Computer Networks X_400487

@Large Research
Massivizing Computer Systems

VU VRIJE UNIVERSITEIT AMSTERDAM

Lecture 1: Introduction to Computer Networks (+ a tiny bit of Chapter 2)

Welcome! Lecture starts at 09:00

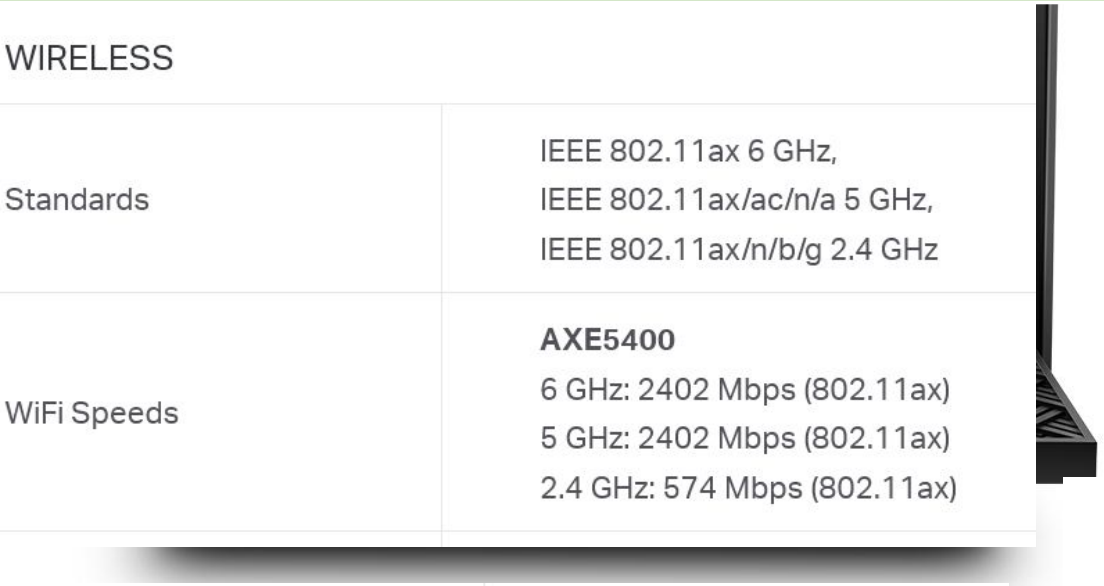



Lecturers: Jesse Donkervliet, Gonçalo Amado Mesquita, Nehir Kırkgöz, Daniel-Ştefan Halasz

https://unsplash.com/photos/6wdRuK7bVTE, https://unsplash.com/photos/npxXWgQ33ZQ, https://unsplash.com/photos/6vvxiBUf9pM, https://unsplash.com/photos/rbDE93-0hHs, https://unsplash.com/photos/3YAIvBNlZM4,

1. After this course, you understand router specifications

WAN Types	Dynamic IP Static IP PPPoE PPTP L2TP
NAT Forwarding	Port Forwarding Port Triggering DMZ UPnP Virtual Server
	IGMP Proxy
	Tag VLAN
DHCP	Address Reservation DHCP Client List Server
DDNS	TP-Link NO-IP DynDNS

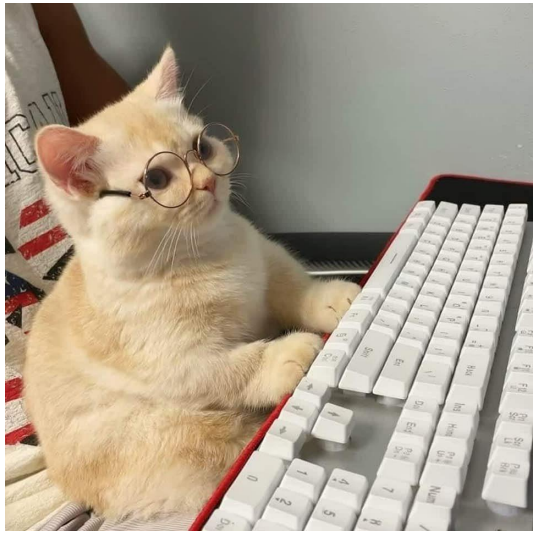


WIRELESS	
Standards	IEEE 802.11ax 6 GHz, IEEE 802.11ax/ac/n/a 5 GHz, IEEE 802.11ax/n/b/g 2.4 GHz
WiFi Speeds	**AXE5400** 6 GHz: 2402 Mbps (802.11ax) 5 GHz: 2402 Mbps (802.11ax) 2.4 GHz: 574 Mbps (802.11ax)

Working Modes	Router Mode Access Point Mode
WiFi Capacity	OFDMA Simultaneously communicates with multiple Wi-Fi 6 clients Airtime Fairness Improves network efficiency by limiting excessive occupation

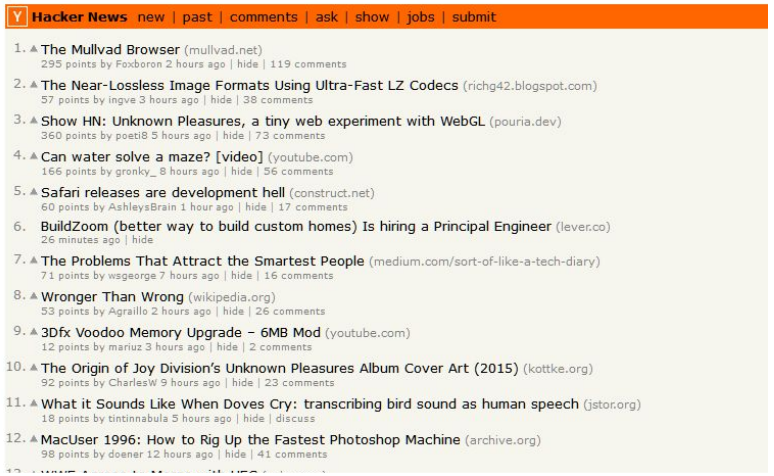
https://www.tp-link.com/en/home-networking/wifi-router/archer-axe75/#overview

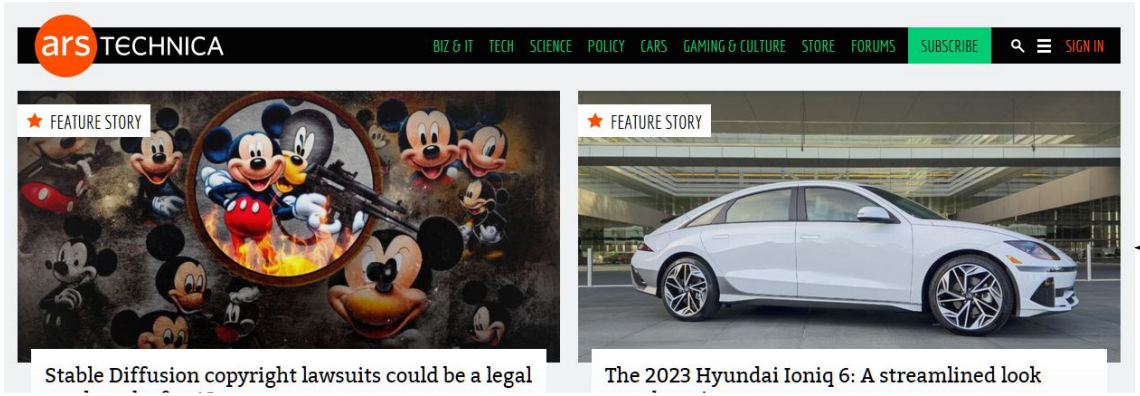
(a) Type address in browser



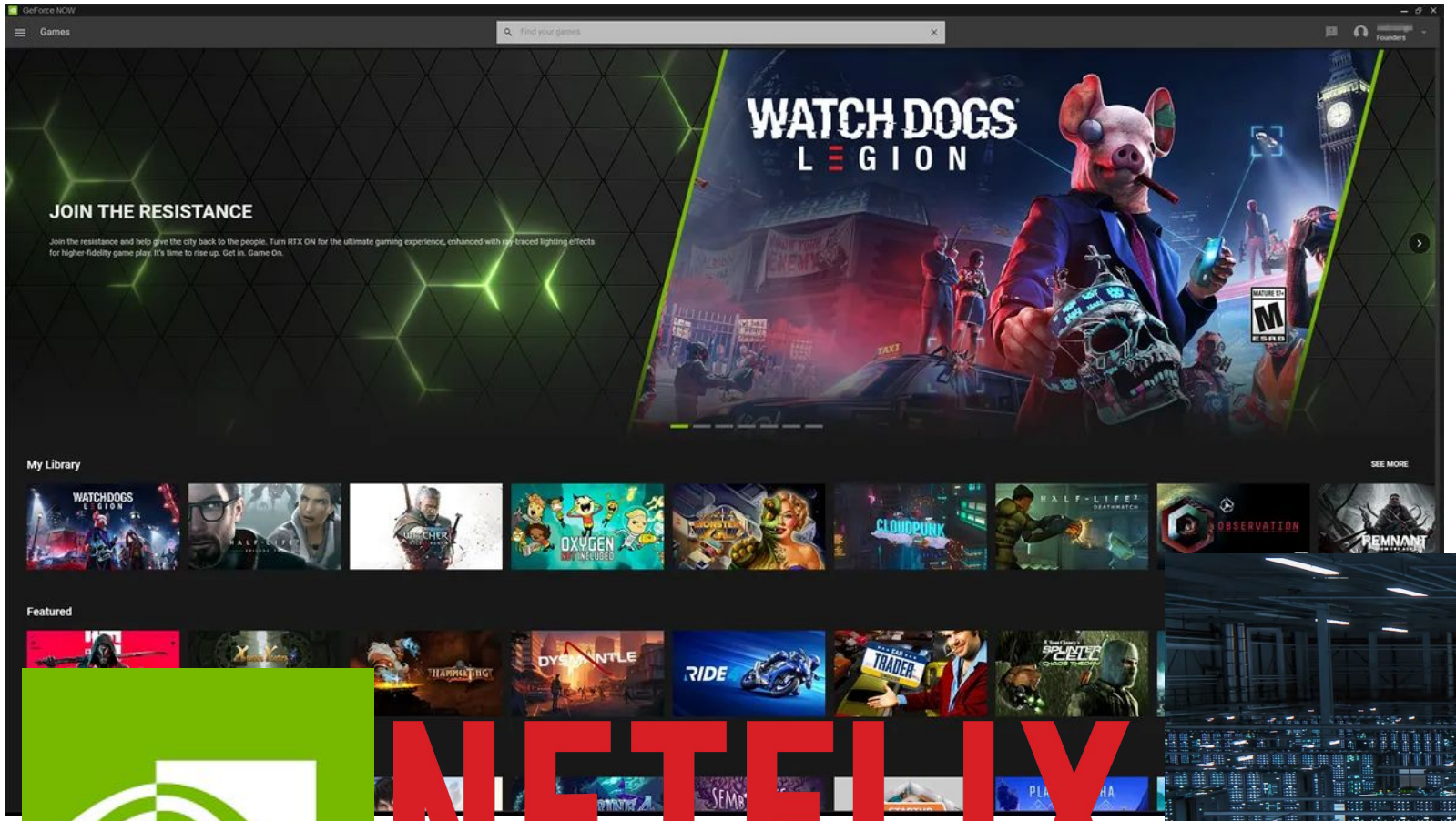
(b) Browser does magic

(c) You get a Web page





2. After this course, you understand browser magic



NETFLIX

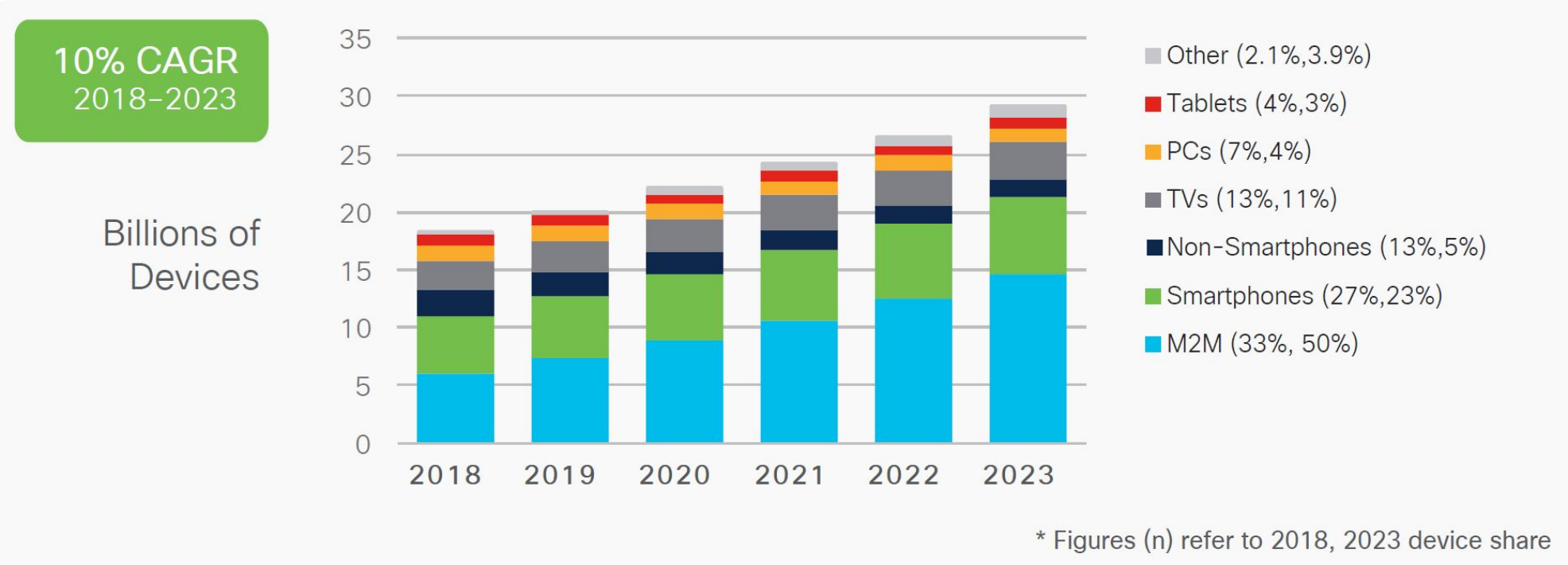
Claude

3. After this course, you understand how networks enable new applications

Number of devices connected to the Internet

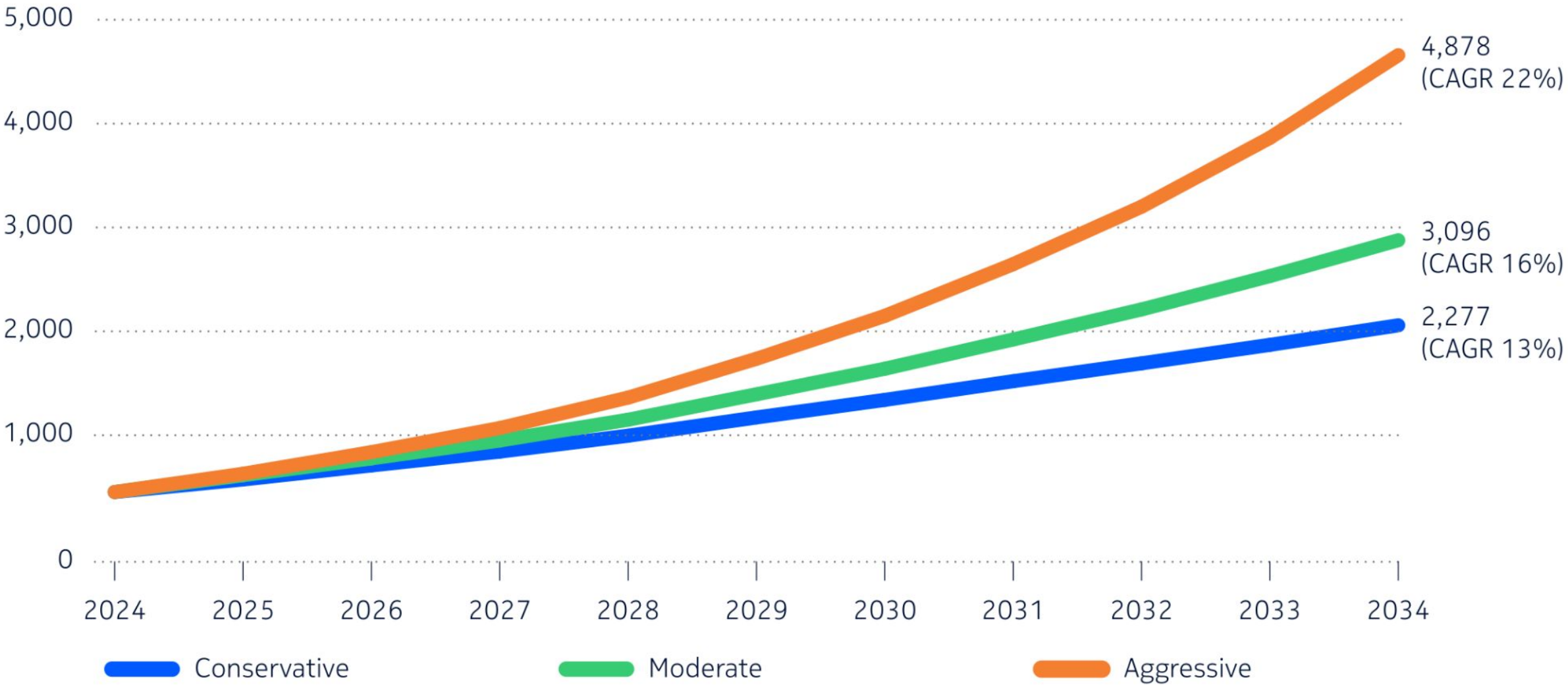
- Likely exceeds 20 billion connected devices
- Yearly increase of 10%

Q: How much traffic is generated by these users?



Download Cisco report: https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper-c11-741490.html

Global WAN traffic, EB/month



https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/vni-hyperconnectivity-wp.html

The New York Times

Google Services Go Down in Some Parts of U.S.

People experienced outages of services like Gmail, YouTube and Google Meet.

CONFIGURATION SABOUTAGE —

Facebook's outage likely cost the company over $60 million

Configuration change cascaded down the data centers, bringing systems to a halt.

