers provide student discount.
- Ali Cloud, Tencent Cloud…

App-layer protocol defines

- **Architecture:** **CS or/and P2P**
- **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
- **Message timing:** when and how

Open protocols:

- Defined in RFCs
- Allows for interoperability
- e.g., HTTP, SMTP, FTP

Private protocols:

- e.g., Skype, Games, you own protocols…

What kinds of transport service do we need?

Transport service requirements

Data Integrity

- 100% reliable data transfer

or

- Tolerate some loss

Throughput

- Some apps require minimum amount of throughput to be “effective”
- Others do not require

Timing

- Some apps require low delay

Security

- Some apps require encryption
- Data integrity check

Transport service requirements: common apps

Applications	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 video/audio	Loss-tolerant	Based on quality*	Yes 100 ms
Stored video/audio	Loss-tolerant	Based on quality*	Yes few second
Interactive games	Loss-tolerant	Few kpbs	Yes 100 ms
Text messaging	No loss	Elastic	Yes or No

* Audio: 5k to 1Mpbs, Video: 10kpbs - 10 Mbps or more

Internet transport protocols services

TCP ->

<- UDP

Internet transport protocols services

TCP service:

- **Reliable transport** between sending and receiving process
- **Flow control:** sender won't overwhelm receiver
- **Congestion control:** throttle sender when network overloaded
- **Does not offer:** timing, minimum throughput guarantee, security
- **Connection-oriented:** setup required between client and server processes

Internet transport protocols services

UDP service:

- **Unreliable data transfer** between sending and receiving process
- **Does not offer:** reliability, flow control, congestion control, timing, throughput guarantee, security, or connection setup,
- Looks so bad… But…

Why do we still need UDP?

Simple and fast!

Application vs transport protocols

Application	App layer protocol	Underlying transport Protocol
E-mail	SMTP [RFC 2821], POP3, IMAP	TCP
Remote terminal Access	Telnet [RFC 854], SSH	TCP
Web	HTTP [RFC 2616] HTTPS	TCP
File Transfer	FTP [RFC 959], SFTP	TCP
Multimedia	HTTP / RTP [RFC 1889]	TCP or UDP
VoIP	SIP, RTP or proprietary	TCP or UDP

Securing TCP - Secure Sockets Layer - SSL

TCP & UDP

- No encryption
- Cleartext psws -> Internet

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 psw -> encrypted psw -> Internet
- Lecture 11/12 will talk more

Lecture 2 – Application Layer (1)

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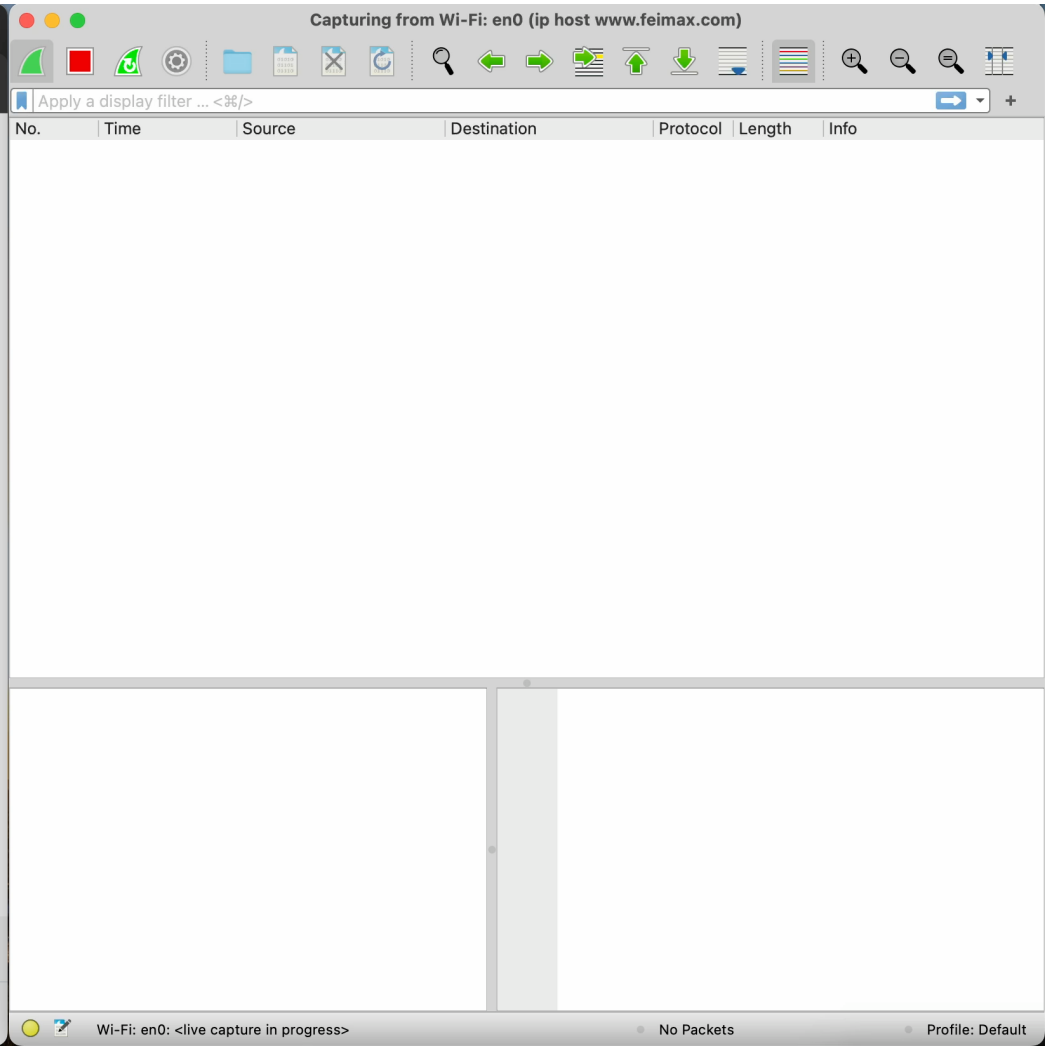
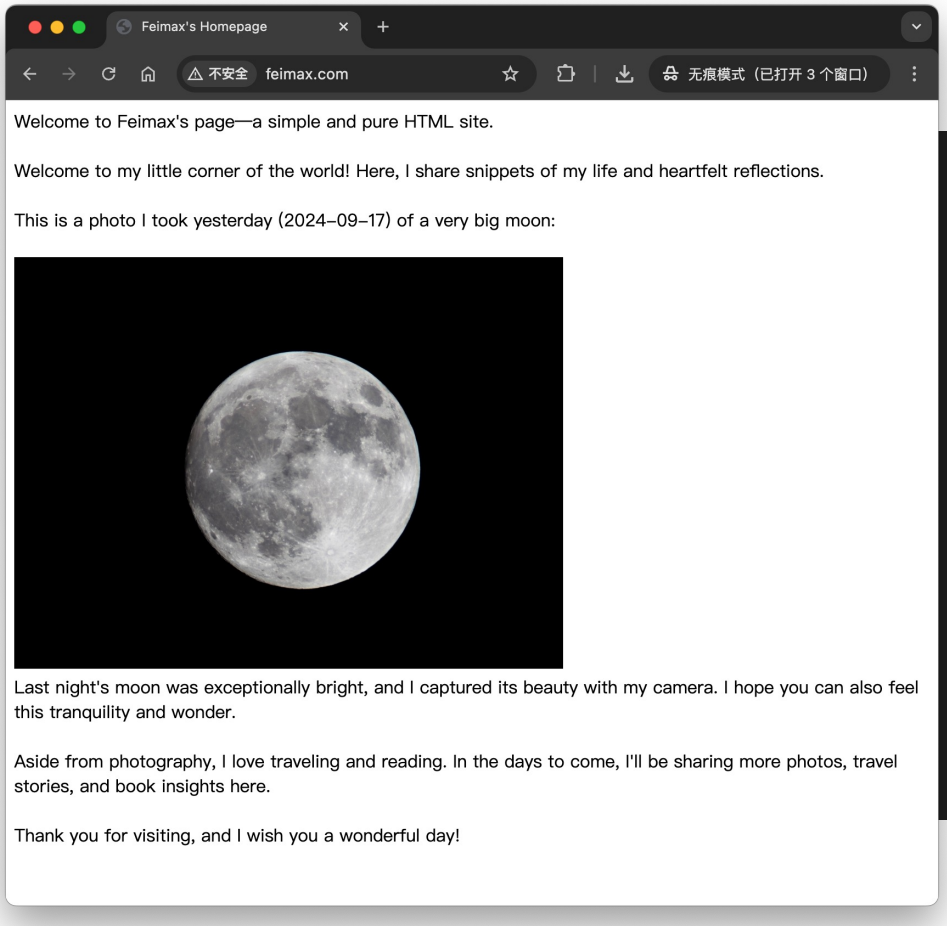
HTTP = WEBPAGE?

Chrome



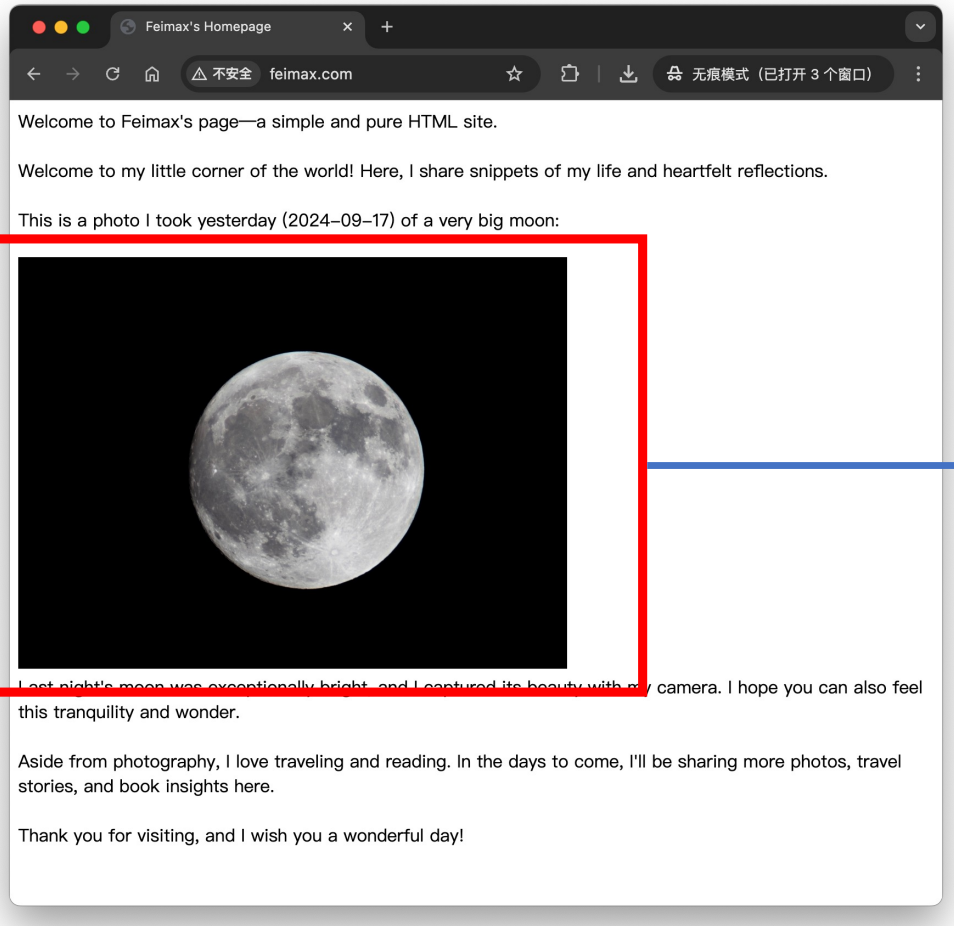
Wireshark



Page

```html
<!DOCTYPE html>
<html>
<head>
<meta charset="utf-8">
<title>Feimax's Homepage</title>
</head>
<body>
    Welcome to Feimax's page—a simple and pure HTML site.</br></br>

    Welcome to my little corner of the world! Here, I share snippets of my life and hear

    This is a photo I took yesterday (2024-09-17) of a very big moon:</br></br>

    <img src='20240917.jpg' style="width: 500px;" />
</br>
    Last night's moon was exceptionally bright, and I captured its beauty with my camera

    Aside from photography, I love traveling and reading. In the days to come, I'll be s

    Thank you for visiting, and I wish you a wonderful day!
</body>
```

