Computer Networks X_400487

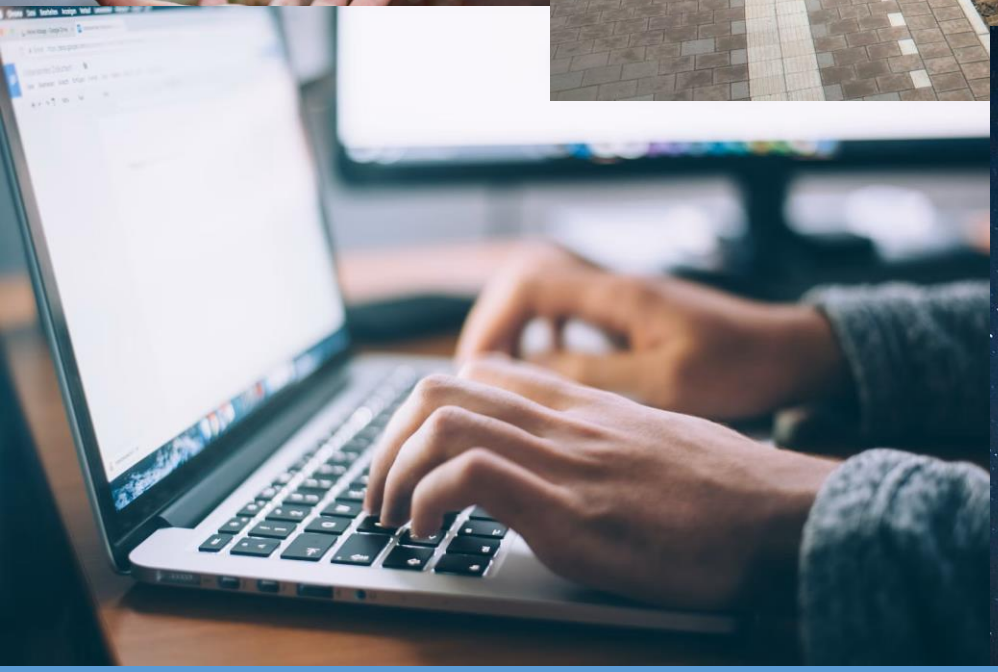
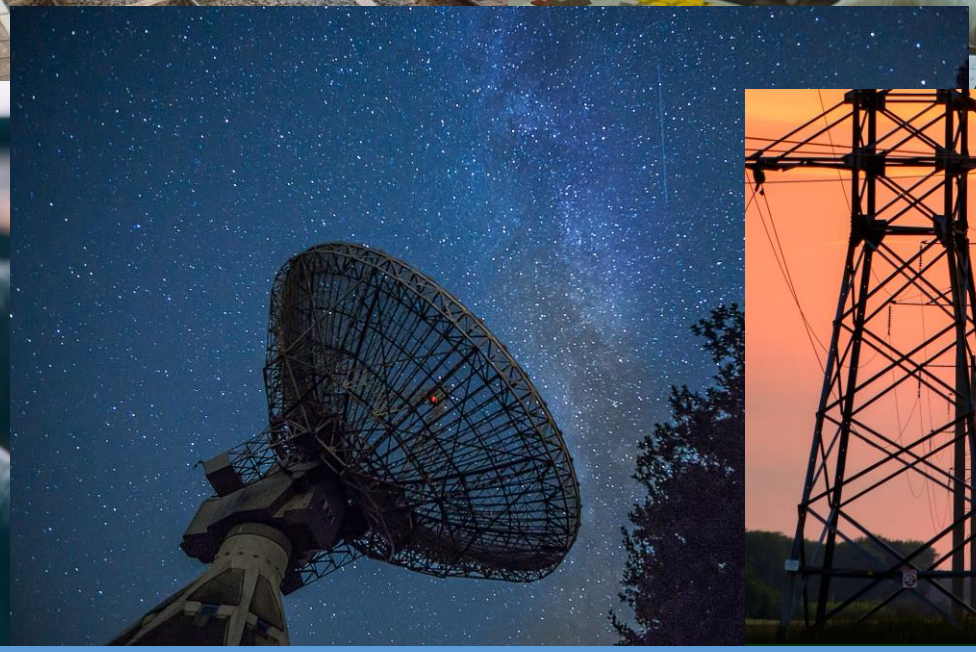
Lecture 1: Introduction to Computer Networks