AX SHARMA - 10/5/2021, 2:33 PM

TECH | AMAZON

An Amazon server outage caused problems for Alexa, Ring, Disney Plus, and deliveries

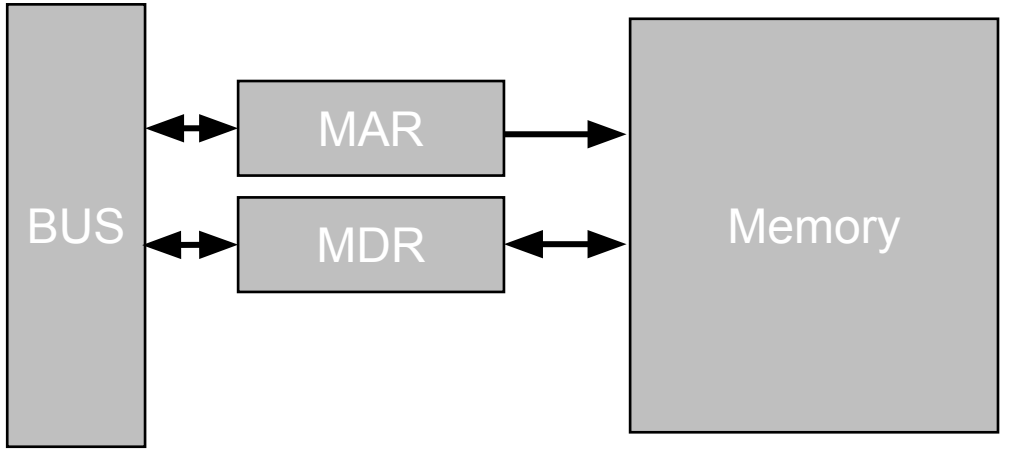
Amazon says "many services have already recovered"

By Richard Lawler | @rjcc | Updated Dec 7, 2021, 7:25pm EST

Further reading on Facebook outage:

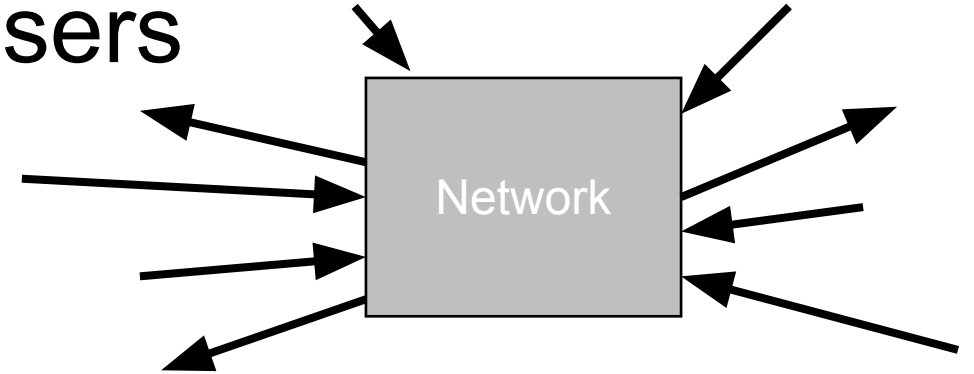
1. https://blog.cloudflare.com/october-2021-facebook-outage/
2. https://engineering.fb.com/2021/10/05/networking-traffic/outage-details/

What makes networks different from connected components in a single machine?



Examples of challenges:

1. Latency is unknown and/or unbounded
2. Data channels are unreliable
3. Sharing resources with multiple users
4. …



Today's Lecture

1. Intro
2. **Computer Networking History**
3. From Waves to Bits
4. Course Structure and Logistics

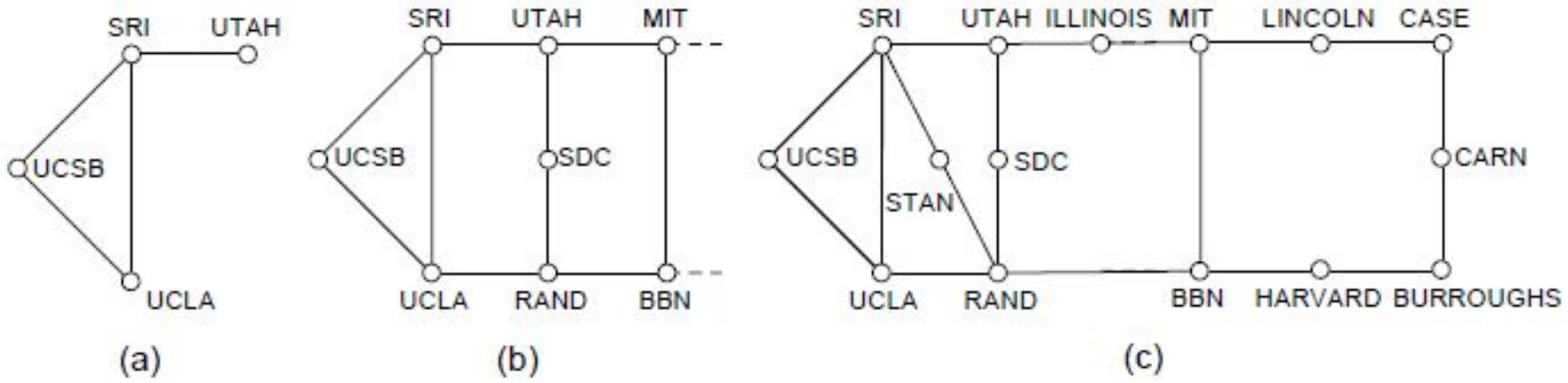
The ARPANET
Growth over time

Growth of the ARPANET.

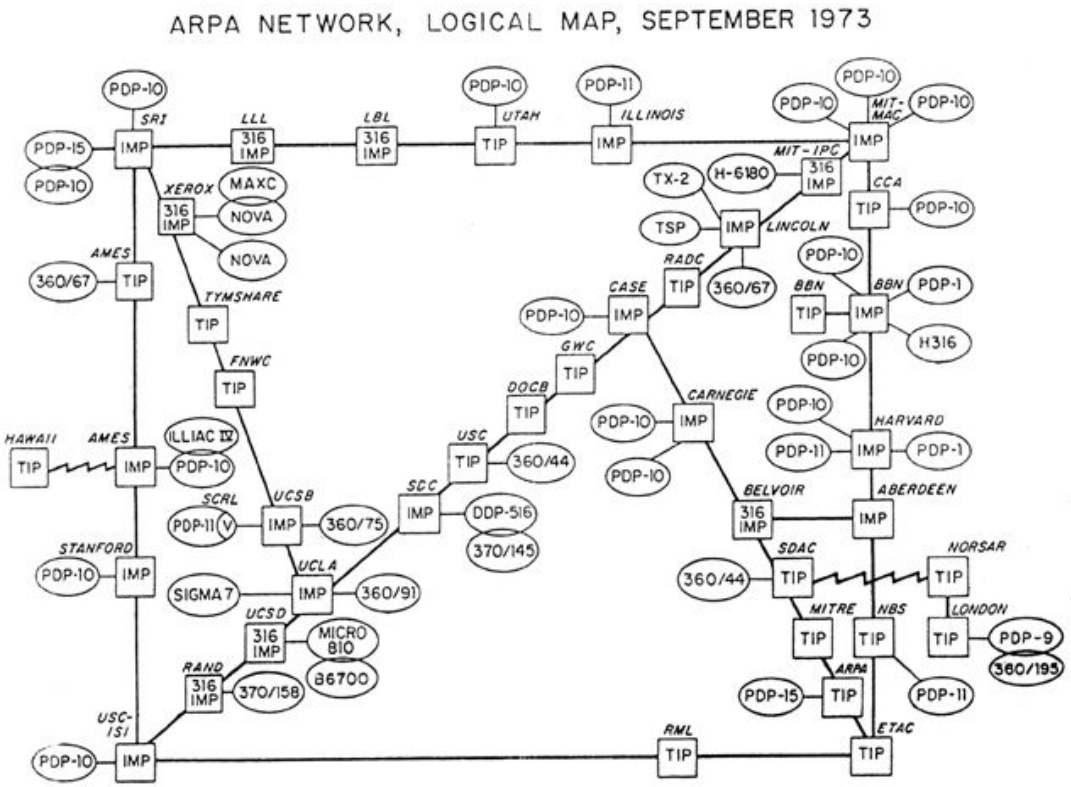
(a) December 1969.

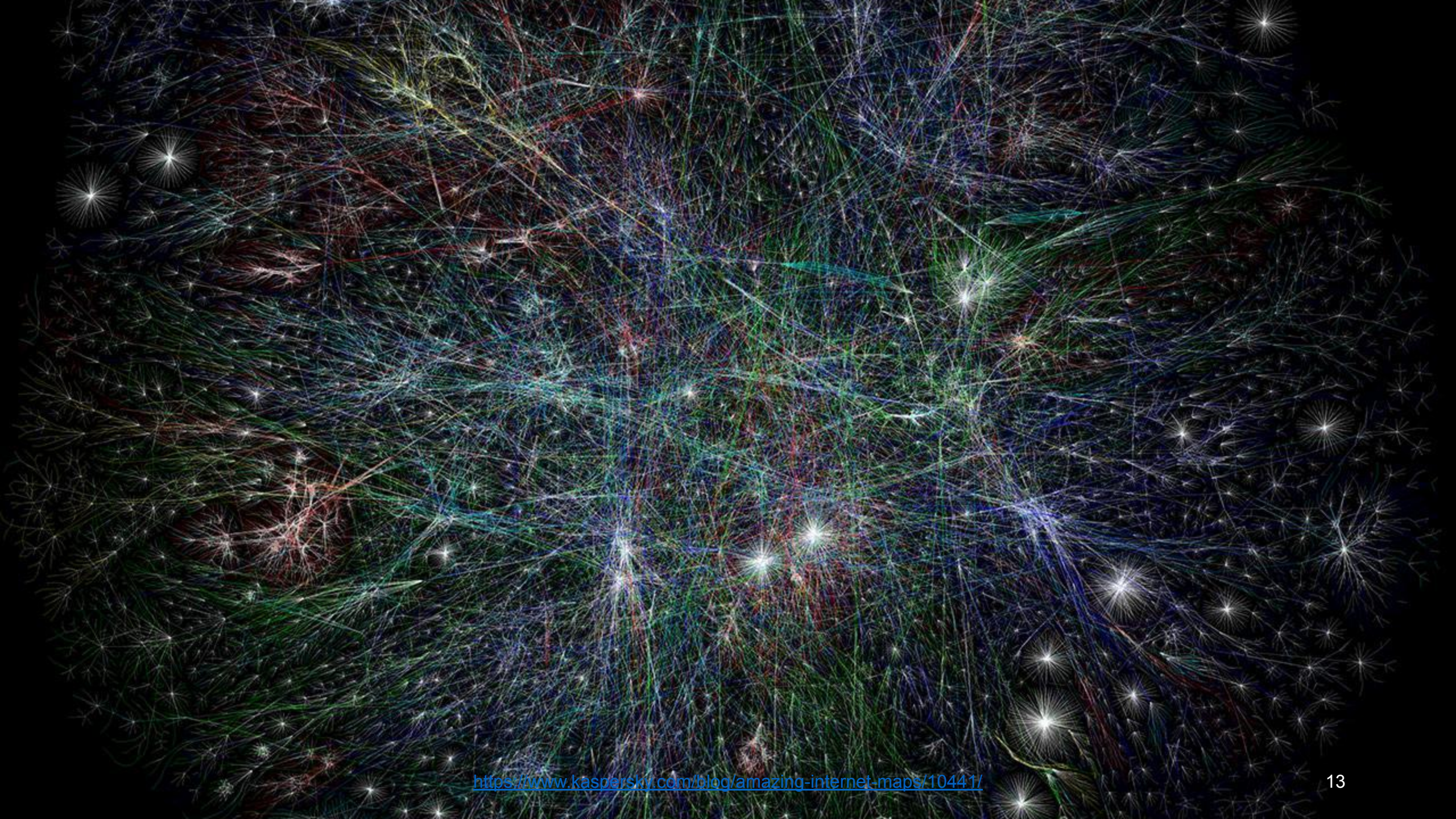
(b) July 1970.

(c) March 1971.



The ARPANET
Network state in 1973





https://www.kaspersky.com/blog/amazing-internet-maps/10441/

How scale affects networks design

Personal Area Network (PAN)

- Example: Bluetooth

Local Area Network (LAN)

- Examples: WiFi (802.11)

Metropolitan Area Network (MAN)

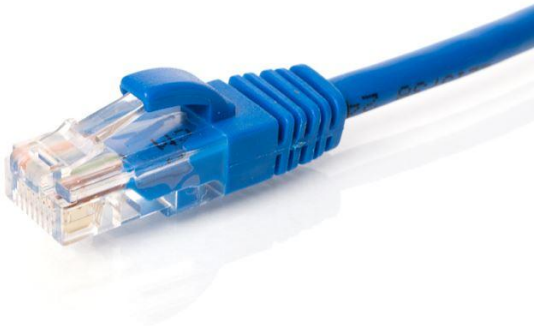
Wide Area Network (WAN)

The Internet

Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

How the medium affects network design

Different frequencies have different physical properties!

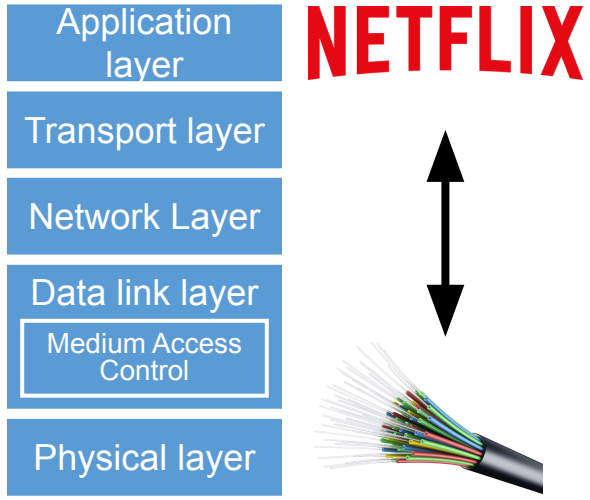


Layered architecture

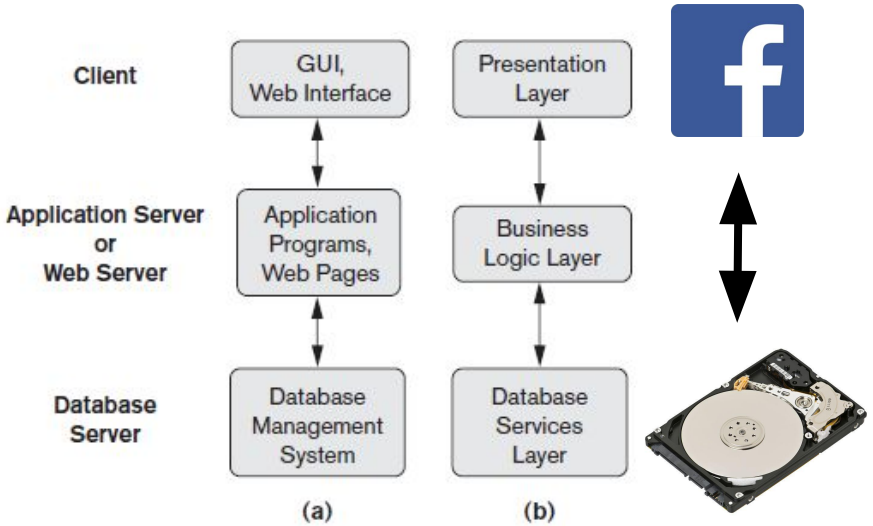
Q: Discuss the concept of a (layered) architecture; Give one advantage and one disadvantage

