CS 348
Computer Networks
Lec 5

Spring 2020 IIT Goa

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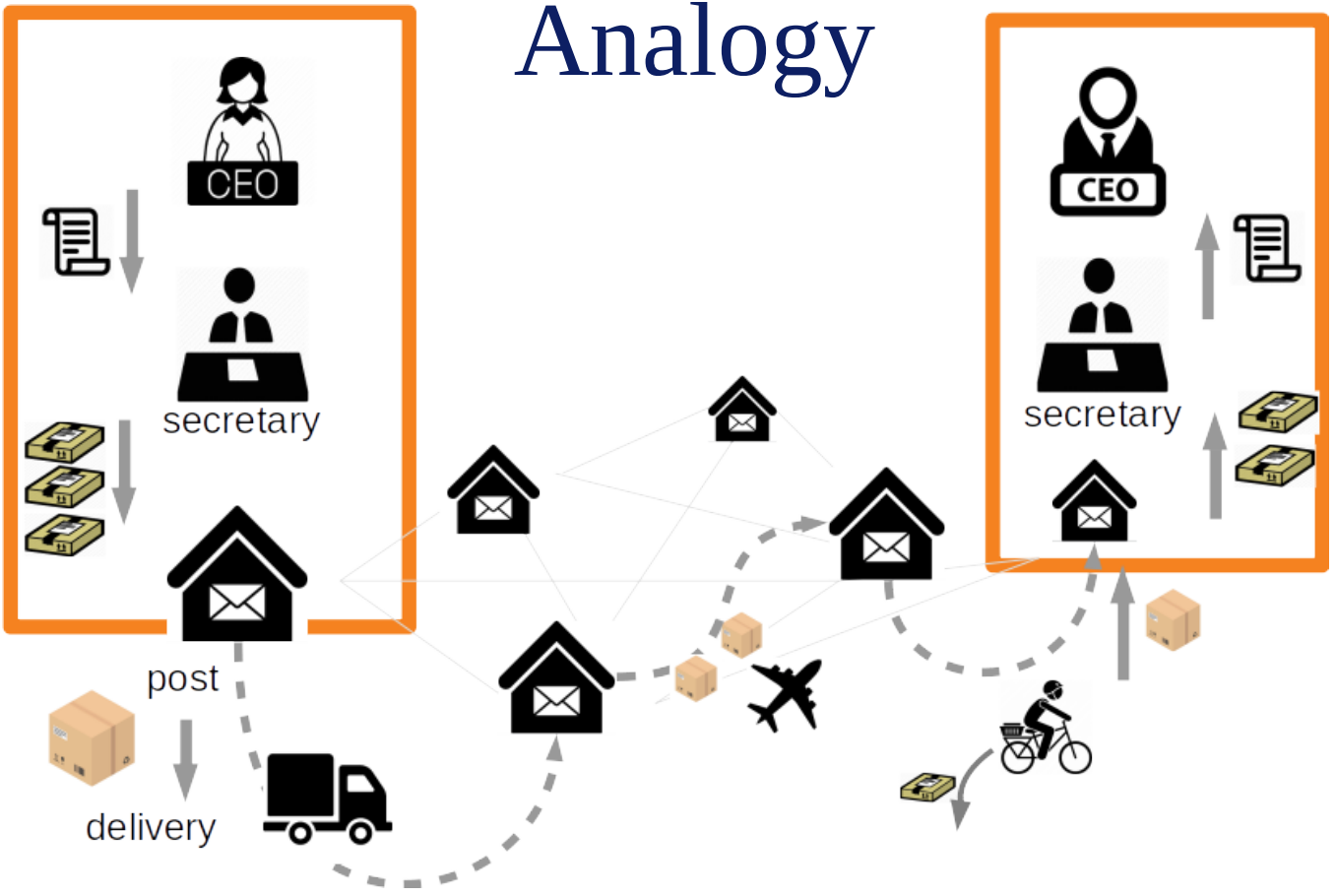
Disclaimer: These slides are adapted from Computer Networking: A Top-down Approach by Kurose & Ross, 6th ed. For copyright information visit: http://www-net.cs.umass.edu/kurose-ross-ppt-6e/