Welcome! Lecture starts at 15:30

Lecturer: Jesse Donkervliet

VU VRIJE UNIVERSITEIT AMSTERDAM

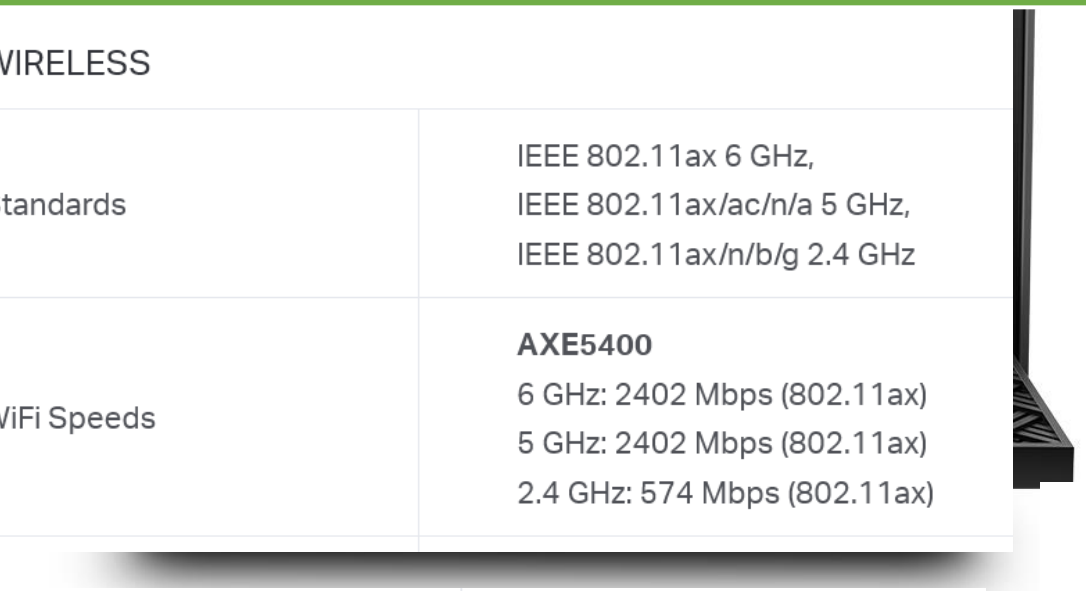



https://unsplash.com/photos/6wdRuK7bVTE, https://unsplash.com/photos/npxXWgQ33ZQ, https://unsplash.com/photos/6vvxiBUf9pM, https://unsplash.com/photos/rbDE93-0hHs, https://unsplash.com/photos/3YAIvBNlZM4,

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

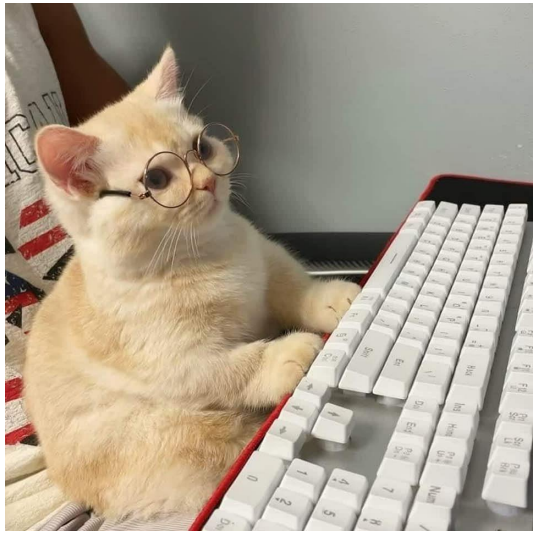


WIRELESS	
Standards	IEEE 802.11ax 6 GHz, IEEE 802.11ax/ac/n/a 5 GHz, IEEE 802.11ax/n/b/g 2.4 GHz
WiFi Speeds	**AXE5400** 6 GHz: 2402 Mbps (802.11ax) 5 GHz: 2402 Mbps (802.11ax) 2.4 GHz: 574 Mbps (802.11ax)

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

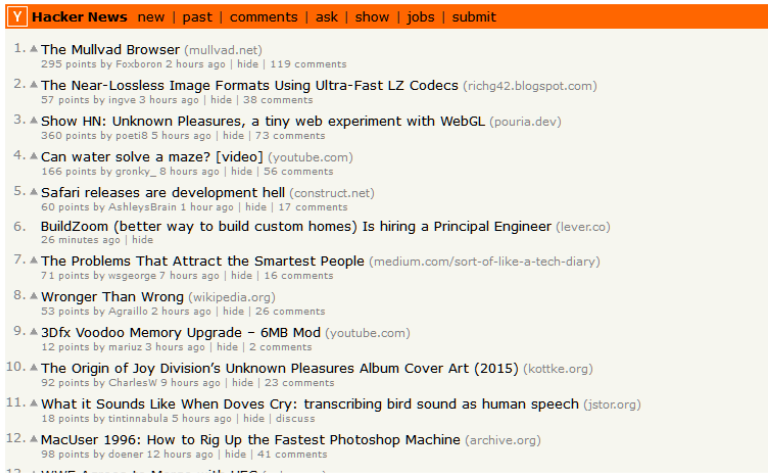
https://www.tp-link.com/en/home-networking/wifi-router/archer-axe75/#overview

