NETWORKING REVIEW

CS 361S

Spring 2020

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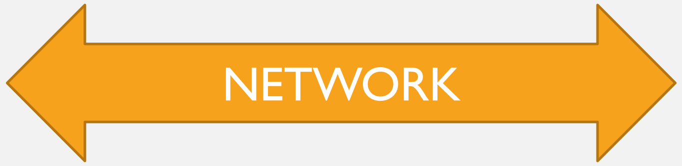
COMPUTING 1960-1980 (ISH)



“DUMB” TERMINAL

MAINFRAME

COMPUTING 1980-2000 (ISH)

COMPUTING 2000 – PRESENT

NETWORK

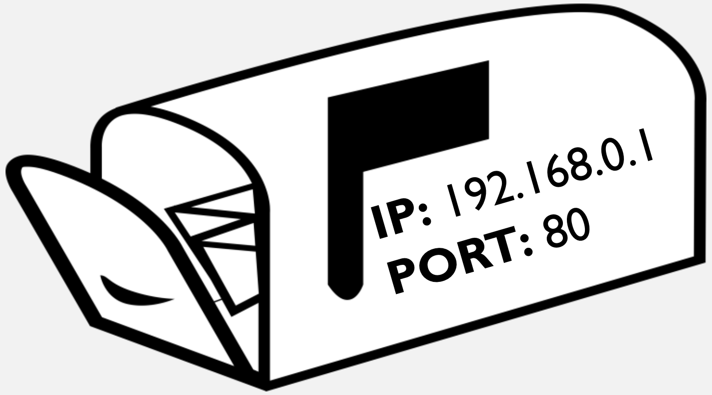
GENERAL IDEAS BEHIND CLIENT-SERVER

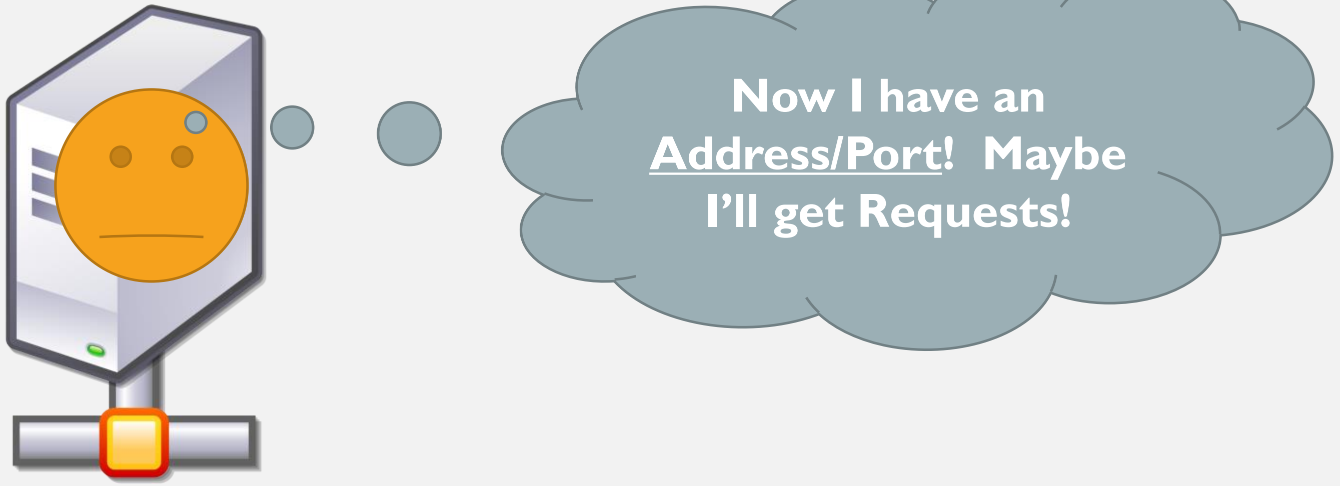
- Put a bunch of resources in a high-performance, centralized machine
- Clients can be much "dumber" *by comparison*
- Much more efficient
  - Sharing data between devices, applications, and people (and marketing)
  - Access from multiple locations (including hackers!)
  - Time-sharing a central machine is more scalable and cost-effective