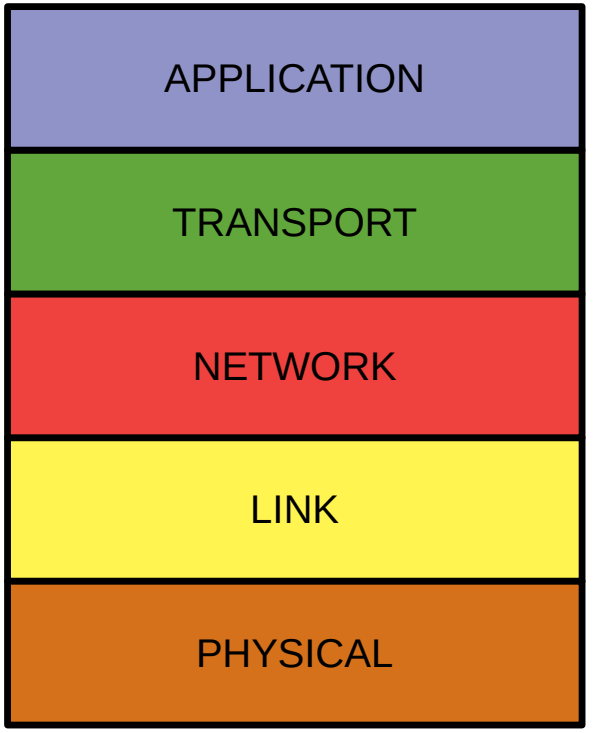
So far ...

- What are the Physical Components of the Internet?
- What is the Structure of the Internet?
- What is the Scale of the Internet?
- **How is the Internet designed, and how does it work?**
  - Layered design: the TCP/IP model
  - Encapsulation