HTML code (response)



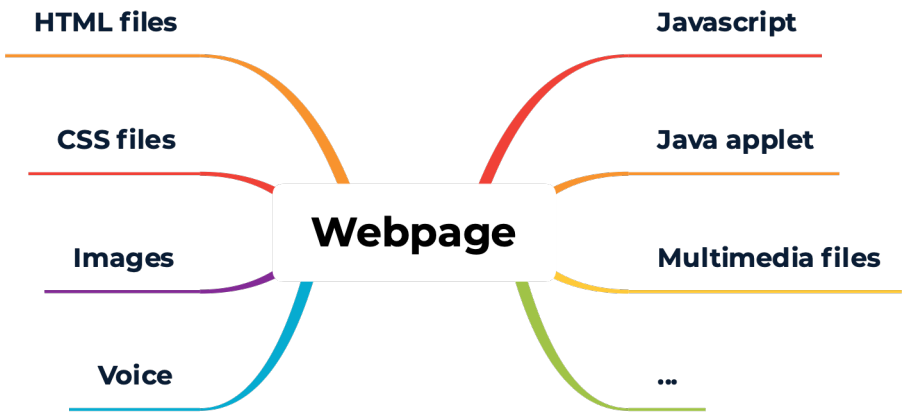
Page

http://www.feimax.com/20240917.jpg

HTML code (response)

Web, HTTP and WWW

- WWW: World Wide Web
- HTTP: Hypertext Transfer Protocol

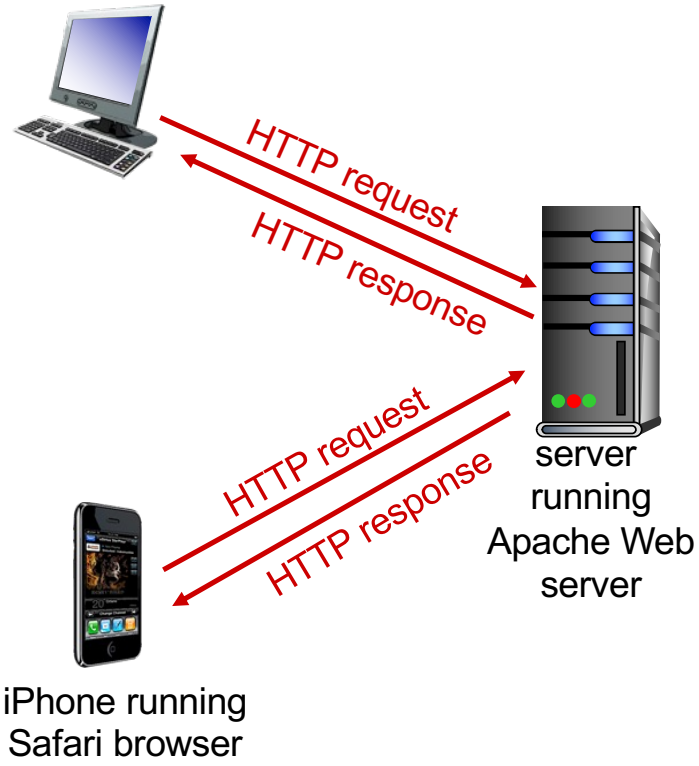


- Web page consists of *base HTML-file* which includes *several referenced objects, addressable by a URL (uniform resource locator)*

Features of HTTP (1.1)

HTTP: hypertext transfer protocol
(超文本传输协议)

- **Application layer protocol**
- **Client/server model**
  - *Client:* browser that requests, receives, (using HTTP protocol) and show Web objects（Render）
  - *Server:* Web server sends (using HTTP protocol) objects in response to requests



Features of HTTP (1.1)

Uses TCP:

1. Client initiates TCP connection (creates socket) to server, port **80(443 for https)**
2. Server accepts TCP connection from client
3. HTTP messages (application-layer protocol messages) exchanged between browser (HTTP client) and Web server (HTTP server)
4. TCP connection closed

HTTP is "stateless"

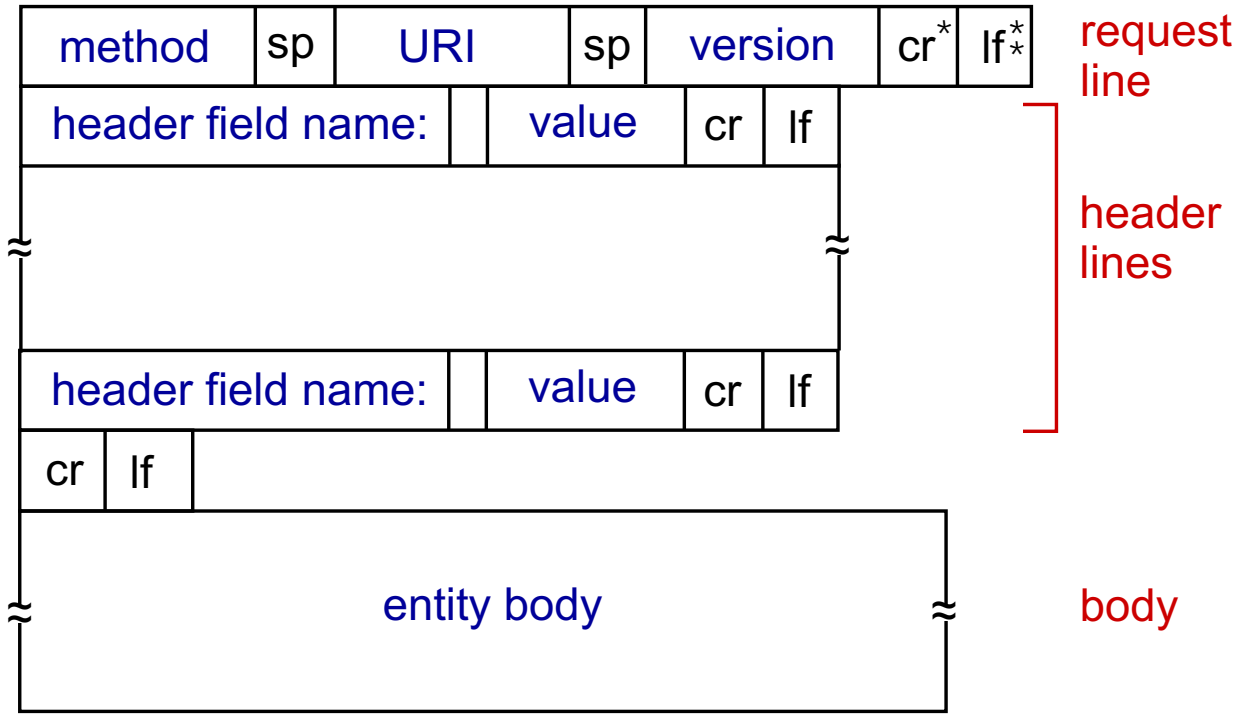
- server maintains no information about past client requests

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: general format



*carriage return character 回车

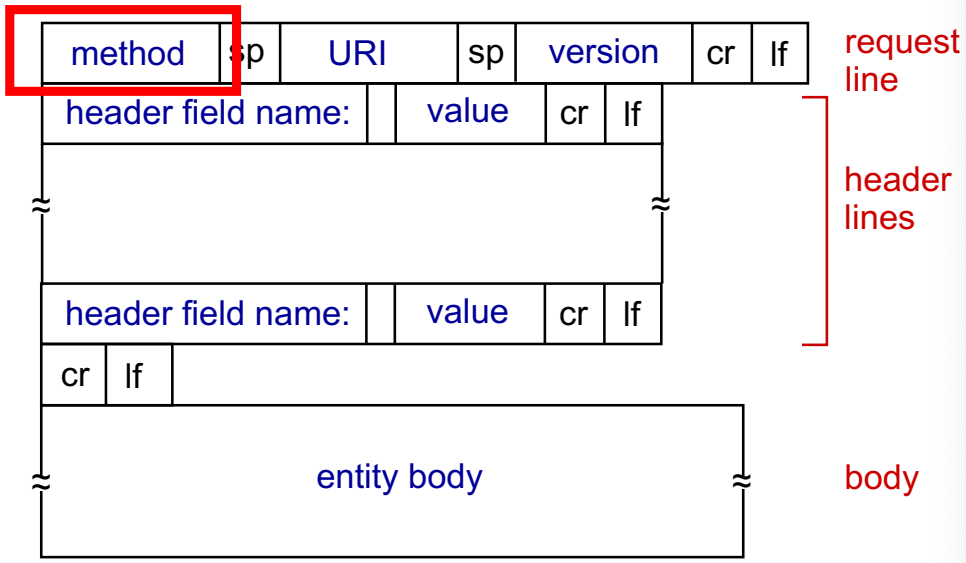
** line-feed character 换行

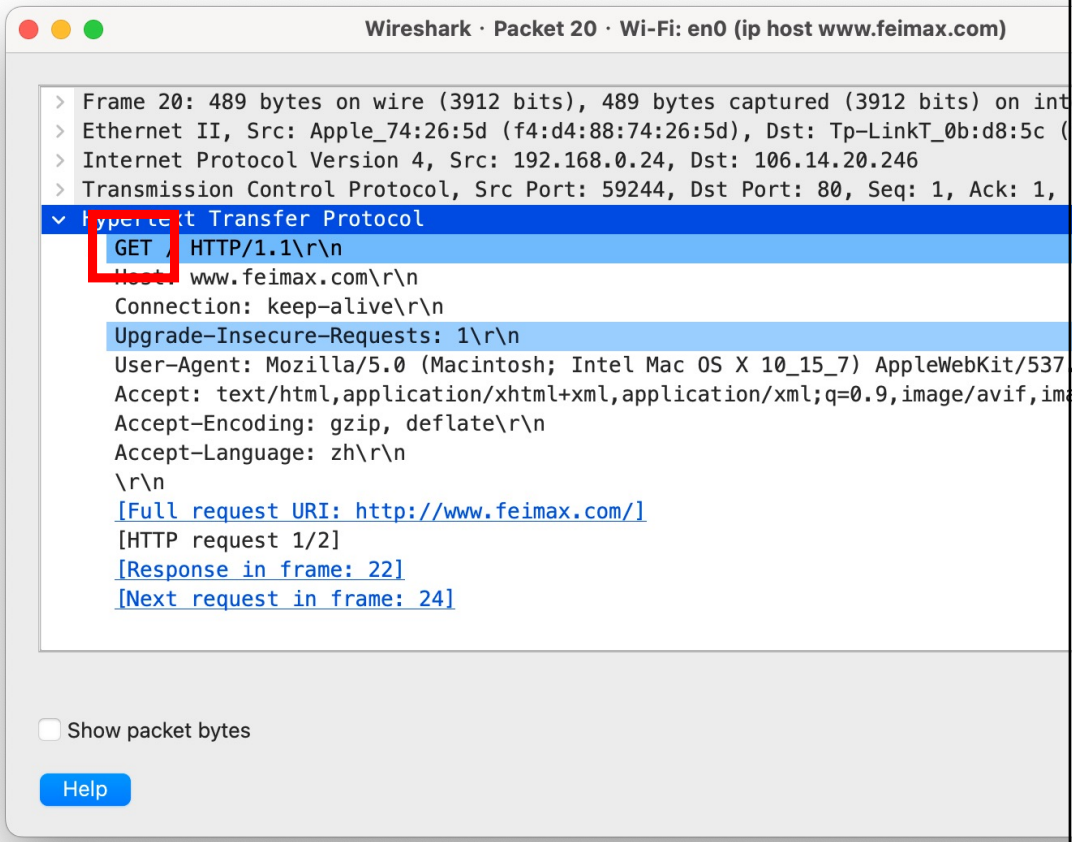
Note: No IP address is included in the HTTP request. Why?