SERVER ABSTRACTION

SERVER ***LISTENS*** FOR INCOMING REQUESTS

PREVIEW OF TCP/IP





SERVER HAS AN **IP ADDRESS** AND **TCP PORT**

MEANWHILE, CLIENT ABSTRACTION

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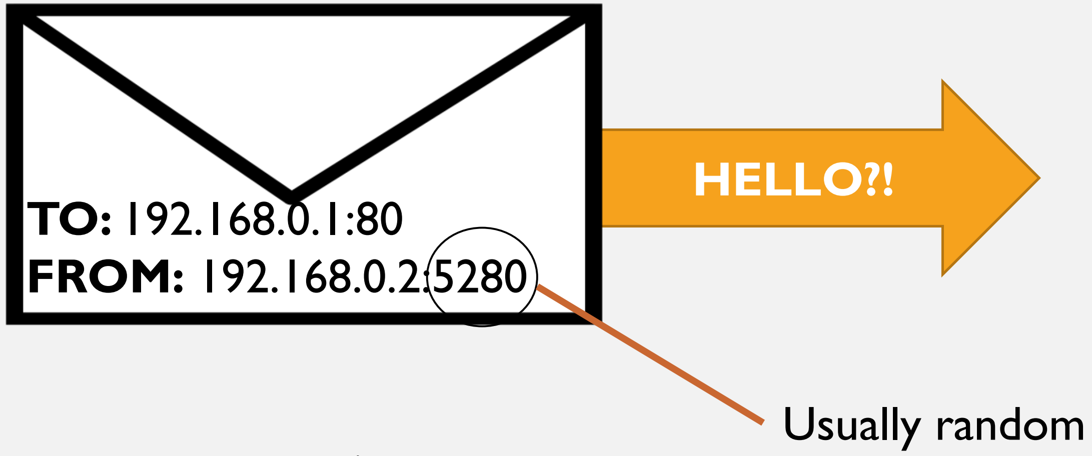
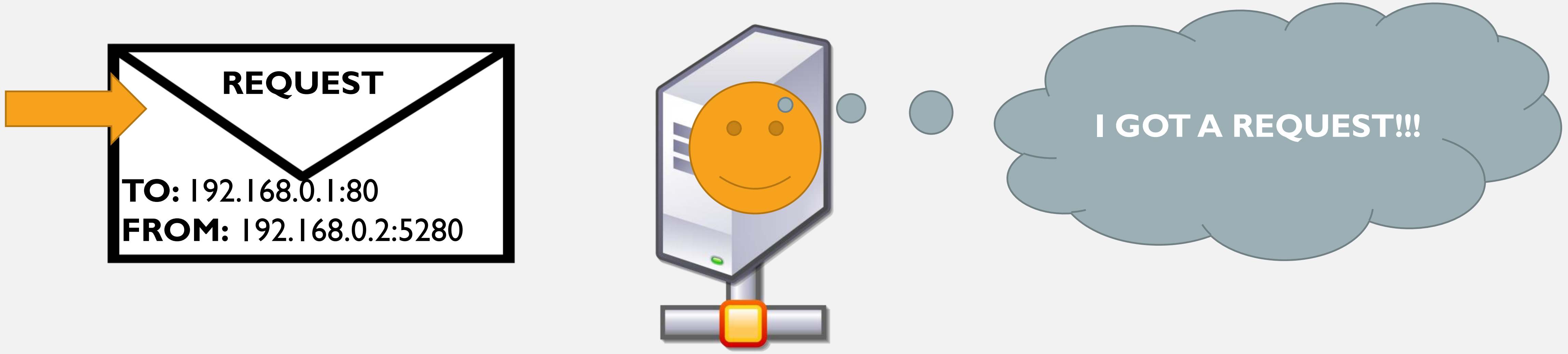
CLIENT ***CONNECTS*** TO MAKE OUTBOUND REQUESTS