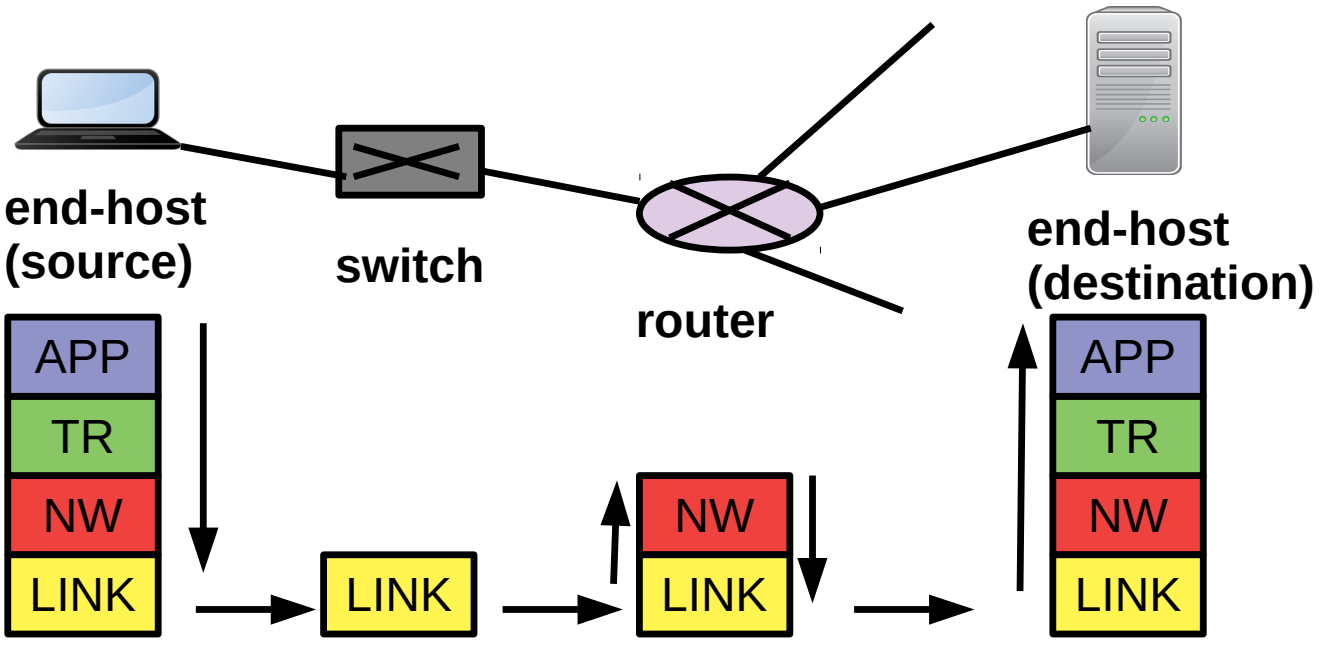
Layering: A Postal Analogy



Recap: Layers of the Internet
The TCP/IP Model



Where are the Layers Implemented?



The Application Layer

- **Consists of Applications (or Processes) running on hosts**
- Applications determine **“what”** is the data/message being sent across, and what to do with received messages.
- Use the services of the layers below to send/receive messages across the network (not concerned with **“how”** the messages get across)

Different **applications** might **require different types of services** from the layers below

- Reliable, In-order delivery of a stream of Bytes

  Example: Web browsing, Email ...

  OR

- Simple, unreliable delivery of a stream of Bytes (ok if some Bytes get lost)

  Example: Video streaming, Skype, ...

The Transport Layer

- **Provides Process-to-process message delivery service to Applications**
- Applications can choose between **different types of services** offered by the Transport layer:
  - **TCP: Reliable, In-order delivery** of a stream of Bytes
    - Performs numbering and re-ordering of packets, re-sending lost packets, etc.
    - Also does congestion control, flow control
  - **UDP: Simple, best-effort, unreliable delivery** of Bytes
    - Just send the packets across

The Network Layer

- Also known as The **Internet Layer**
- **Provides Host-to-host delivery service to the Transport layer**
- Responsible for:
  - **Routing a packet** to a given destination host (determine which path to take)