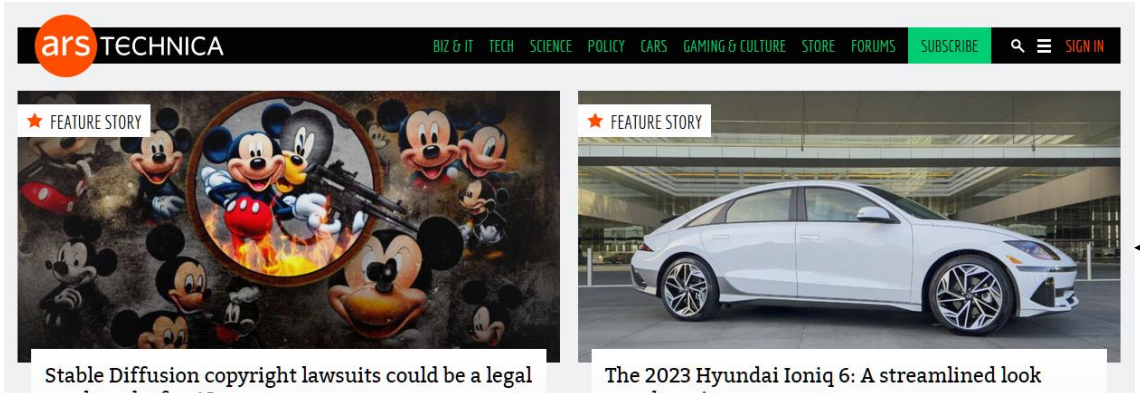
(a) Type address in browser



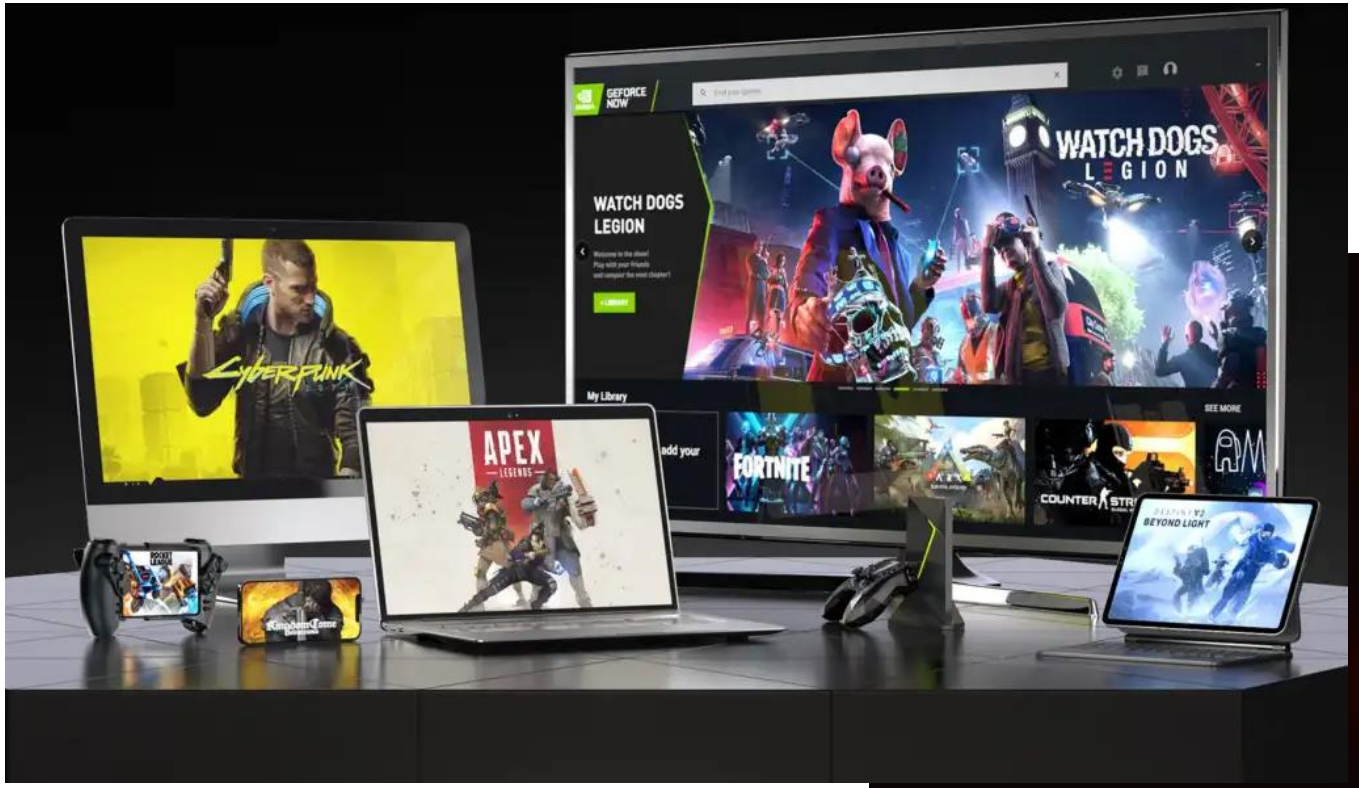
(b) Browser does magic

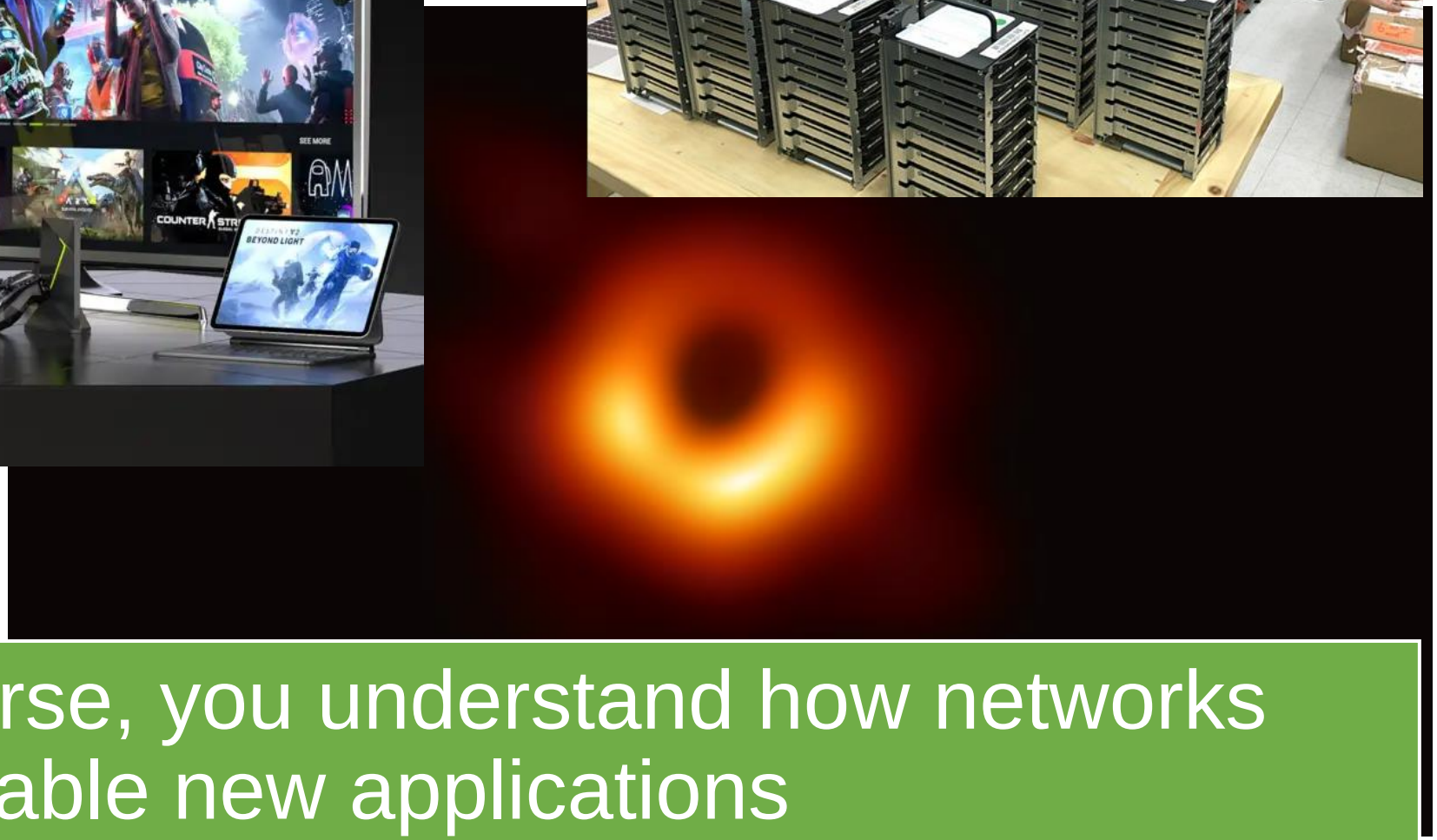
(c) You get a Web page





2. After this course, you understand browser magic





