Computer Network Recap

Internet-of-Things (IoT)

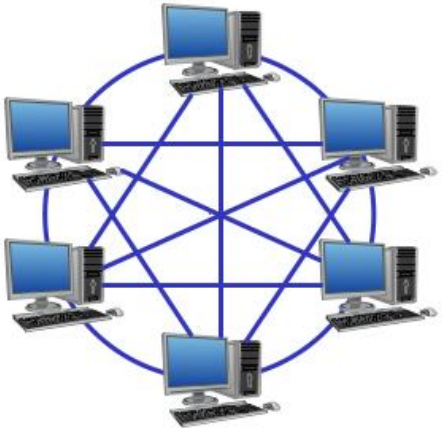
COCOS20

University of Notre Dame

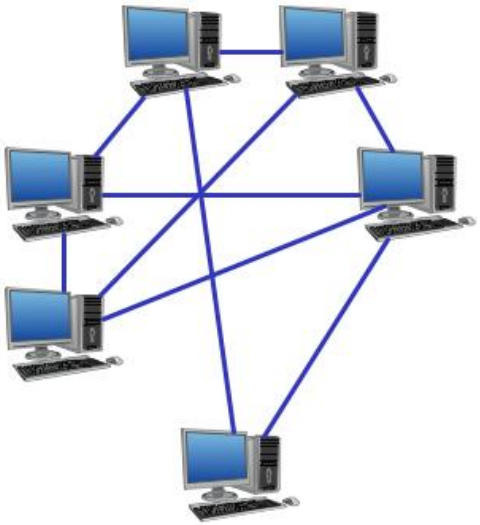
Computer Network Terminology

- **Network:** group of computers and associated devices that are connected by communication facilities
- **Wide Area Network (WAN)**: world-wide (Internet)
- **Metropolitan Area Network (MAN):** city-scale.
- **Local Area Network (LAN):** laboratory/office-scale (Ethernet).
  - **WLAN:** wireless LAN (Wi-Fi).
  - **WPAN:** wireless personal area network (Bluetooth).
  - **WBAN:** wireless body area network.

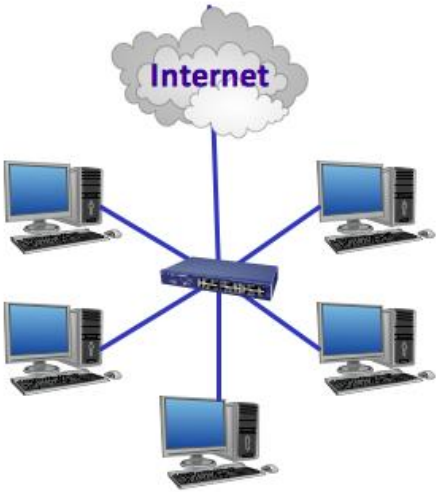
Network Topologies



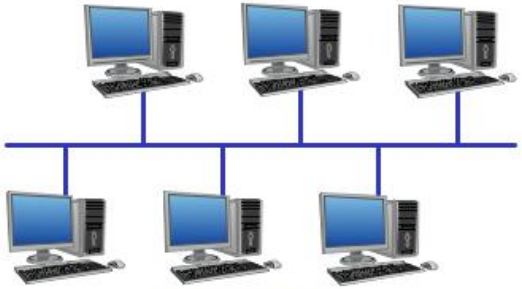
Fully Connected Network Topology



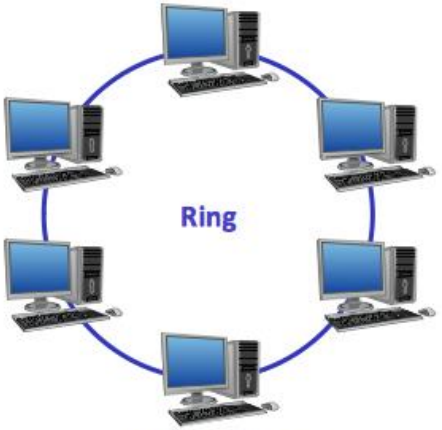
Mesh Network Topology



Star Network Topology



Common Bus Topology



Ring Network Topology

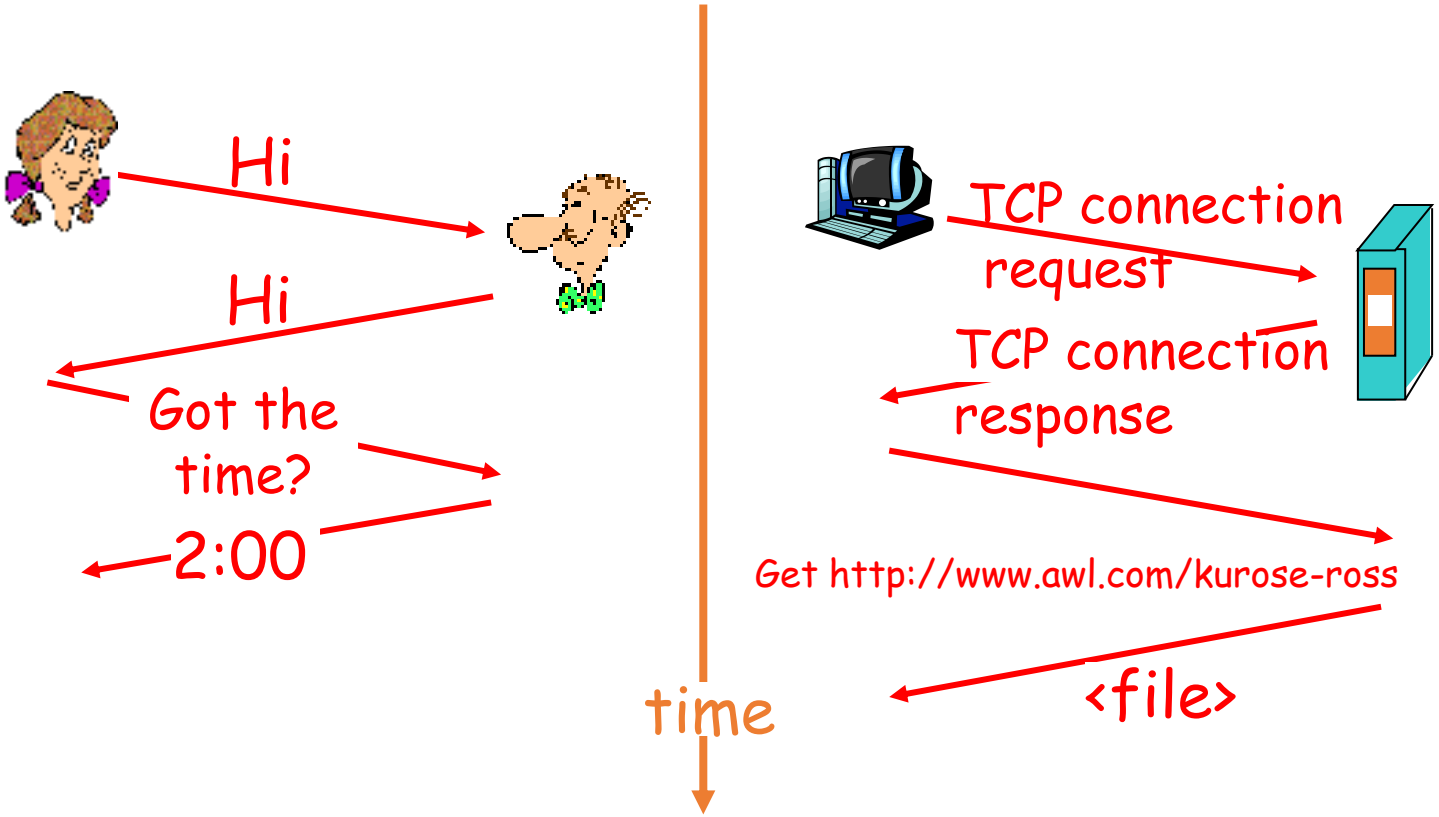
Network Protocols

- Protocols are the **building blocks** of a network architecture.
- Formal standards and policies enabling communication.
- IEEE (Institute of Electrical and Electronics Engineers): standardization
  - Example: Project 802
    - 802.3: Ethernet
    - 802.11: WLAN
    - 802.15: WPAN