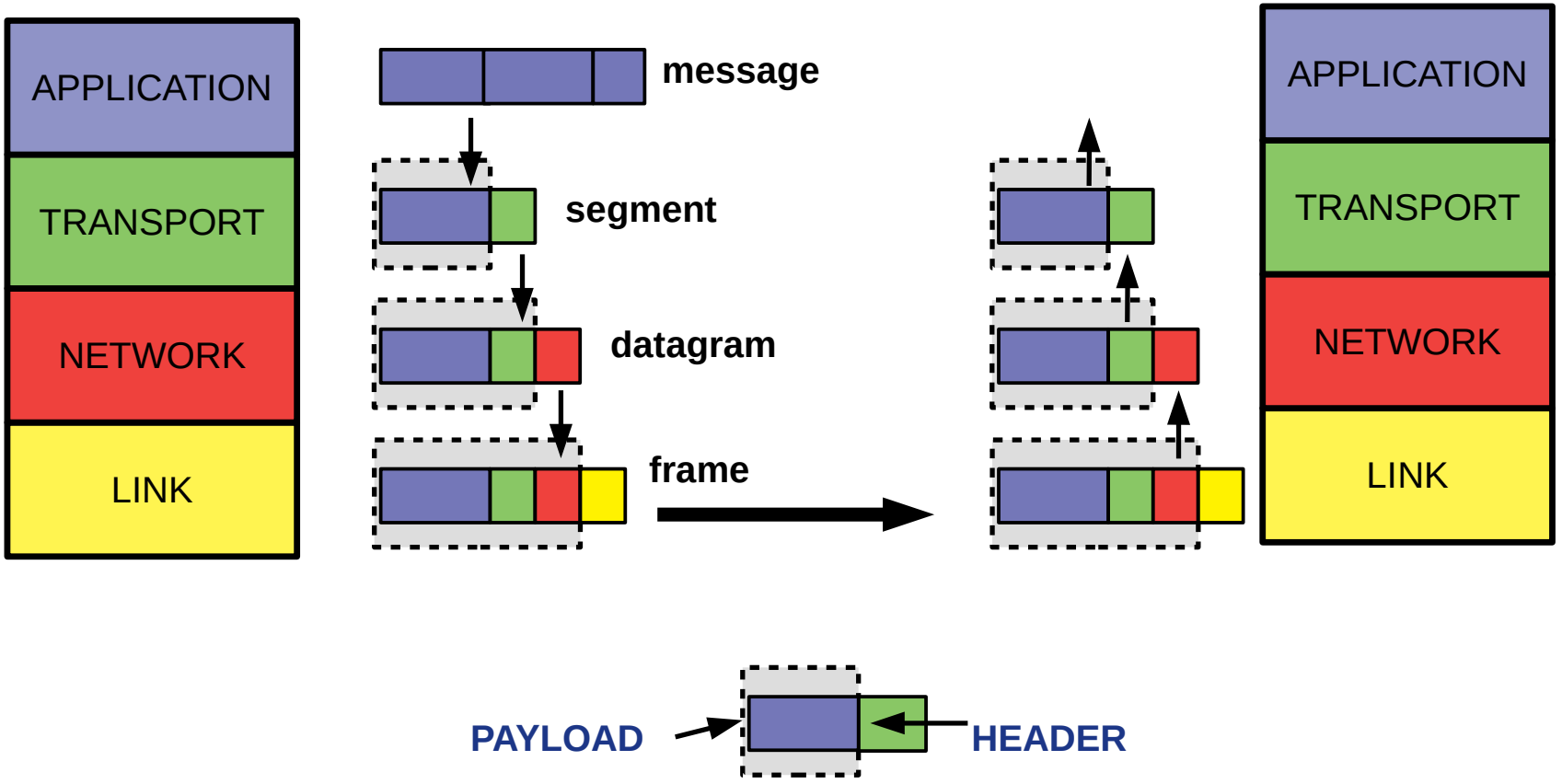
The Link Layer

- Responsible for **delivering a packet along a single link/hop**
- Different types of links: Ethernet, WiFi etc.
- The link layer hides details of “how” to send a packet along a single type of link.
- Some responsibilities of the Link layer:
  - In case of a broadcast medium, who gets to transmit? What happens on a collision? How to send packet to only one recipient?
  - Some links may provide error detection/error correction