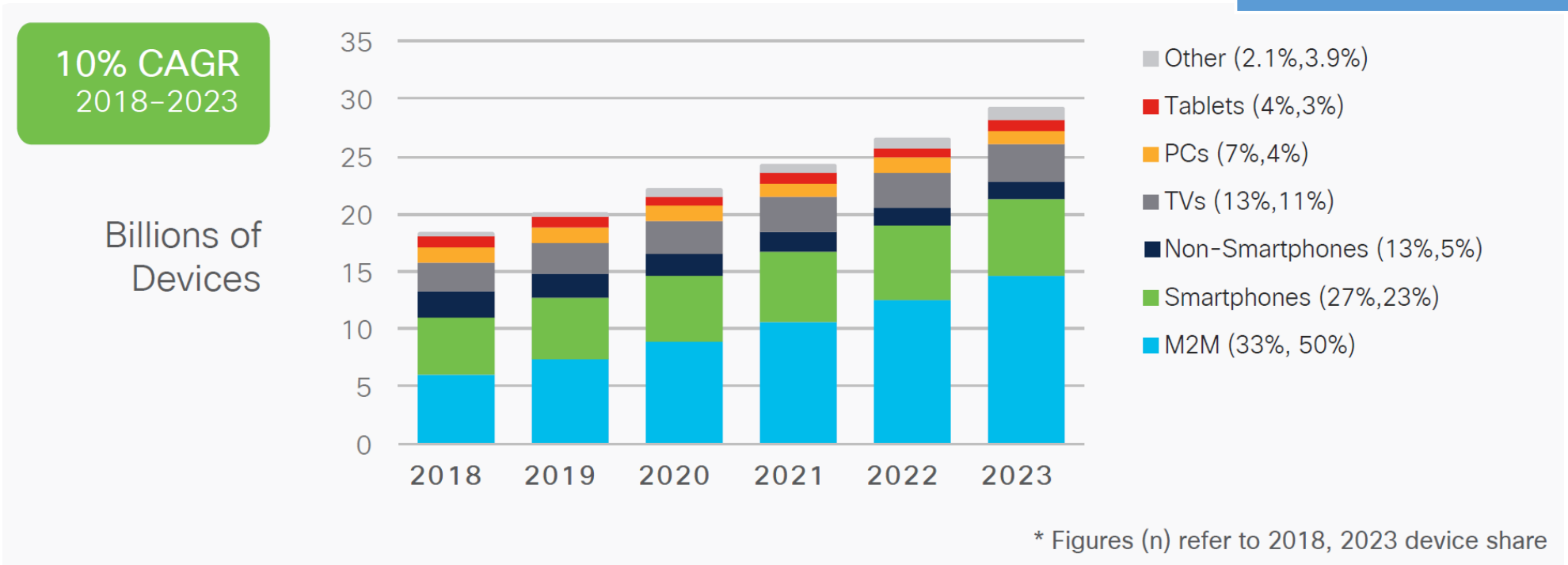
3. After this course, you understand how networks enable new applications

Image source: Nvidia, NASA, https://www.pbs.org/newshour/science/katie-bouman-hardly-knew-what-a-black-hole-was-her-algorithm-helped-us-see-one

