Networking Introduction

CSE 333 Fall 2022

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Administrivia

- No exercises due for a while!
  - First networking exercise out this Thursday after sections, due next Monday
    - DNS and TCP client-side (covered in class and sections this week); somewhat longer than usual exercise, but needed warmup for hw4

- hw3 due Thursday, 11 pm
  - Usual reminders: don’t forget to tag, then be sure to clone elsewhere and recompile / retest
  - Usual latedays apply (*if* you have any left – don’t run over)

Administrivia

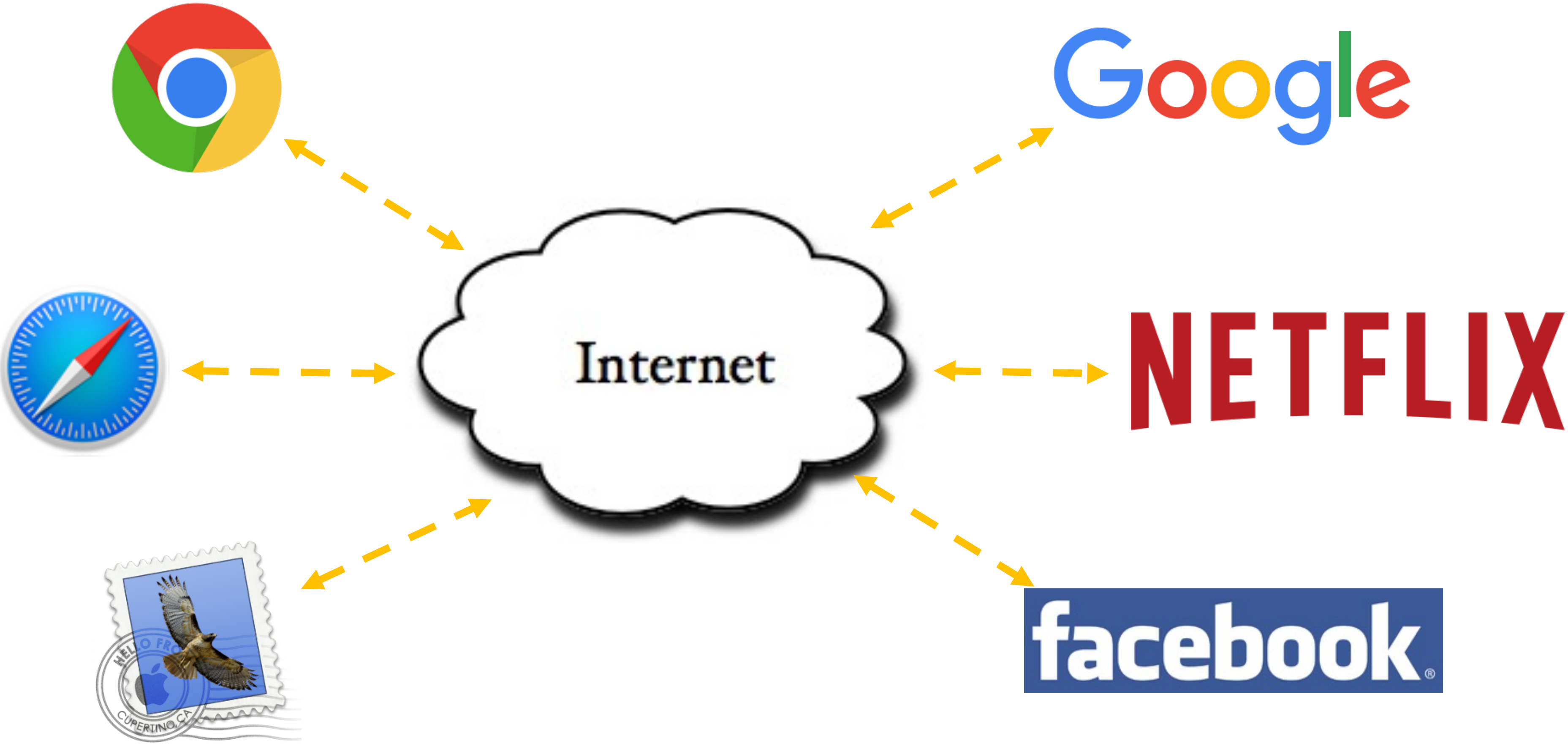
- Rest of the quarter:
  - Topics: Networking; Concurrency, Processes, and Threads
  - A few more exercises (~3)
    - Networking client side, server side, concurrency
  - hw4: file-search web server
    - Out late this week; due Thursday, December 8 (last week of classes)
    - Demo in class this Friday or next Monday