Q W E R T Y U I O P
A S D F G H J K L
Z X C V B N M
TAB
M-R

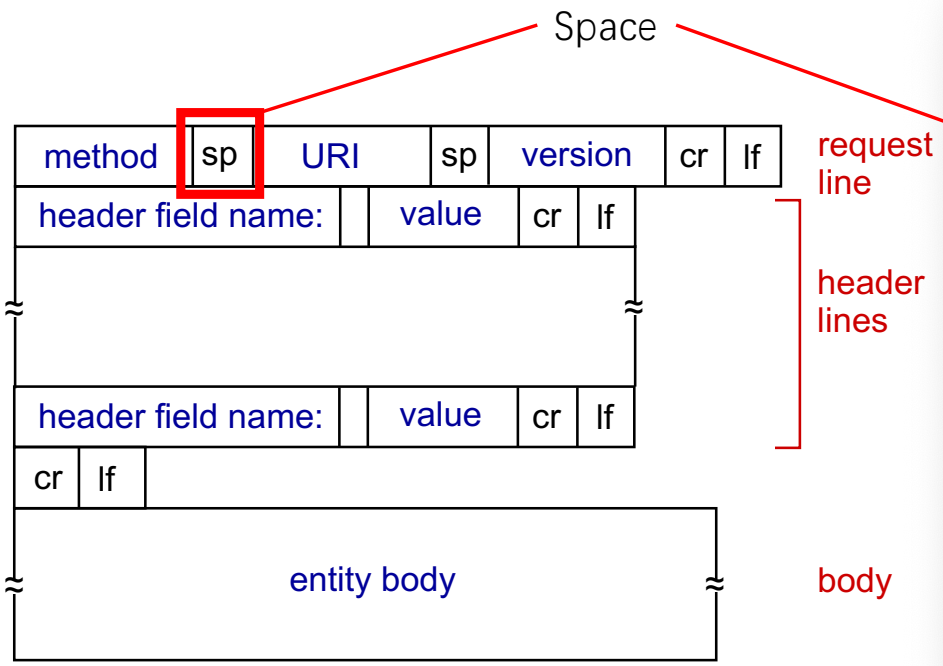
https://www.youtube.com/watch?v=M9RunwrxStw&ab_channel=DR.TYPEWRITER-VenneburgTypewriters

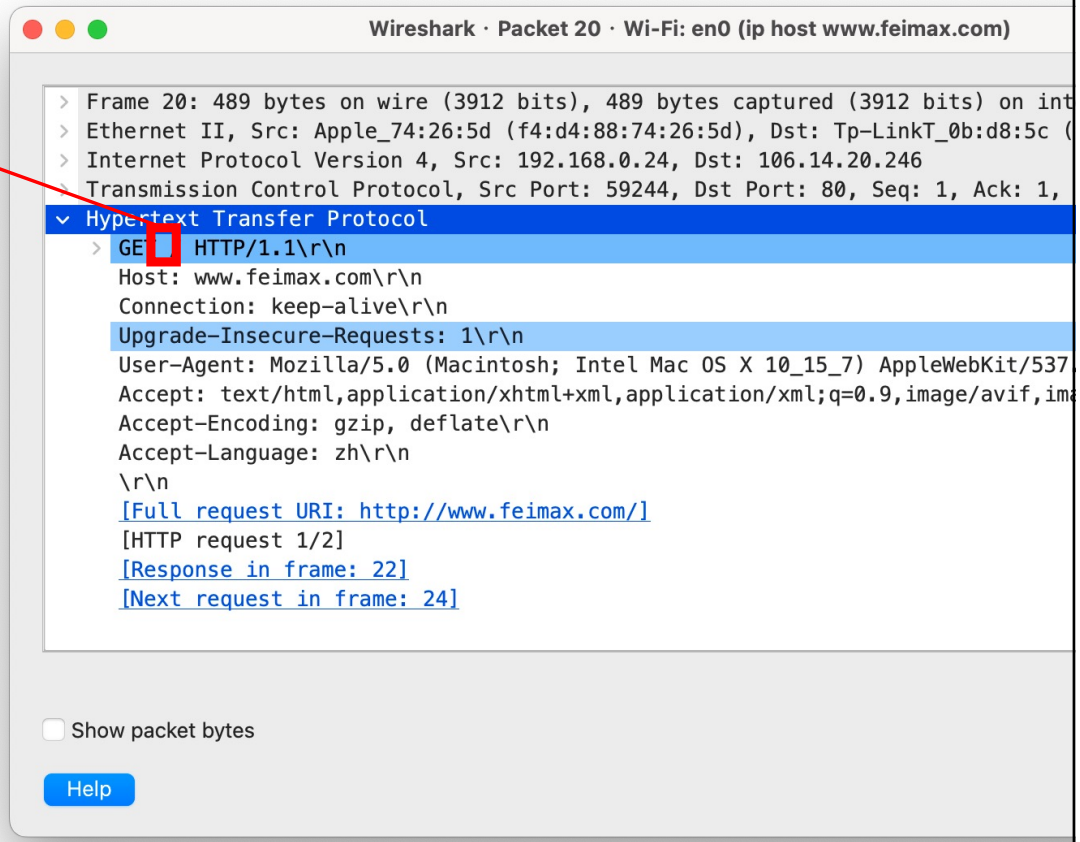
HTTP request message: general format





HTTP request message: general format





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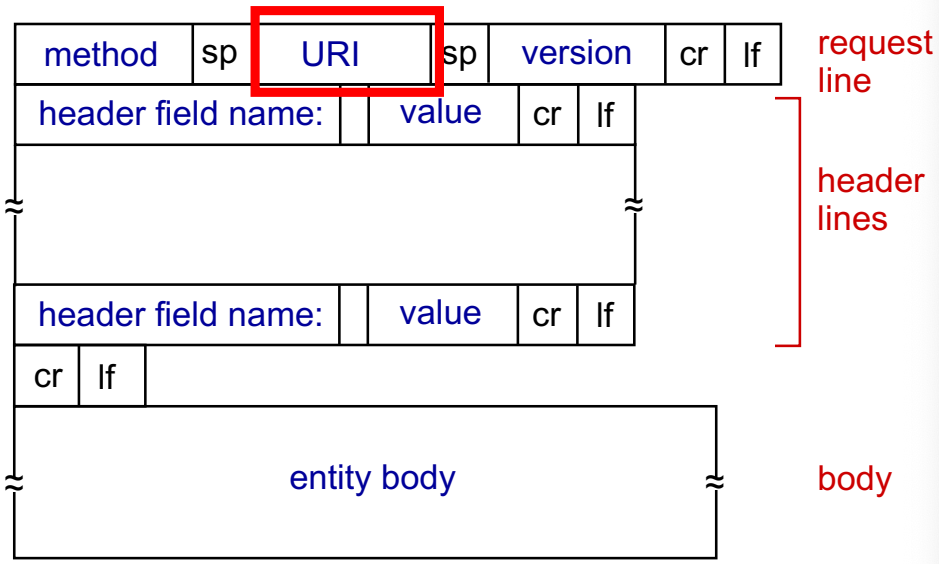

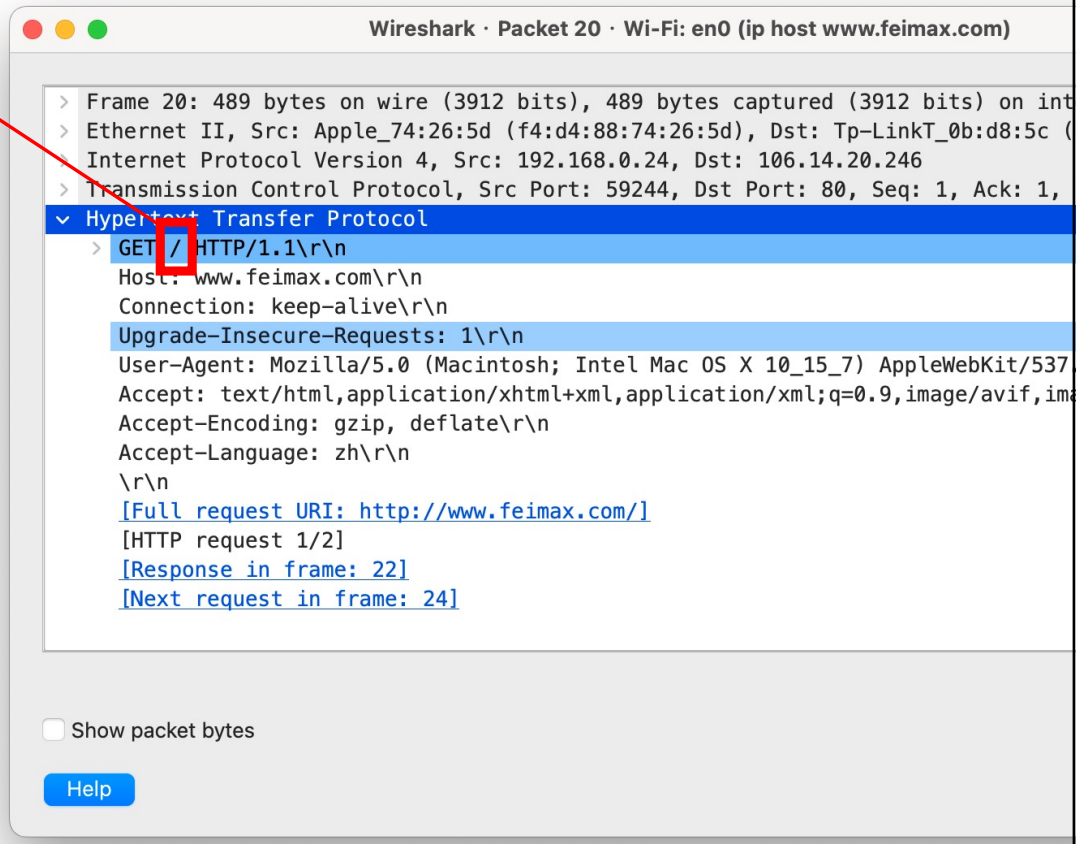

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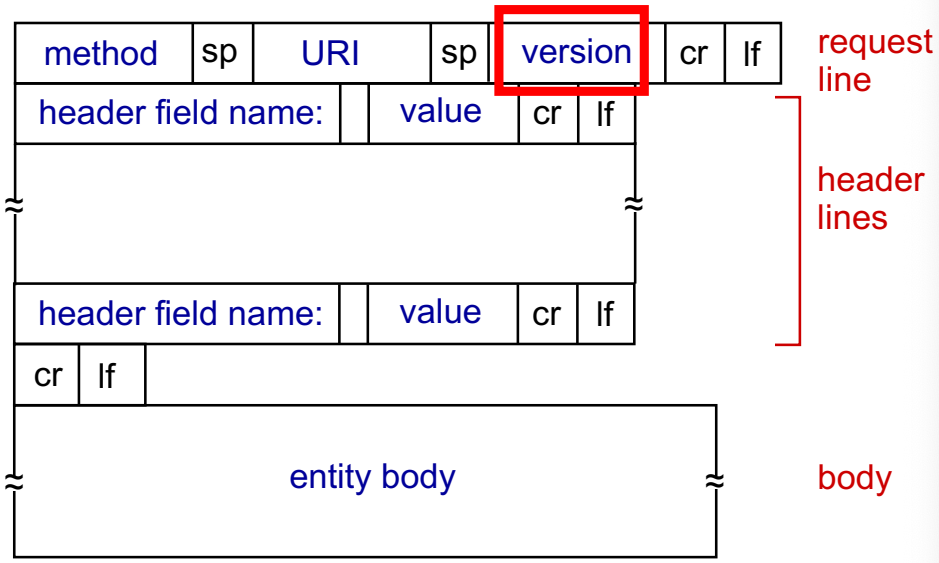