Can be found in…

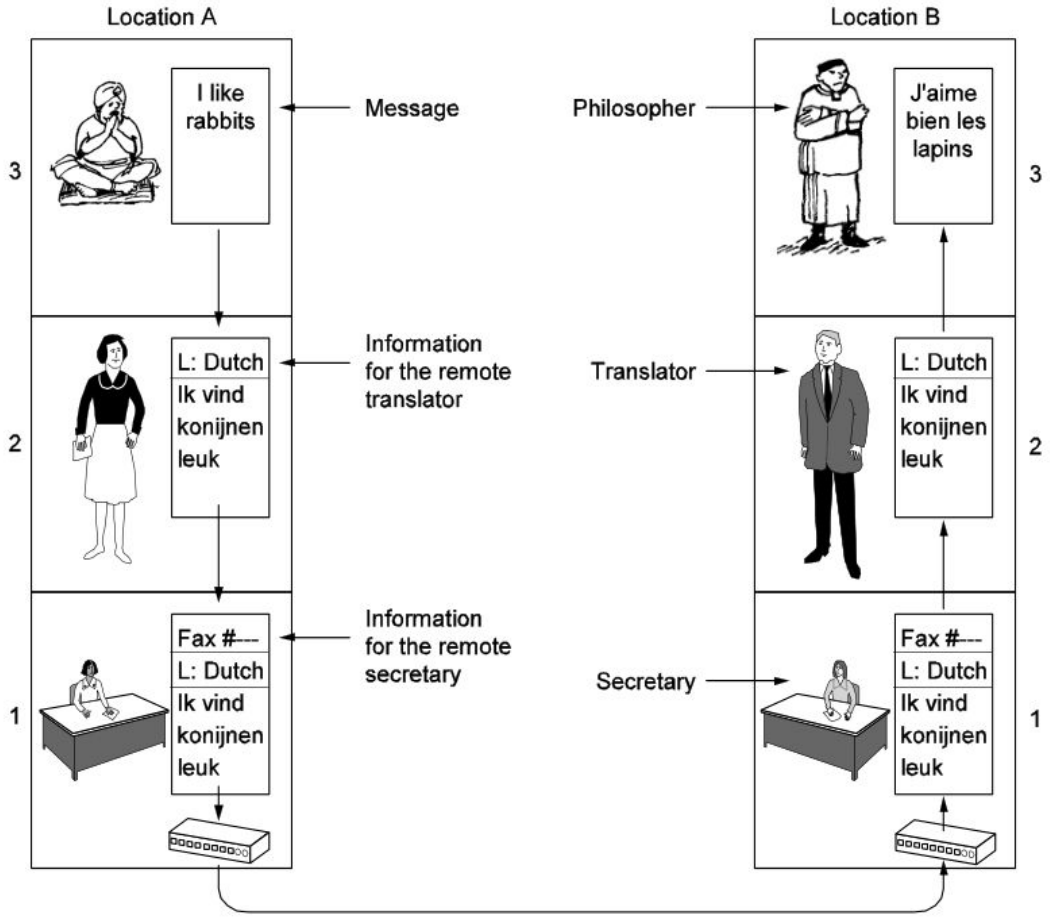
…computer networks…



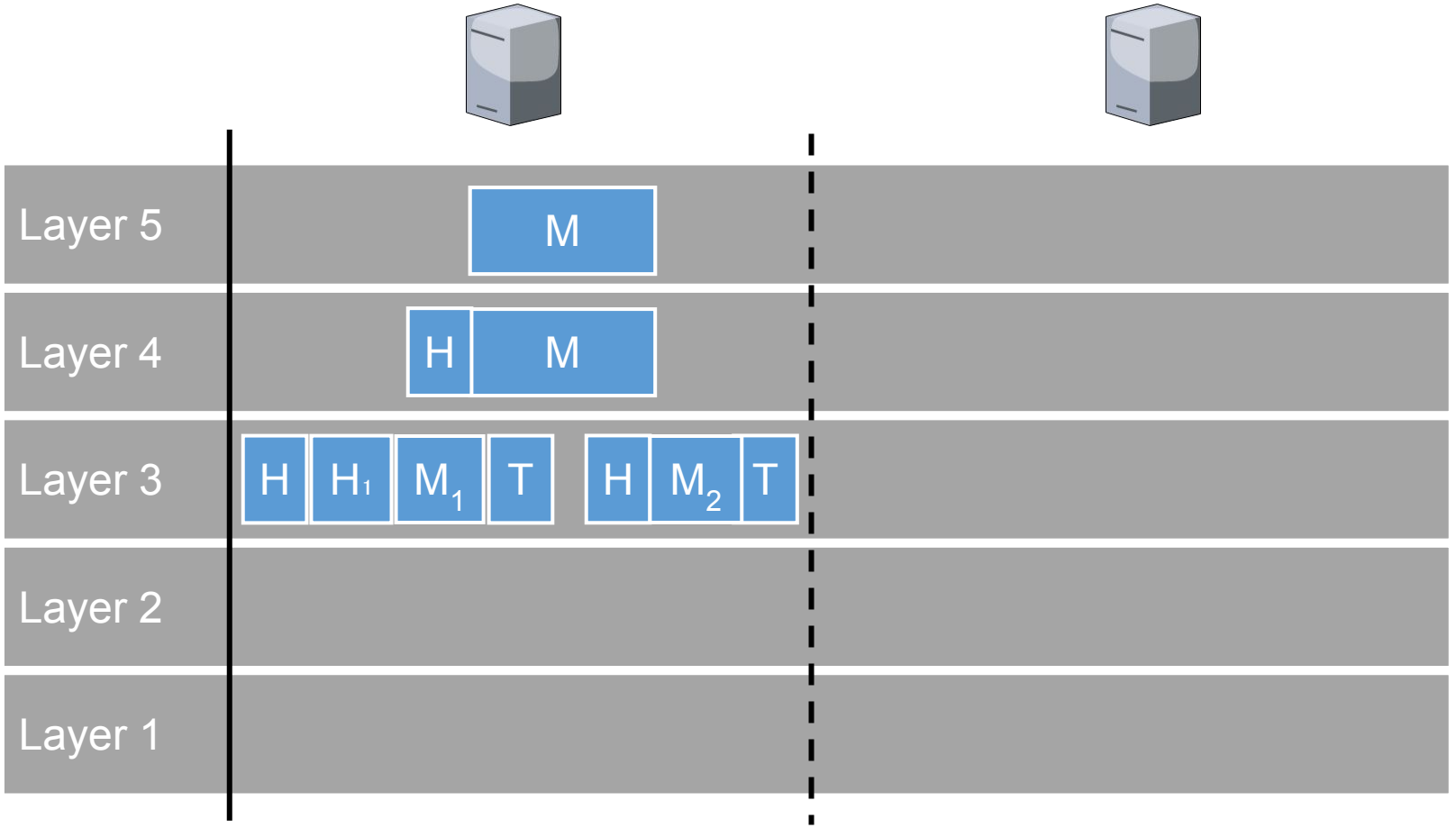
…and other domains



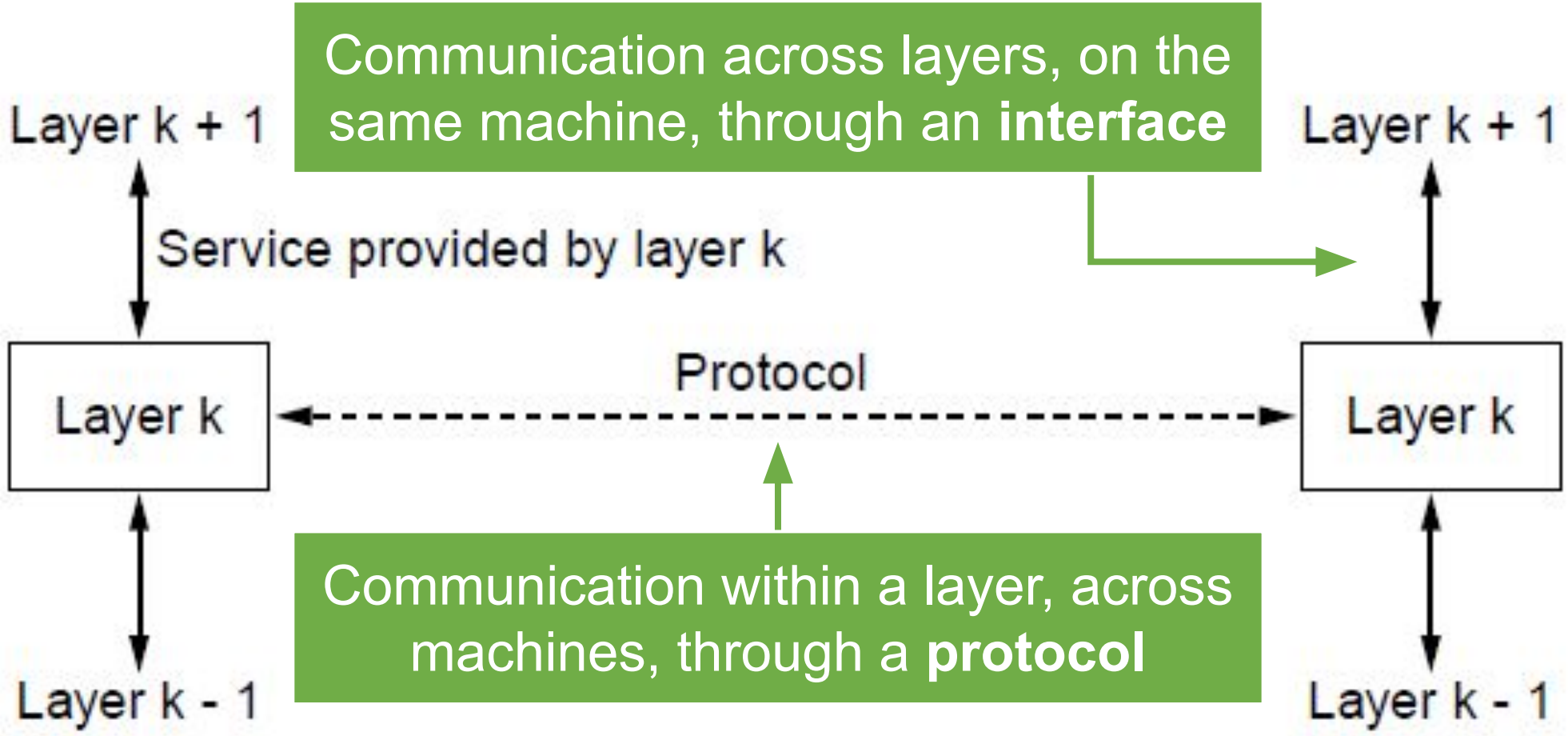
Layered architecture in computer networks: an analogy



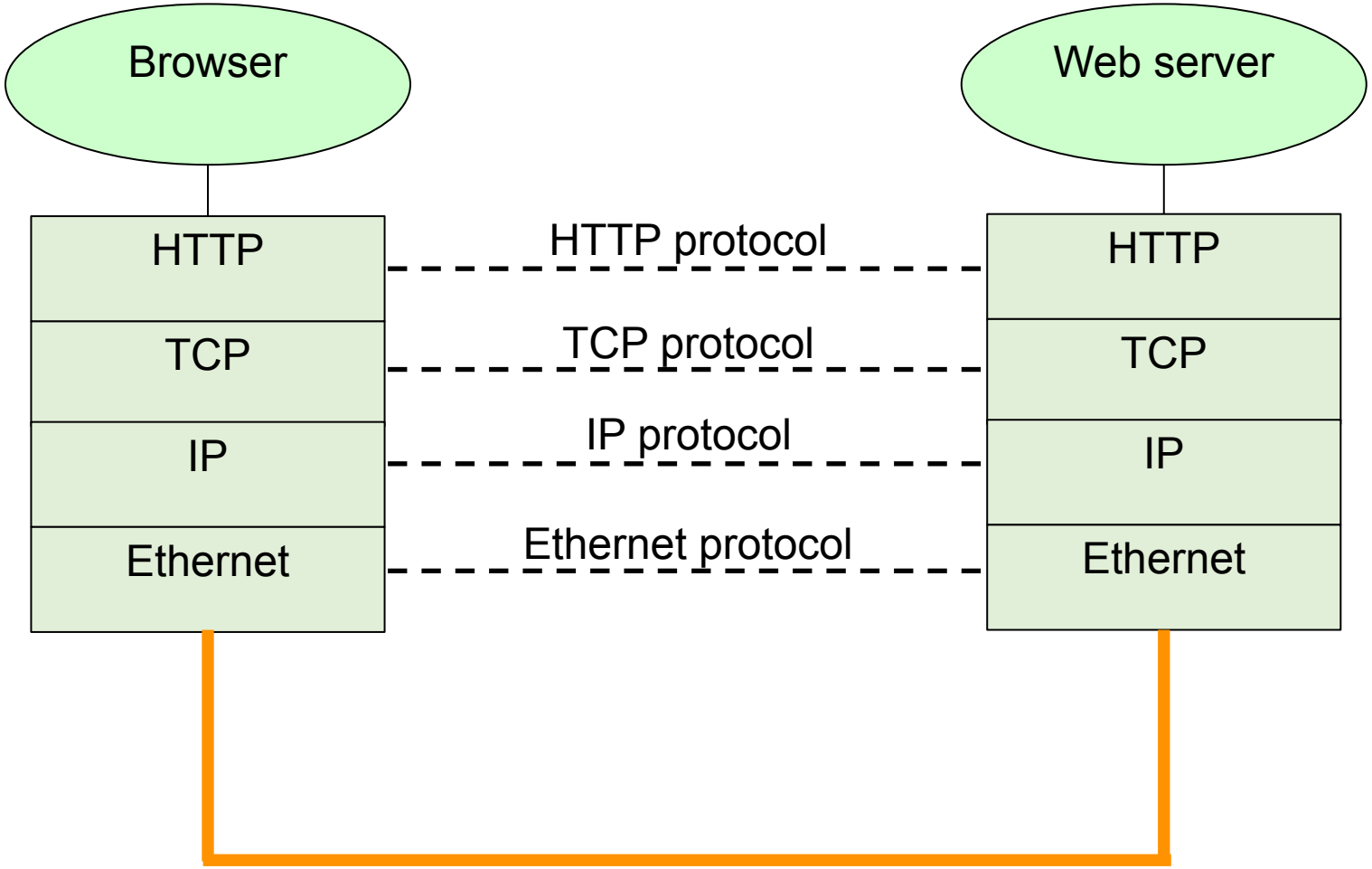
Layered architecture in computer networks: an overview



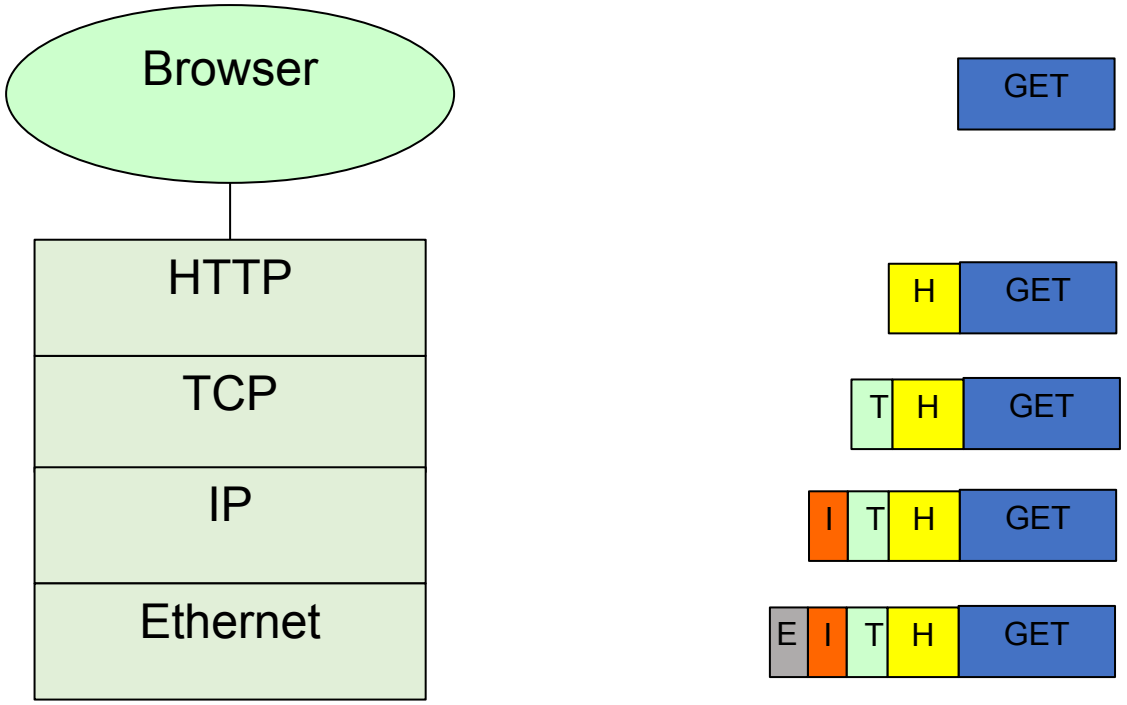
Illusion of direct communication



An example protocol

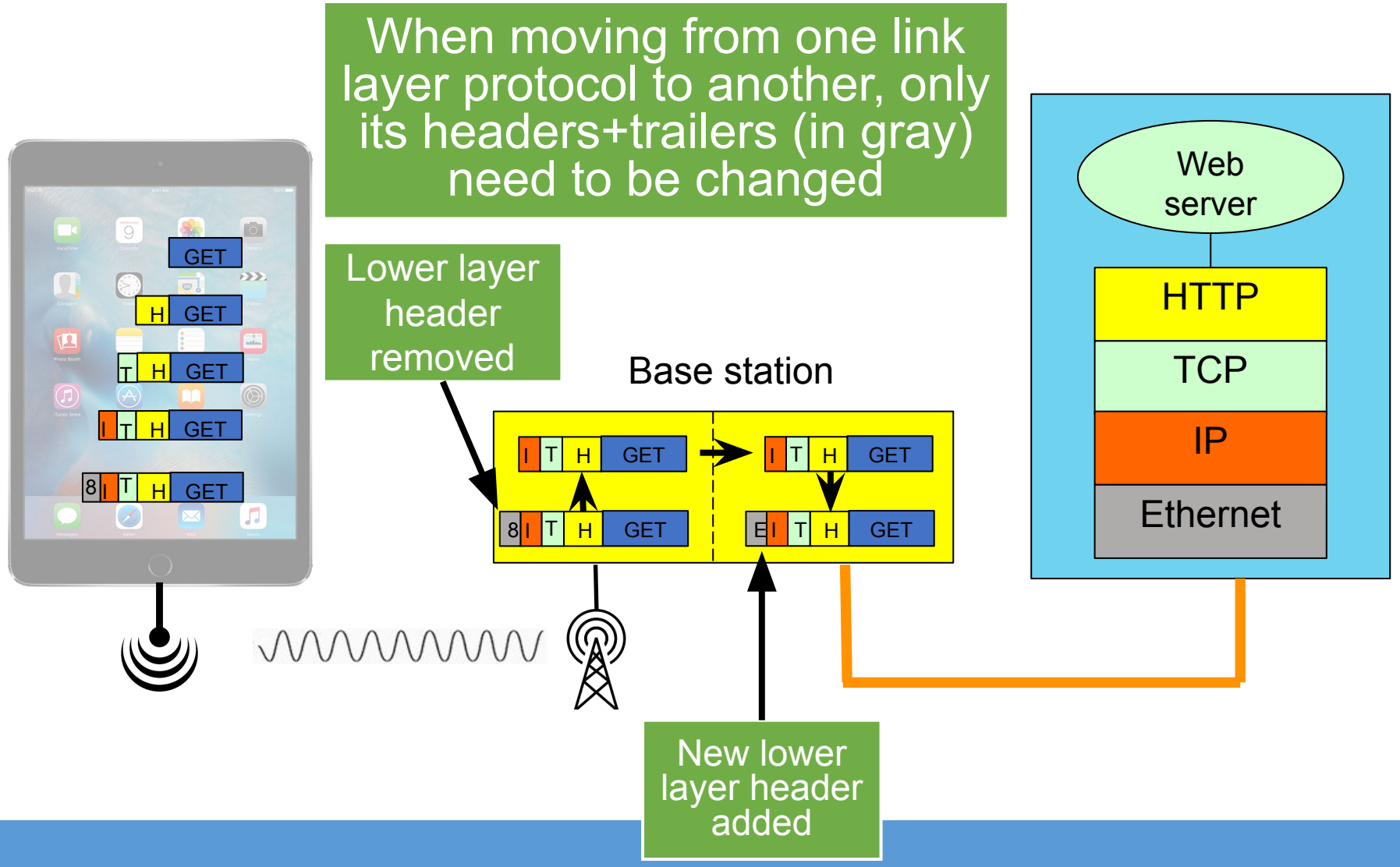


Encapsulation in a protocol stack

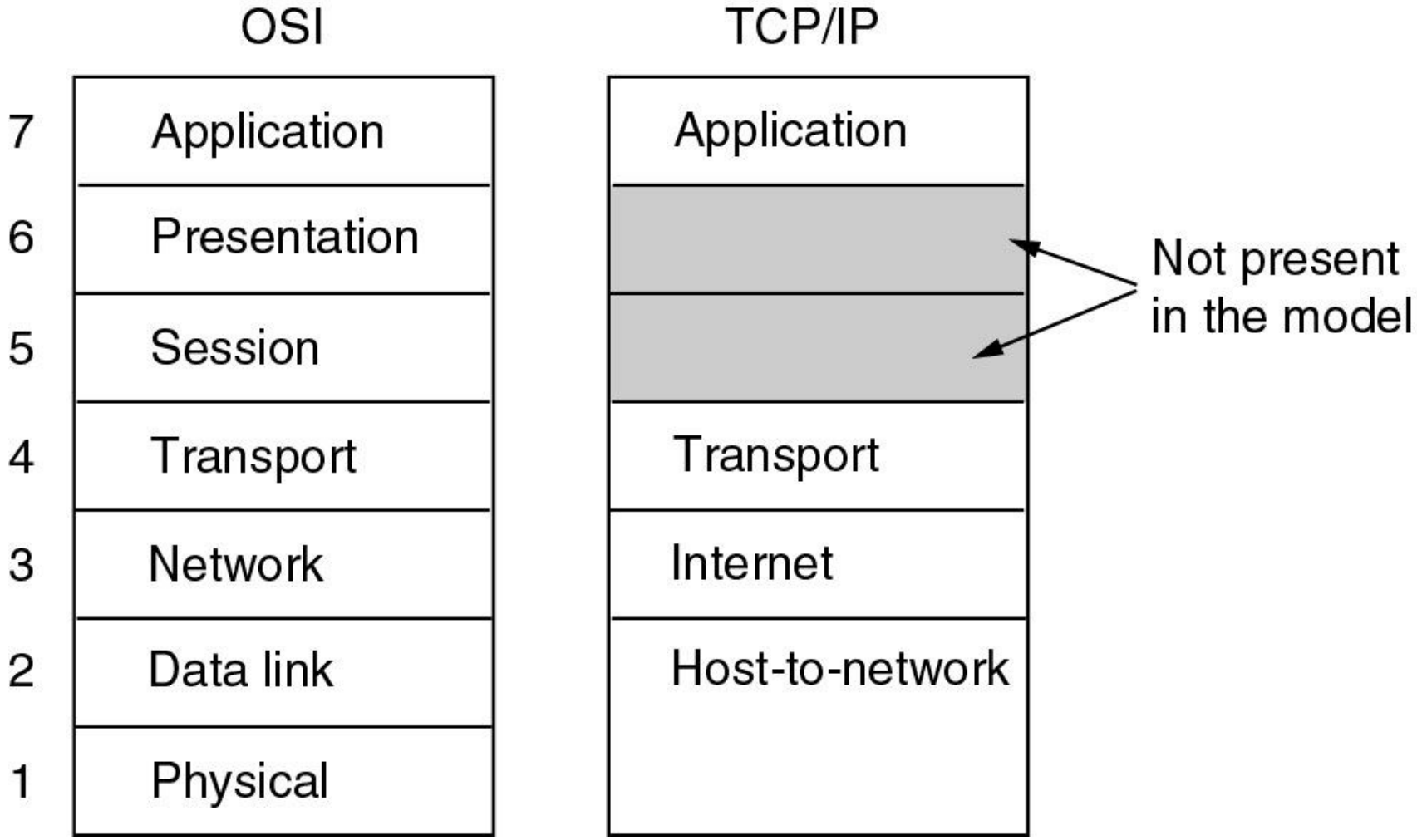


The power of a layered design

When moving from one link layer protocol to another, only its headers+trailers (in gray) need to be changed