TCP/IP AGAIN



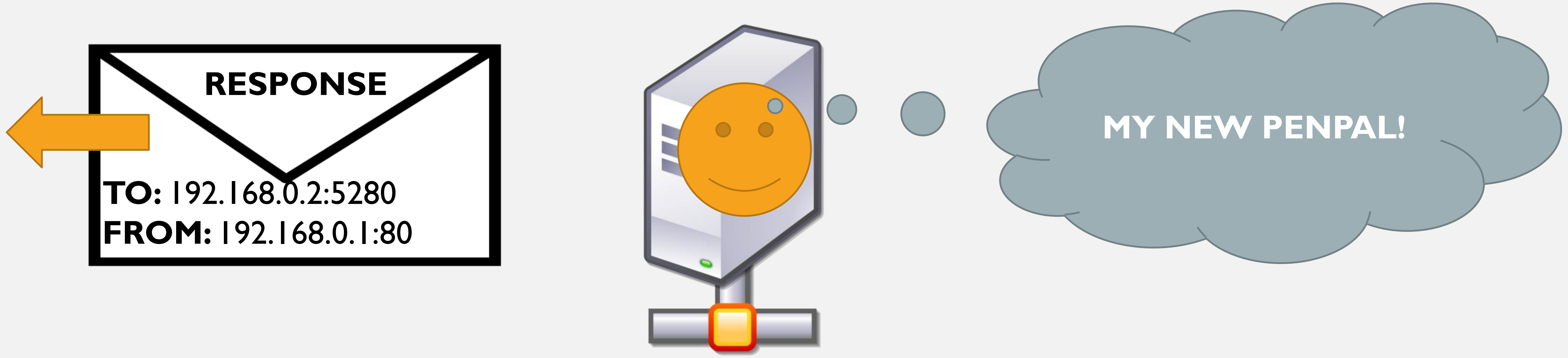
CLIENT ***CONNECTS*** TO MAKE OUTBOUND REQUESTS

INCOMING REQUEST



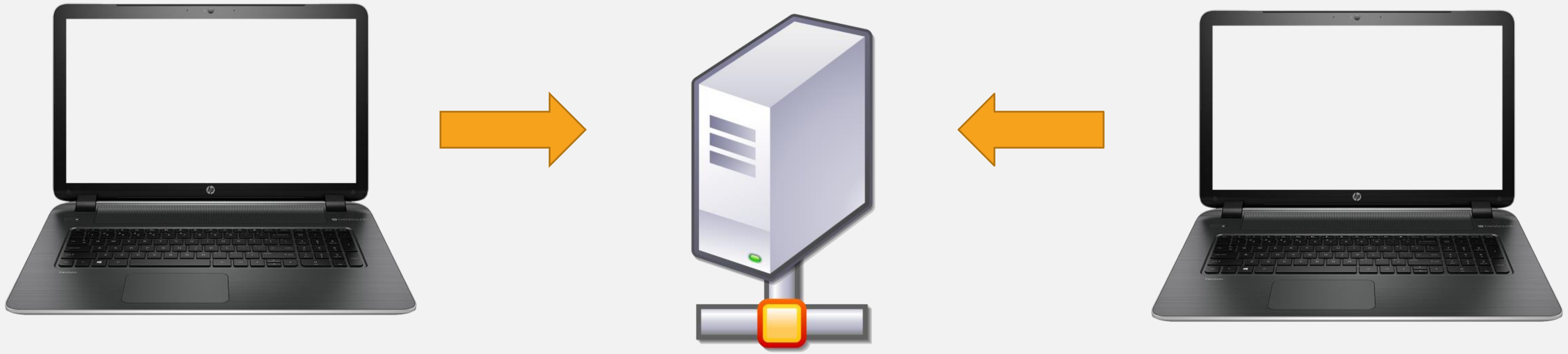
SERVER RECEIVES REQUEST

REQUEST RESPONSE



SERVER **INVERTS TO/FROM** FOR RESPONSE

SERVER LISTENS TO MANY REQUESTS



SERVER USES **(SRC IP, SRC PORT, DST IP, DST PORT)*** TO MULTIPLEX

This is how one server on one port (e.g., webserver) handles many clients

WHAT IS A PROTOCOL?

- A protocol is the set of rules that govern the interaction of two or more parties
- In the context of networking, it defines how two nodes communicate
  - When a party can communicate
  - What a party can communicate, *including message structure*
  - How a party responds to received communications
- ***Certain outcomes or results are guaranteed when the rules are followed***

OVERLOADED TERM

- Actually, a protocol often refers to two separate things
- **FIRST**, the rules/specification referred to on the previous slide
- **SECOND**, the computer module that *implements* the rules

COMMON CONTEMPORARY PROTOCOLS

- HTTP – HyperText Transfer Protocol
- IP – Internet Protocol
- SMTP – Simple Mail Transport Protocol