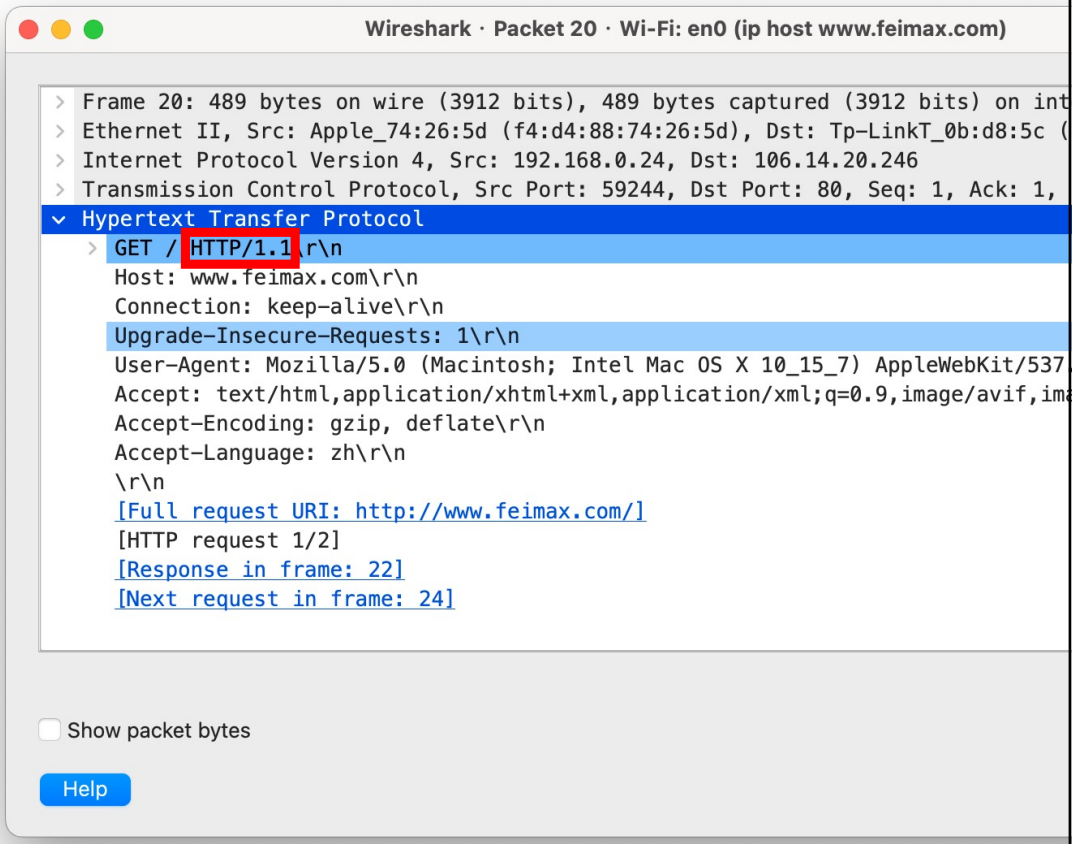

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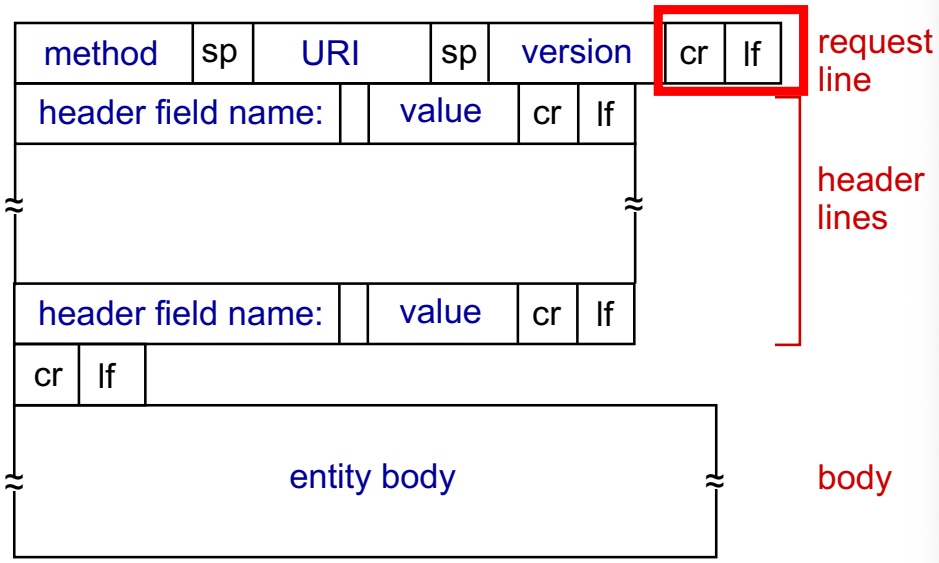