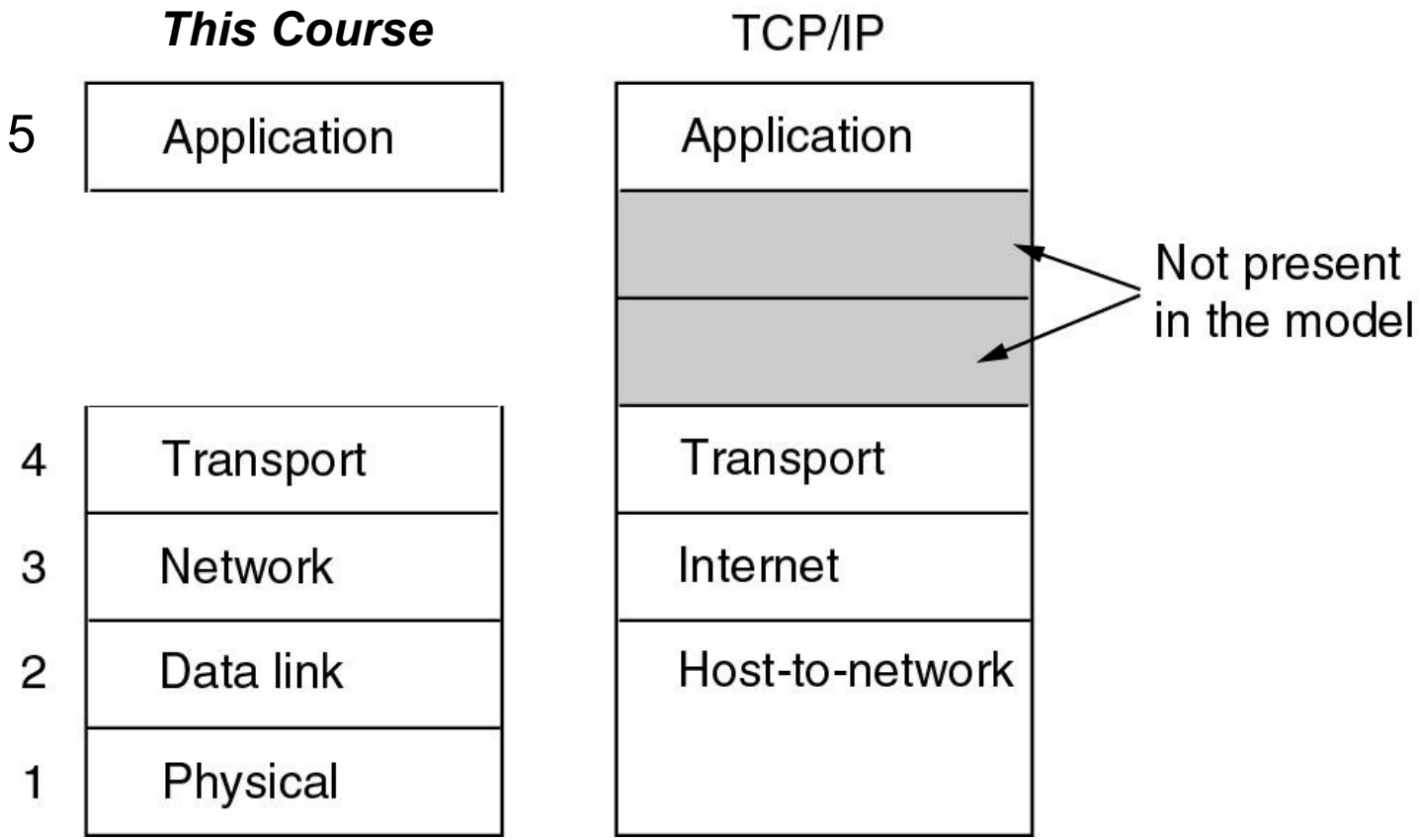
OSI versus TCP/IP



The model used in this course

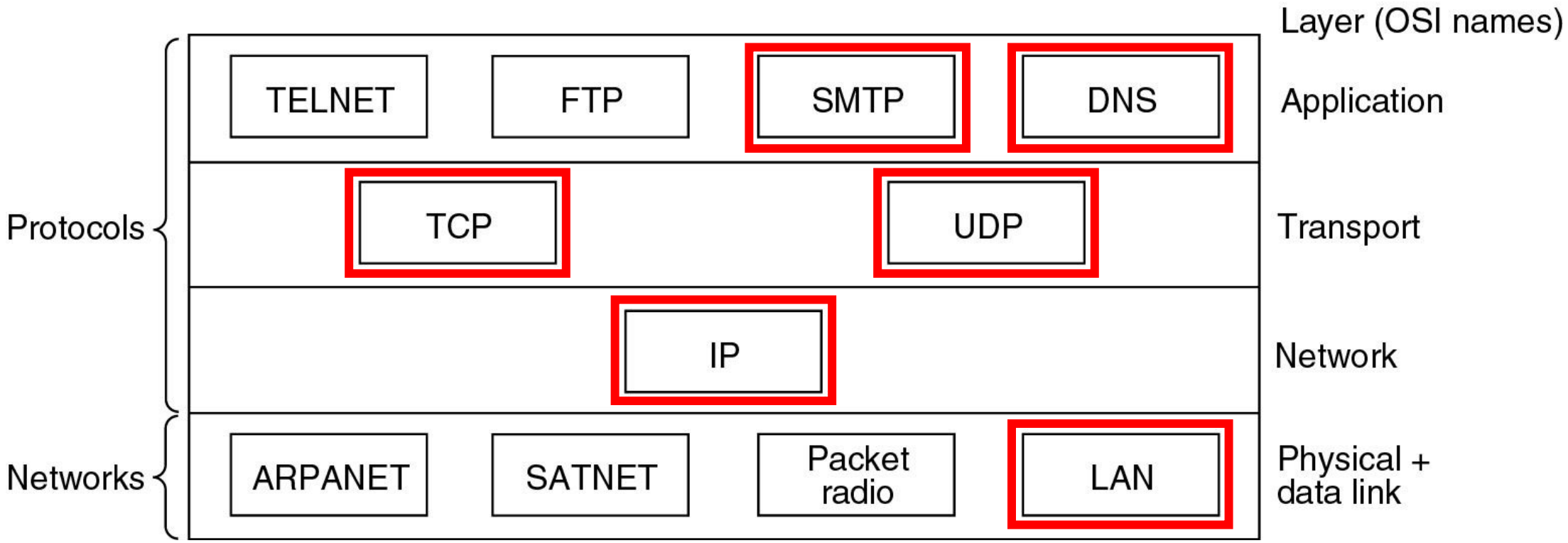
The OSI model is well-designed, but, in practice,* layer 5 and 6 are almost empty

So we skip them!



*Although responsibilities of these layers are still important, there are few dedicated protocols for them. Instead, in practice, these responsibilities are addressed in the application layer.

Protocols and Networks from the TCP/IP model



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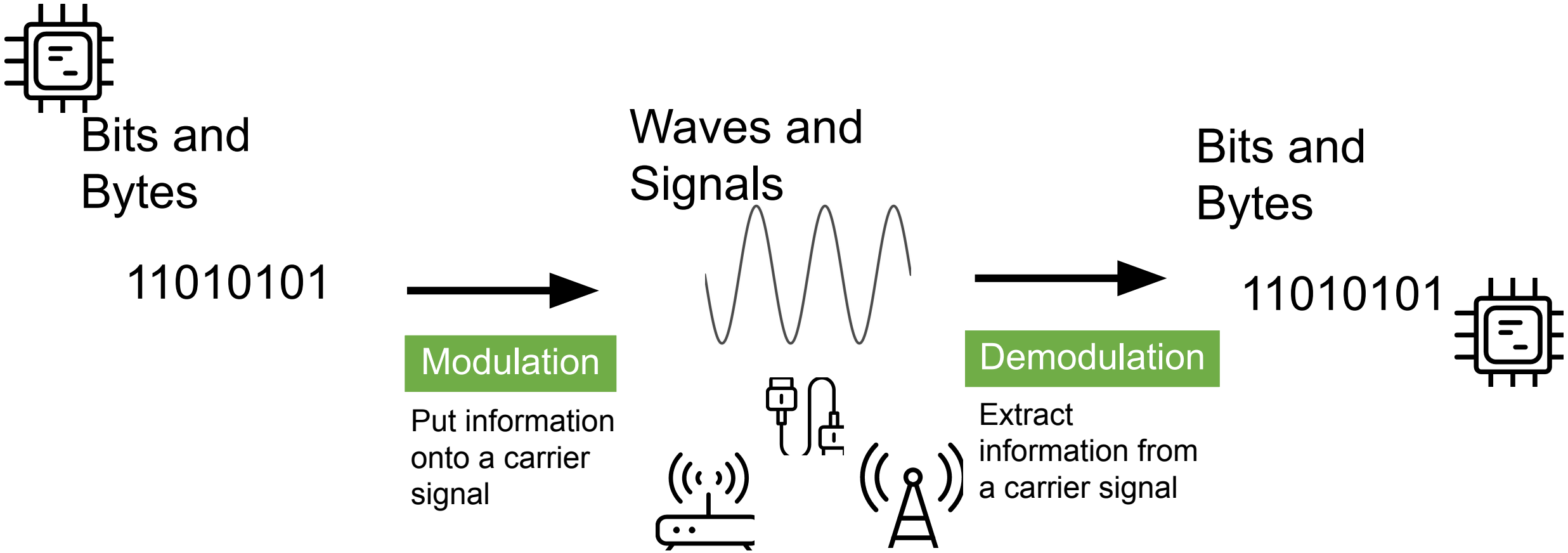
Digital Modulation

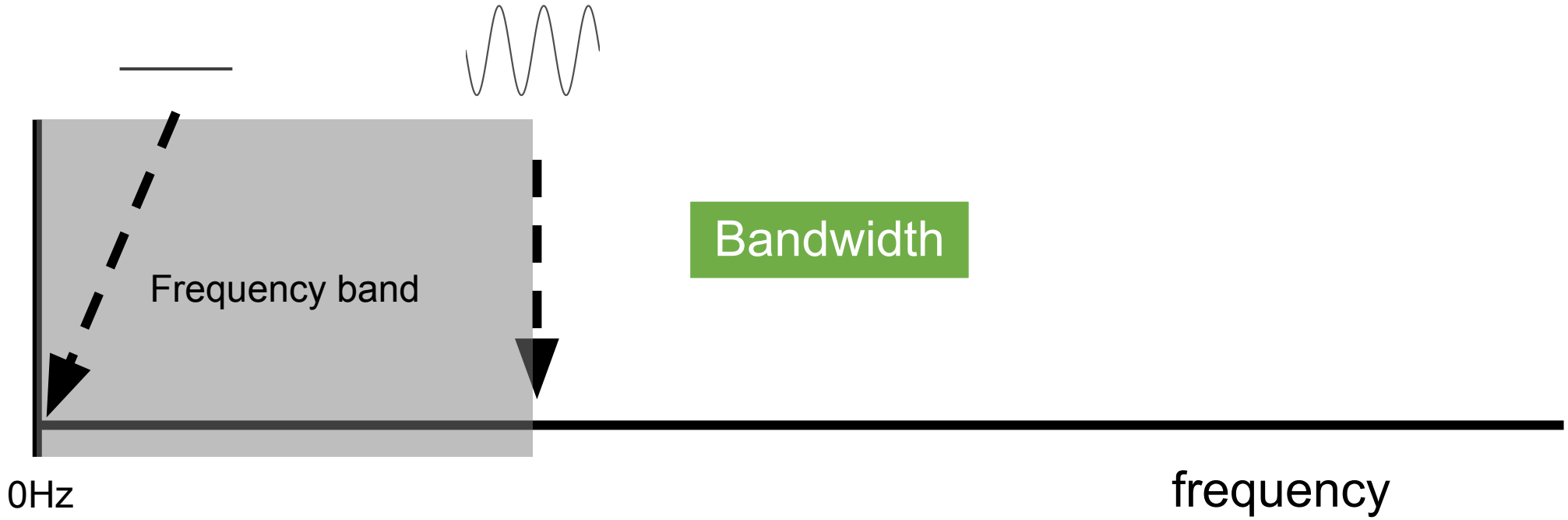
Q: How to communicate bit strings (e.g., 101011101) between computer systems?



Bandwidth (analog, in Hz)

This implies: higher frequency → higher bitrate

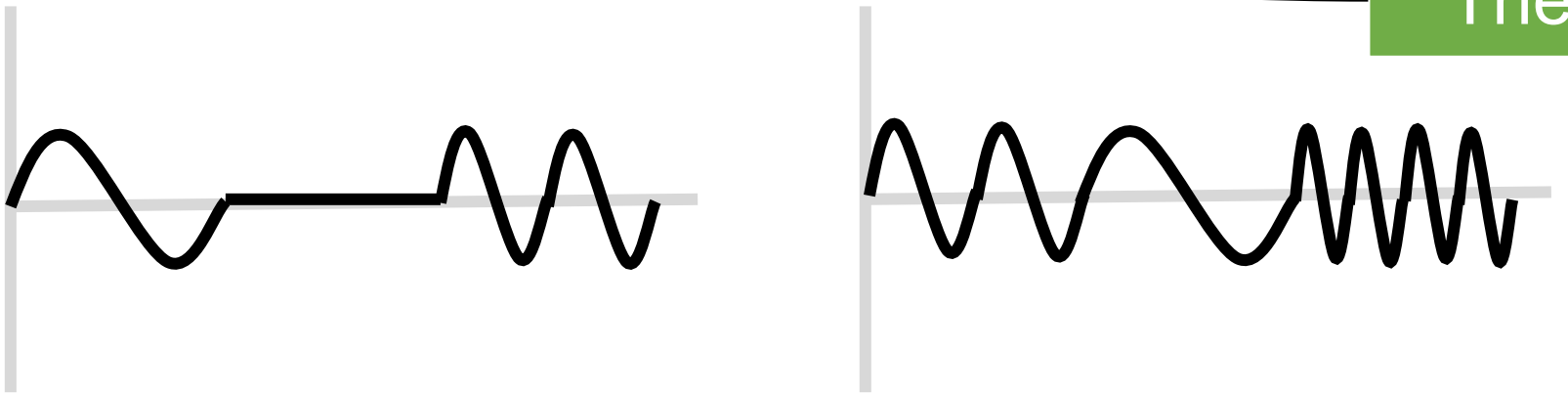
Assumption: frequency starts from 0
Consequence: higher frequency → larger frequency band (i.e., bandwidth)



Passband transmission

Wireless signals cannot start from 0Hz (why not?)
Solution: move from **[0, B] Hz** to **[S, S+B] Hz**.

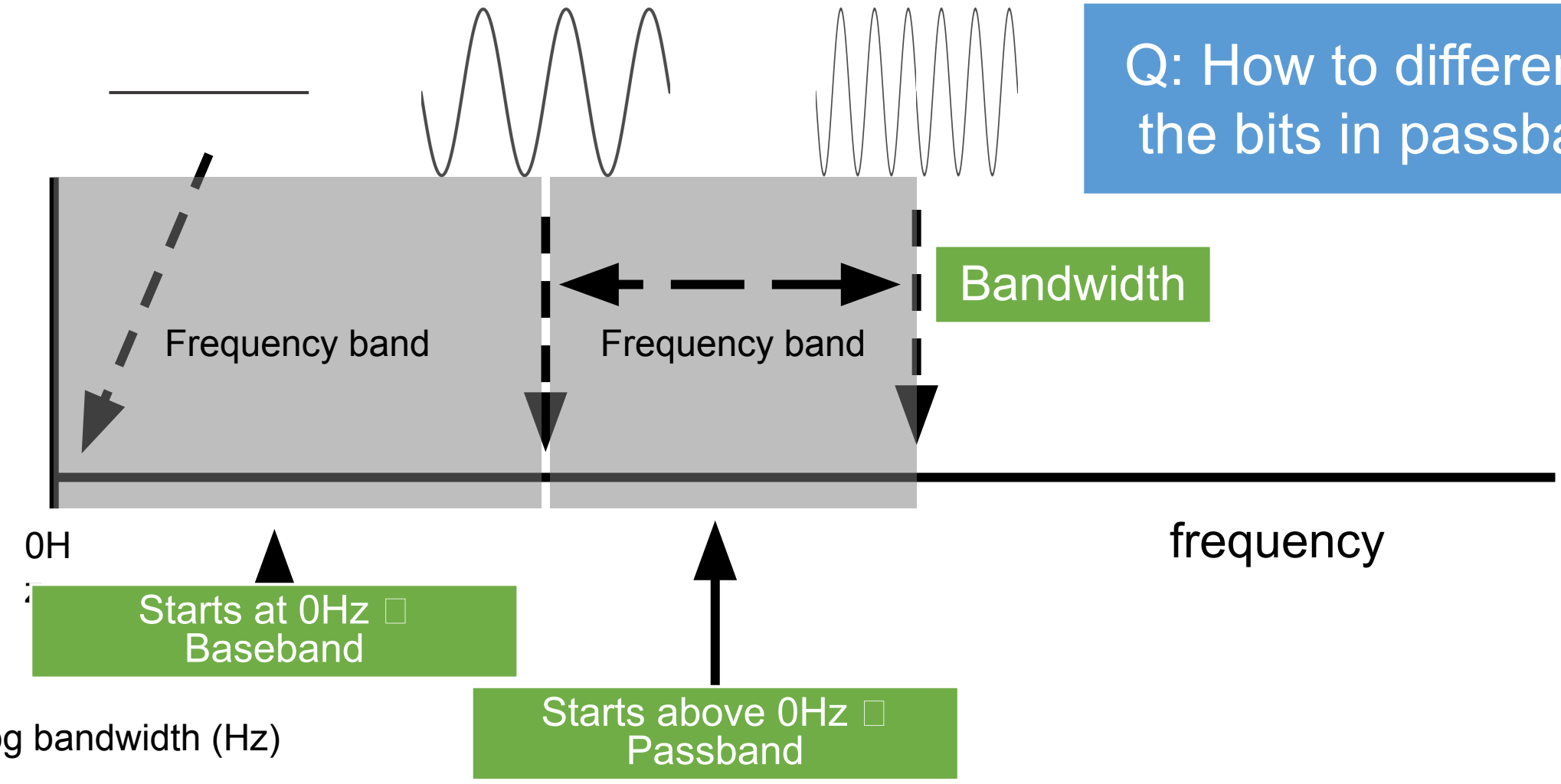
The *passband*



Frequency can be 0 Hz

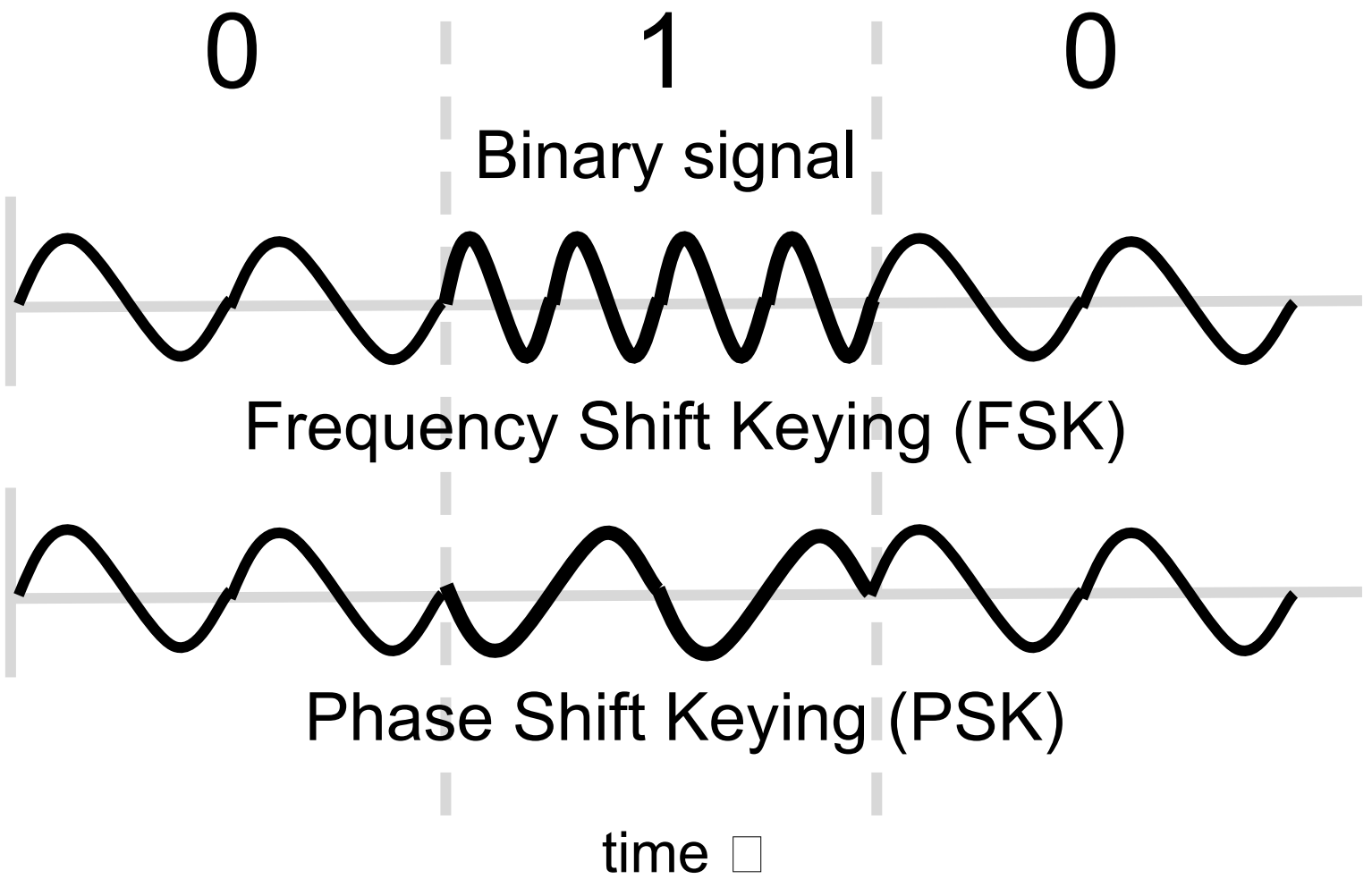
Minimum frequency of S Hz

Baseband, Passband, and Bandwidth*



*Analog bandwidth (Hz)

Digital Modulation



Nyquist's Theorem

Computing the maximum data rate for a noiseless channel

$$R = 2B \log_2(V)$$

R = maximum data rate (in bits per second)

B = bandwidth (in Hz)

V = number of discrete signal levels

Nyquist's Theorem Example

A signal that uses 4 signal levels over a wired channel with 500kHz bandwidth

$R = 2B \times \log_2(V)$
$B = 500{,}000 \quad V = 4$
$R = 2 \times 500{,}000 \times \log_2(4)$
$R = 2{,}000{,}000$
$R = 2\text{Mbps}$

Q: Can we exceed the maximum Nyquist data rate? Under what assumptions does this model hold?