Lecture Outline

- **Introduction to Networks**
  - **Layers upon layers upon layers…**

more awesome pictures at THEMETAPICTURE.COM

Networks From 10,000 ft

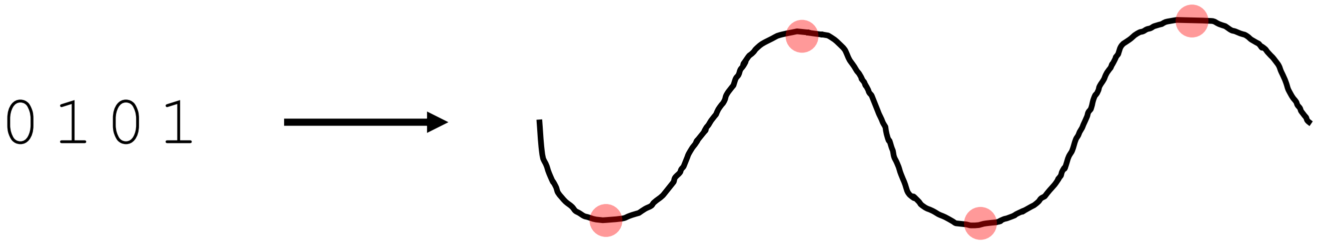


clients

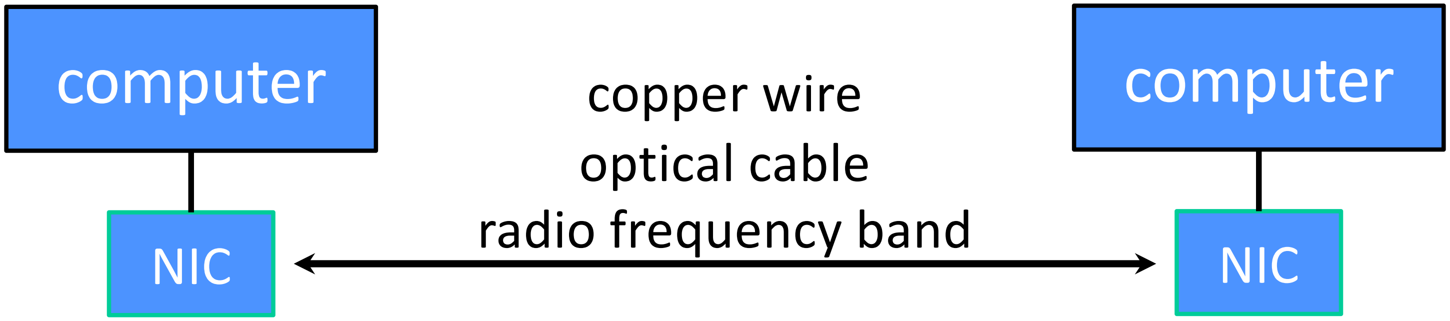
servers

The Physical Layer

- Individual bits are modulated onto a wire or transmitted over radio
  - Physical layer specifies how bits are encoded at a signal level
  - Many choices, e.g., encode “1” as +1v, “0” as -0v; or “0”=+1v, “1”=-1v, …



0 1 0 1



computer

NIC

copper wire
optical cable
radio frequency band

computer

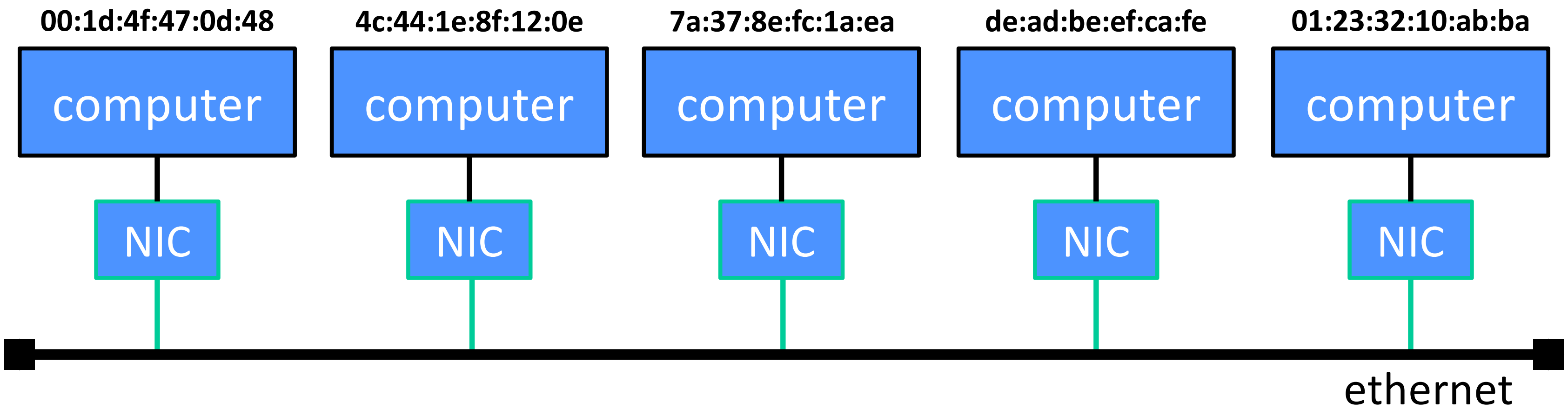
NIC

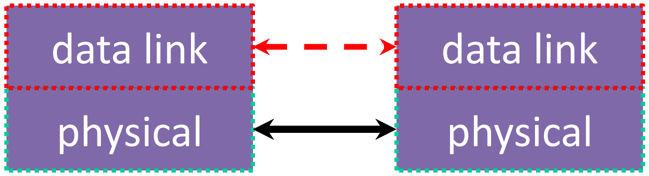
physical

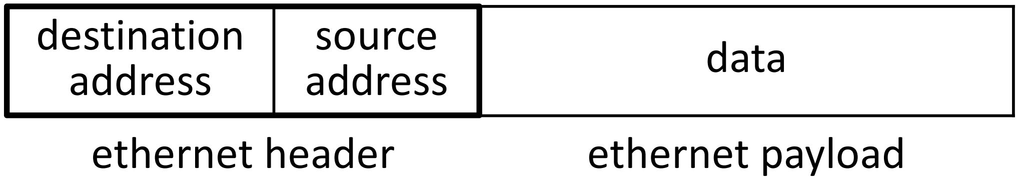
physical

The Data Link Layer

- Multiple computers on a LAN contend for the network medium
  - Media access control (MAC) specifies how computers cooperate
  - Link layer also specifies how bits are “packetized” and network interface controllers (NICs) are addressed