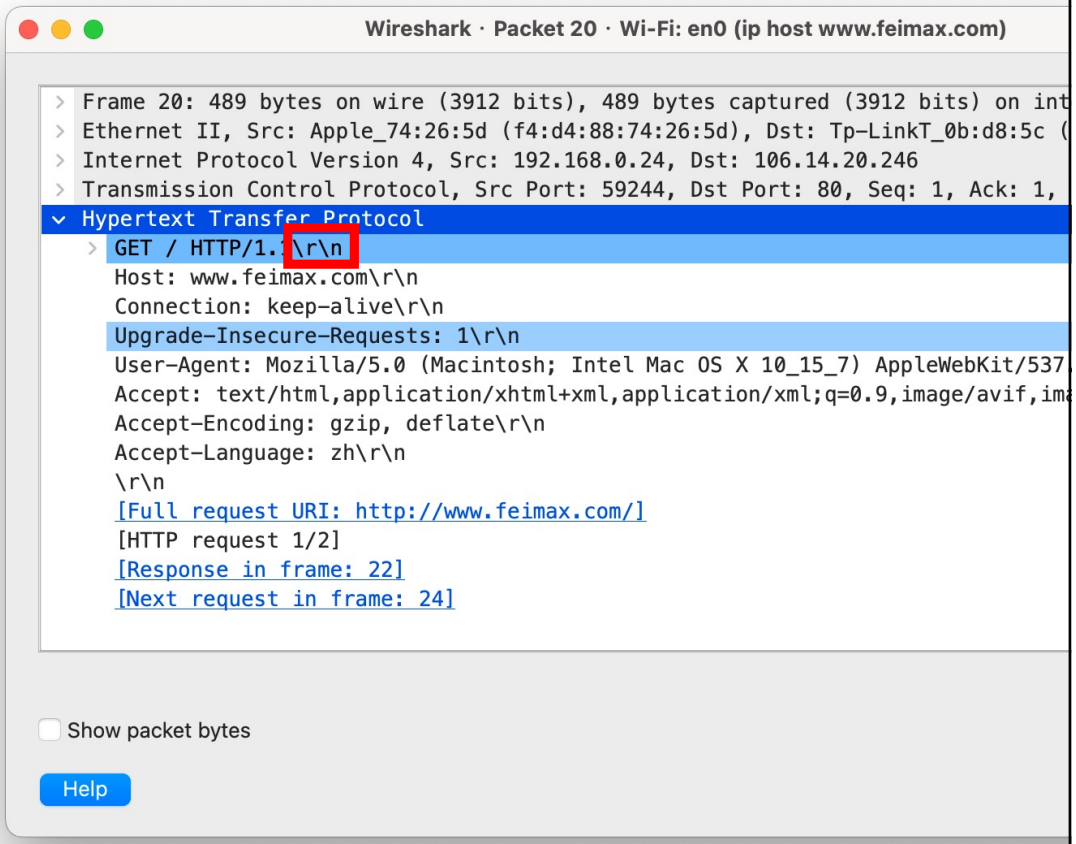

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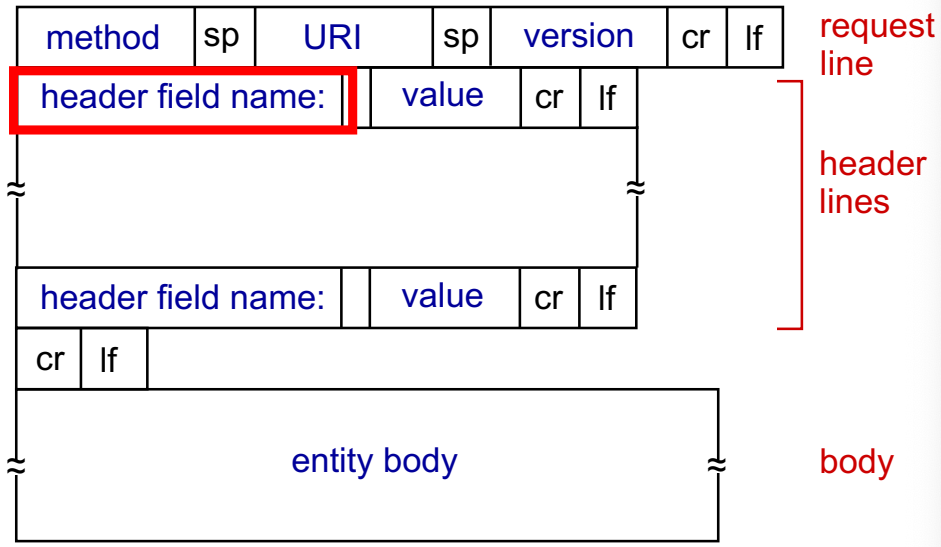
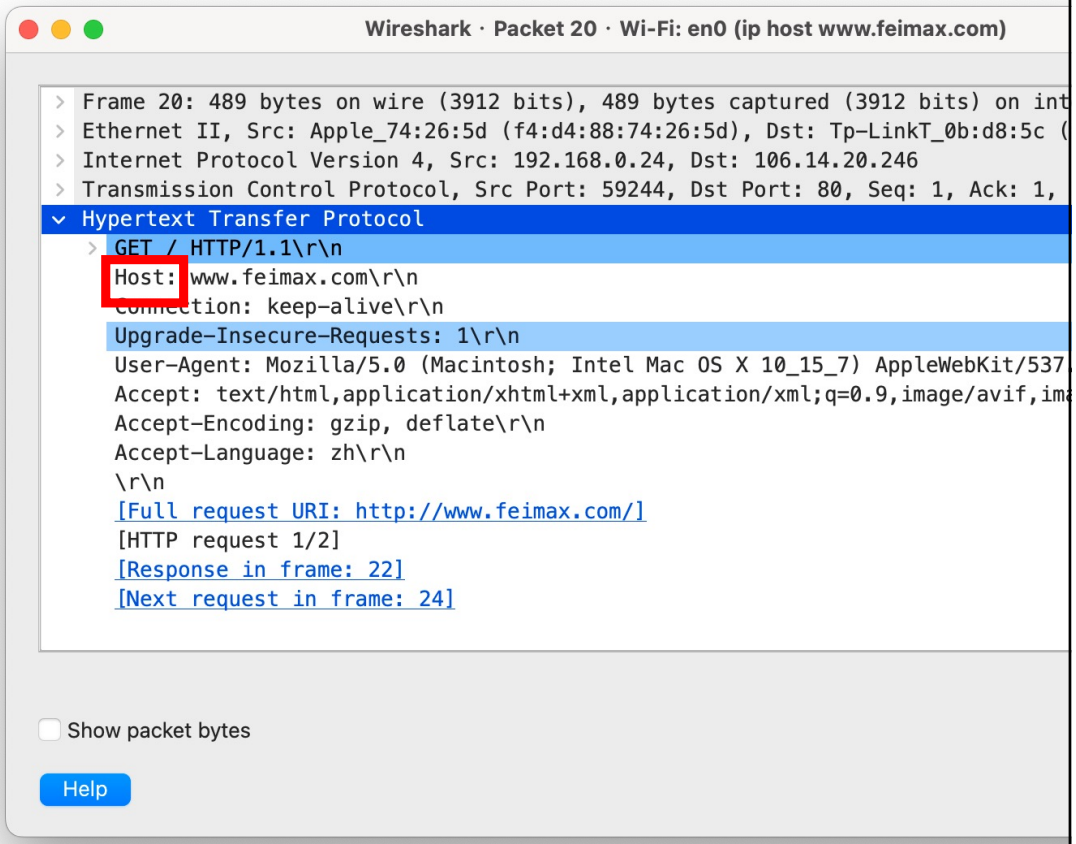
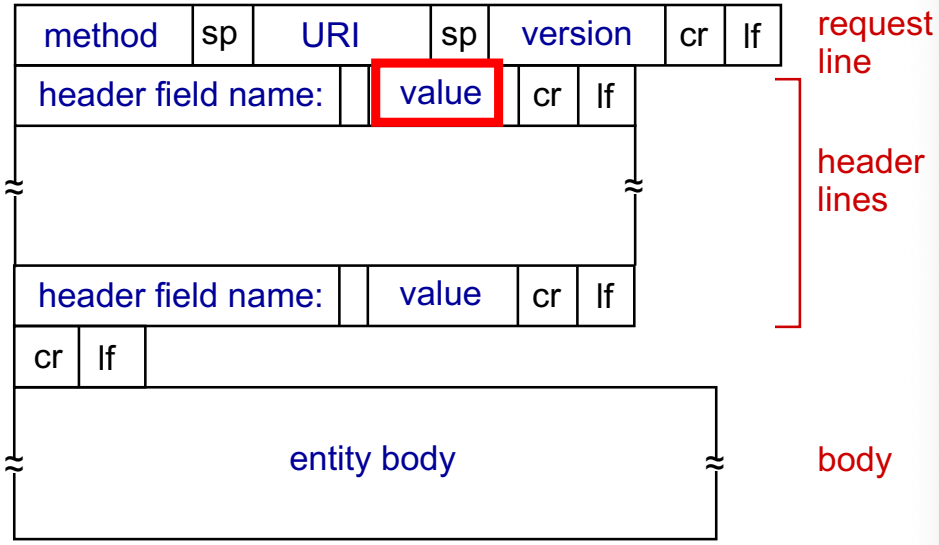
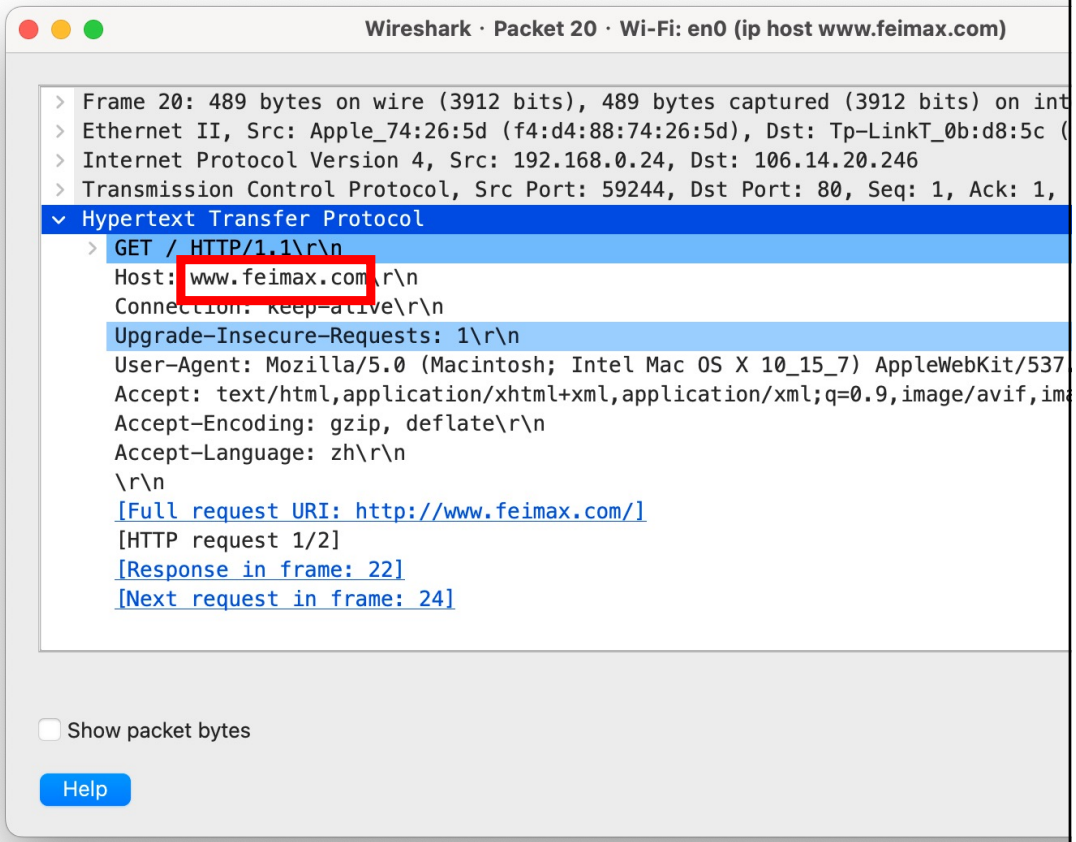