Communication

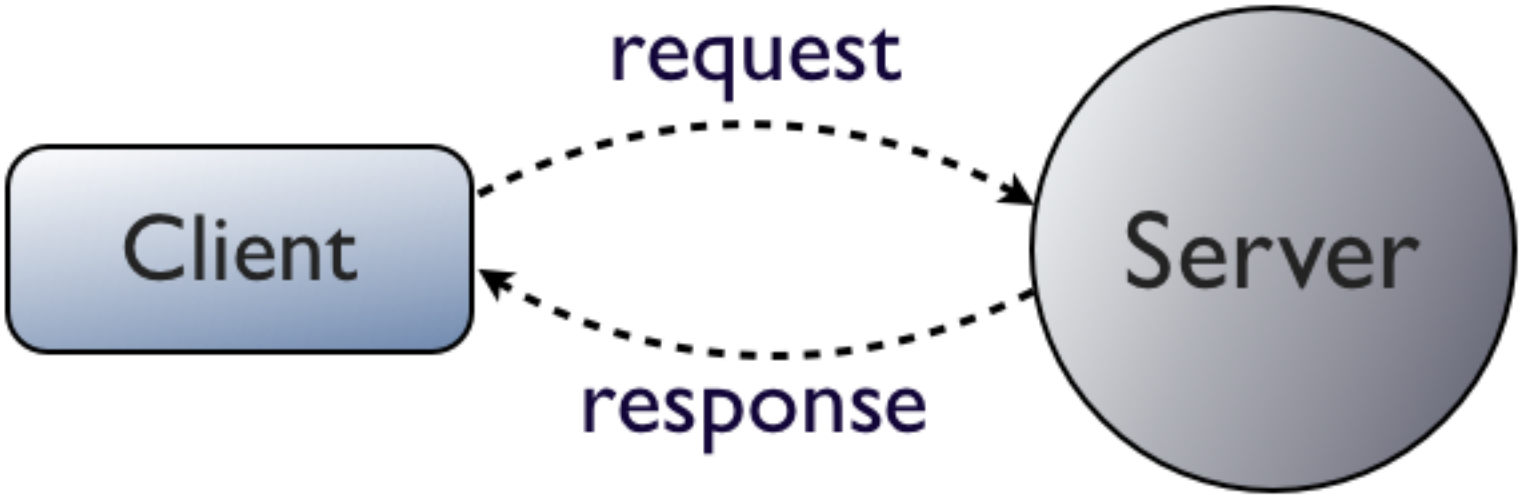
- Who initiates communication?
- Order of communication?
- How long can I talk?
- How loud can I speak?
- Do I have to say something specific at beginning or end?
- Do I have to add meta information?
- What do I do if I get interrupted?
- What do I do if I was not understood?

Protocols


Hi
Hi
Got the time?
2:00
TCP connection request
TCP connection response
Get http://www.awl.com/kurose-ross
<file>
time

Client/Server Model

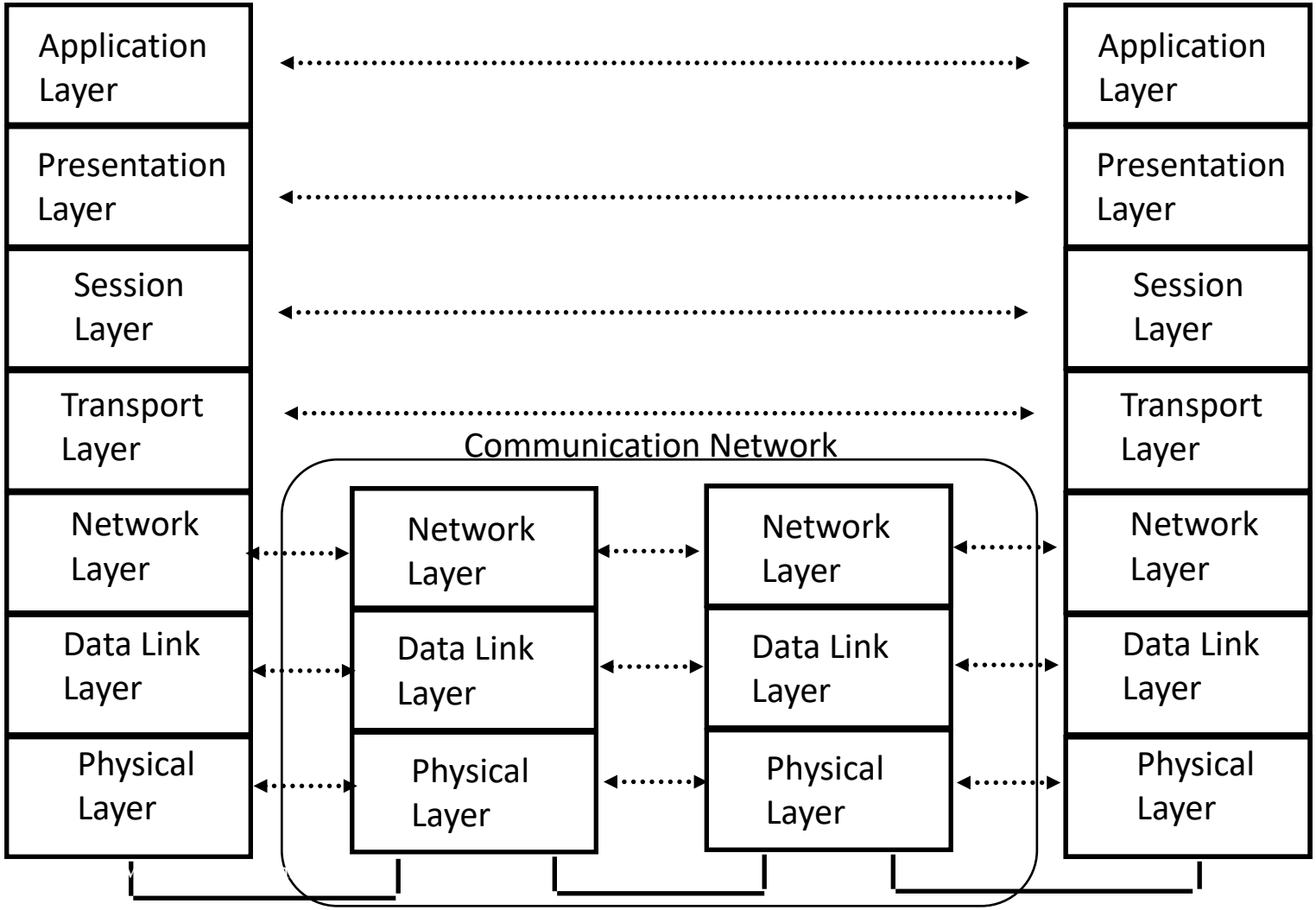
- Client: “active” (initiates communication)
- Server: “passive” (listens and responds)