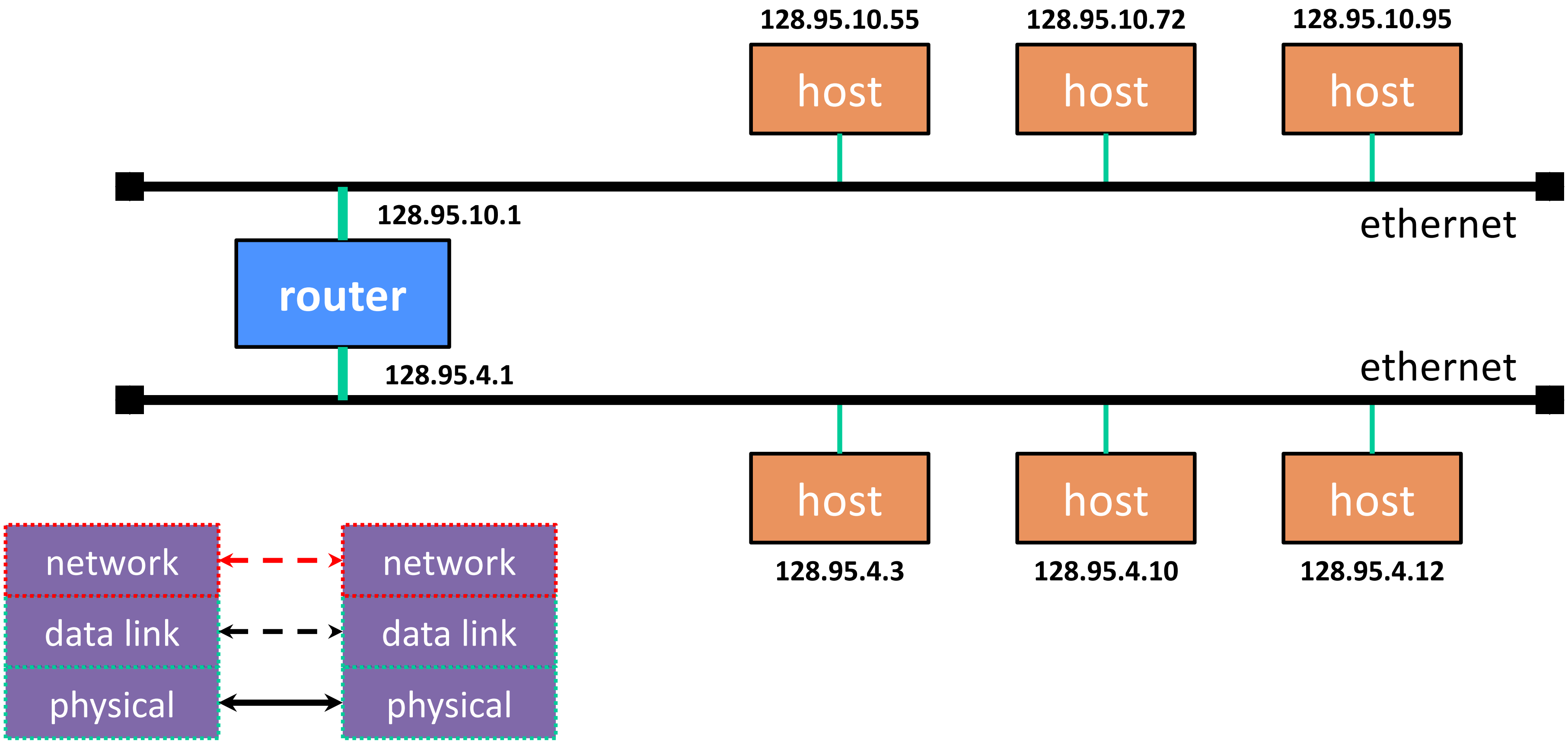






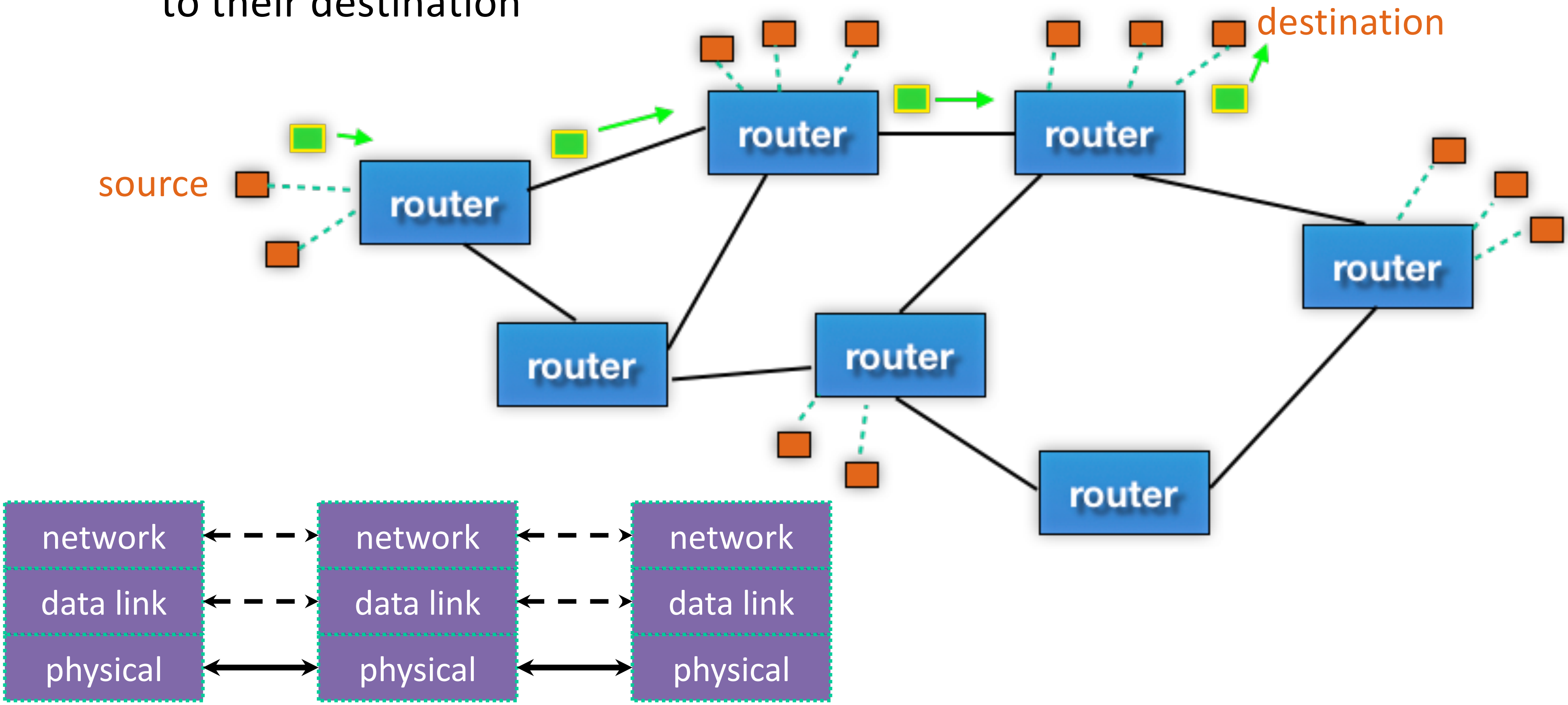
The Network Layer (IP)

- Internet Protocol (IP) routes packets across multiple networks
  - Every computer has a unique IP address
  - Individual networks are connected by routers that span networks