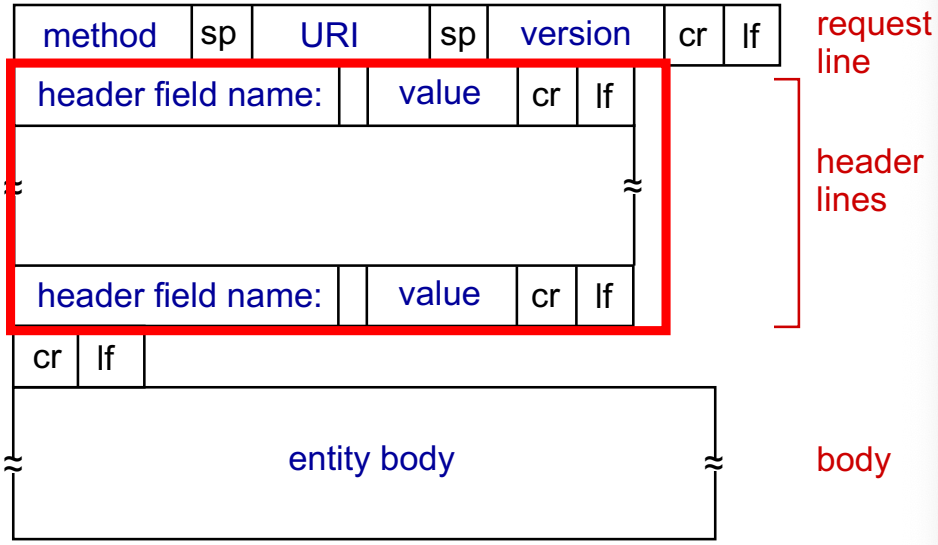


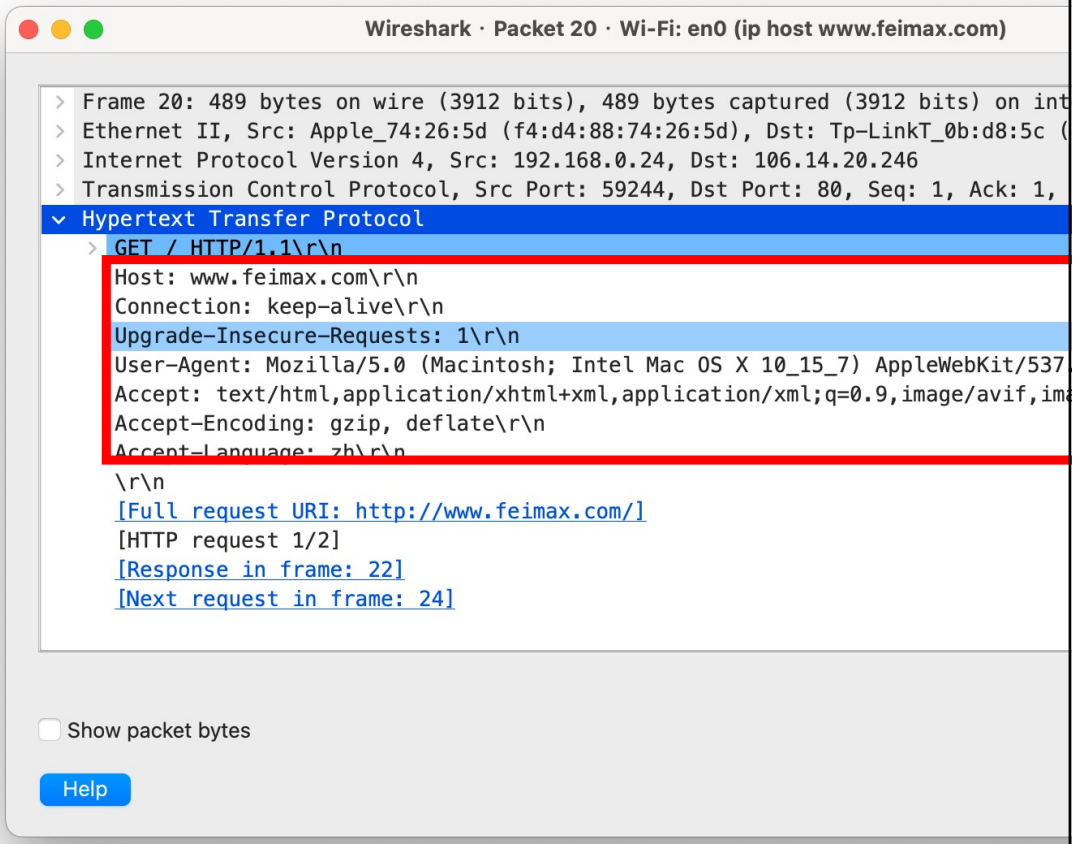
HTTP request message: general format



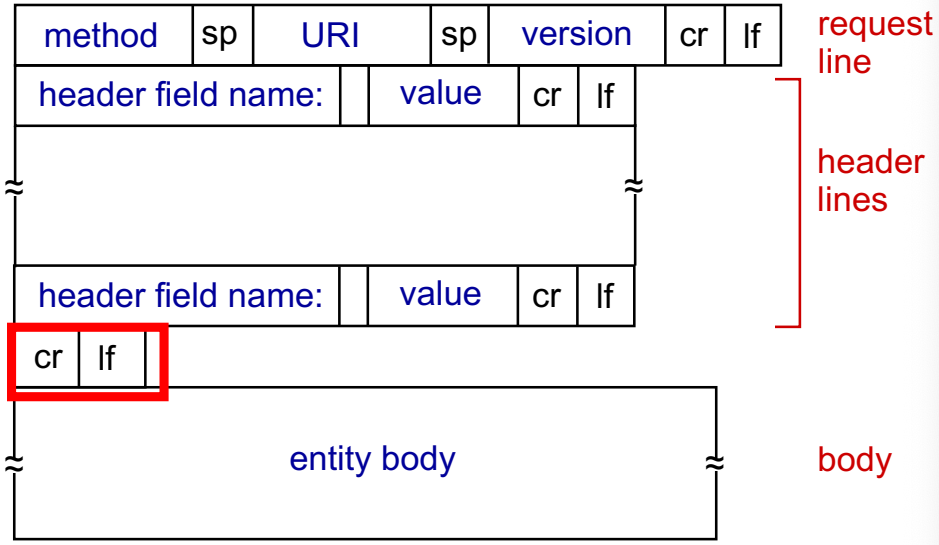


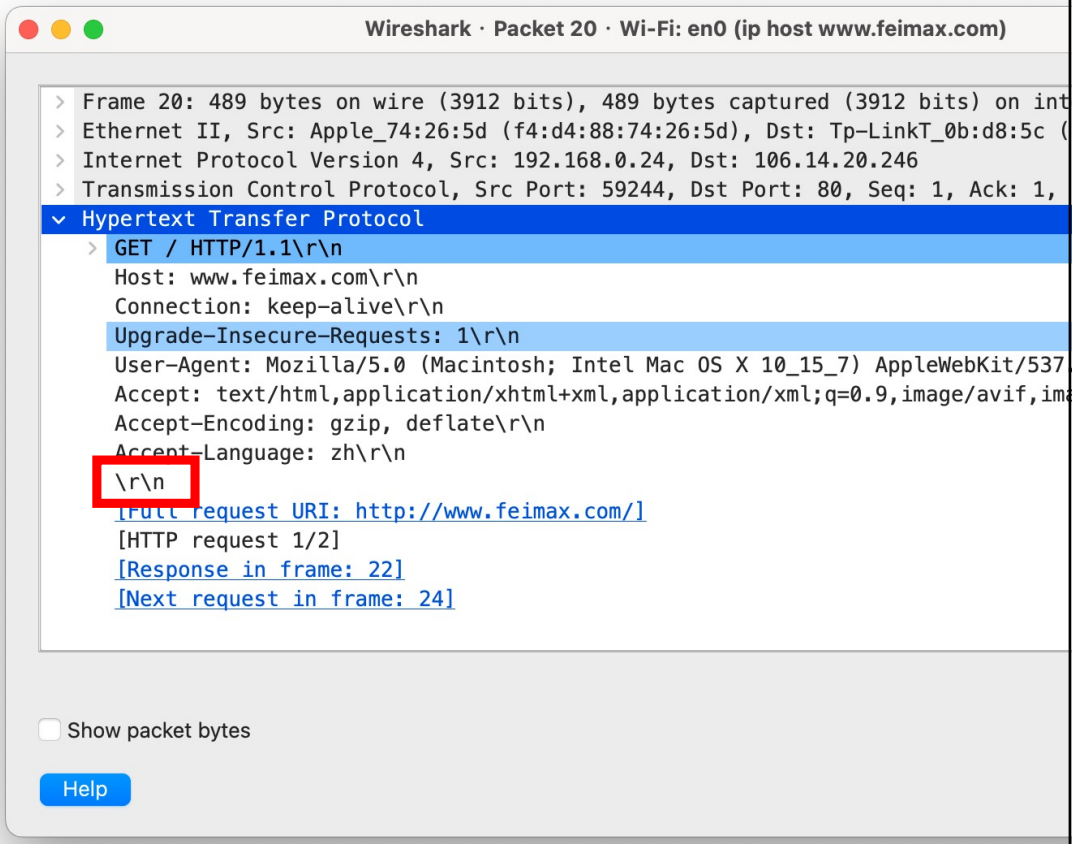
HTTP request message: general format

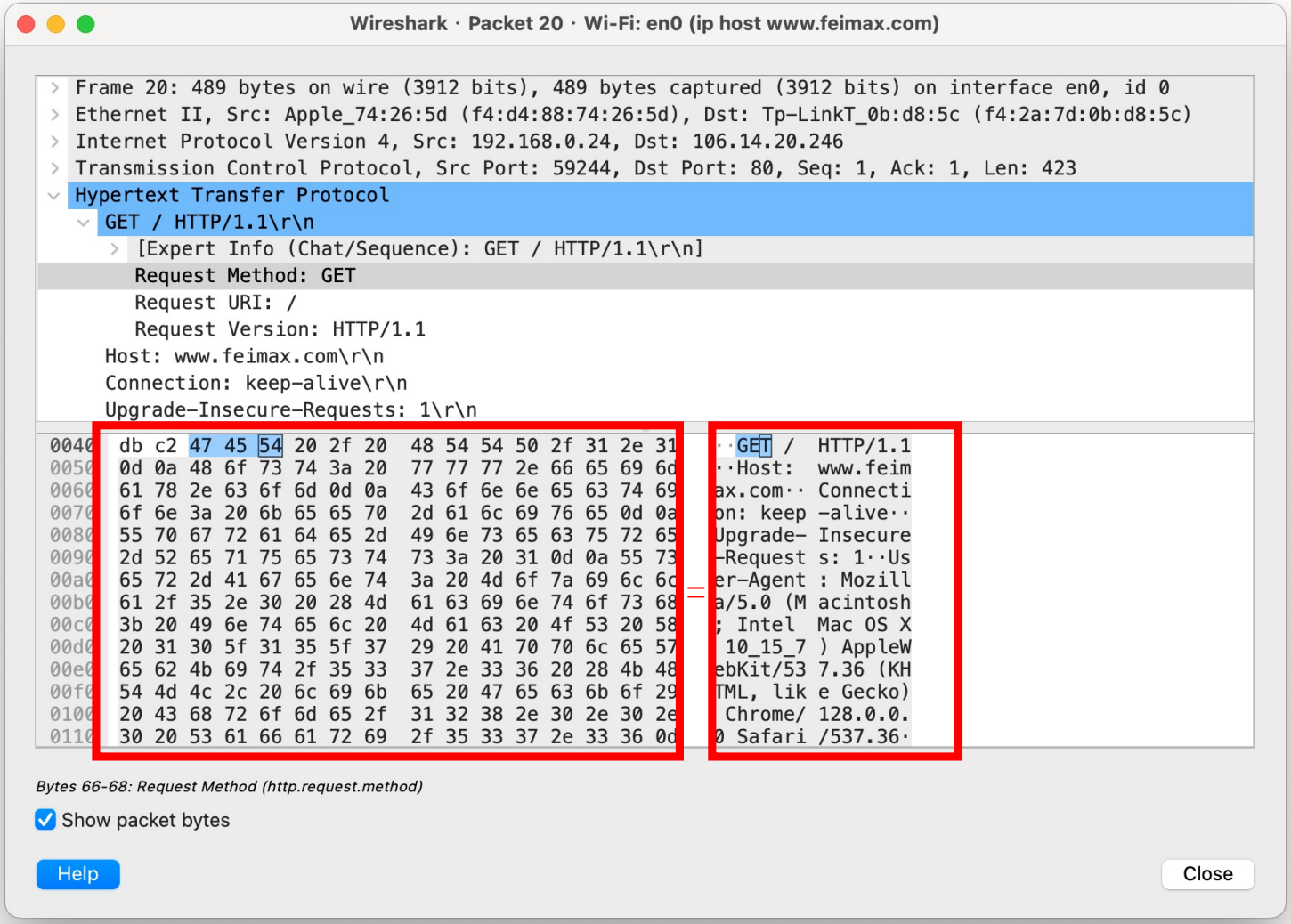




HTTP request message: general format







Human Readable!

HTTP 1.1 request method

- **What do we need from a web protocol?**

CRUD

HTTP 1.0 1.1 Additional methods

- GET
- POST
- PUT
- DELETE
- PATCH
- HEAD
- TRACE
- OPTIONS
- CONNECT

https://www.w3.org/Protocols/rfc2616/rfc2616-sec9.html

HTTP 1.1 request headers

- **Key-value pairs, metadata about the request and the client:**
  - Host name
  - Authentication
  - Content types
  - User-agent information
  - Caching / Cookies
  - Types of connections
  - …

Types of connections

Non-persistent HTTP

- **At most one object sent over TCP connection**
  - connection then closed
- **Downloading multiple objects required multiple connections**

Persistent HTTP

- **Multiple objects can be sent over single TCP connection between client, server**

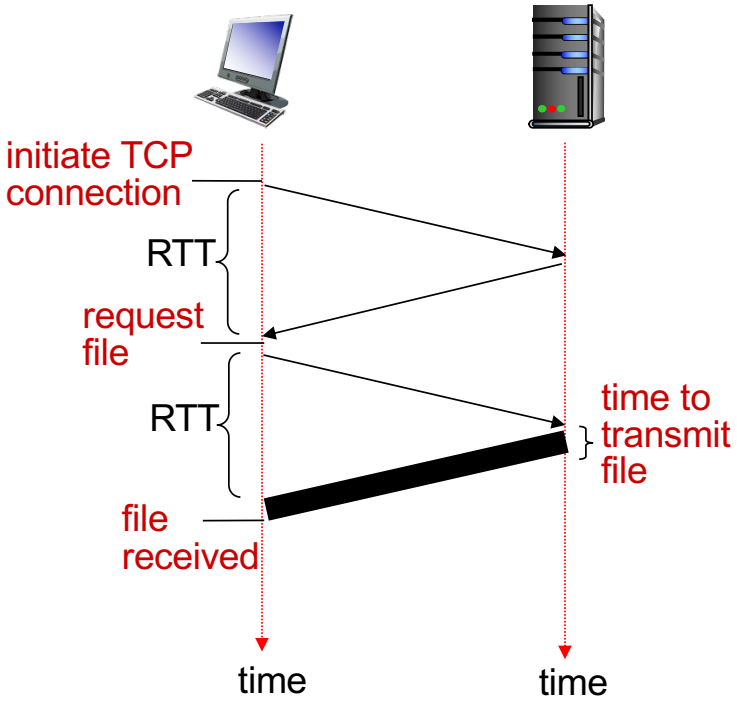
Non-persistent HTTP: response time

RTT (Round Trip Time): time for a small packet to travel from client to server and back round trip time