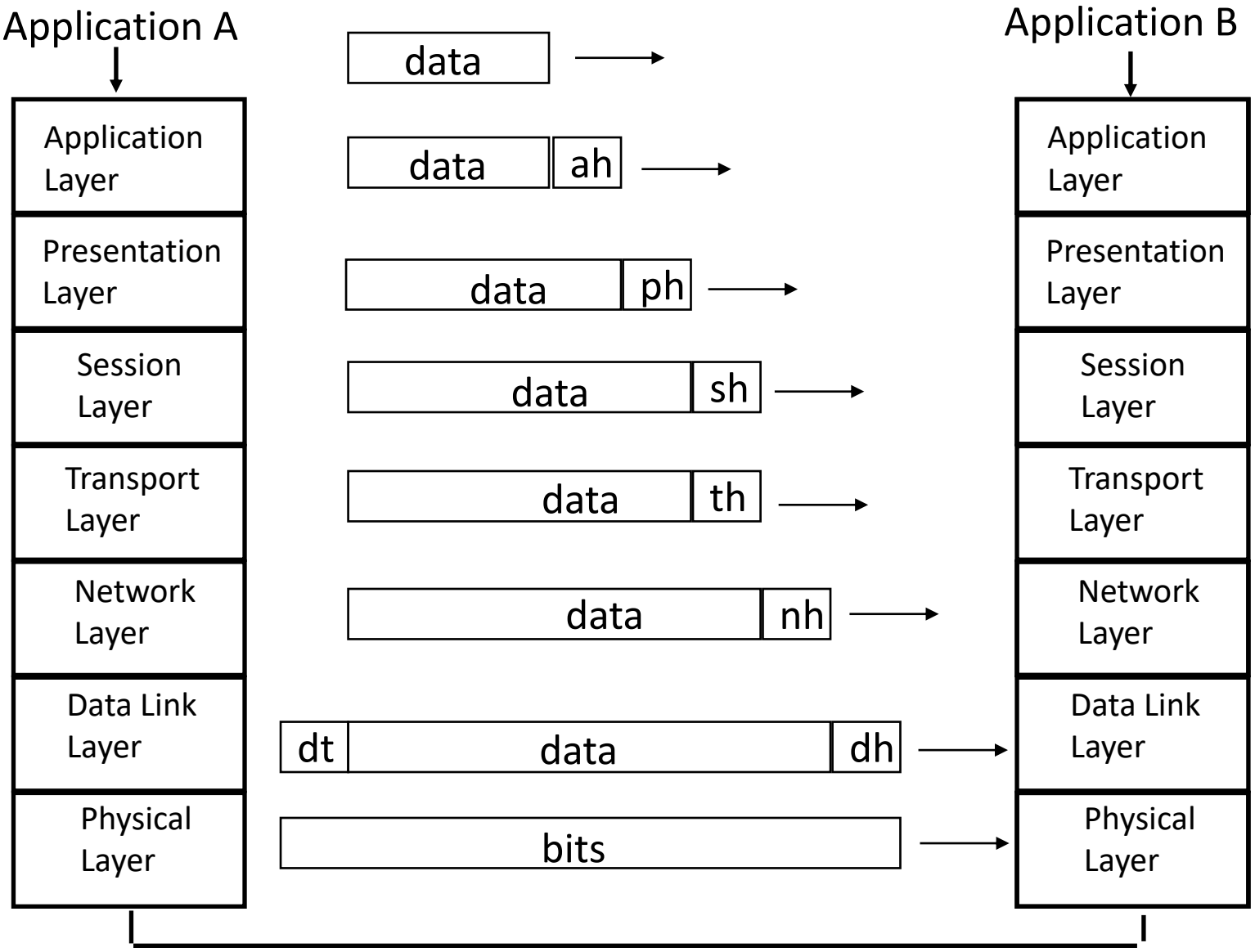
Client/Server Model Examples

- HTTP (Hypertext Transfer Protocol)
- SMTP (Simple Mail Transfer Protocol)
- SSH (Secure Shell)
- DNS (Domain Name System)
- NFS/AFS (Network/Andrew File System)

Network Protocols (“Protocol Stack”)



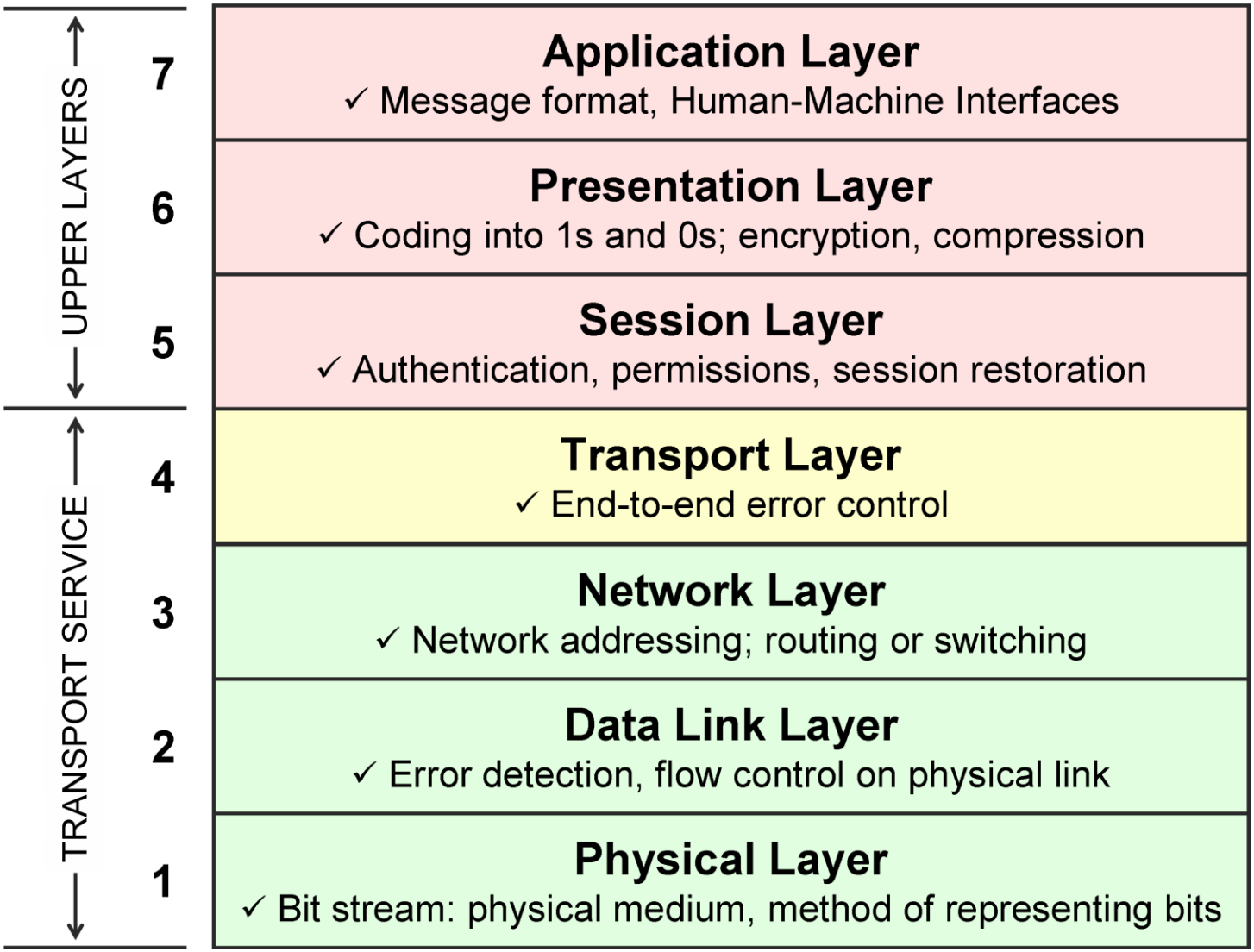
Network Protocols (Headers/Trailers)



Why a Layered Design?