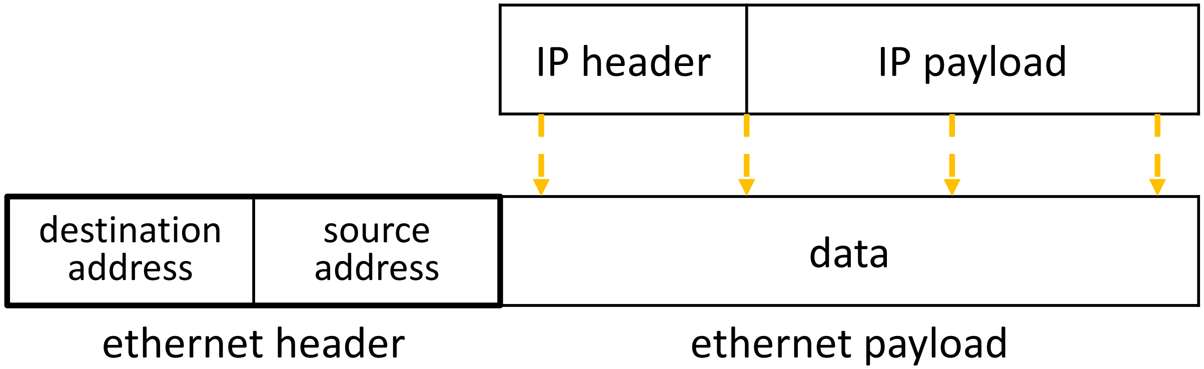
The Network Layer (IP)

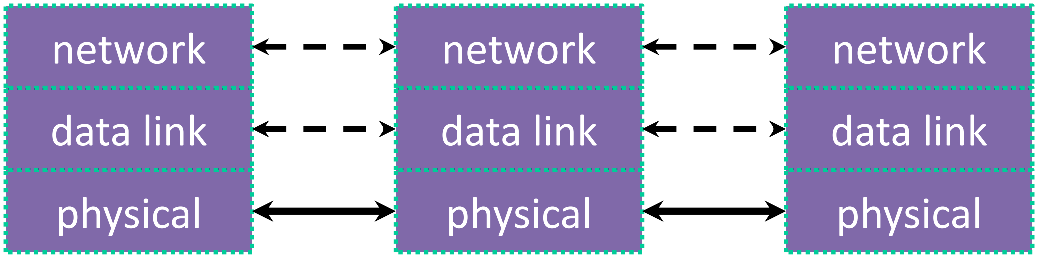
- There are protocols to:
  - Let a host map an IP to MAC address on the same network
  - Let a router learn about other routers to get IP packets one step closer to their destination



The Network Layer (IP)