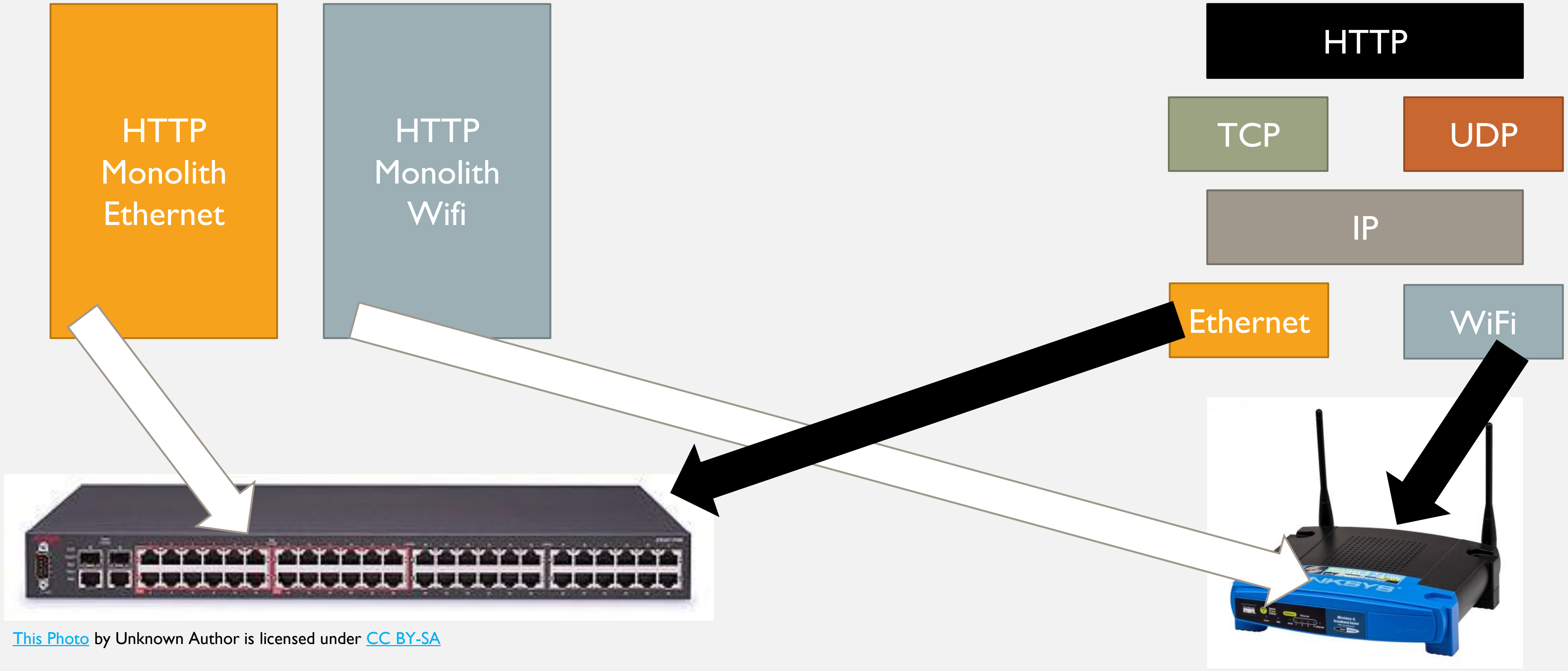
ONE PROTOCOL IS NOT ENOUGH

- There are too many rules for any one protocol to handle
- Also, behavior/rules need to change for different hardware/goals
- For example, consider HTTP
  - HTTP protocol shouldn’t need to worry about the IP protocol rules
  - HTTP definitely shouldn’t need to worry about Ethernet rules
  - And HTTP should work even after a switch from Ethernet to Wifi

PROTOCOL *STACKS*

- Object-oriented design has been around long before object-oriented programming
  - Modularity
  - Abstraction
  - Information hiding
- Protocols are designed in an object-oriented fashion
  - Protocols are combined to solve more complex problems
  - Each protocol should focus on one purpose/goal (High Cohesion)
  - Different component protocols can be swapped (Low coupling)
- We call a group of protocols that work together a *protocol stack*
- In computer networking, a *network protocol stack* or a *network stack*