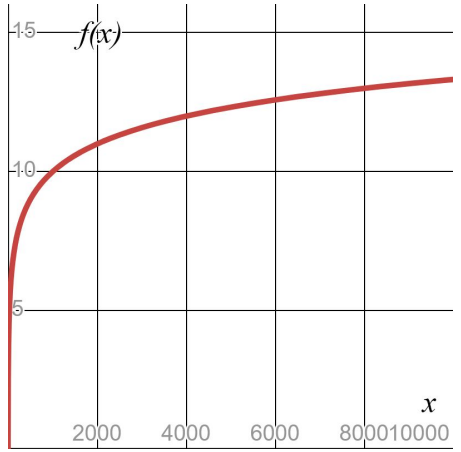
Shannon's Theorem

Q: Should we reduce noise or increase bandwidth?

Shannon's Theorem + signal attenuation □ limited cable length

In practice, *noise* reduces the maximum data rate.

$$R = B \times \log_2\left(1 + \frac{S}{N}\right)$$



The signal to noise ratio (S/N or SNR) is expressed in decibel.
SNR of 40 dB means $S/N = 10^4$

Q: Why use decibels?

I.e., Signal power is 10,000 times stronger than Noise power

The name of this theorem refers to Claude Shannon, the same person whose 1938 MSc thesis laid the groundwork for all digital computing, by showing that Boolean algebra can be used to understand and synthesize digital circuits. See https://dspace.mit.edu/handle/1721.1/11173

Shannon's Theorem Example

Signal level not used!

Consider the signal and channel from before (4 signal levels, 500kHz bandwidth). What happens if the SNR is 40dB?

$$R = B \log_2\left(1 + \frac{S}{N}\right)$$

$$B = 500{,}000$$

$$\frac{S}{N} = 40\text{dB} = 10^{\frac{40}{10}} = 10{,}000$$

$$R = 500{,}000 \log_2(1 + 10{,}000)$$

$$R \approx 500{,}000 \times 13 = 6{,}500{,}000\text{bps} = 6.5\text{Mbps}$$

$$\log_2 10001 \approx 13.29 \approx 13$$

$$2^{10} = 1024,\ 2^3 = 8,\ 2^4 = 16$$

$$2^{13} = 8192,\ 2^{14} = 16348$$

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Roadmap of the Computer Networks Course

Lets distributed applications communicate

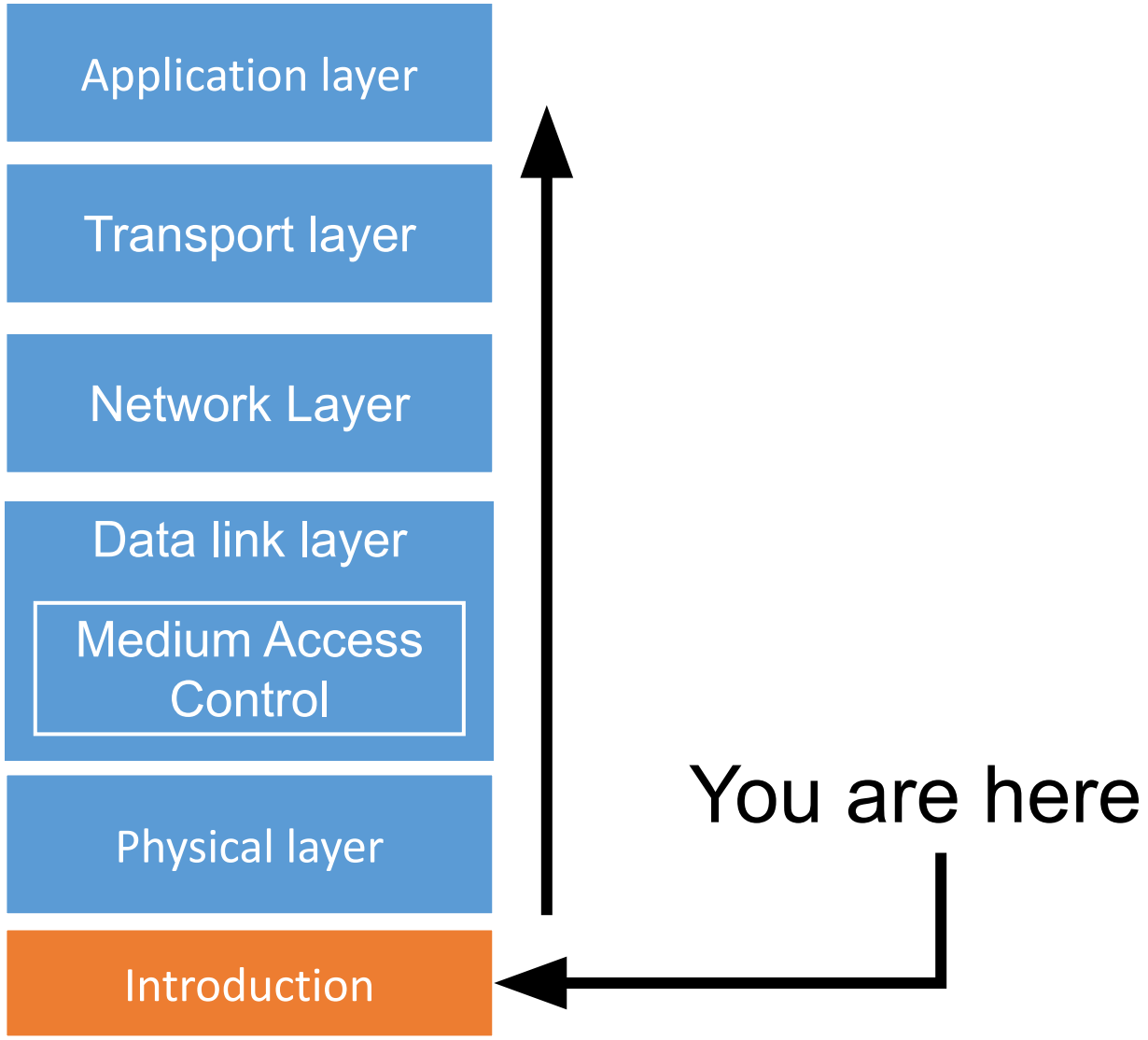
Sends segments from one **process** to another (over a network)

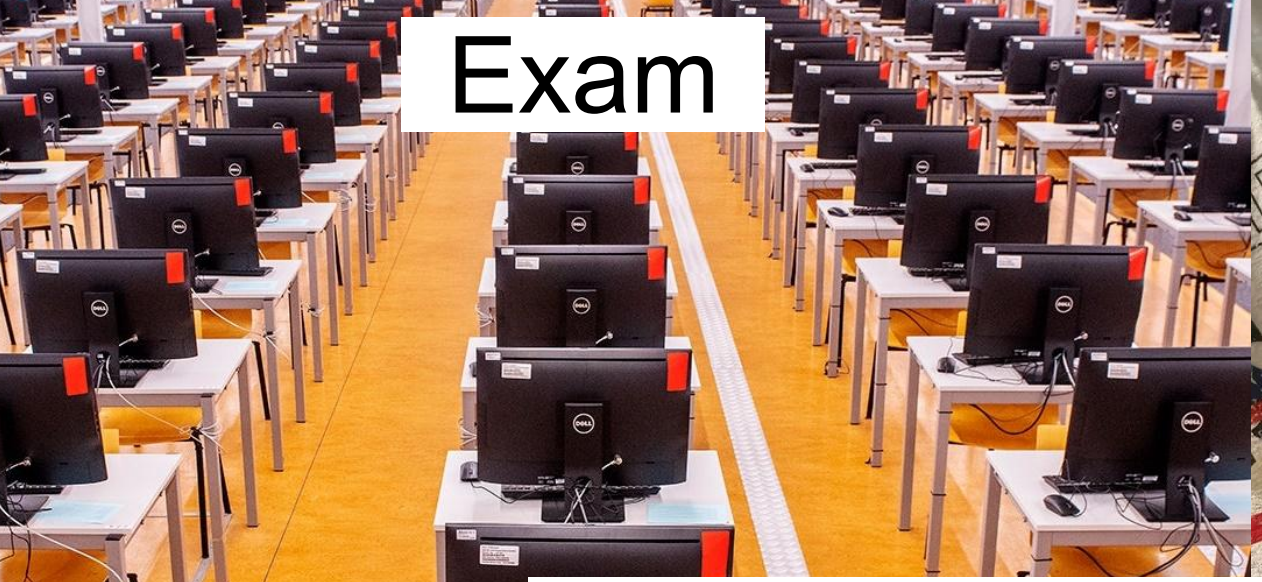
Sends packets from one **machine** to another over a network

Sends frames from one machine to another over a single link

Sends bits over a physical medium

Basic principles and course overview





Exam

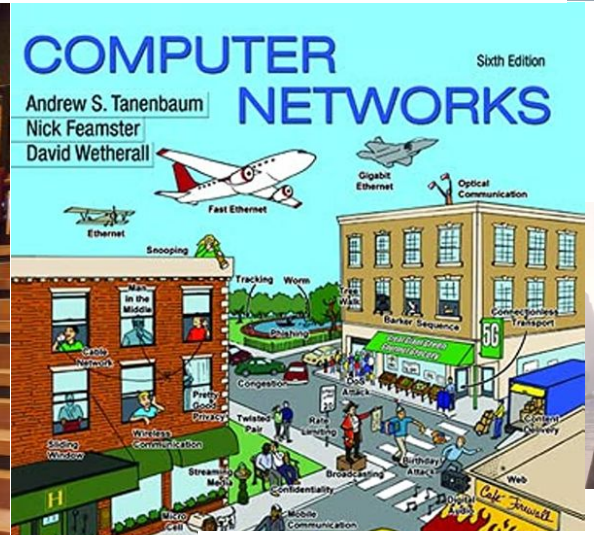
Lab

```python
import socket
sock = socket.socket(socket.AF_INET
host_port = ("127.0.0.1", 4321)
sock.connect(host_port)

string_bytes = "Sockets are great!".encode("
bytes_len = len(string_bytes)
num_bytes_to_send = bytes_len
while num_bytes_to_send > 0:
    b = string_bytes[bytes_len-num_bytes_to_
    num_bytes_to_send -= sock.send(b)
```

Computer Networks

Lectures+Tutorials

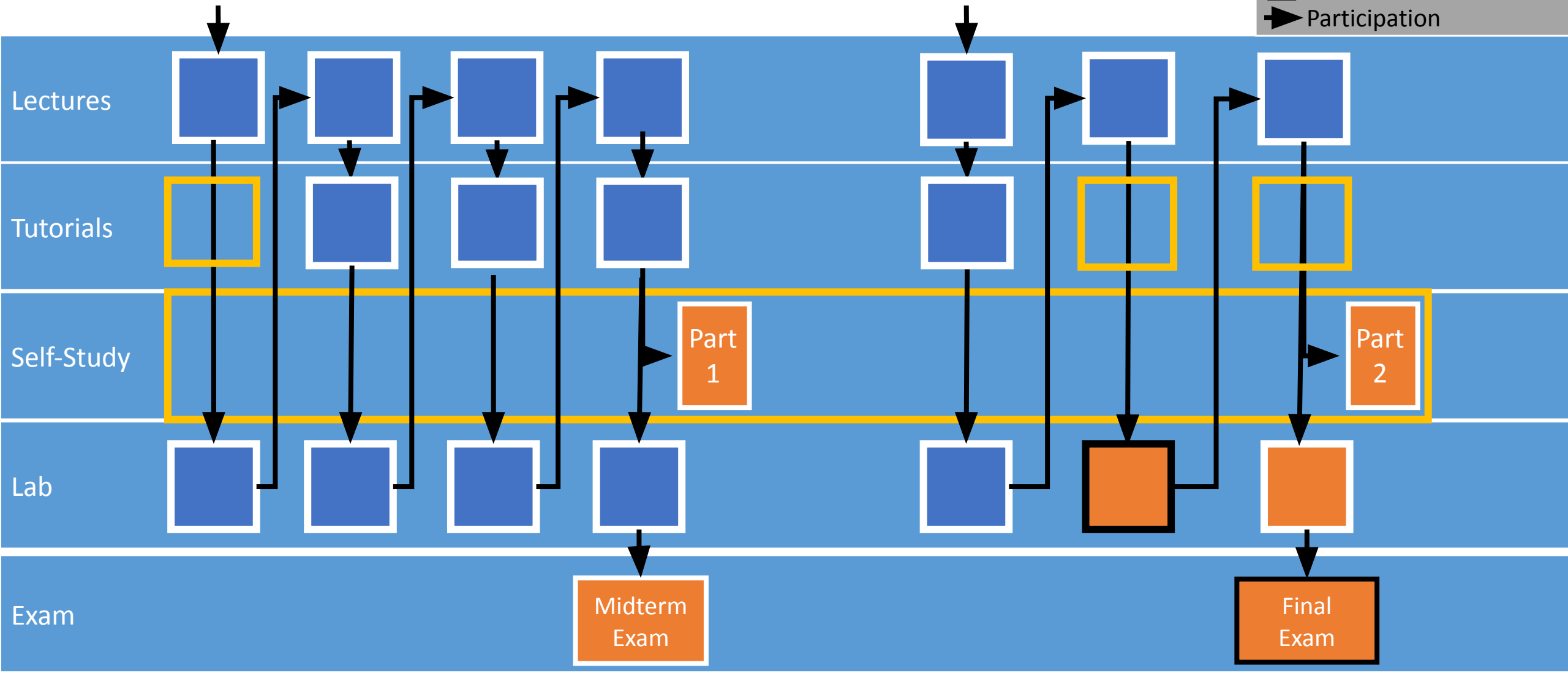


28. Suppose there is a change in the service (set o
does this impact services at layers k-1 and k+1

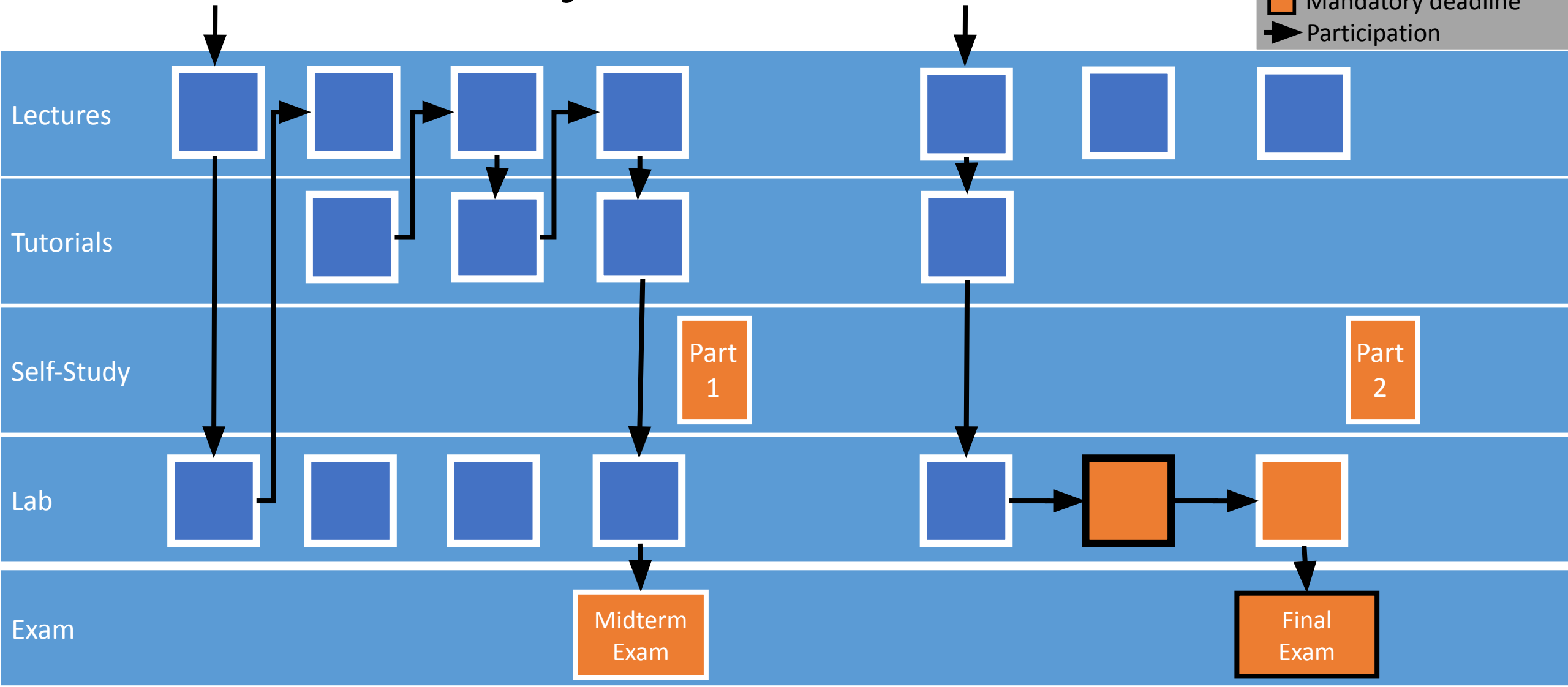
29. Provide a list of reasons for why the response
best-case delay.