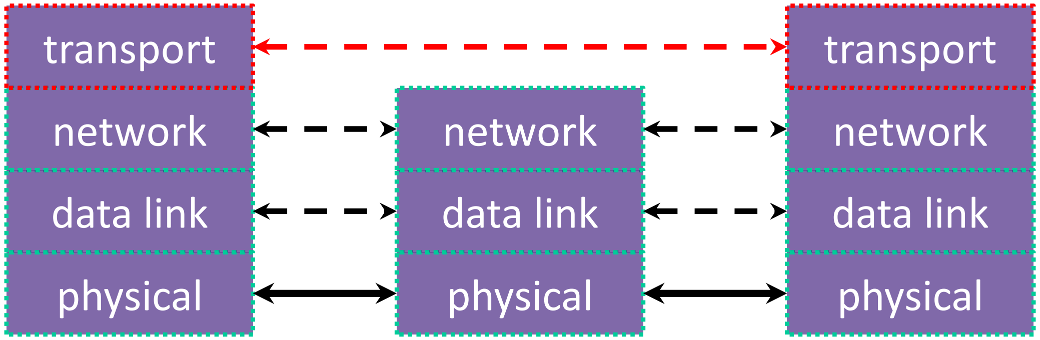
- Packet encapsulation:
  - An IP packet is encapsulated as the payload of an Ethernet frame
  - As IP packets traverse networks, routers pull out the IP packet from an Ethernet frame and plunk it into a new one on the next network





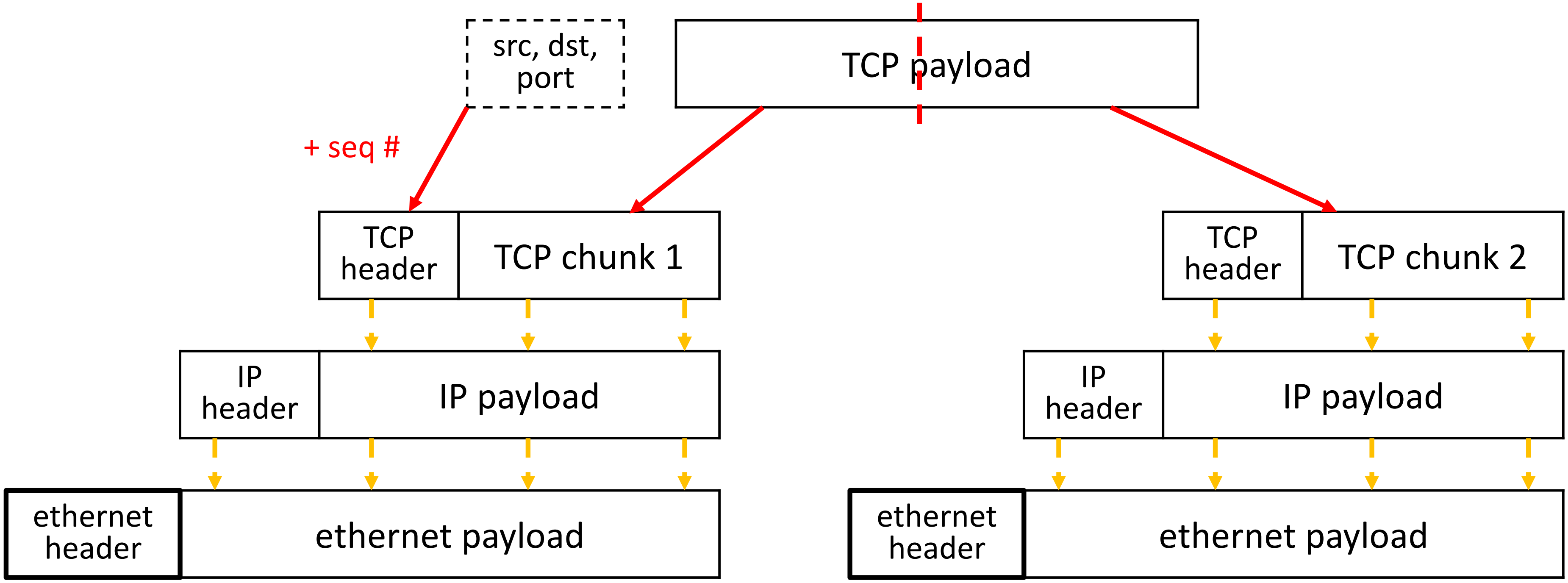
The Transport Layer (TCP)

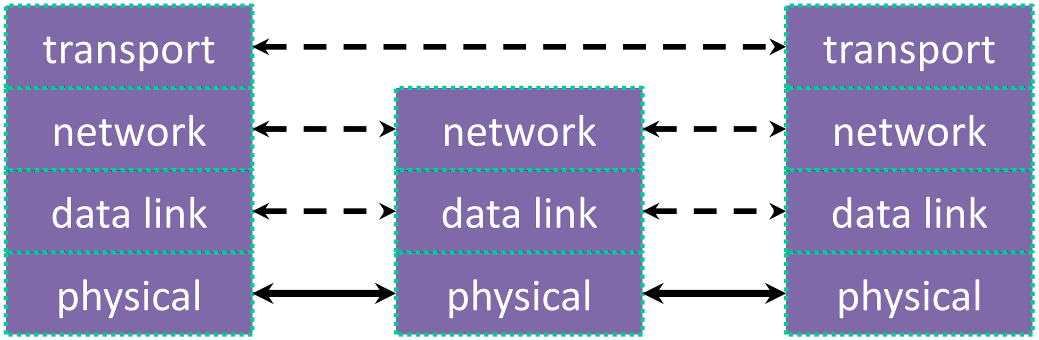
- Transmission Control Protocol (TCP):
  - Provides applications with reliable, ordered, congestion-controlled byte streams
    - Sends stream data as multiple IP packets (differentiated by sequence numbers) and retransmits them as necessary
    - When receiving, puts packets back in order and detects missing packets
  - A single host (IP address) can have up to 2^{16} = 65,535 "ports"
    - Kind of like an apartment number at a postal address (your applications are the residents who get mail sent to an apt. #)