- An explicit structure for dealing with a complex system
- Simplifies the design process
- Modularity of layers eases maintenance and updating of system components
- Accommodates incremental changes

Open System Interconnection (OSI)



Physical Layer (Layer 1)

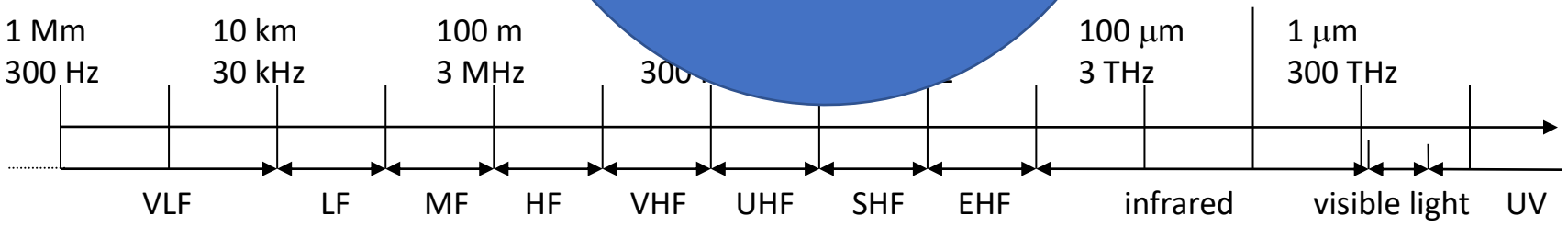
- **Physical/electrical characteristics**
- Cable type, length, connectors, voltage levels, signal durations, ...
- Binary data (bits) as electrical or optical signals
- Frequencies (wireless)

Wireless Characteristics

- VLF = Very Low Frequency
- LF = Low Frequency
- MF = Medium Frequency
- HF = High Frequency
- VHF = Very High Frequenc
- UHF = Ultra High Frequency
- r High Frequency
- h Frequency
- ight

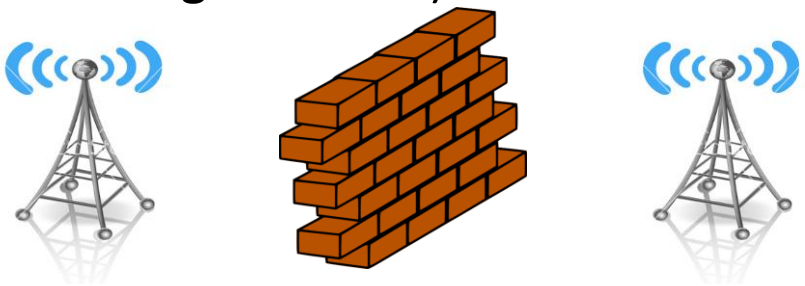
What is Frequency?

- Frequency and wave le
  - $\lambda = c/f$
  - wave length λ, speed of



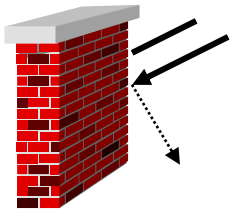
Frequencies for Mobile Communication

- Low Frequencies:
  - low data rates
  - travel long distances
  - follow Earth's surface
  - penetrate objects and water (submarine communication)
- High Frequencies:
  - high data rates
  - short distances
  - straight lines
  - cannot penetrate objects ("**Line of Sight**" or **LOS**)

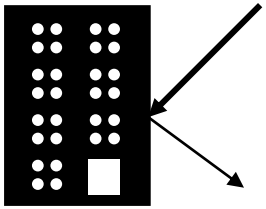


Other Propagation Effects

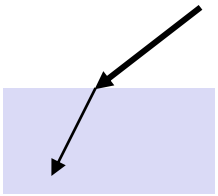
- **Shadowing**
- **Reflection** at large obstacles
- **Refraction** depending on the density of a medium
- **Scattering** at small obstacles
- **Diffraction** at edges



shadowing



reflection



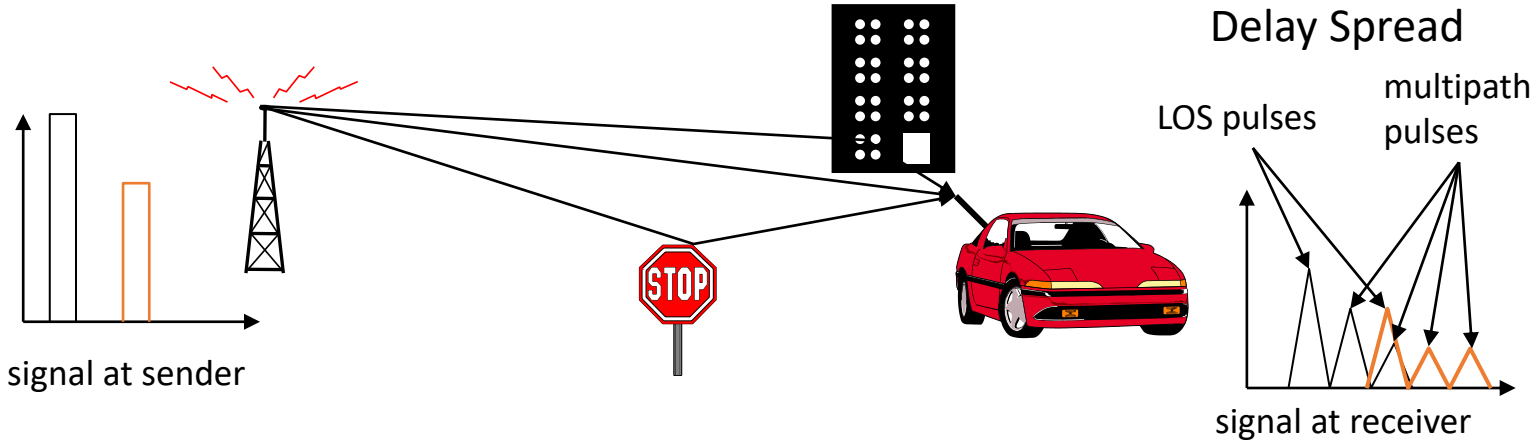
refraction

scattering

diffraction

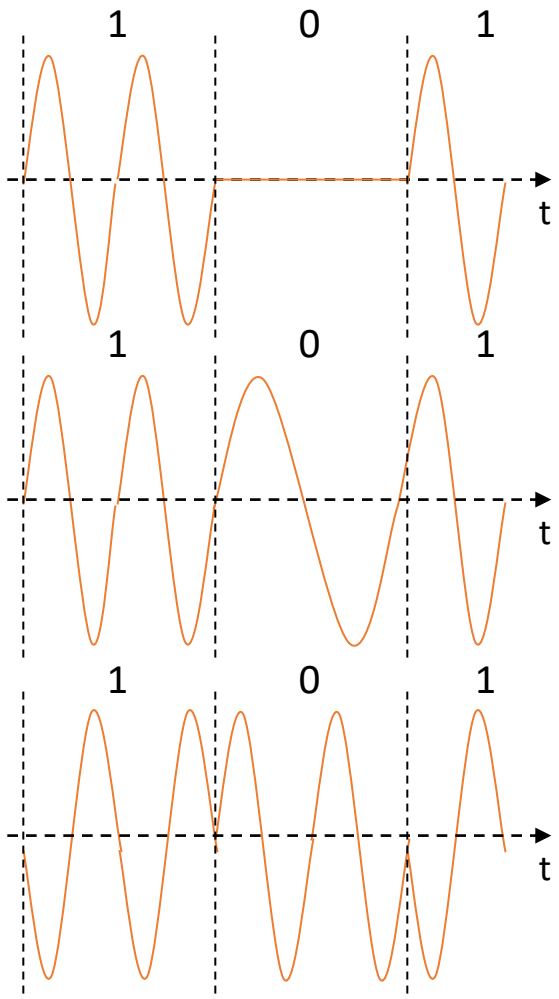
Multipath Propagation

- Signal can take **many different paths** between sender and receiver due to reflection, scattering, diffraction