MONOLITHIC VS MODULAR



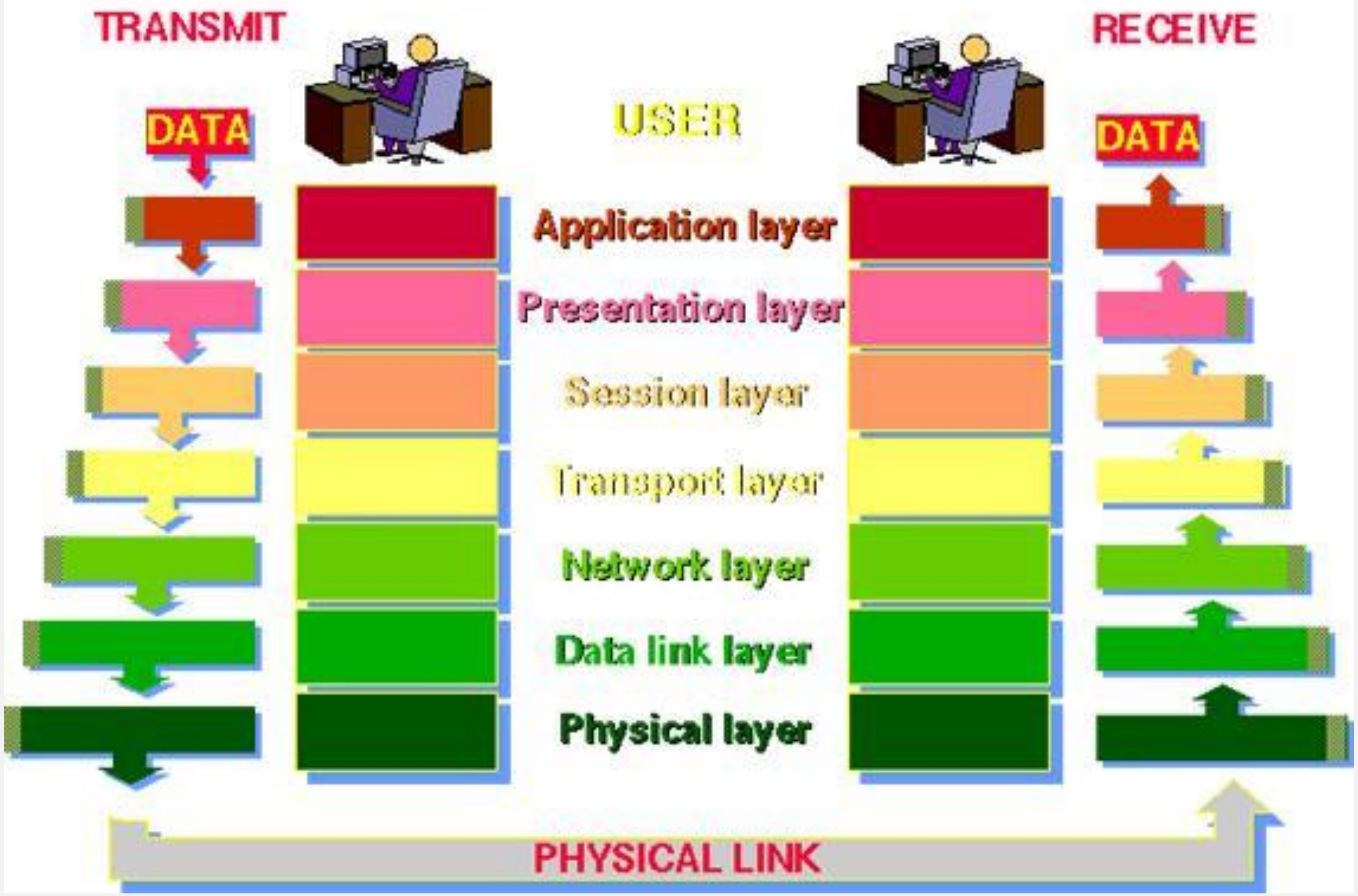
OTHER PROBLEMS WITH MONOLITHIC

- No separation of user/kernel space components
- Code cannot be reused; code bloat
- NxM combinations
- Patching nightmare
- Testing limitations
- List goes on and on

OSI MODEL

- Good object-oriented design is implementation independent
- ISO defined a guide for any given network stack called the OSI Model
- It has seven layers:
  - 7: Application
  - 6: Presentation
  - 5: Session
  - 4: Transport
  - 3: Network
  - 2: Data Link
  - 1: Physical

THE 7 LAYERS OF OSI



THE OSI MODEL IN PRACTICE

- Like most OO-designs, the abstraction often breaks down
- Many stacks have multiple protocols in "one layer", and none in another
- Modularity/abstraction/information hiding break down
- The TCP/IP stack really only uses the following layers:
  - Application (Layer 7; example: HTTP)
  - Transport (Layer 4; TCP)
  - IP (Layer 3; IP)
  - Data Link (Layer 2; example: Ethernet)
- NOTE: It's common to just refer to a layer by it's number (e.g., a layer-4 protocol)

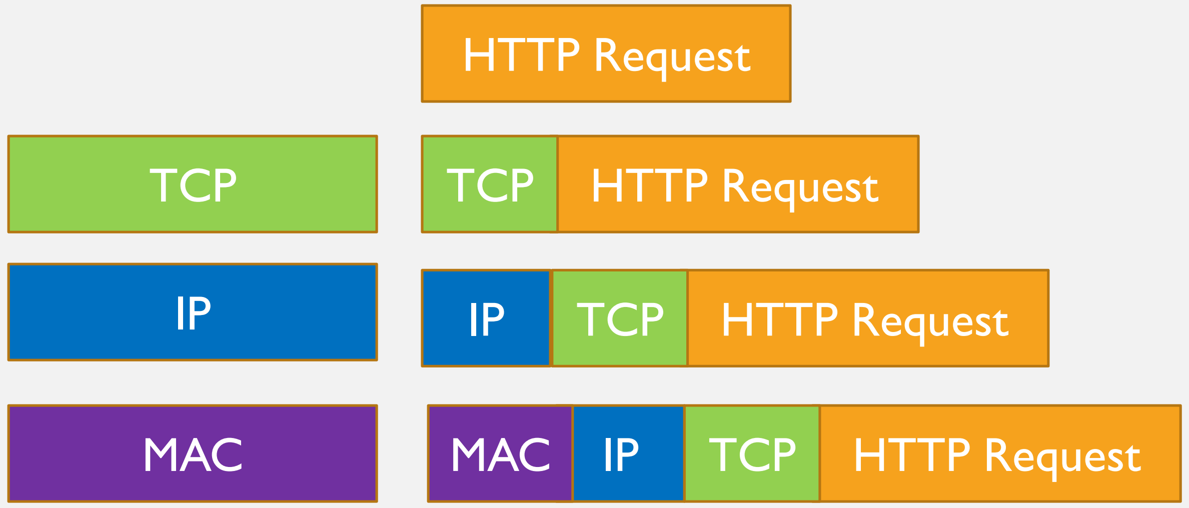
TCP/IP STACK

- For our purposes, we will focus on TCP/IP and TCP/IP-like stacks
- The TCP and IP layers are, obviously, fixed for layers 3 and 4.
- But layers 7 and 2 vary widely
- Millions of networked applications work over TCP/IP at layer 7
- Many layer 2 protocols such as WiFi, Ethernet
  - Networked applications work over WiFi or Ethernet without any change
  - Sometimes called a MAC protocol (Media Access Protocol)
  - TCP/IP work over a walkie-talkie with an appropriate MAC protocol

HOW DOES DATA MOVE IN A STACK?