The Transport Layer (TCP)

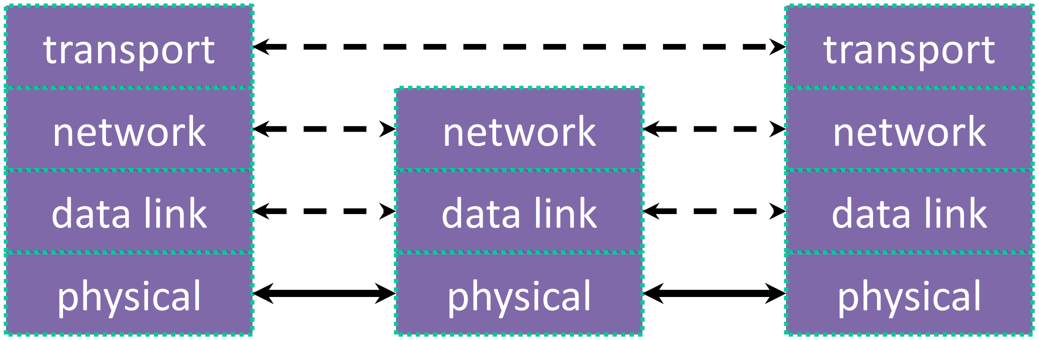
- Packet encapsulation – one more nested layer!





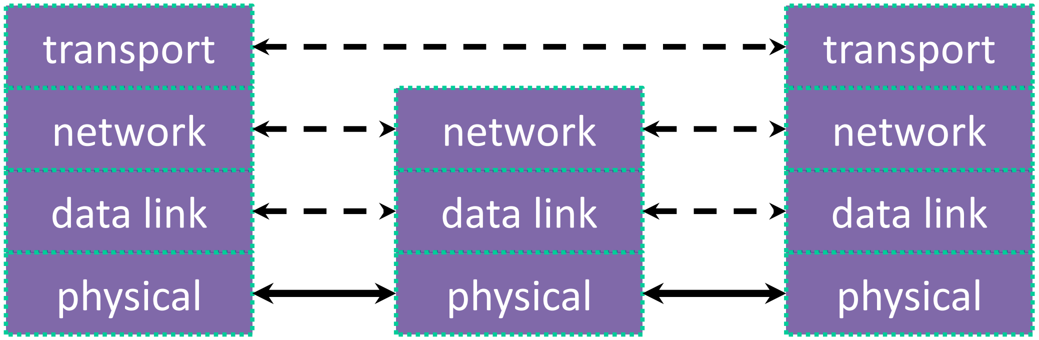
The Transport Layer (TCP)

- Applications use OS services to establish TCP streams:
  - The "Berkeley sockets" API
    - A set of OS system calls
  - Clients `connect()` to a server IP address + application port number
  - Servers `listen()` for and `accept()` client connections
  - Clients and servers `read()` and `write()` data to each other



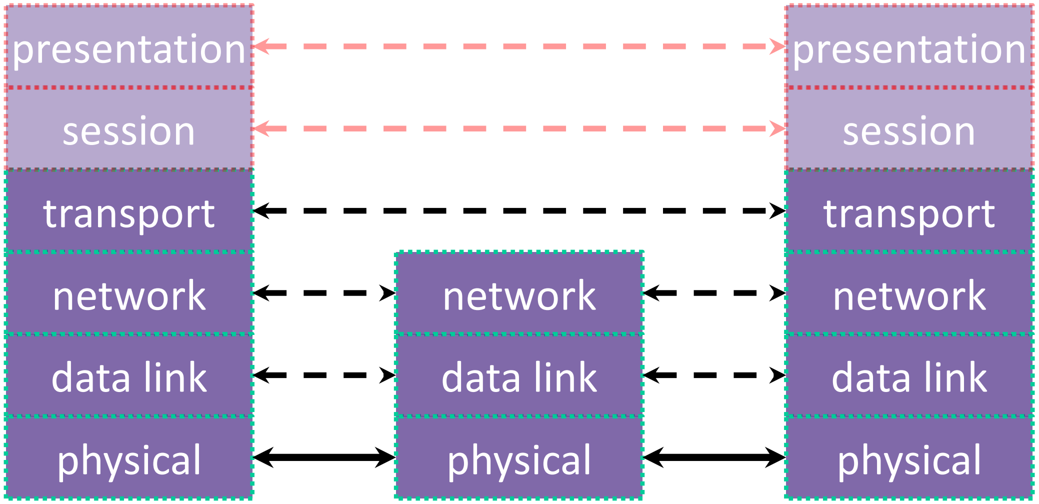
The Transport Layer (UDP)

- User Datagram Protocol (UDP):
  - Provides applications with *unreliable* packet delivery
  - UDP is a really thin, simple layer on top of IP
    - Datagrams still are fragmented into multiple IP packets