Self-Study

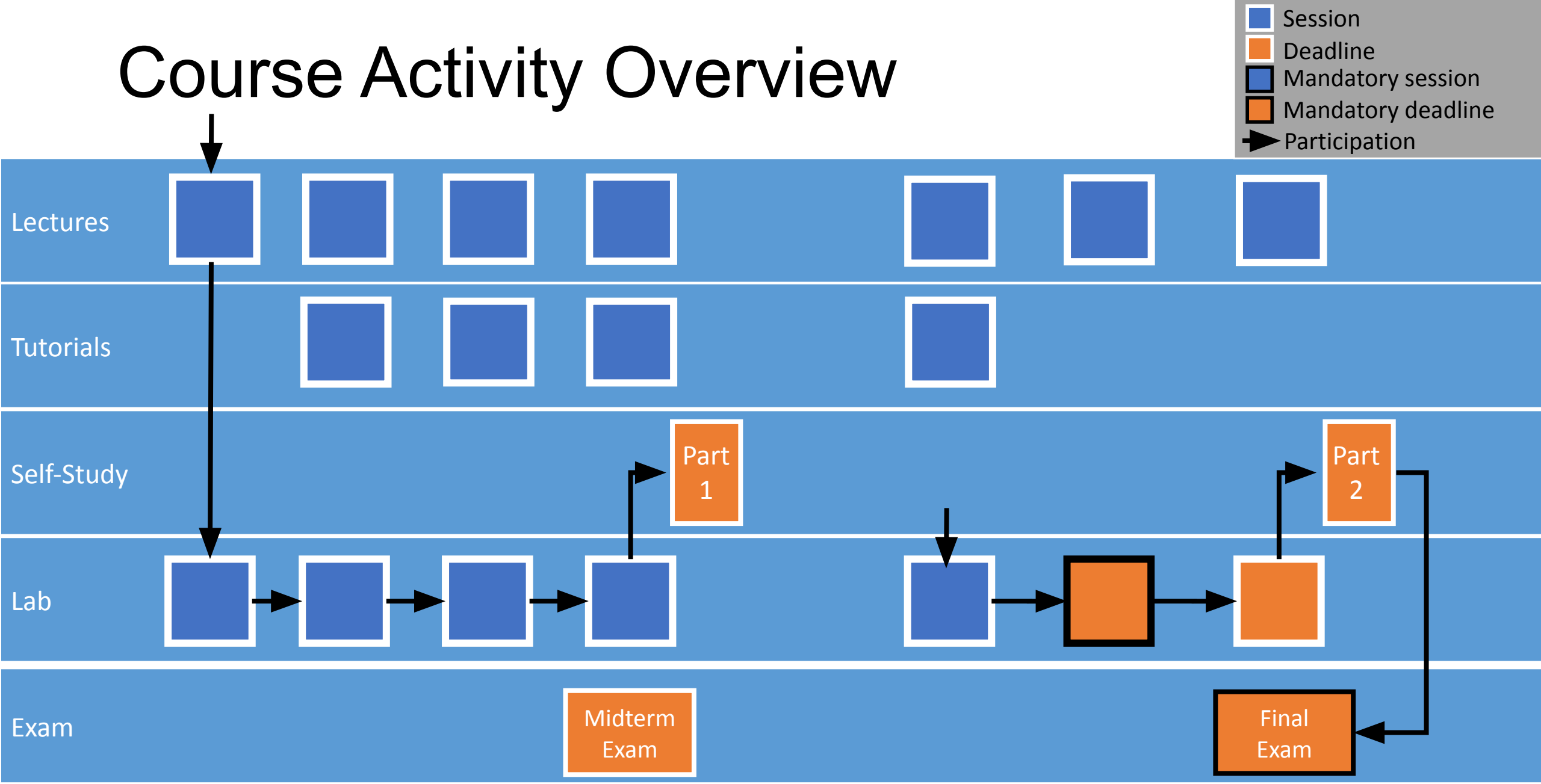
Course Activity Overview



Course Activity Overview



Course Activity Overview



How Am I Graded?

$$\text{grade} = \frac{\text{exam} + \text{lab} + \text{in class} + \text{self study}}{1000}$$

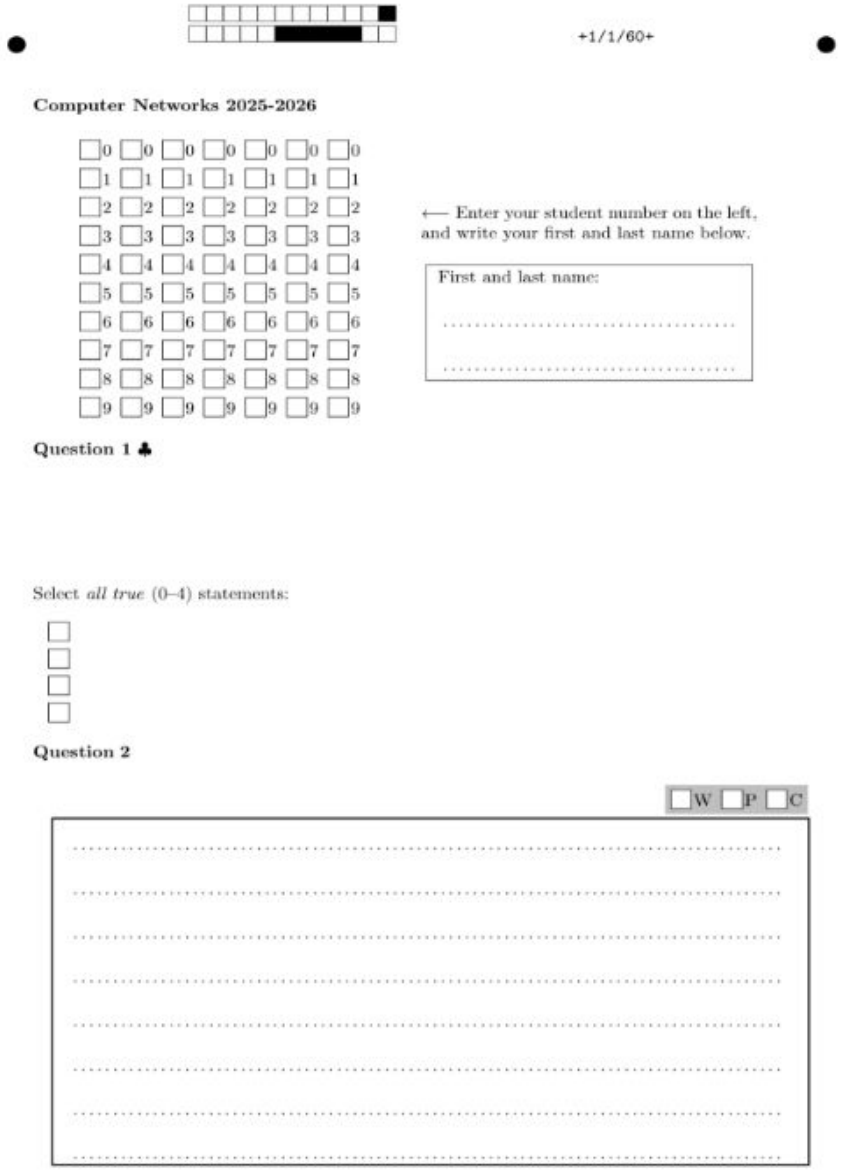
*Additional conditions apply, such as passing the mandatory lab assignments (A1+A2) and the final exam. For details, see the course grading page.

Lectures

Collect points by:

- Giving good answers to questions
- Answering correctly questions from the *in-lecture quizzes*

First quiz is today!



First and last name:

. . . . . .

. . . . . .

☐0 ☐0 ☐0
☐1 ☐1 ☐1
☐2 ☐2 ☐2
☐3 ☐3 ☐3
☐4 ☐4 ☐4 ☐4 ☐4 ☐4 ☐4
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☐9 ☐9 ☐9 ☐9 ☐9 ☐9 ☐9

Question ♣ Consider the following

What is the name of this course?

Select *all true* (0–4) statements:

☐
☐
☐
☐

☐W ☐P ☐C

☐C

. . . . . .

. . . . . .

. . . . . .

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Tutorials: Plenary Practice Sessions

Please use:

- Pen
- Paper

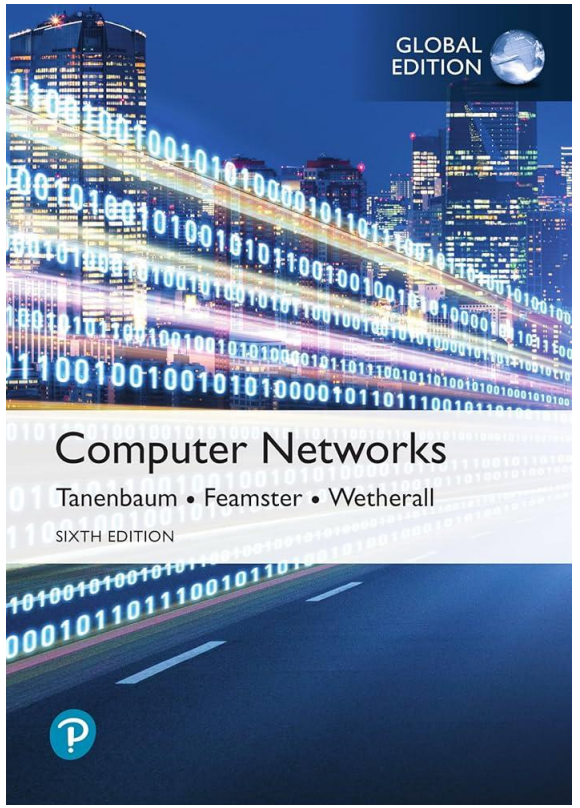
Do not use:

- Calculators
- AI Chatbots
- Other external tools

Self-Study: Completing Book Exercises

Complete exercises from the book in a group.

Earn more points by
completing more chapters.



Self-Study Checkpoints

Graded at two “checkpoints.”

Part 1 – 600 points

- Chapters 3 and 4

Part 2 – 900 points

- Chapters 5, 6, and 7

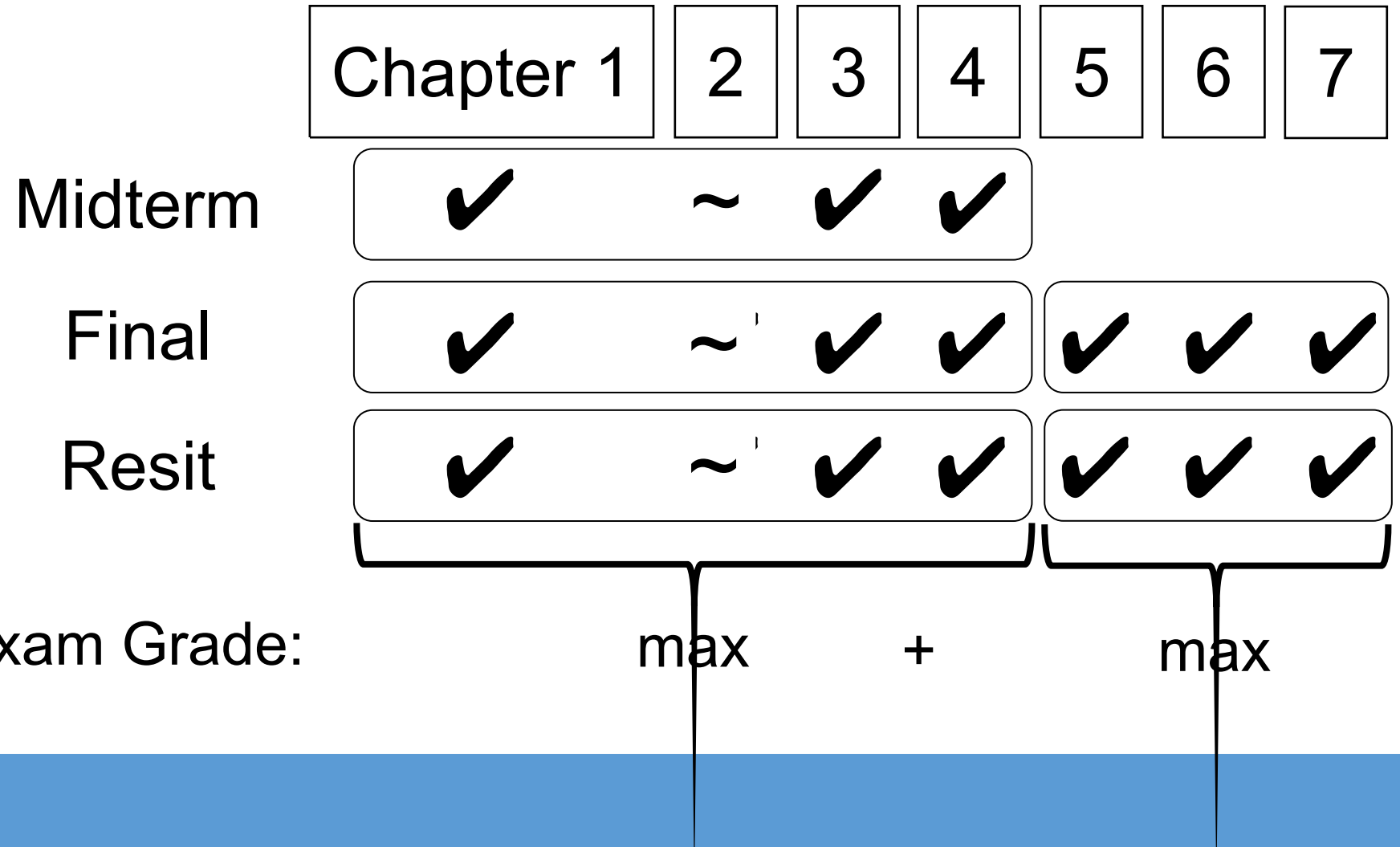
Exams

- Midterm (April 21) and Final (May 22)
- Computer-based (TestVision)
- Multiple-choice questions
- Every correctly answered question earns you 300 points

Getting 60% on the exam is not sufficient to pass the course!

Register for the exam on VUnet

Exam Content and Grades



Lab

Logistics

Lab

Labs on Tuesdays and Fridays [Starting Next week], 09:00 – 12:45.
This week (tomorrow): Lab setup session, 09:00 – 12:45.

Use the Canvas groups page to enroll for the one of the sessions.
Deadline for registration: Friday, April 3rd, 23:59

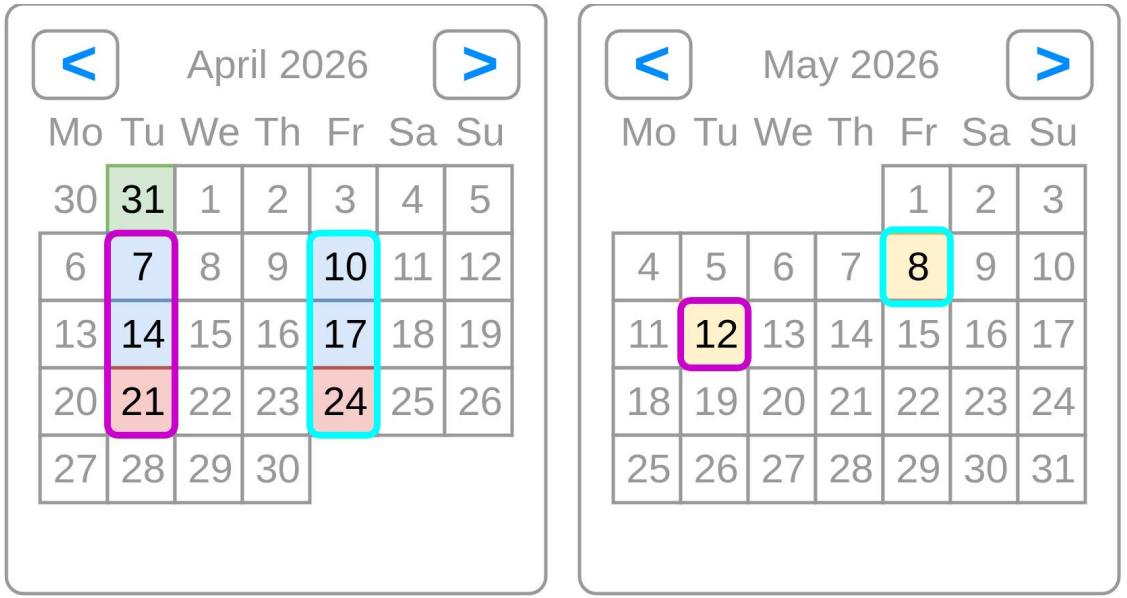
Warning: different deadlines based on registration.

Lab — passing the course

Lab Manual specifies several optional assignments.

*Assignment 1 and 2 are **mandatory** to pass the course*

For assignment descriptions, see the **Lab Manual** on the course website.



Lab setup session

Regular lab session

Mandatory lab assignments deadline

Extra lab assignments deadline

Your lab deadline depends on the session (Tuesday/Friday) that you registered for. You may not exceed the deadline for your registered session.

= Tuesday session = Friday session

Lab

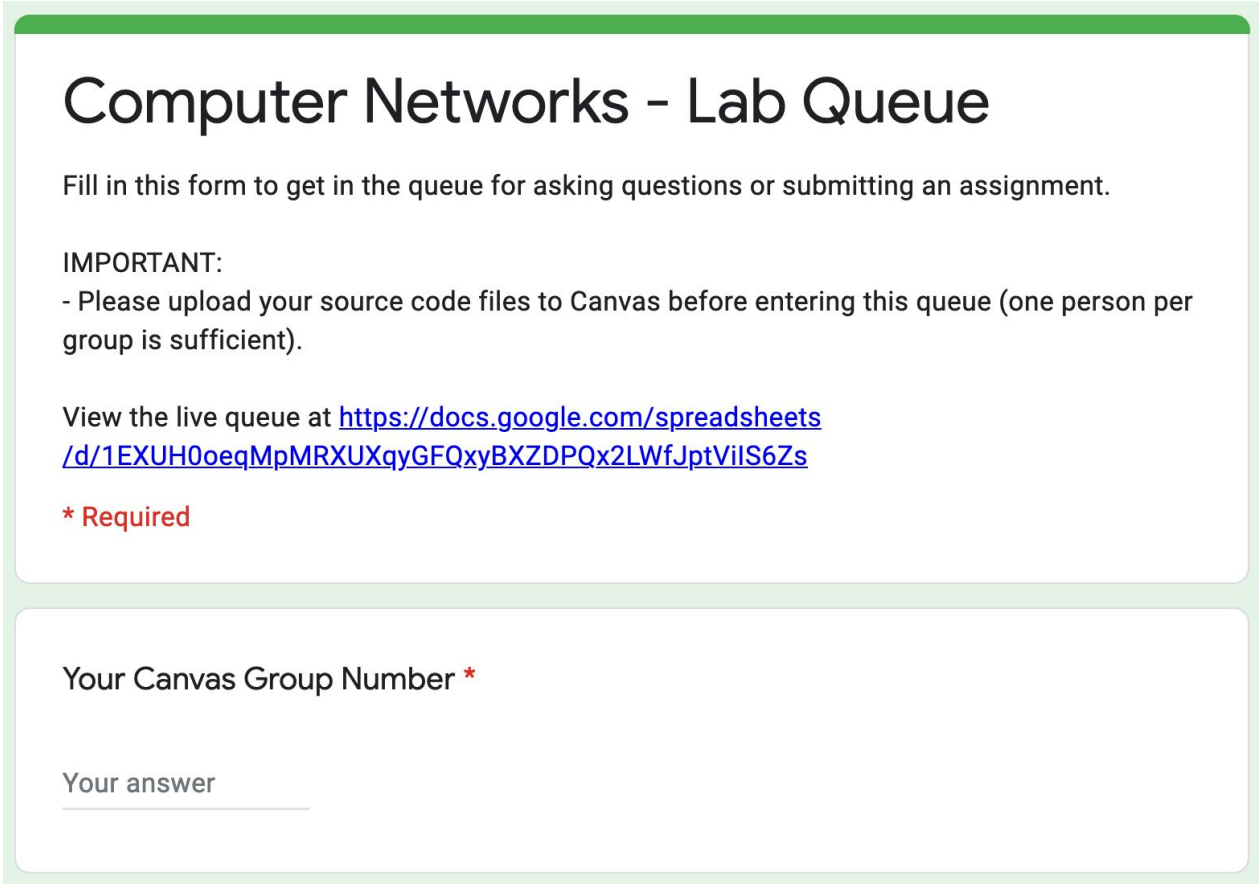
Collect points by completing Lab assignments.