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 traffic

1 Exabyte =

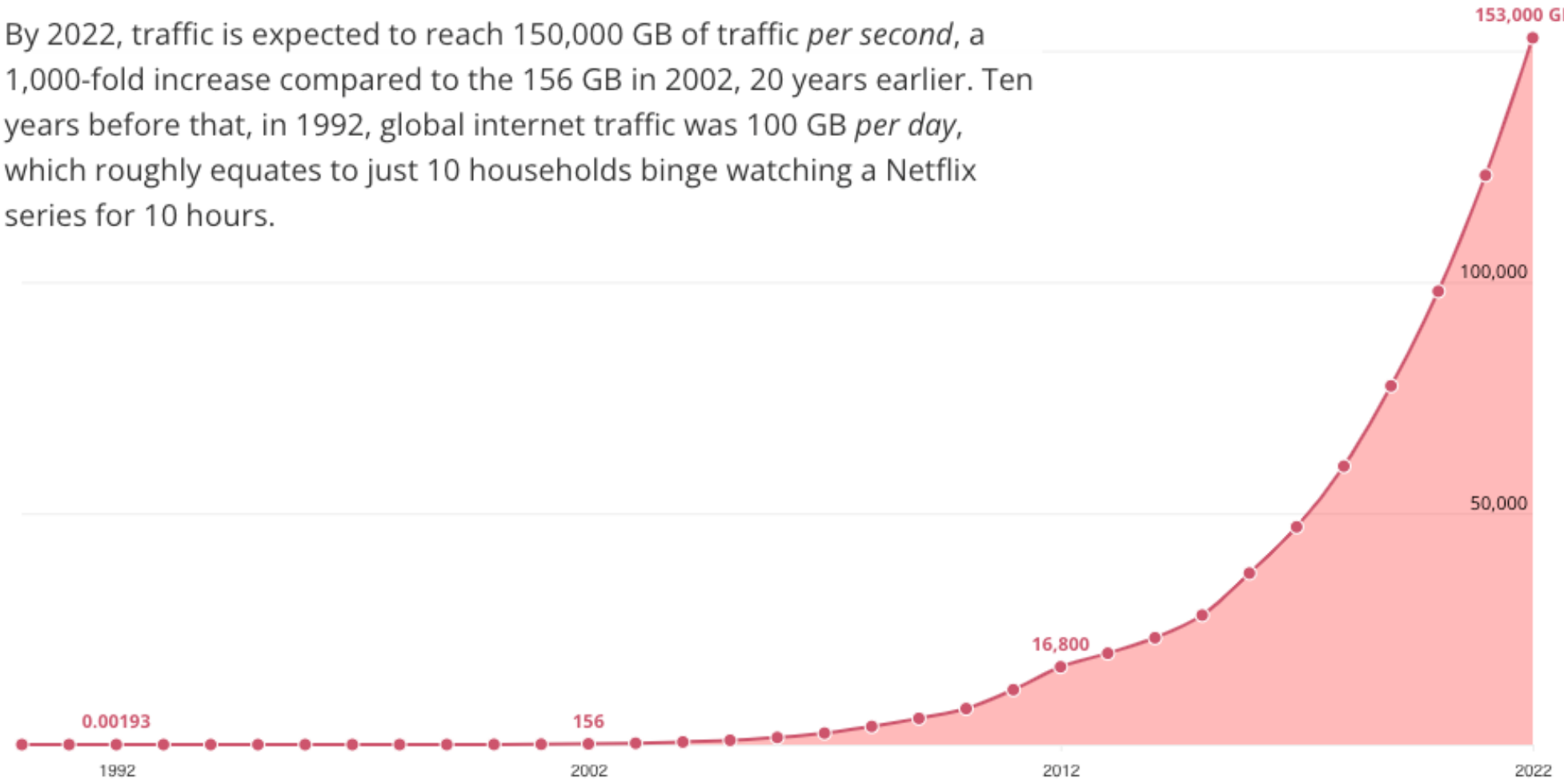
24% CAGR
2016–2021

Exabyte
per mon

Figures (n) refer to 2016, 20
Source: Cisco VNI Global IP T

Growth of global internet traffic in the past 30 years

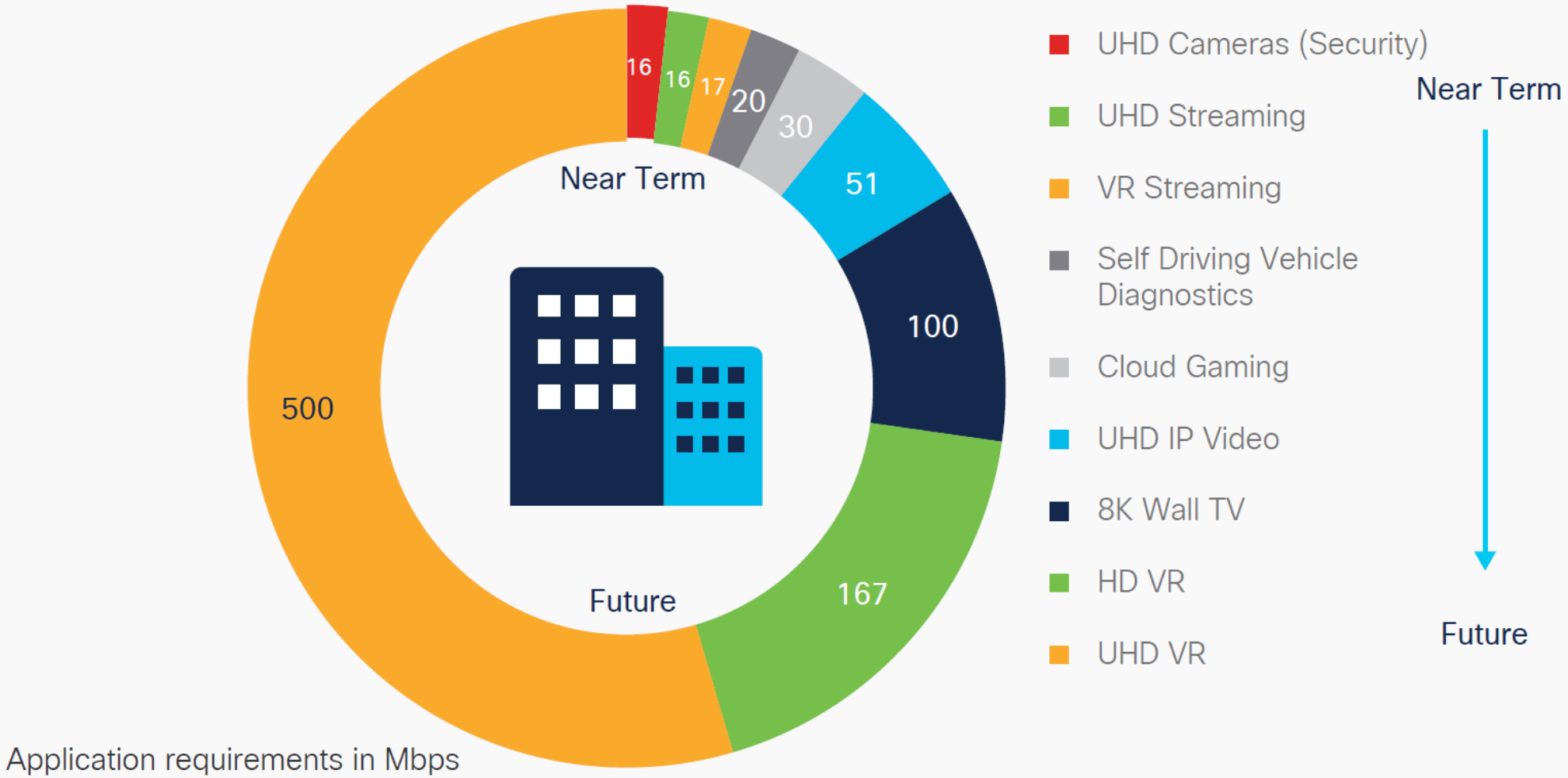
By 2022, traffic is expected to reach 150,000 GB of traffic *per second*, a 1,000-fold increase compared to the 156 GB in 2002, 20 years earlier. Ten years before that, in 1992, global internet traffic was 100 GB *per day*, which roughly equates to just 10 households binge watching a Netflix series for 10 hours.