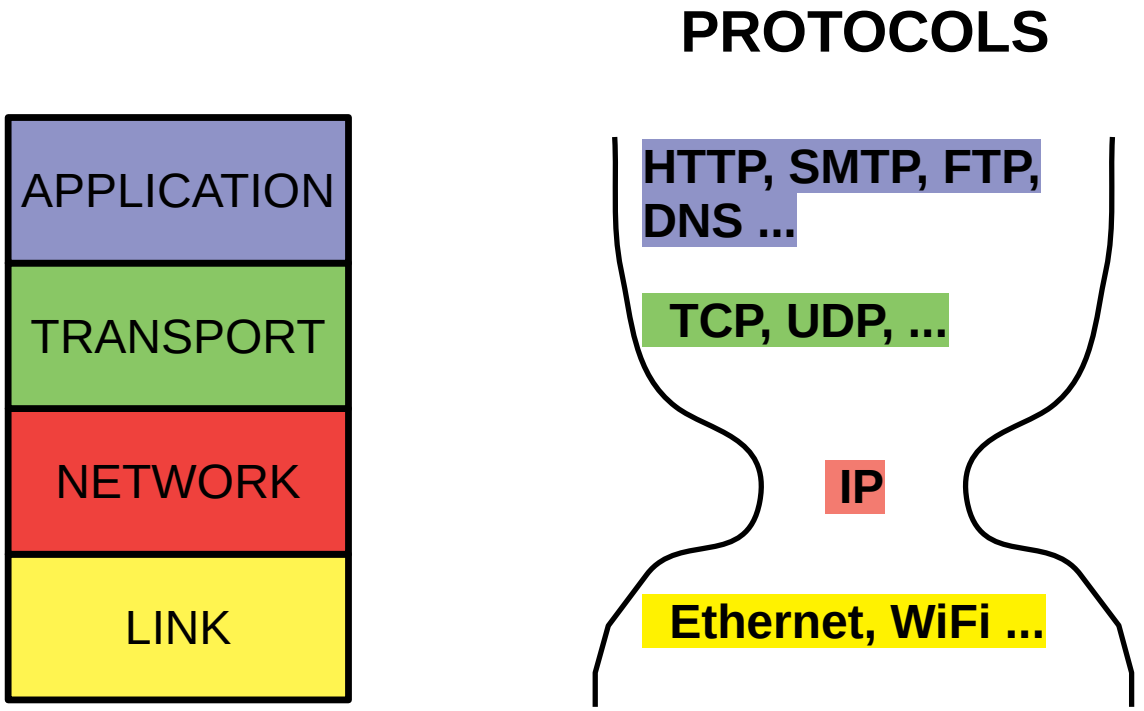
The Physical Layer

- Responsible for:
  - How to **transmit “bits” over a physical medium**?
  - How are 0s and 1s encoded? What is the maximum range/length supported
- Many protocols/standards exist, for different types of communication links

Key Idea: Encapsulation



The Protocol Stack



The TCP/IP Model

- This layered model is also known as **The Internet Model**, or **The Internet Protocol Suite** or **The 5-layer TCP/IP Model.**
- Named after the two “main” protocols that make up its design:
  - TCP (Transmission Control Protocol)
  - IP (Internet Protocol)
- Who proposed this model? When ? **Why**? Any alternatives?

The TCP/IP Model

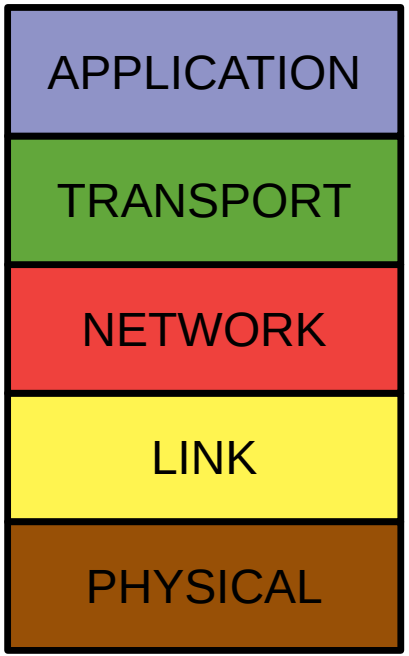
- Who proposed this model? When ? **Why**? Any alternatives?
- A Brief history:
  - 1974: Research at ARPANET on how to “Interconnect” different local networks together, hiding their implementation details using an “**Internetwork Protocol**”. End-hosts are responsibe for reliability. Leads to a “Transmission Control Program”
  - Later split into two protocols: IP for internetworking, and TCP for reliability
  - Key people: **Robert Kahn** and **Vinton Cerf**
- 1983: ARPANET adopts TCP/IP with IP version number 4 (IPV4 is still in use!)
- Currently: Standards maintained by **IETF** (Internet Engineering Task Force)

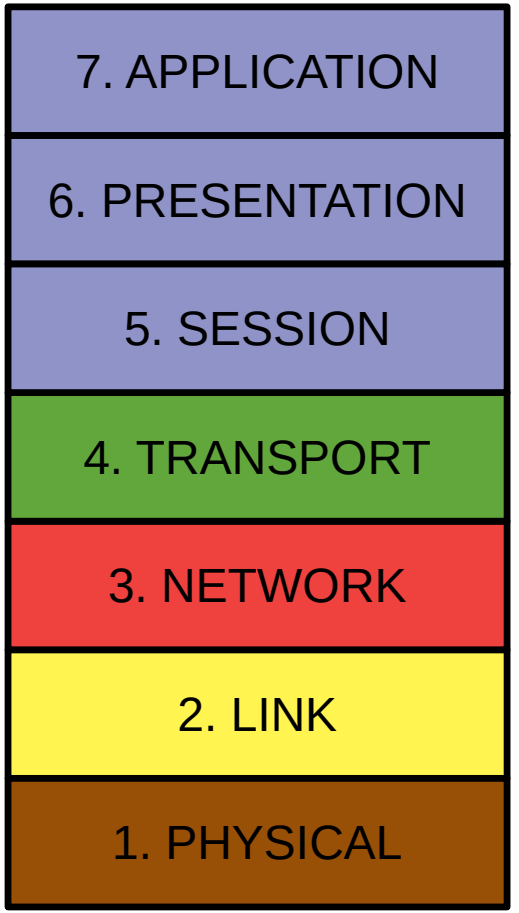
The TCP/IP Model

- Assigned Reading (Brief History of the Internet):
  - https://en.wikipedia.org/wiki/Internet_protocol_suite#History
  - https://en.wikipedia.org/wiki/ARPANET