- To send, data is inserted (pushed) at the top-most protocol
- The receiving protocol
  - Processes the data, potentially splitting, recoding, etc
  - Derives one or more chunks of data
  - Typically affixes a header to each, but sometimes a footer and/or other meta-data
  - Each chunk, along with the meta-data is a "packet"
  - The packet is inserted (pushed) down to the next layer
- When data is received, the process is reversed

TCP/IP STACK EXAMPLE



DIVISION OF LABOR IN TCP/IP

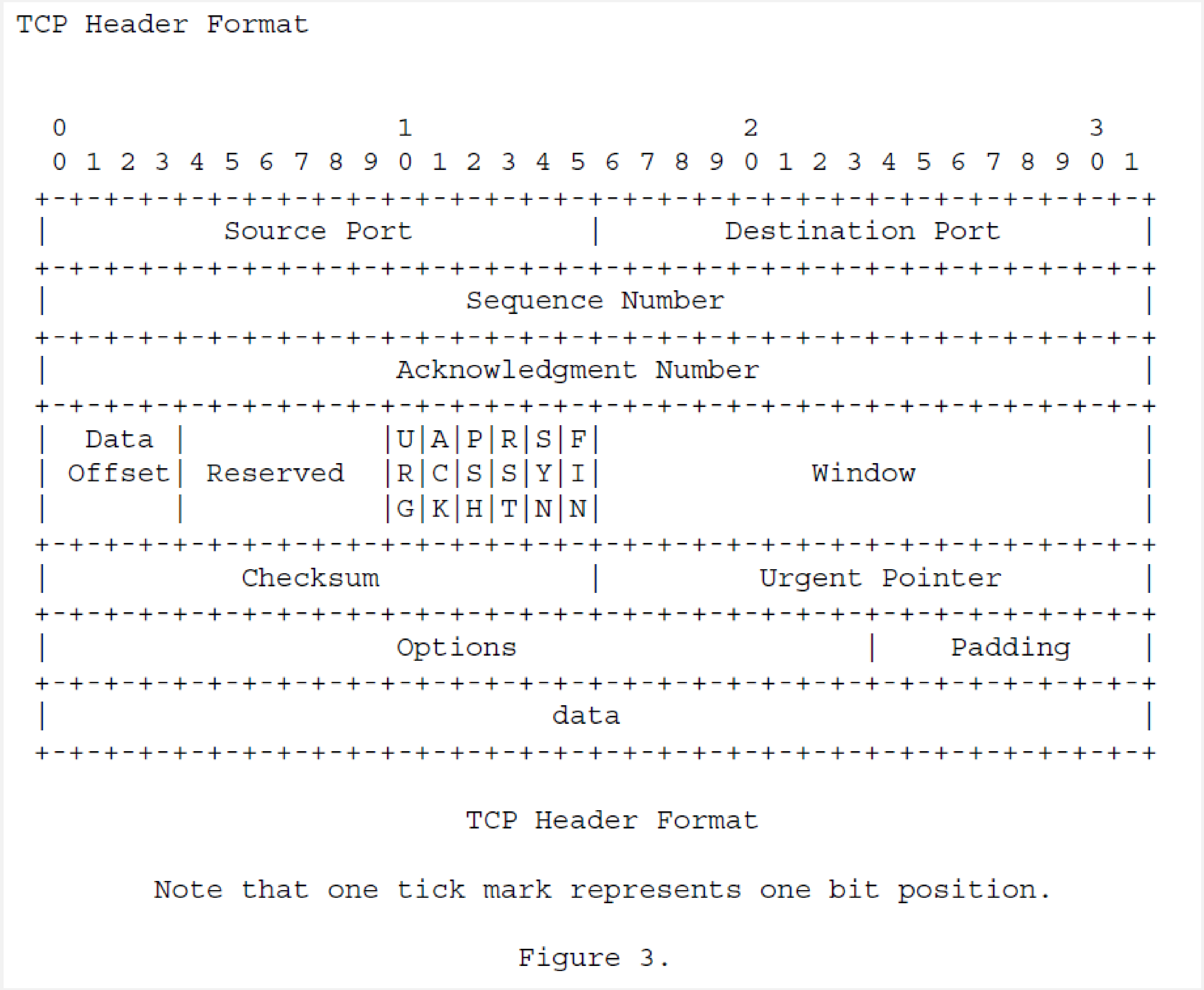
- At the lowest layer, the MAC protocol simply connects two endpoints. Typically:
  - Has its own addressing scheme (MAC address)
  - Controls who talks when
  - Provides error detection and *error correction*
- IP (Internetwork Protocol)
  - Connects many different networks of different media types
  - Global addressing scheme
- TCP
  - Reliable, in-order delivery (Session)
  - Multiplexing