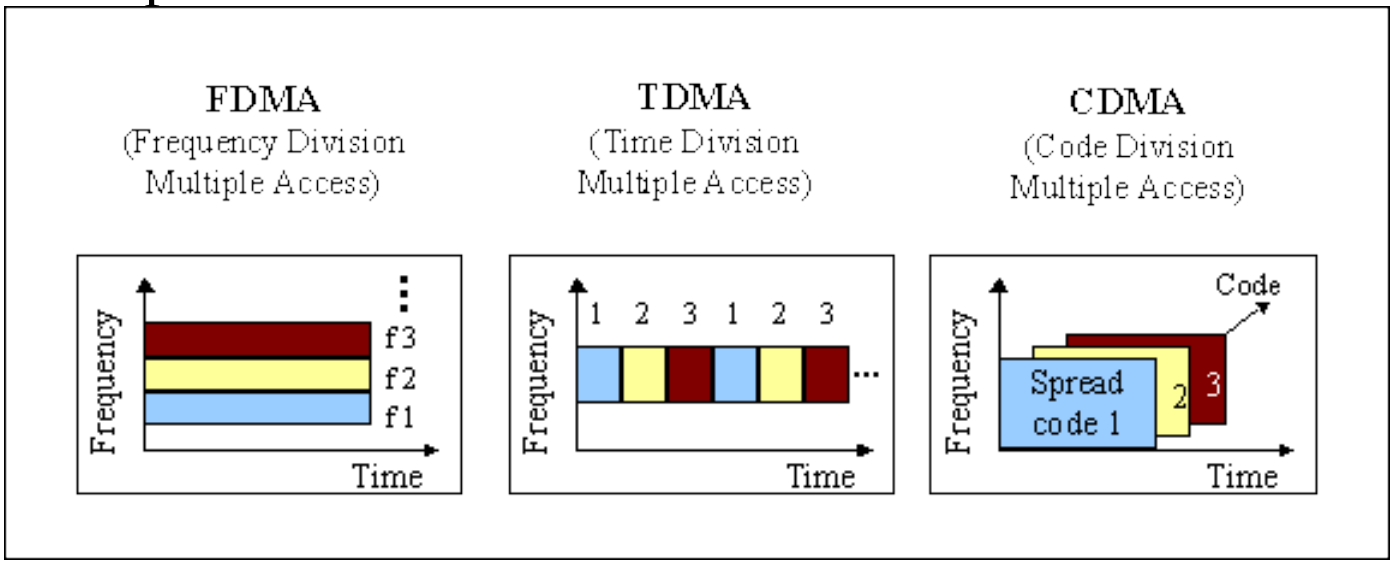
Digital Modulation

- **Amplitude Shift Keying (ASK)**
- **Frequency Shift Keying (FSK)**
- **Phase Shift Keying (PSK)**



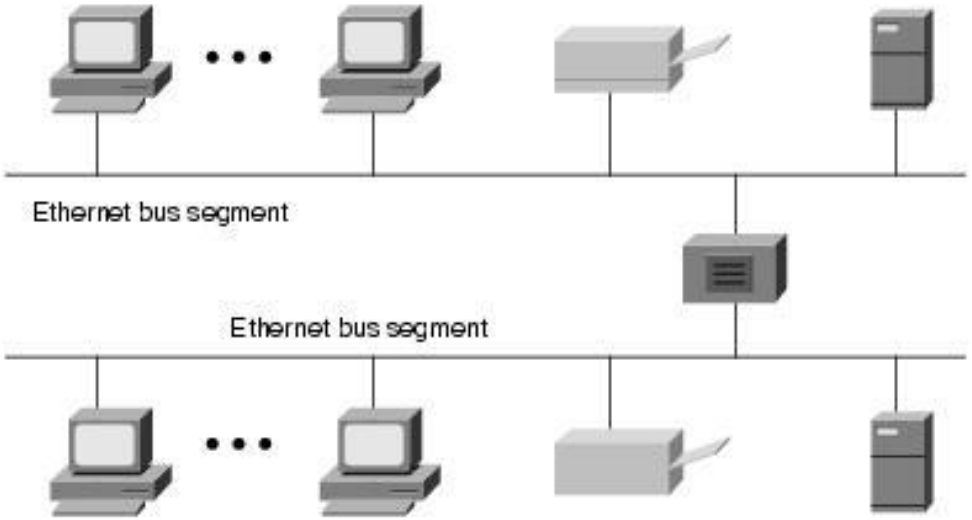
Data Link Layer (Layer 2)

- **Defines when/how medium will be accessed for transmission**
- Units typically called “frames”; error detection/correction; divided into sublayers, including: **MAC = Medium Access Control** (MAC address 6f:00:2b:23:1f:32)
- Cell phone example:



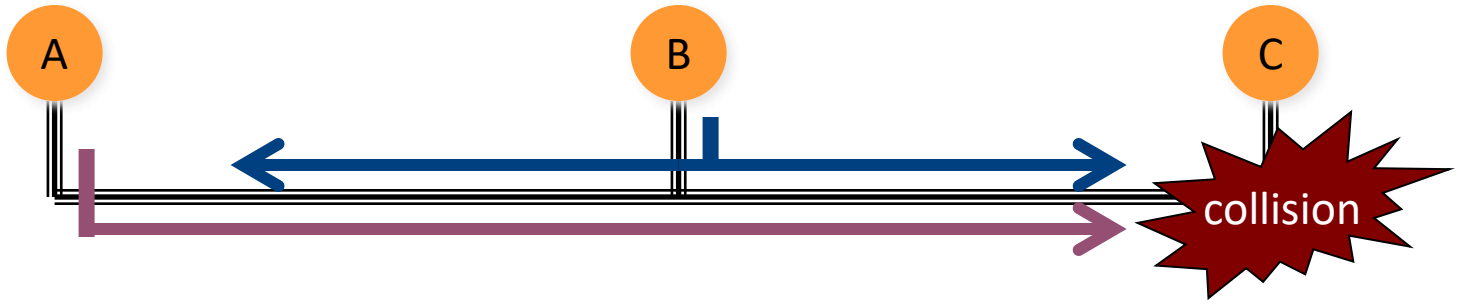
Example: Ethernet (802.3)

- Most popular LAN technology, uses bus architecture
- Easy to install, inexpensive
- Data is broken into **packets**

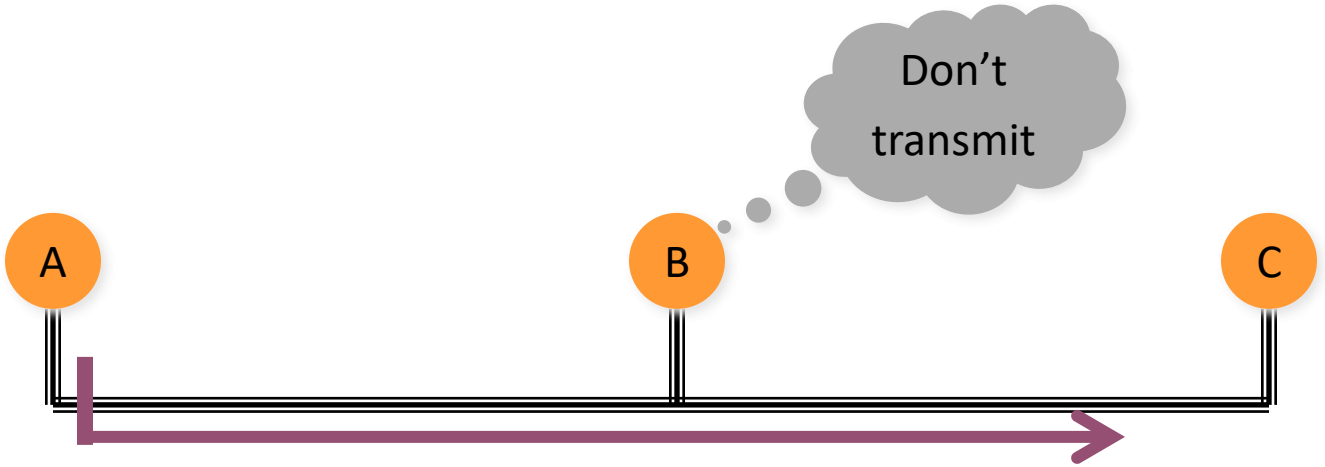


Example: Ethernet

- Medium Access Control (MAC) protocol
- **CSMA/CD** Protocol
  - **C**arrier **S**ense
  - **M**ultiple **A**ccess
  - **C**ollision **D**etection