- Small reward for the mandatory assignments [500 points]
- Larger rewards for the optional assignments [up to 4000 points]
- Many potential small rewards for active participation during the labs

How to Hand in Lab Assignments

Submission System:

1. Complete assignment.
2. Upload to CodeGrade, pass all the tests
3. Enter Queue ➡
4. Interview with TA [limited number of attempts]
5. ✅ Assignment approved.
   -or-
   ❌ Go to step 1.



Computer Networks - Lab Queue

Fill in this form to get in the queue for asking questions or submitting an assignment.

IMPORTANT:
- Please upload your source code files to Canvas before entering this queue (one person per group is sufficient).

View the live queue at https://docs.google.com/spreadsheets/d/1EXUH0oeqMpMRXUXqyGFQxyBXZDPQx2LWfJptViIS6Zs

* Required

Your Canvas Group Number *

Your answer

How to Hand in Lab Assignments

We use a ***queue***, which means First-Come, First-Serve (FCFS)

Important:

1. Queue closes **before** the end of the lab session.
2. Closed queue not a valid excuse for not completing assignments.

Enqueue on time

Do not wait until last session before the deadline

Lab Assignments

Getting Started

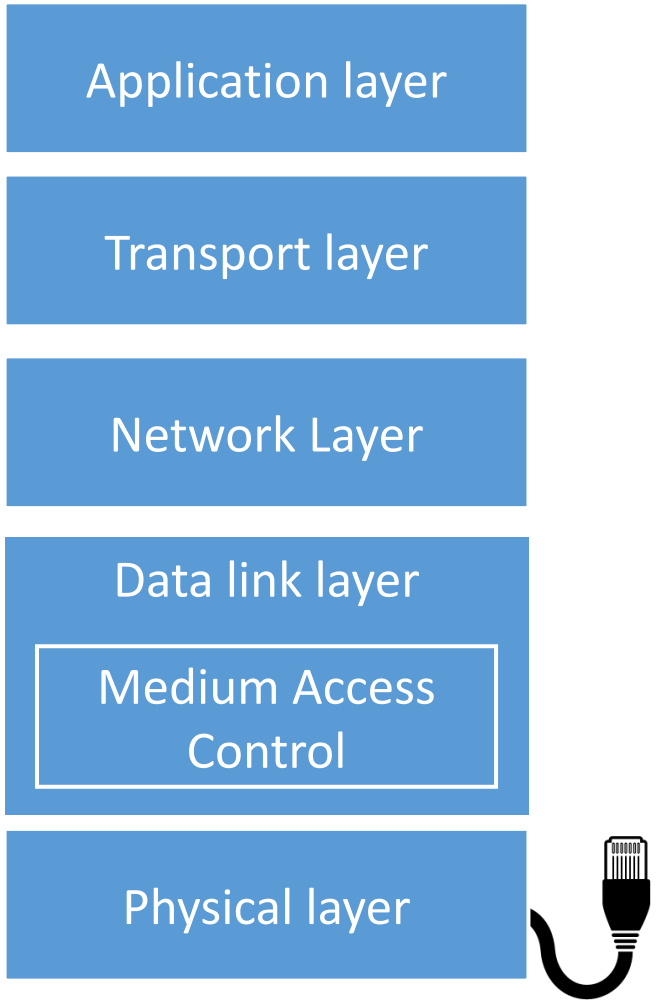
Network layer services

Sends segments from one **process** to another (over a network)

Sends packets from one **machine** to another over a network

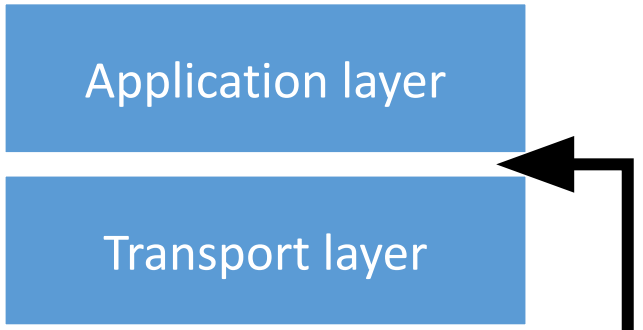
Sends frames from one machine to another over a single link

Sends bits over a physical medium



Network layer services

Sends segments from one **process** to another (over a network)



This is the service used by your application

What kind of interface does it use?

Socket Primitives in TCP

Socket – create a new communication *endpoint*.

Connect – connect to a remote *listening* socket.

Q: Are we missing something?

Used to allow incoming connections

Bind – assign a *local address* to the socket.

Listen – wait for a connection.

Accept – passively accept an incoming *connection request*.

Send – send data to the other application.

Receive – receive data from the other application.

Close – close the connection.

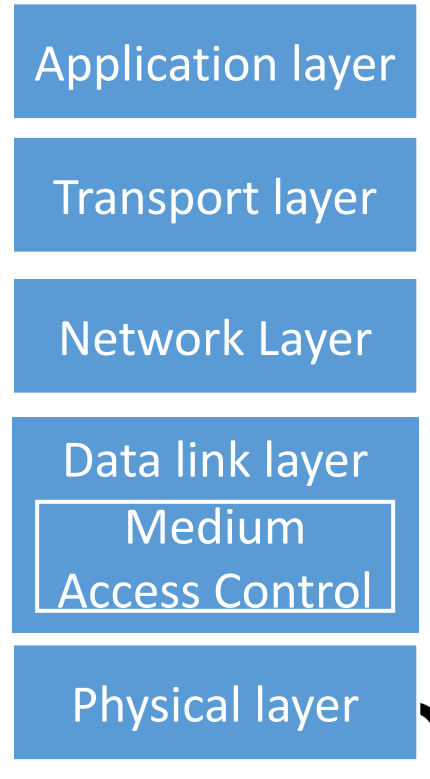
TCP Sockets in Python

```
# Import the socket library.
import socket
# Create a new socket.
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
# Connect to another application.
s.connect(("hostname", port_number))
# Send bytes.
num_bytes_sent = s.send(buffer)
s.sendall(buffer)
# Receive bytes.
buffer = s.recv(2048)
# Close connection.
s.close()
```

Network layer protocol

Transport layer protocol

Max number of bytes to receive



TCP provides a reliable byte-stream

Q: What does this mean for your application?

1. The program waits until data is available
2. It may return an arbitrary number of bytes

s.recv(2048)

s.recv(2048)

s.recv(2048)

s.recv(2048)

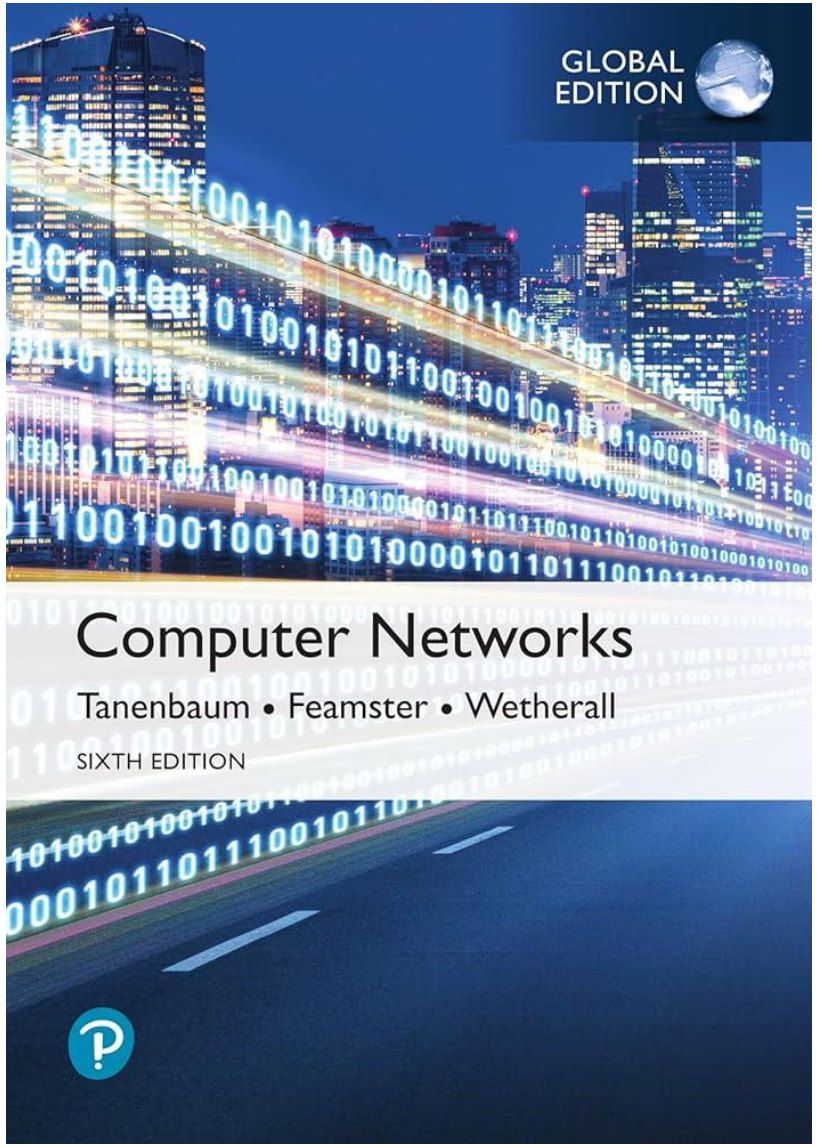
Threading Python

```
# Import threading library.
import threading
# A regular call to print.
print("Hello", "World")
# A threaded call to print.
t = threading.Thread(target=print, args=("Hello", "World"))
# Run target in new thread.
t.start()
# Wait 100ms for thread to finish.
t.join(0.1)
```

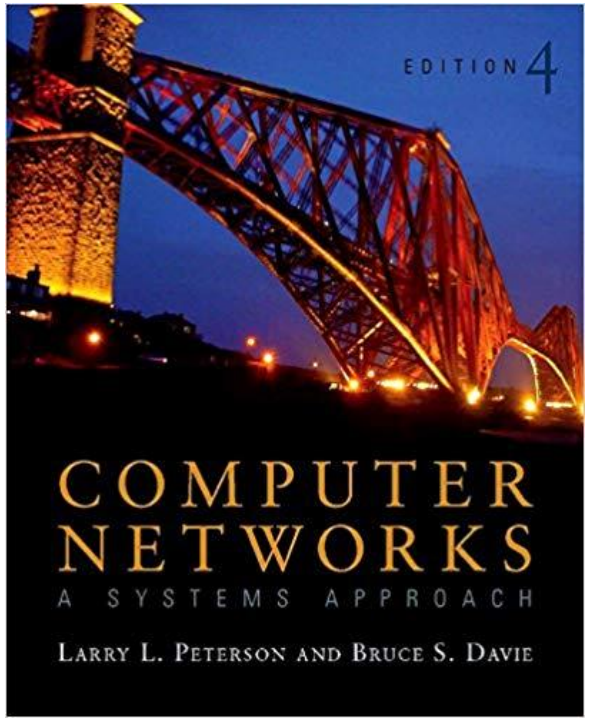
Course Material

Course Material:

1. Course Slides
2. Book:
   Computer Networks,
   6th edition,
   Andrew S. Tanenbaum, Nick Feamster,
   and David J. Wetherall

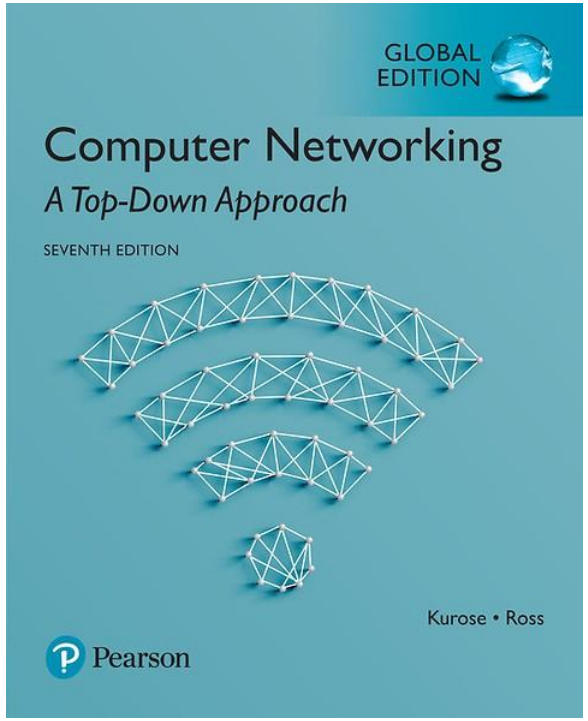


Other Computer Networks Books



Peterson and Davie

Available for free at
https://book.systemsapproach.org



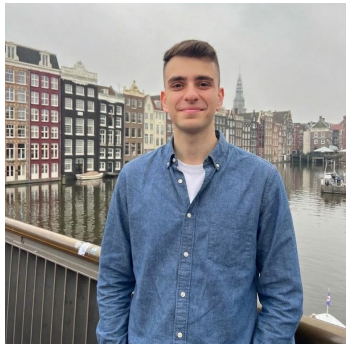
Kurose and Ross

Meet the Team!





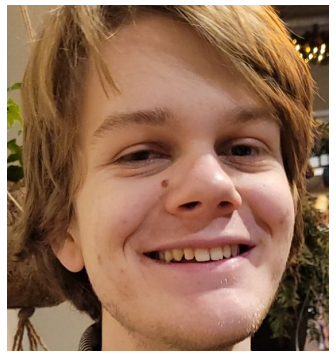










Next steps

1. Participate in the Entry Quiz! Earn your first points!
2. Read the course Website
3. Obtain a copy of the book
4. Find a lab partner.
   The lab is done in teams of **2** students.
   1. Register your group on Canvas
   2. Can’t find a partner? Look for one on the Canvas discussion board
   3. Contact the Computer Networks team
5. Start looking for a self-study team

Computer Networks X_400487

@Large Research
Massivizing Computer Systems

VU VRIJE UNIVERSITEIT AMSTERDAM

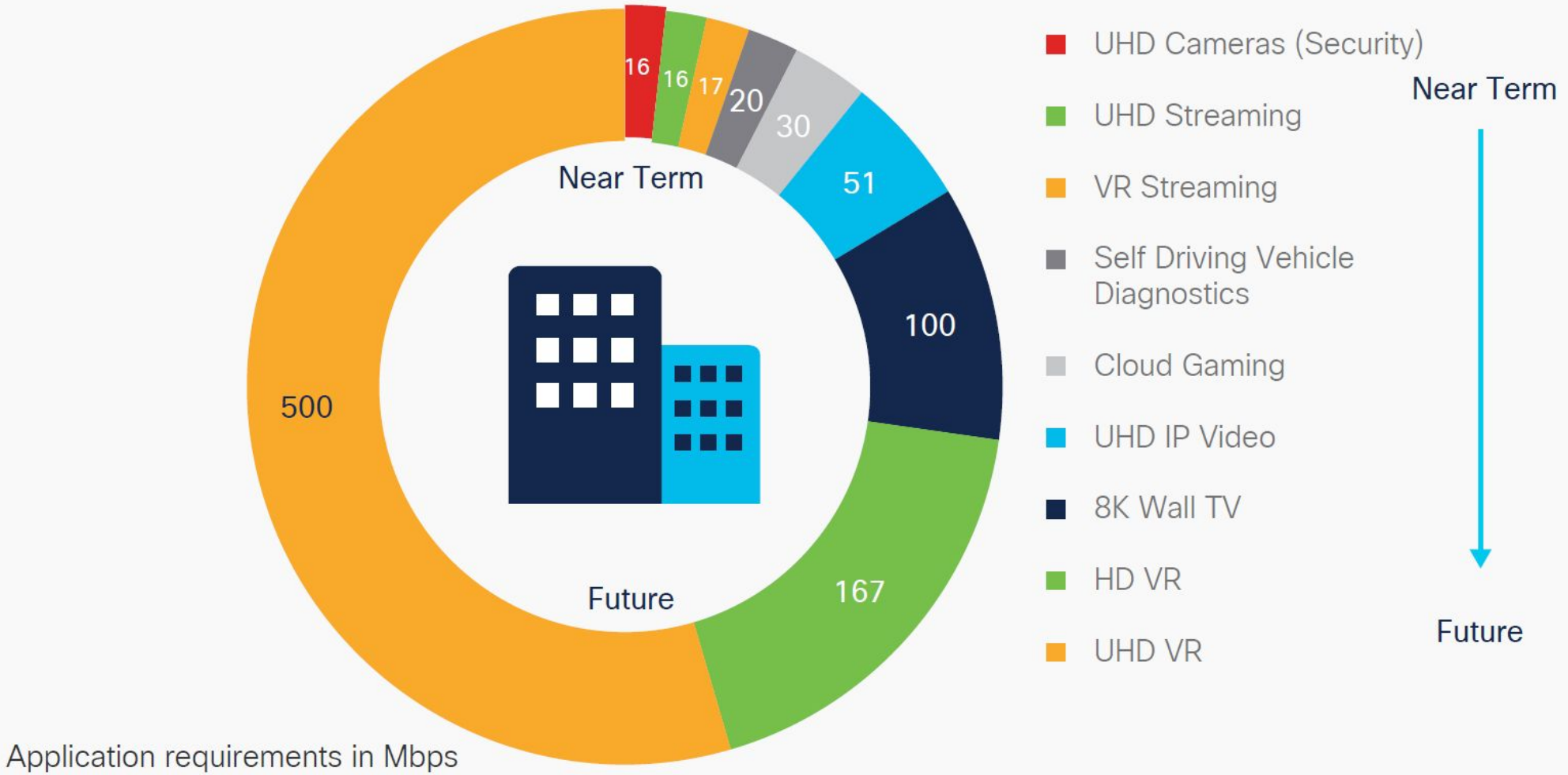
Lecture 1: Introduction to Computer Networks (+ a tiny bit of Chapter 2)