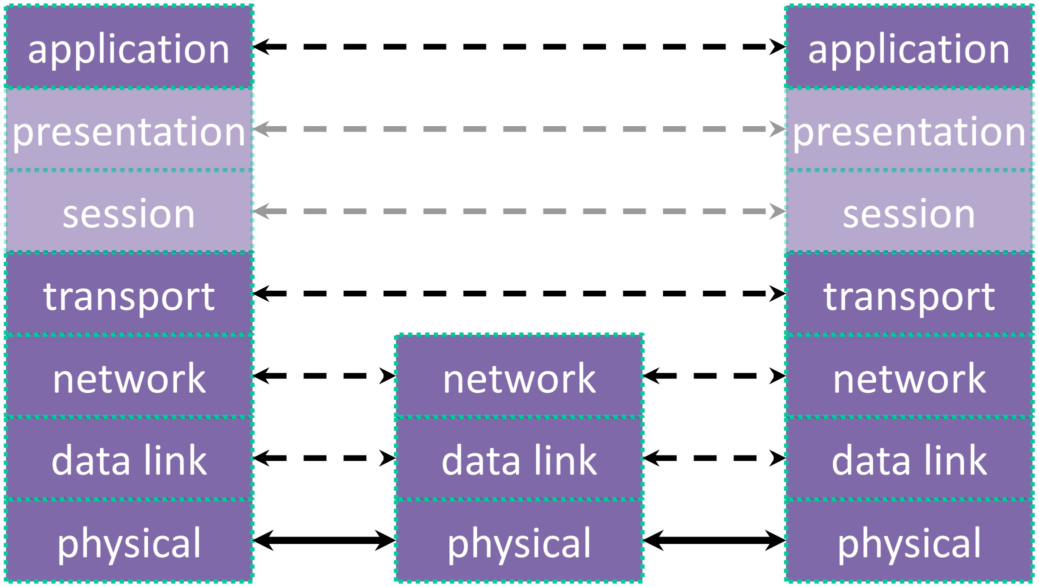
The (Mostly Missing) Layers 5 & 6

- Layer 5: Session Layer
  - Supposedly handles establishing and terminating application sessions
  - Remote Procedure Call (RPC) kind of fits in here
- Layer 6: Presentation Layer
  - Supposedly maps application-specific data units into a more network-neutral representation
  - Encryption (SSL) kind of fits in here



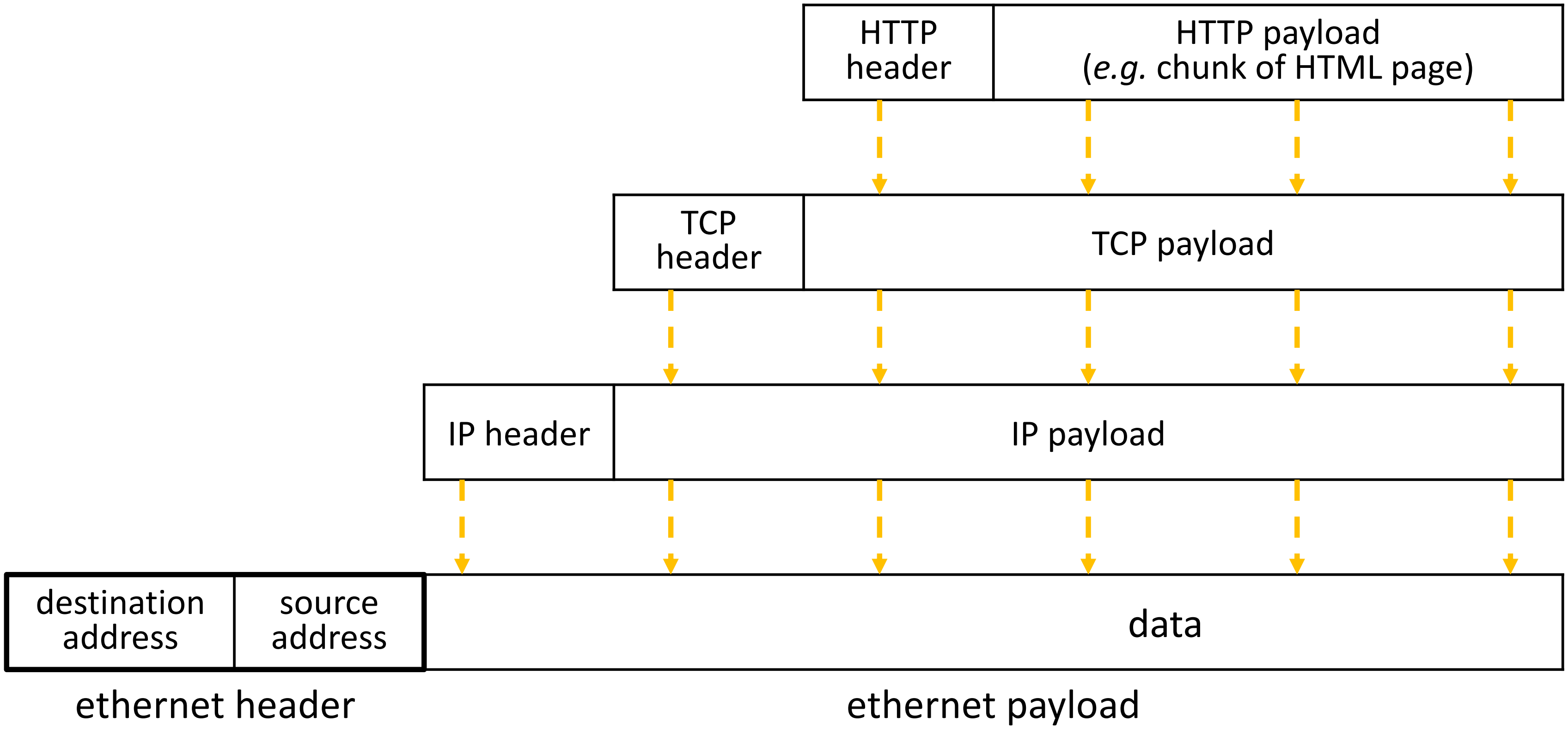
The Application Layer

- Application protocols
  - The format and meaning of messages between application entities
  - Example: HTTP is an application-level protocol that dictates how web browsers and web servers communicate
    - HTTP is implemented *on top of* TCP streams