Source: WDR 2021 team calculations and Cisco Visual Networking Index: Forecast and Trends, 2017–2022.

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

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



Source: Cisco Annual Internet Report, 2018–2023

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/

FEATURE

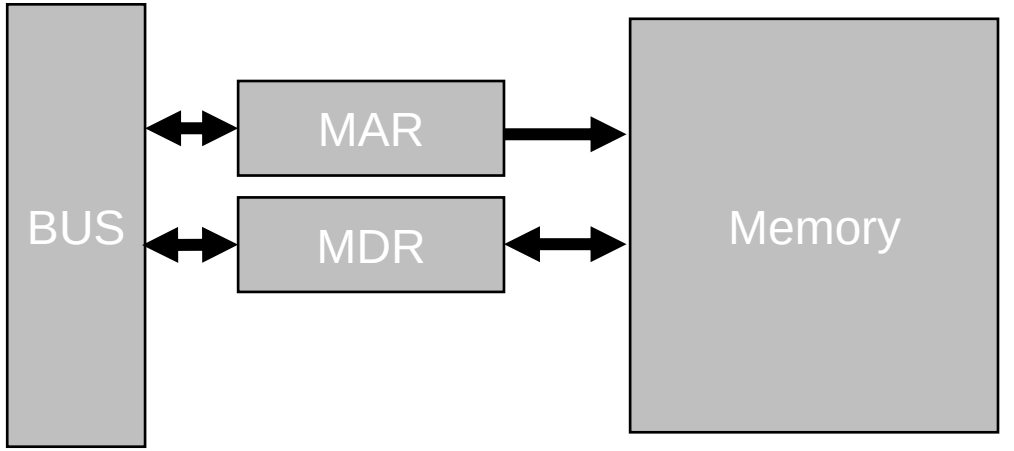
Eve Online is getting crushed by its own success

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."

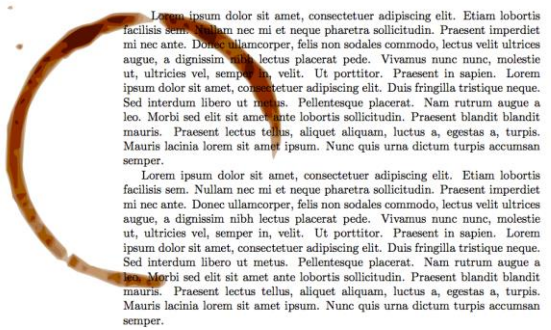
https://www.polygon.com/features/2021/1/15/22228837/eve-online-m2-mittani-papi-server-failure-hellcamp
https://www.polygon.com/2021/1/5/22214982/eve-online-world-record-massacre-m2-xfe-ghost-titans