HTTP 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
- Non-persistent HTTP response time =

2RTT+ file transmission time



Persistent HTTP

Non-persistent HTTP issues:

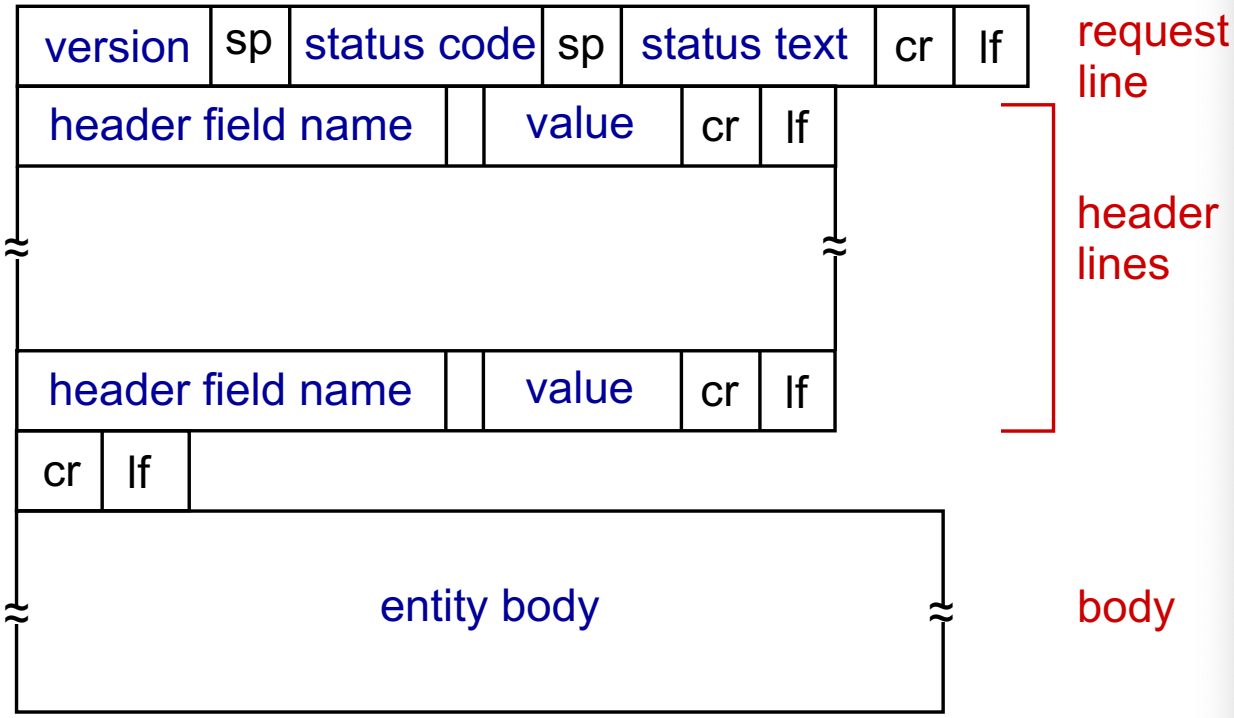
- Requires 2 RTTs per object
- OS overhead for *each* TCP connection
- Browsers often open parallel TCP connections to fetch referenced objects

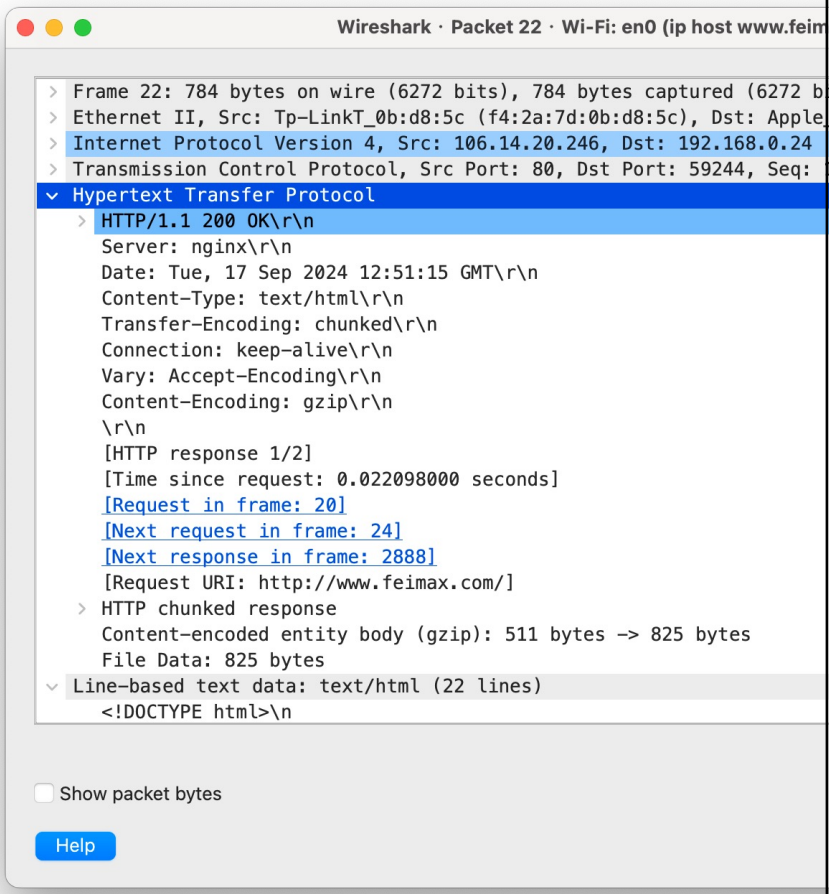
Q: Is persistent HTTP perfect? <=

Persistent HTTP issues:

- 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

HTTP response message: format





HTTP response status codes

- **Status code appears in 1st line in server-to-client response message.**
- **Some sample codes:**
  - 200 OK
  - 301 Move Permanently
  - 400 Bad Request
  - 404 Not Found
  - 505 HTTP Version Not Supported

https://www.w3.org/Protocols/rfc2616/rfc2616-sec6.html#sec6.1.1

- 1xx: Informational - Request received, continuing process
- 2xx: Success - The action was successfully received, understood, and accepted
- 3xx: Redirection - Further action must be taken in order to complete the request
- 4xx: Client Error - The request contains bad syntax or cannot be fulfilled
- 5xx: Server Error - The server failed to fulfill an apparently valid request

https://www.w3.org/Protocols/rfc2616/rfc2616-sec6.html#sec6.1.1

- 1xx: Informational - Request received, continuing process
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- 3xx: Redirection - Further action must be taken in order to complete the request
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- 5xx: Server Error - The server failed to fulfill an apparently valid request

```
Status-Code    =
      "100"  ; Section 10.1.1: Continue
    | "101"  ; Section 10.1.2: Switching Protocols
    | "200"  ; Section 10.2.1: OK
    | "201"  ; Section 10.2.2: Created
    | "202"  ; Section 10.2.3: Accepted
    | "203"  ; Section 10.2.4: Non-Authoritative Information
    | "204"  ; Section 10.2.5: No Content
    | "205"  ; Section 10.2.6: Reset Content
    | "206"  ; Section 10.2.7: Partial Content
    | "300"  ; Section 10.3.1: Multiple Choices
    | "301"  ; Section 10.3.2: Moved Permanently
    | "302"  ; Section 10.3.3: Found
    | "303"  ; Section 10.3.4: See Other
    | "304"  ; Section 10.3.5: Not Modified
    | "305"  ; Section 10.3.6: Use Proxy
    | "307"  ; Section 10.3.8: Temporary Redirect
    | "400"  ; Section 10.4.1: Bad Request
    | "401"  ; Section 10.4.2: Unauthorized
    | "402"  ; Section 10.4.3: Payment Required
    | "403"  ; Section 10.4.4: Forbidden
    | "404"  ; Section 10.4.5: Not Found
    | "405"  ; Section 10.4.6: Method Not Allowed
    | "406"  ; Section 10.4.7: Not Acceptable

    | "407"  ; Section 10.4.8: Proxy Authentication Required
    | "408"  ; Section 10.4.9: Request Time-out
    | "409"  ; Section 10.4.10: Conflict
    | "410"  ; Section 10.4.11: Gone
    | "411"  ; Section 10.4.12: Length Required
    | "412"  ; Section 10.4.13: Precondition Failed
    | "413"  ; Section 10.4.14: Request Entity Too Large
    | "414"  ; Section 10.4.15: Request-URI Too Large
    | "415"  ; Section 10.4.16: Unsupported Media Type
    | "416"  ; Section 10.4.17: Requested range not satisfiable
    | "417"  ; Section 10.4.18: Expectation Failed
    | "500"  ; Section 10.5.1: Internal Server Error
    | "501"  ; Section 10.5.2: Not Implemented
    | "502"  ; Section 10.5.3: Bad Gateway
    | "503"  ; Section 10.5.4: Service Unavailable
    | "504"  ; Section 10.5.5: Gateway Time-out
    | "505"  ; Section 10.5.6: HTTP Version not supported
    | extension-code
```

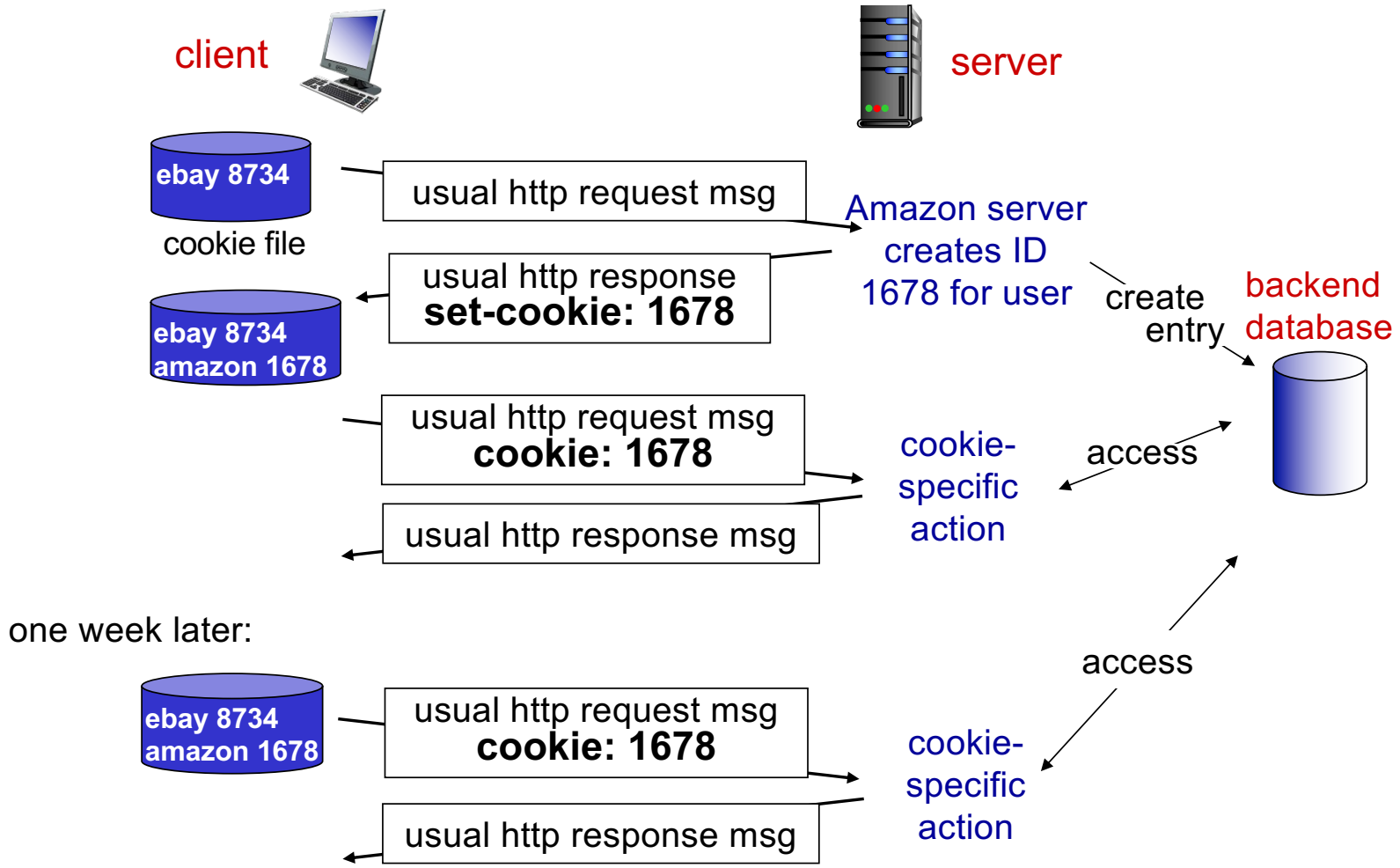
HTTP is "stateless" !
So…

User-server state: cookies

- **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:

- Bob always access Internet from PC
- Visits Taobao site for first time
- When initial HTTP requests arrives at site, site creates:
  - unique ID -> cookie
  - entry in backend database for ID


client
server
ebay 8734
cookie file
usual http request msg
Amazon server
creates ID
1678 for user
create
entry
backend
database
usual http response
set-cookie: 1678
ebay 8734
amazon 1678
usual http request msg
cookie: 1678
cookie-
specific
action
access
usual http response msg
one week later:
access
ebay 8734
amazon 1678
usual http request msg
cookie: 1678
cookie-
specific
action
usual http response msg

Cookies

What cookies can be used for:

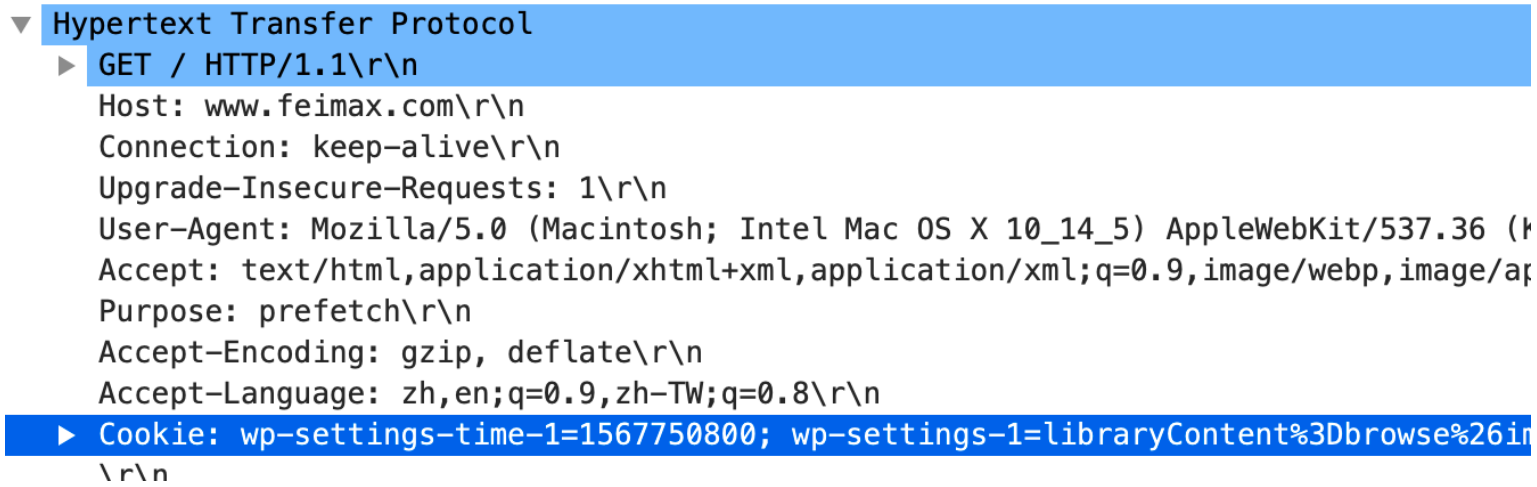
- **Authorization**
- **Recommendations**
- **User session state**
- **…**

aside

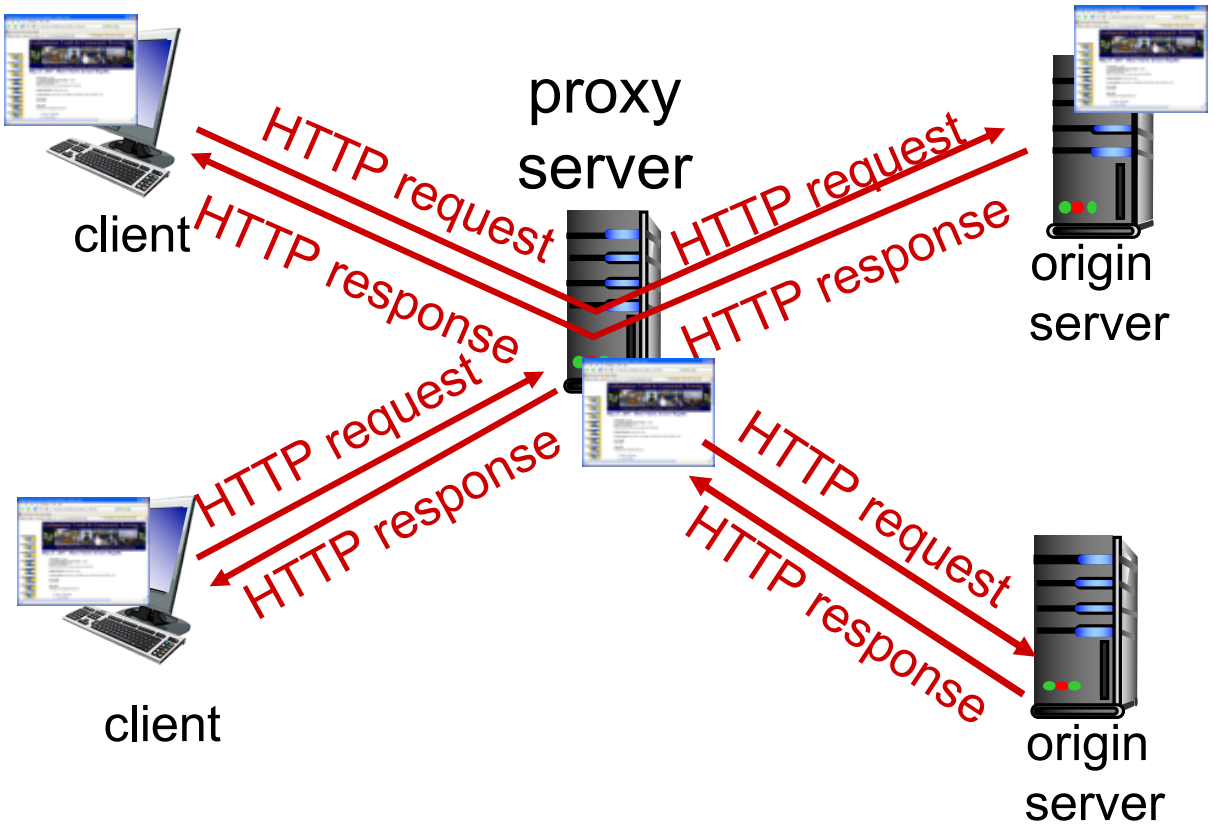
Cookies and privacy:

- Cookies permit sites to learn a lot about you
- Remember to clean your cookies

Wireshark Test



Web caches


proxy
server
client
HTTP request
HTTP response
HTTP request
HTTP response
origin
server
client
HTTP request
HTTP response
HTTP request
HTTP response
origin
server

More about Web caching

- **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?

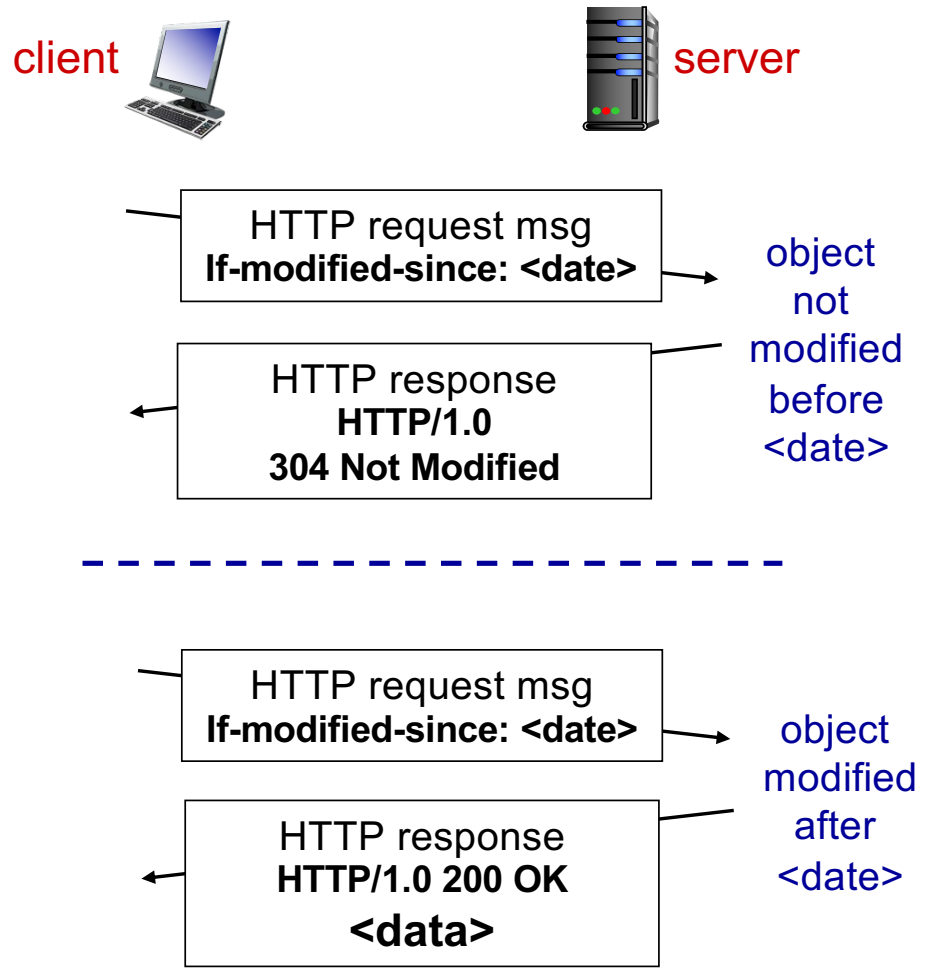
- reduce response time for client request
- reduce traffic on an institution's access link
- Internet dense with caches: enables "poor" content providers to effectively deliver content (so too does P2P file sharing)

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`



HTTP = WEBPAGE?

Thanks.