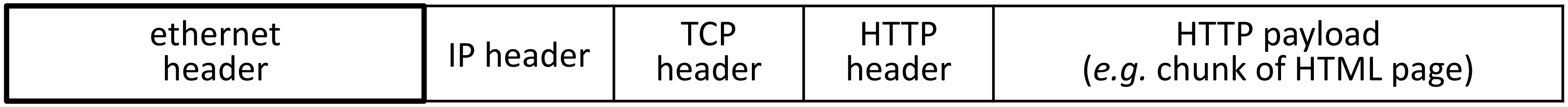
The Application Layer

- Packet encapsulation:



The Application Layer

- Packet encapsulation:



ethernet header

IP header

TCP header

HTTP header

HTTP payload
(*e.g.* chunk of HTML page)

The Application Layer

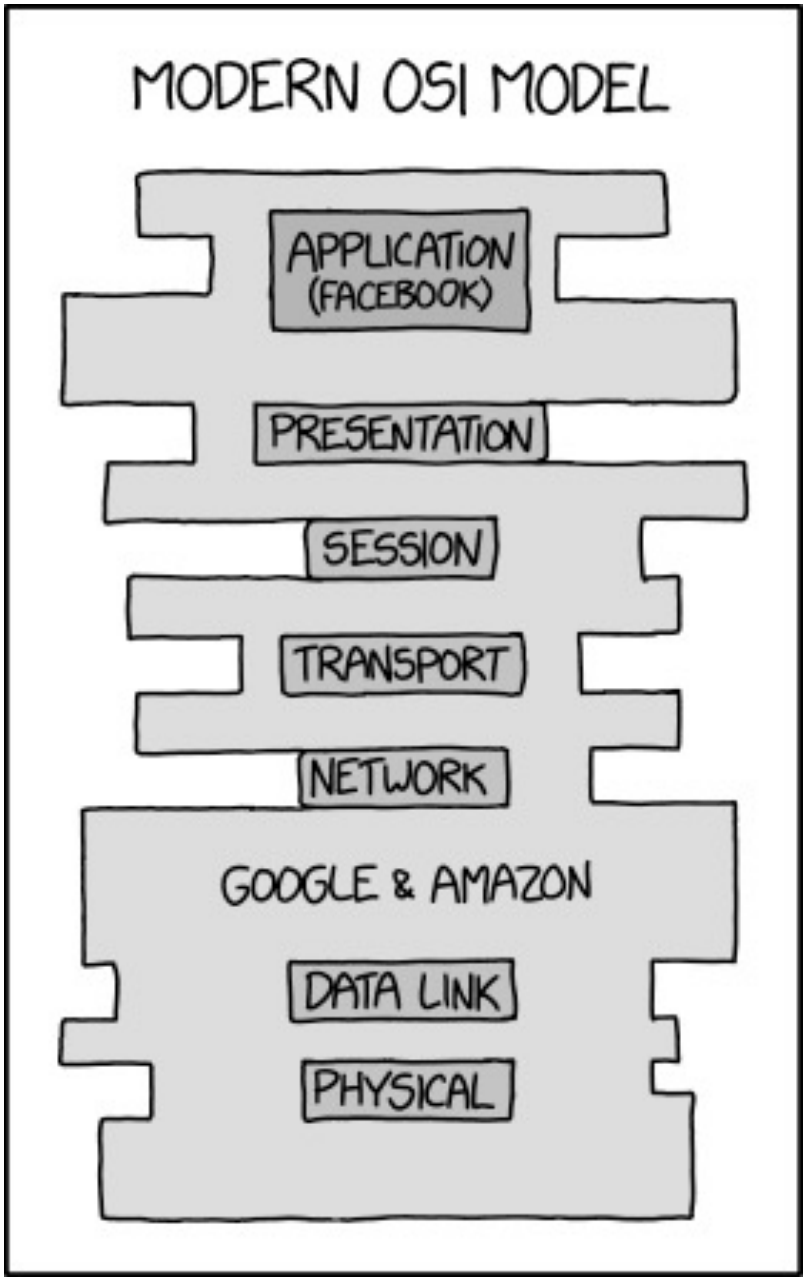
- Popular application-level protocols:
  - **DNS:** translates a domain name (*e.g.* www.google.com) into one or more IP addresses (*e.g.* 74.125.197.106)
    - Domain Name System
    - An hierarchy of DNS servers cooperate to do this
  - **HTTP:** web protocols
    - Hypertext Transfer Protocol
  - **SMTP, IMAP, POP:** mail delivery and access protocols
    - Secure Mail Transfer Protocol, Internet Message Access Protocol, Post Office Protocol
  - **SSH:** secure remote login protocol
    - Secure Shell
  - **bittorrent:** peer-to-peer, swarming file sharing protocol

netcat demo (if time)

- netcat (`nc`) is "a computer networking utility for reading from and writing to network connections using TCP or UDP"
  - https://en.wikipedia.org/wiki/Netcat

  - Listen on port: `nc -l <port>`
  - Connect: `nc <IPaddr> <port>`
    - Local host: `127.0.0.1`

The Future of Networking?


MODERN OSI MODEL
APPLICATION (FACEBOOK)
PRESENTATION
SESSION
TRANSPORT
NETWORK
GOOGLE & AMAZON
DATA LINK
PHYSICAL