The 7 layer ISO-OSI Model

The TCP/IP Model





The Session Layer

- Managing communication sessions (multiple back-and-forth transmissions between two nodes)
- Establish, manage and terminate the connections

The Presentation Layer

- Translation of data between applications, where the end-points may locally use different formats.

- Data compression, Data encryption, Data conversion etc.

The OSI Model

- Open Systems Interconnection (OSI) model, proposed around 1984 by the International Standards Organization (ISO).
- This model further seprates out the services that are typically performed by the application layer in the TCP/IP model, such as data encryption, formatting etc.
- OSI model is was proposed as a reference, but TCP/IP became widely adopted, and is the current standard.

Some characteristics of the Internet that dictate its design ...

Characteristics of the Internet

1. **A Federated System**
   - no single govt/company/organization “owns” the Internet
   - Internet connects together > 40,000 independently owned networks (Autonomous Systems). Some of them are competing entities!
   - Need to cooperate and agree upon standards
   - Innovation is complicated: Can’t “upgrade” the whole Internet!

Some Interesting links:

- **What’s an Autonomous System (AS)?** https://www.cs.rutgers.edu/~pxk/352/notes/autonomous_systems.html
- **List of all ASs in India:** https://ipinfo.io/countries/in

Characteristics of the Internet

2. **Tremendous Scale**
   - About 4.6 Billion users (58% of world population)
   - Over 1.5 Billion Websites and over 1 Trillion unique URLs (web pages)

Characteristics of the Internet

3. **Enormous diversity**
   - Technology: optical, wireless, satellite, copper,...
   - Communication latency: microseconds to seconds
   - Bandwidth: 1Kbits/second to 1 Terabit/second
   - Packet loss: 0 – 90%
   - Endpoint devices: sensors, cell phones, datacenters,...
   - Applications: skype, live video, gaming, remote medicine,...
   - Users: the governing, governed, operators, selfish, malicious,naïve, savvy,...

Slides content from: CS168 Introduction to the Internet: Architecture and Protocols, Sylvia Ratnasamy, Spring 2020

Characteristics of the Internet

4. Prone to Failure

- Many components along a path: software, switches, links, network interface cards, wireless access
- Example: consider 50 components, each work correctly 99% of the time
  - Probability of failure = 1 - 0.99^{50} = Approx 40%
- Links can fail, packets can get corrupted, routers can be malicious

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Key Design Ideas of the Internet

- Layering and Encapsulation
- Keep the network core dumb/simple/fast, keep all intelligence on the end hosts
- Packet switching
- Best-effort delivery
- The End-to-end design Principle

Service Model of the Internet

- What service model does the Internet support?
  - Guaranteed delivery of data ?
  - Guaranteed delivery of data within X amount of time ?
  - Return confirmation of successful delivery or an error ?

Service Model of the Internet

- What service model does the Internet support?
  - ✗ Guaranteed delivery of data ?
  - ✗ Guaranteed delivery of data within X amount of time ?
  - ✗ Return confirmation of successful delivery or an error ?
- **Service Model of the Internet:**
  - ✔ Make the best effort to deliver a packet, no guarantees
  - ✔ No guarantee on whether or when the data will be delivered
  - ✔ No notification of outcome

Next up...

- **Why Packet Switching?**
- **Performance Measures**: Delay, Bandwidth and Throughput

Reference

- **Kurose and Ross, Section 1.5**
- **History of the Internet:**
  - https://en.wikipedia.org/wiki/Internet_protocol_suite
  - Kurose and Ross, 6th ed Section 1.7
- **Interesting Read: Story of the TCP/IP model and why the OSI model didn’t take off**
  - https://spectrum.ieee.org/tech-history/cyberspace/osi-the-internet-that-wasnt