Example: Ethernet

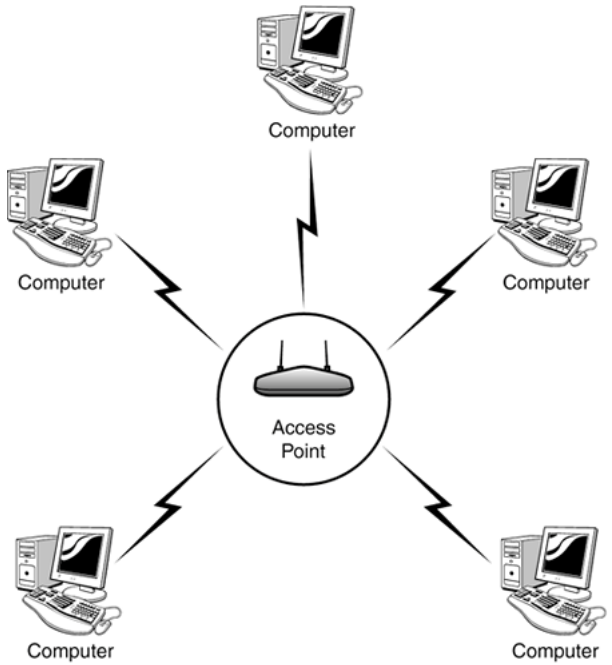


Can collisions still occur?

- "Sense" (listen) carrier ("is anyone else talking right now?")
- If "busy": wait; if "idle": transmit
- CD: Keep listening while transmitting
  - If collision detected: retry at a later time

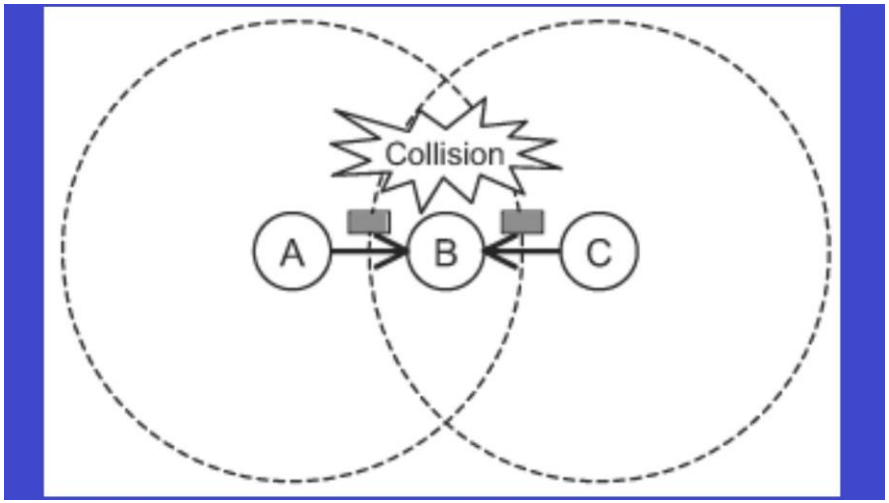
Example: Wi-Fi (802.11)

- Most popular wireless LAN architecture



Access point
Wi-Fi router
Base station
Hotspot

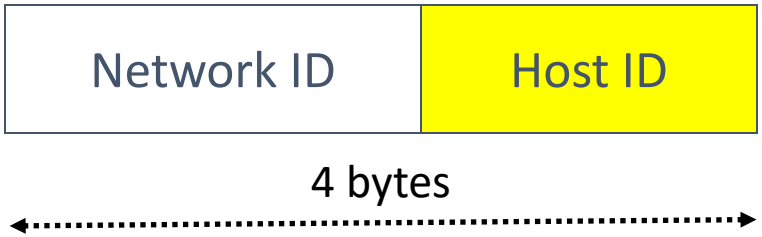
Example: Wi-Fi (802.11)



- **CSMA/CA** Protocol
  - **C**arrier **S**ense
  - **M**ultiple **A**ccess
  - **C**ollision **A**voidance
    - Channel reservations:
      - Transmitter sends request-to-send (RTS)
      - Receiver sends clear-to-send (CTS)
    - Advantages:
      - Nodes hearing RTS and/or CTS keep quiet
      - If collision, only small RTS or CTS packets are lost.

Network Layer (Layer 3)

- **Dominant protocol: IP = Internet Protocol**
- Addressing and routing (sender & receiver IP address)
- Uses 32-bit **hierarchical address space** with location information embedded in the structure



- IPv4 address is usually expressed in dotted-decimal notation, e.g.:

128.100.11.56

IPv4

Class A
Subnet Mask

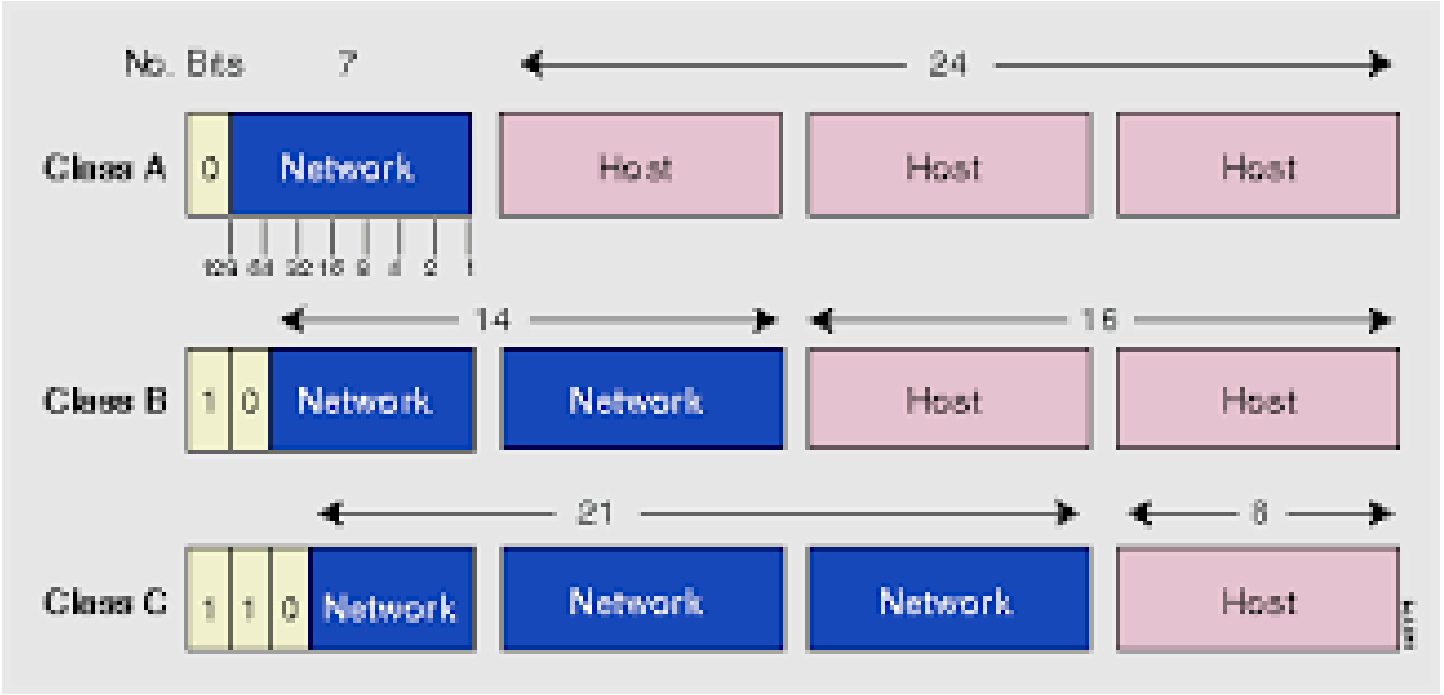
Netwok	Host	Host	Host
255	0	0	0

Class B
Subnet Mask

Netwok	Network	Host	Host
255	255	0	0

Class C
Subnet Mask

Netwok	Network	Network	Host
255	255	255	0



IPv6

- IPv6 addresses are 128 bits long
- 16 bytes of IPv6 address are represented as a group of hexadecimal digits, separated by colons, e.g.:

  2000:fdb8:0000:0000:0001:00ab:853c:39a1
- Shorthand – leave out groups of zeros and leading zeros:

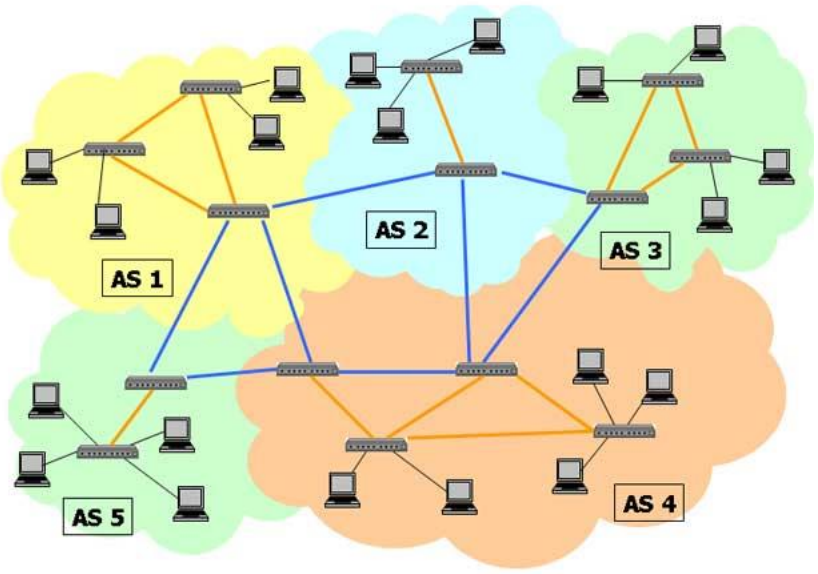
  2000:fdb8:::1:ab:853c:39a1

- IPv4 Address space: 4,294,967,296 Addresses
- IPv6 Address space: ($3.4 * 10^{38}$)

340,282,366,920,938,463,463,374,607,431,768,211,456

Routers

- Form backbone of the Internet
- Use IP layer to identify source and destination of packets
- Look up **routing tables** that determines **“next hop”**



Destination	Next Hop
147.39.21.X	131.19.18.121
89.44.X.X	131.19.22.119
203.21.X.X	137.18.47.48

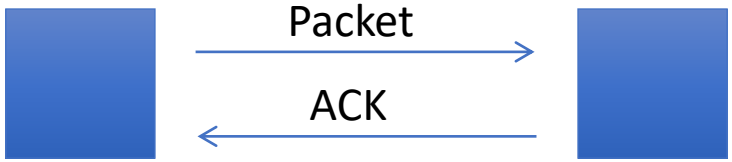
Transport Layer (Layer 4)

- **UDP** (User Datagram Protocol)

- Adds more addressing: "**ports**"
  - IP address tell you which computer
  - Ports tell you which application on that computer
  - Example: a web server "listens" to requests on port 80
  - Web browser: http://www.google.com:80 = http://216.58.216.100:80
    - ":80": optional
  - **Unreliable!**
    - Packets can get lost; packets can arrive out of order

Transport Layer

- **TCP** (Transmission Control Protocol)
- **Reliable** protocol!
- Adds ports (just like UDP), but also provides:
  - In-order delivery of packets (using sequence numbers)
  - Reliable delivery: using acknowledgment (ACK) packets



  - **Flow control & congestion control:**
    - Allows receiver to slow down sender
    - Allows “network” to slow down sender

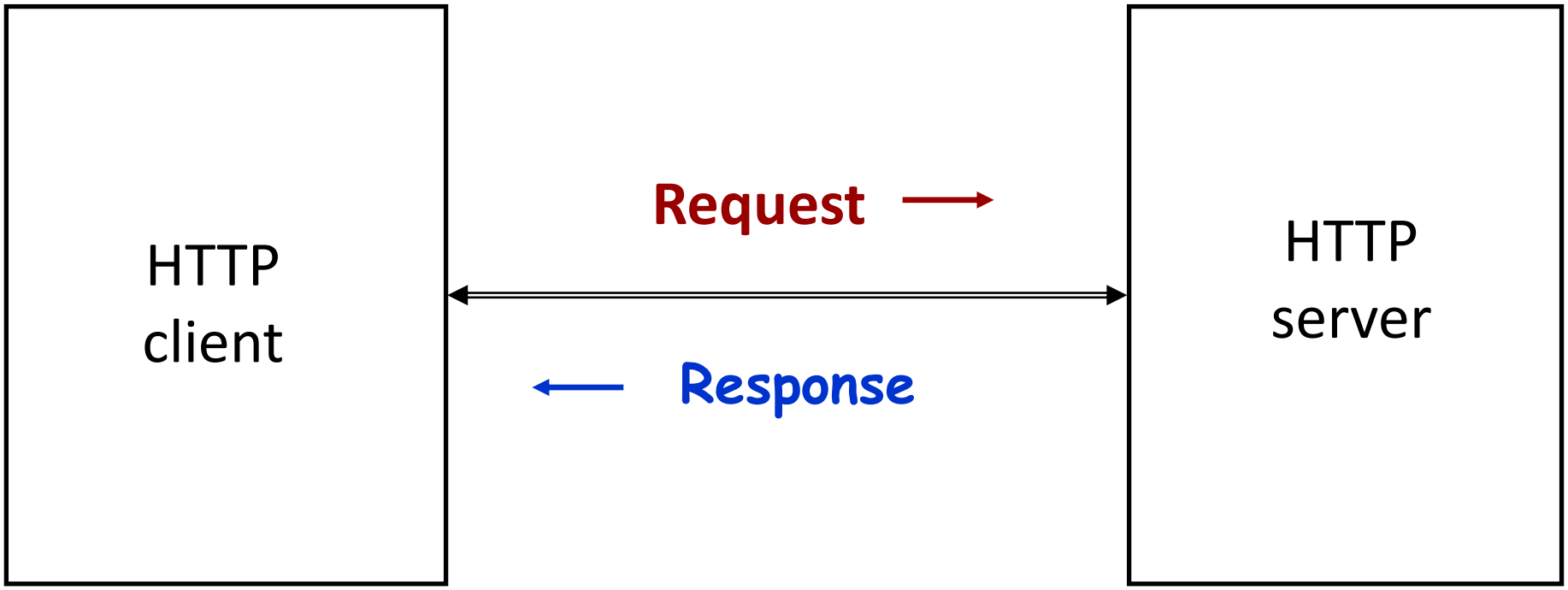
UDP vs TCP

- TCP:
  - typical choice of most applications
  - do not want to lose data, out-of-order arrival, etc.
  - email, web traffic, financial transactions, etc.
- UDP:
  - can be “faster”
    - no flow/congestion control “slowing down” traffic
    - no retransmissions
    - good for “real-time” traffic
  - out-of-order arrival: can also “reorder” at application level
  - loss of data: can be acceptable
    - missing frames in video/audio stream

Upper Layers (Layers 5-7)

- Session Layer
  - Management of “sessions”
- Presentation Layer
  - Data translation, formatting, encryption, compression
- Application Layer
  - Interface between user applications and lower network services