INTEROPERABILITY

- No one company writes all TCP modules; How do they work together?
- Protocol specifications are approved by the IETF (Internet Engineering Task Force)
  - You can find the specifications in RFC's (Request For Comments)
  - RFC 793 was the first specification of TCP (1981)
- So long as an implementation follows the spec, it will be interoperable

RFC 793 (TCP) OVERVIEW

- Data broken into "segments" in section 2.2
- Network layers in section 2.5 (a little different from our usage)
- Section 2.6 lays out critical goal: Reliability
  - Data is delivered reliably (i.e., delivery is assured)
  - Data is delivered in-order
  - How? Sequence numbers and acknowledgements on segments
- Section 2.7 identifies another goal: Multiplexing
  - Different flows get different ports
- Section 2.8 indicates that this is a *stream* based protocol



```
TCP Header Format


    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |          Source Port          |       Destination Port        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                        Sequence Number                        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Acknowledgment Number                      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |  Data |           |U|A|P|R|S|F|                               |
   | Offset| Reserved  |R|C|S|S|Y|I|            Window             |
   |       |           |G|K|H|T|N|N|                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |           Checksum            |         Urgent Pointer        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Options                    |    Padding    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                             data                              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+

                            TCP Header Format

          Note that one tick mark represents one bit position.

                               Figure 3.
```

HTTP PROTOCOL

- Application layer protocol (L7)
- Version 1.0 specified in RFC 1945 in 1996
- In addition to “browsing”, used for API’s and tunnels