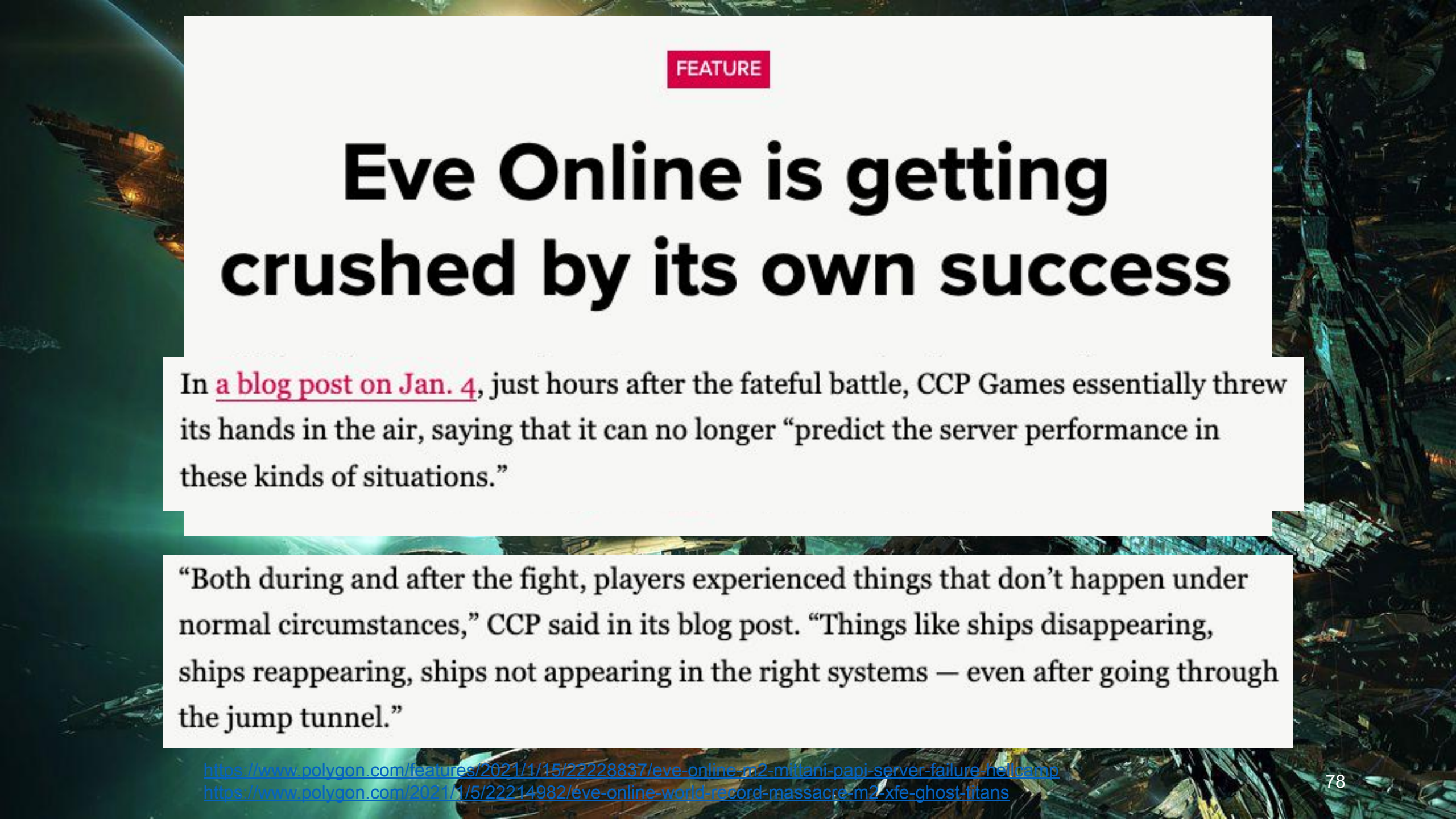

Lecturers: Jesse Donkervliet, Gonçalo Amado Mesquita, Nehir Kırkgöz, Daniel-Ştefan Halasz

Extra Slides

Figure 13. Significant demand for bandwidth and video in the connected home of the future



Source: Cisco Annual Internet Report, 2018–2023



FEATURE

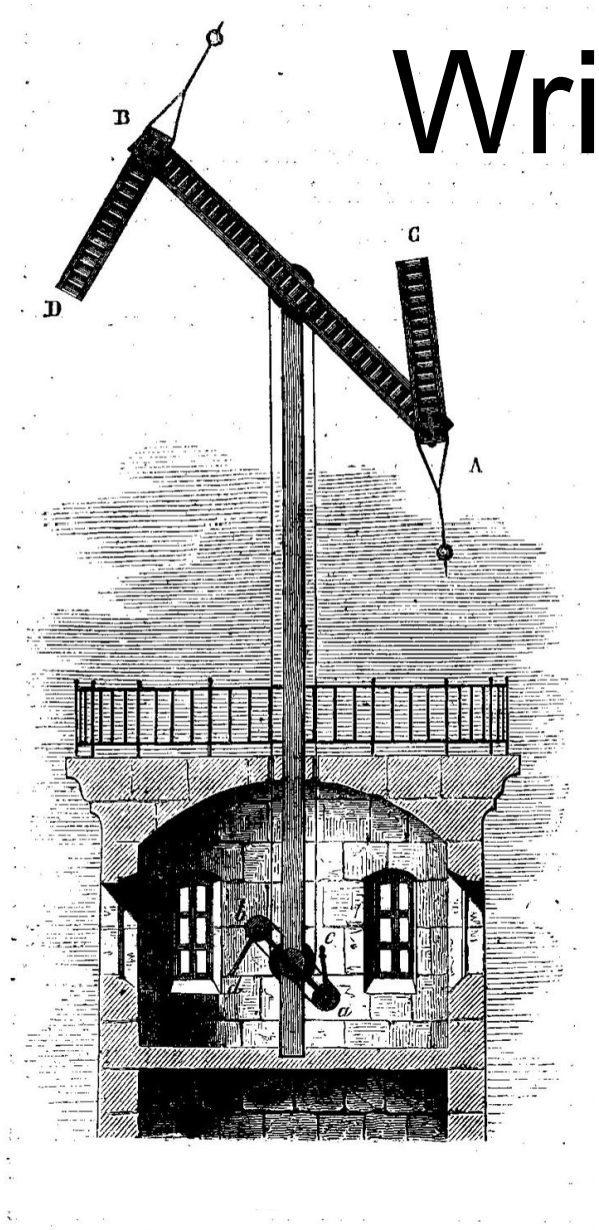
Eve Online is getting crushed by its own success

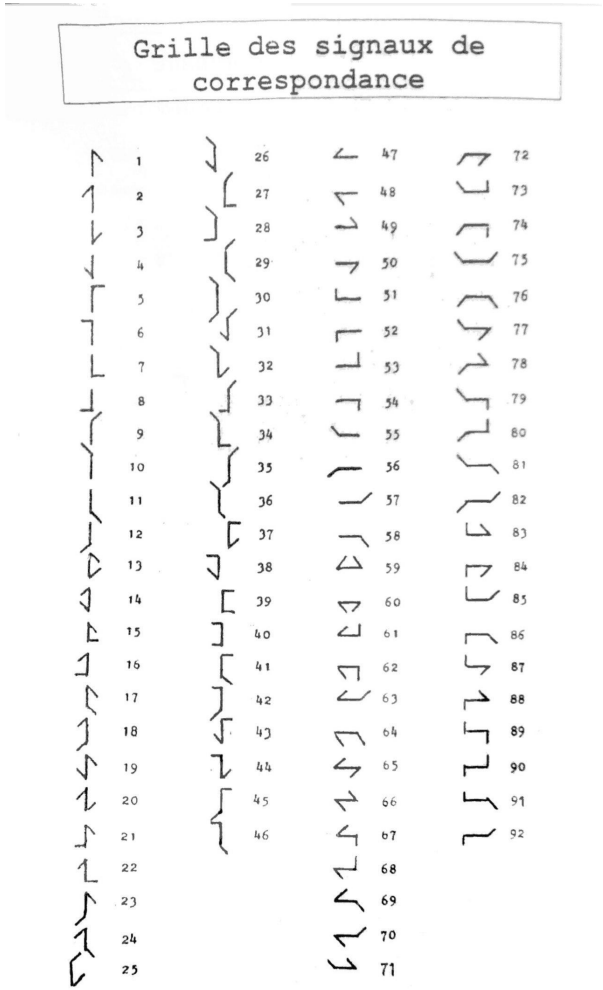
In a blog post on Jan. 4, just hours after the fateful battle, CCP Games essentially threw its hands in the air, saying that it can no longer "predict the server performance in these kinds of situations."

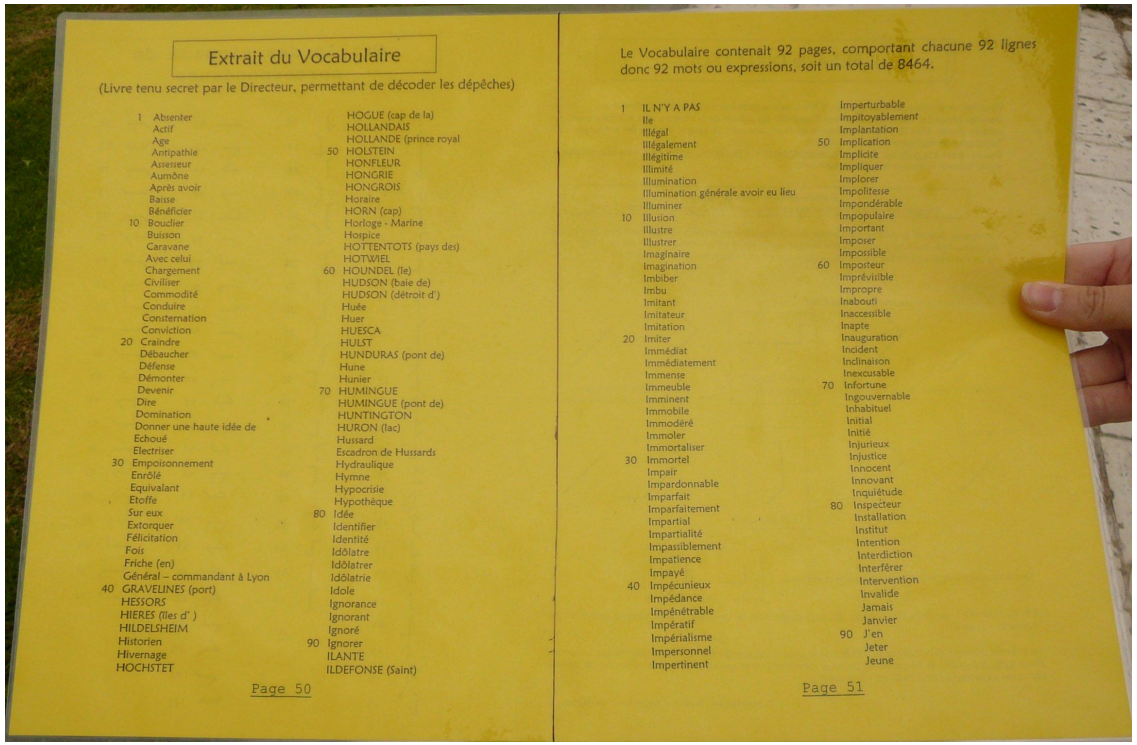
"Both during and after the fight, players experienced things that don't happen under normal circumstances," CCP said in its blog post. "Things like ships disappearing, ships reappearing, ships not appearing in the right systems — even after going through the jump tunnel."

https://www.polygon.com/features/2021/1/15/22228837/eve-online-m2-mittani-papi-server-failure-hellcamp
https://www.polygon.com/2021/1/5/22214982/eve-online-world-record-massacre-m2-xfe-ghost-titans

Writing at a distance (telegraph)







Optical telegraph in use until 1850

https://reach.ieee.org/primary-sources/semaphore-telegraph/
https://en.wikipedia.org/wiki/Chappe_telegraph

Electrical Telegraph

Make possible through scientific and engineering advances in electricity

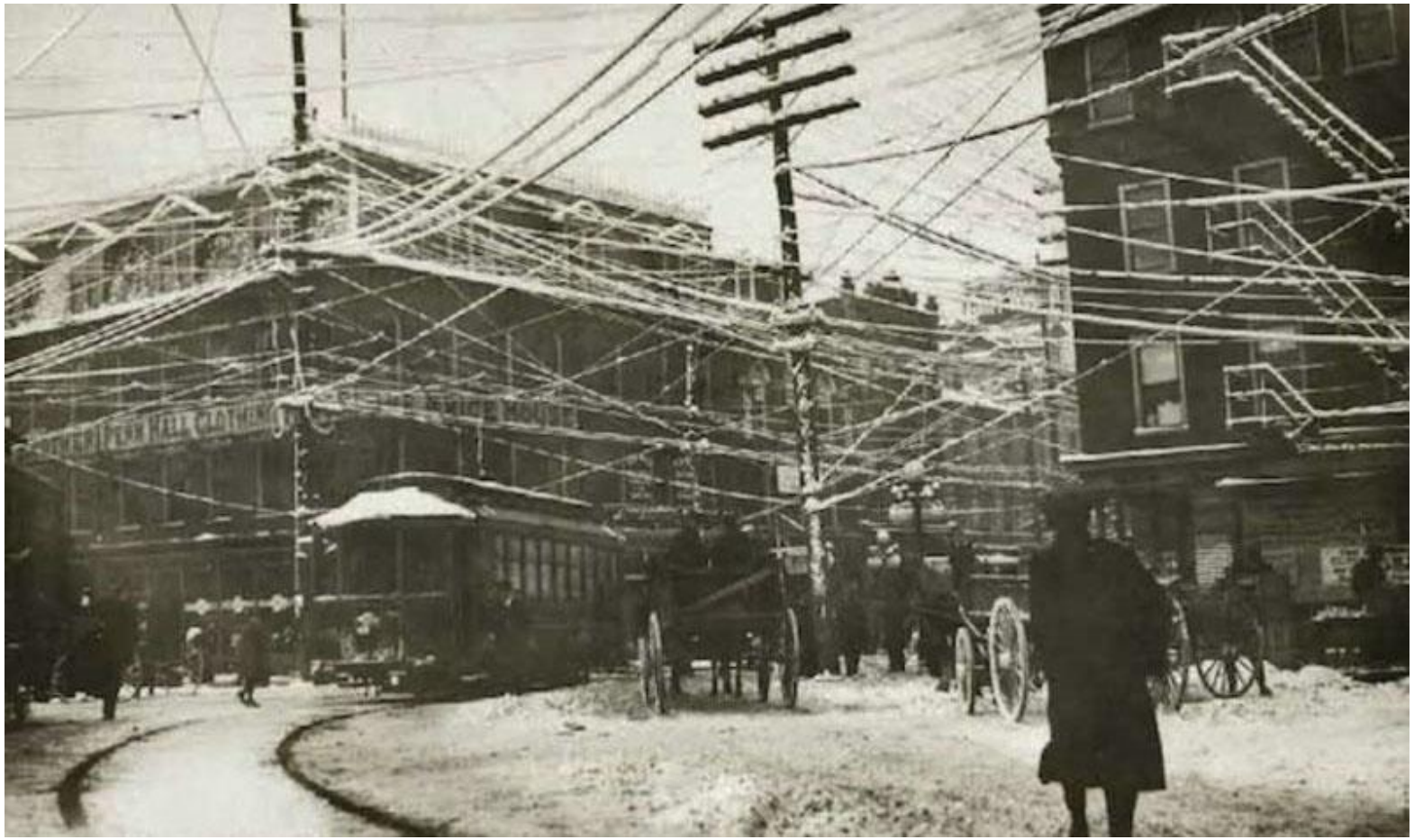
- Used to control train traffic, disseminating news
- International Morse Code was adopted in 1851
- Sounder replaced register by 1856
- Duplex transmission system completed in 1871

Telephone patented by Alexander Graham Bell in 1876

Morse key

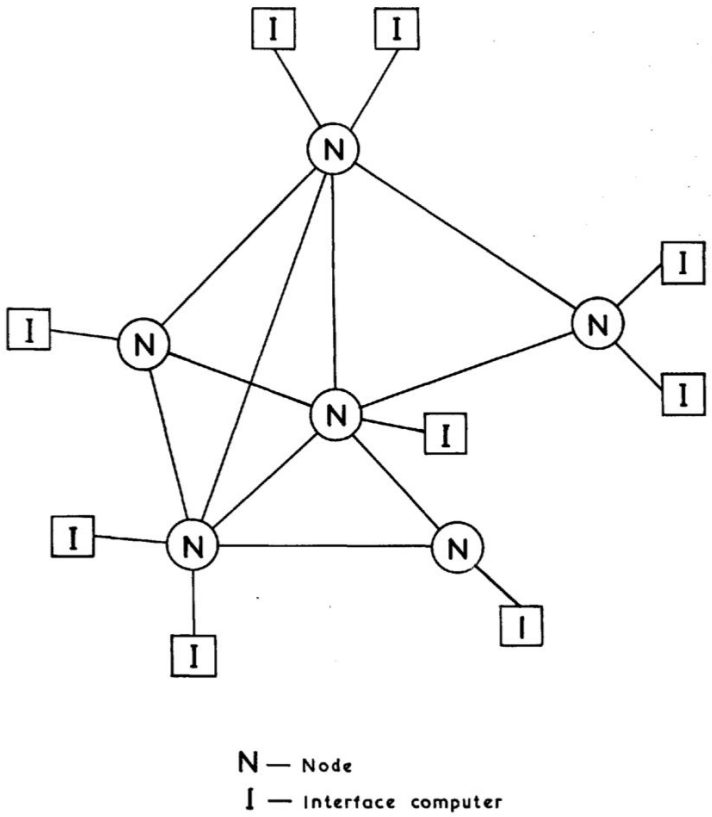
https://www.britannica.com/technology/telegraph/Development-of-the-telegraph-industry
https://www.britannica.com/topic/Morse-Code

Early telephone system



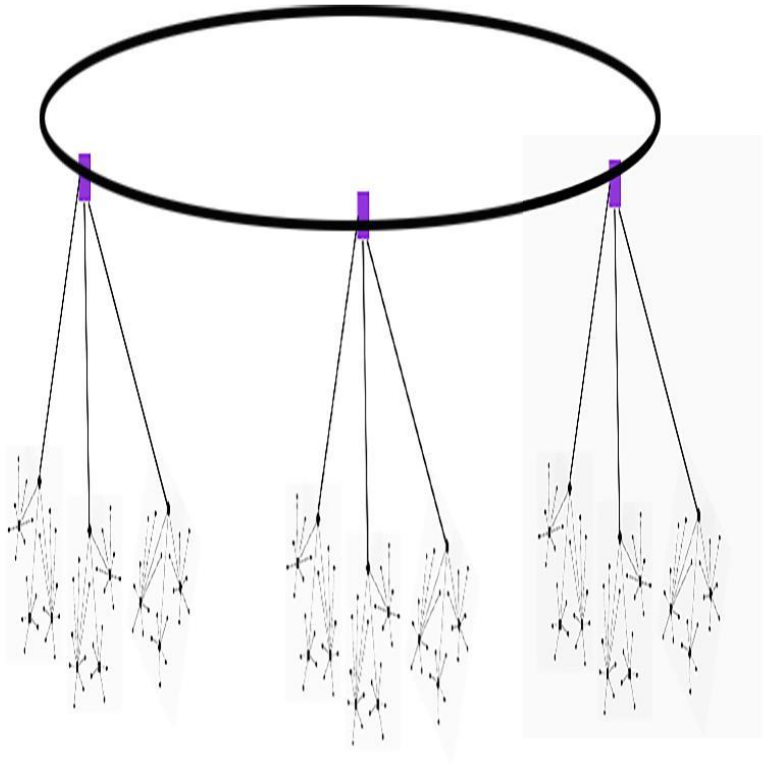
Network designed by the National Physical Laboratory

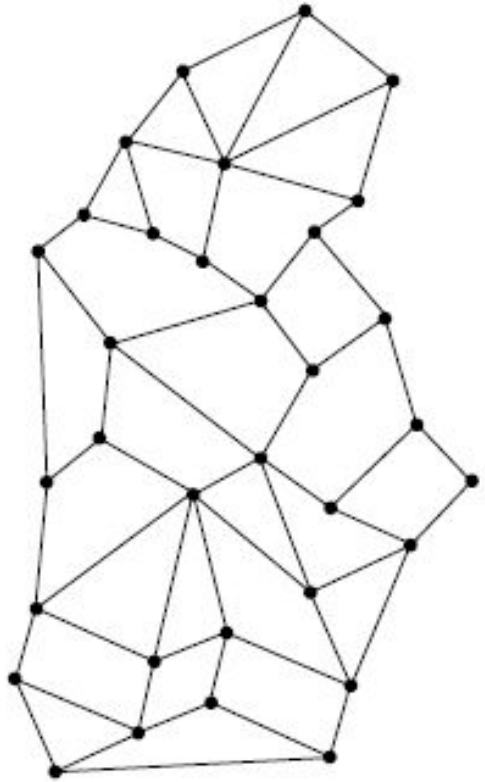
- NPL paper cited Baran but went further
- **Divided files into chunks called packets**
- **Store-and-forward packet switching network**



They did not build a prototype, but described its design.

The ARPANET
A mesh-structured network





The ARPANET
Fault tolerance