Example: Web Servers



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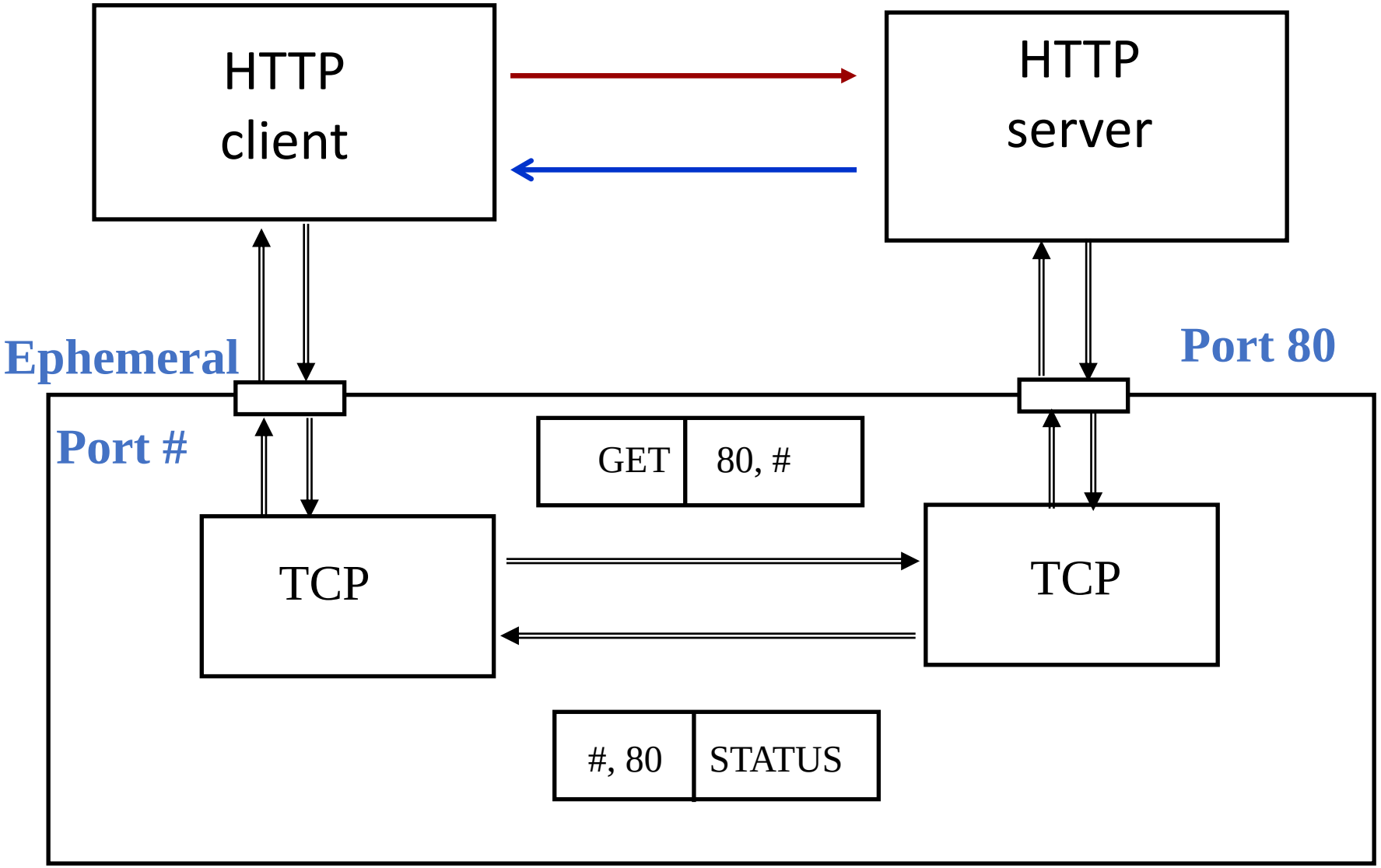

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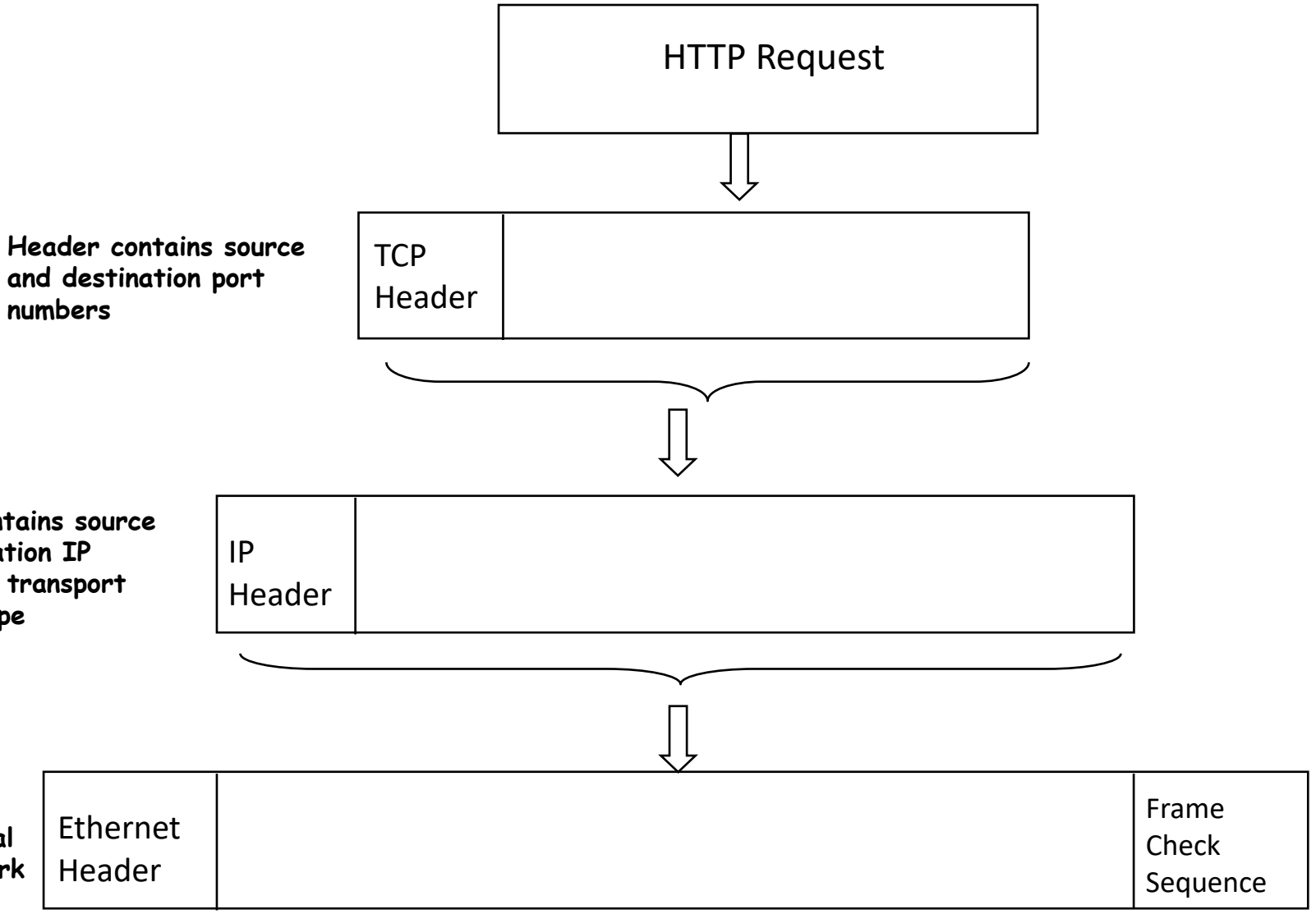

Thank You

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