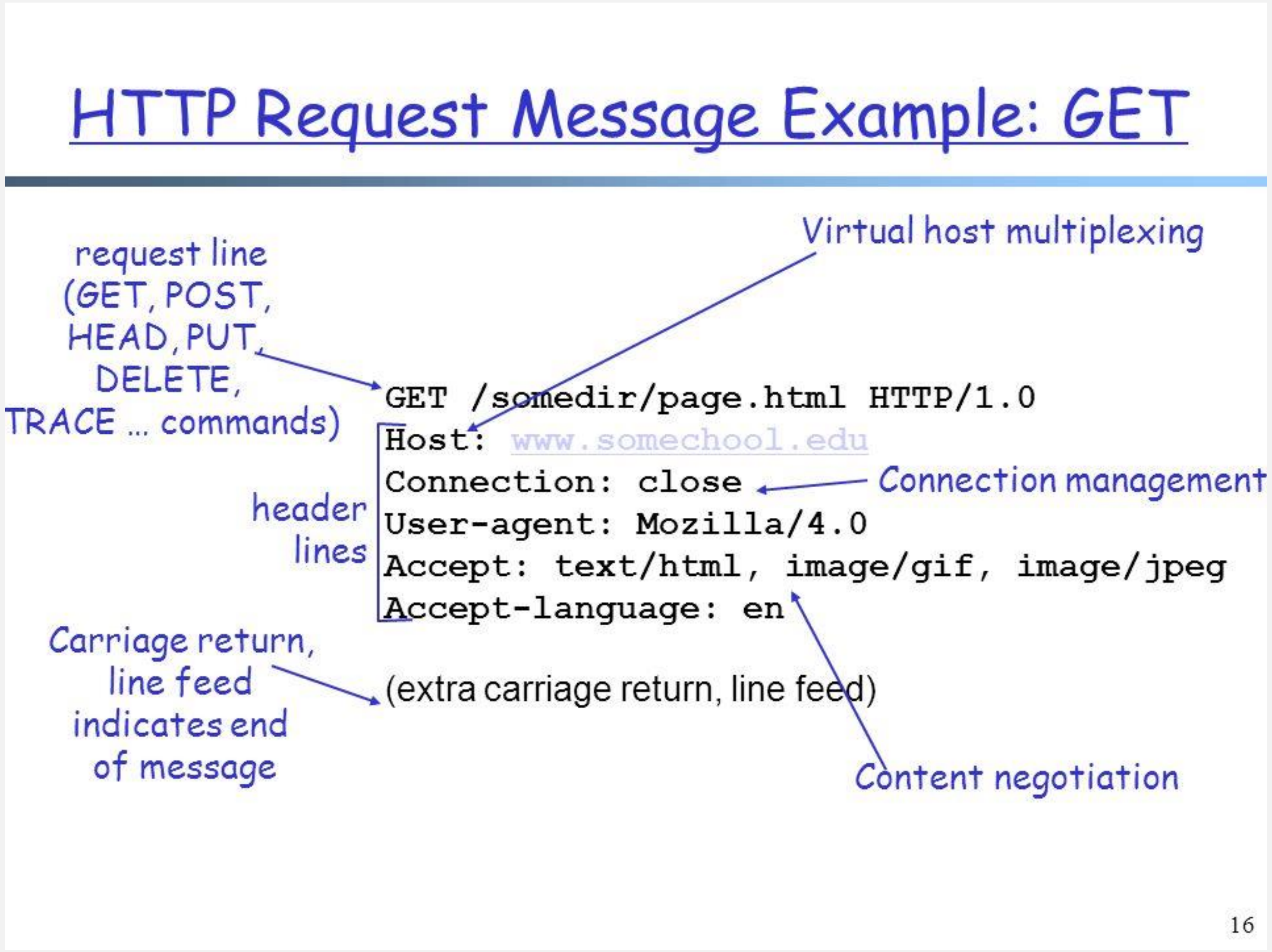
DIFFERENCES BETWEEN HTTP AND TCP

DIFFERENT FORMATS FOR ***REQUESTS*** VERSUS ***RESPONSES***

HUMAN READABLE, LINE-BASED PROTOCOL (***UNTIL HTTP 3.0!***)

ORIGINALLY ***NOT STATEFUL*** (MANY HTTP SERVERS STILL NOT STATEFUL)

HTTP REQUEST



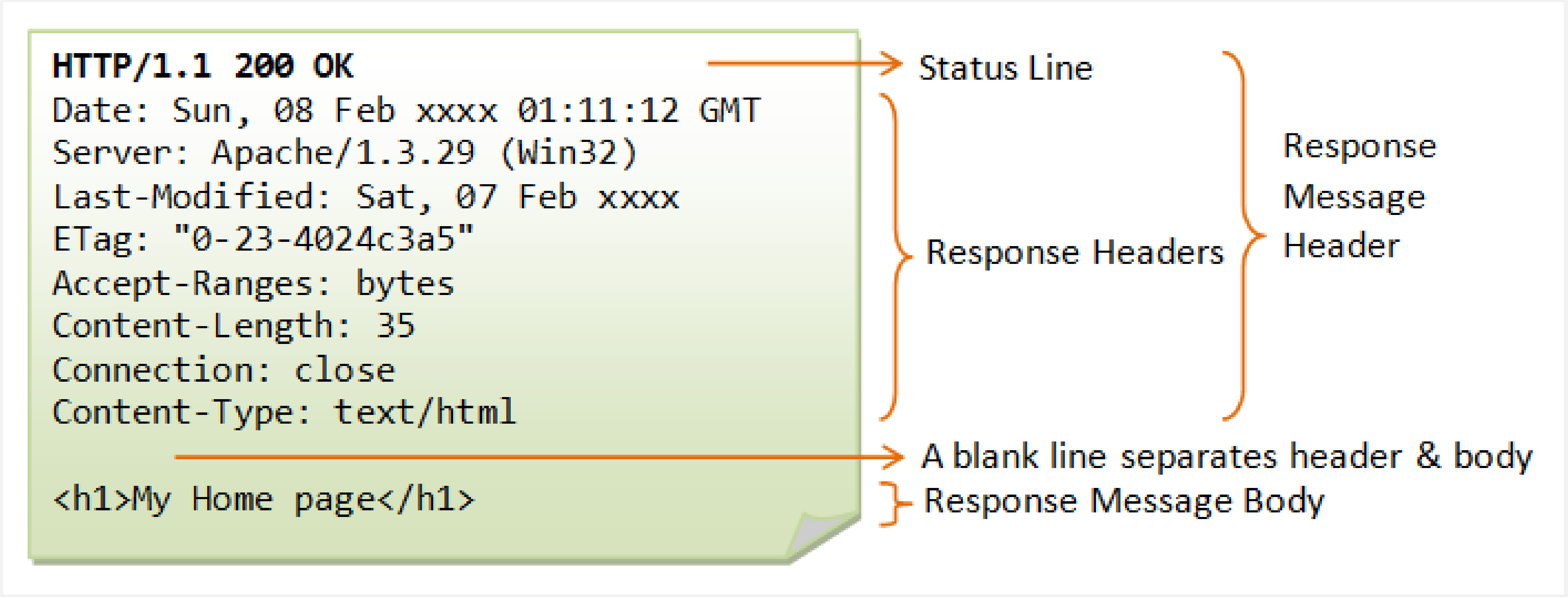
HTTP Request Message Example: GET

```
GET /somedir/page.html HTTP/1.0
Host: www.somechool.edu
Connection: close
User-agent: Mozilla/4.0
Accept: text/html, image/gif, image/jpeg
Accept-language: en
```

(extra carriage return, line feed)

request line (GET, POST, HEAD, PUT, DELETE, TRACE ... commands)
header lines
Carriage return, line feed indicates end of message
Virtual host multiplexing
Connection management
Content negotiation

HTTP RESPONSE



```
HTTP/1.1 200 OK
Date: Sun, 08 Feb xxxx 01:11:12 GMT
Server: Apache/1.3.29 (Win32)
Last-Modified: Sat, 07 Feb xxxx
ETag: "0-23-4024c3a5"
Accept-Ranges: bytes
Content-Length: 35
Connection: close
Content-Type: text/html

<h1>My Home page</h1>
```