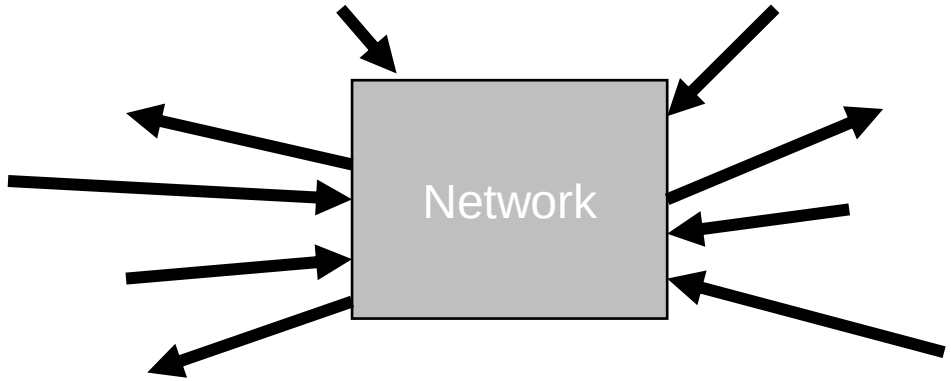
Why are existing systems not good enough?



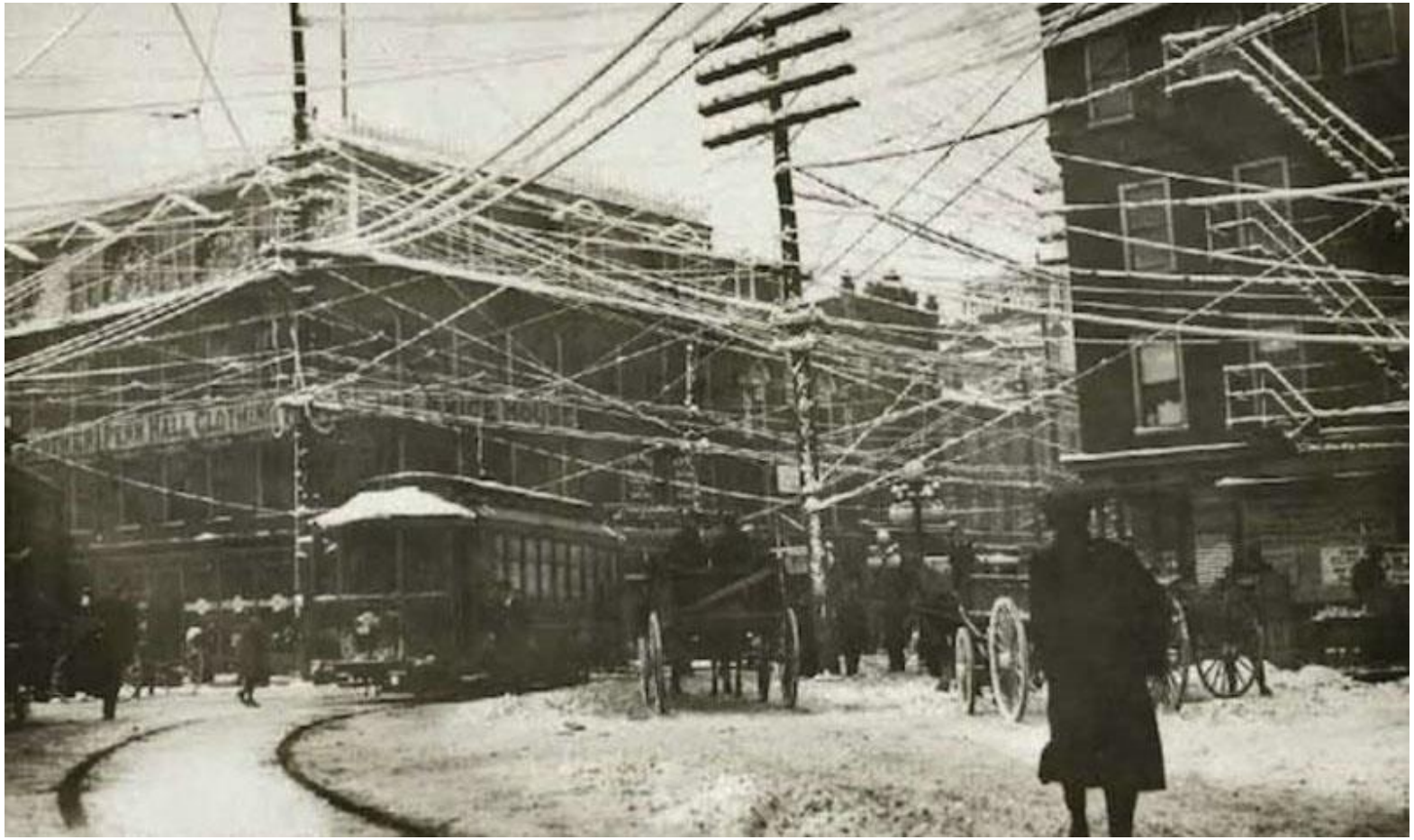
Examples of challenges:

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

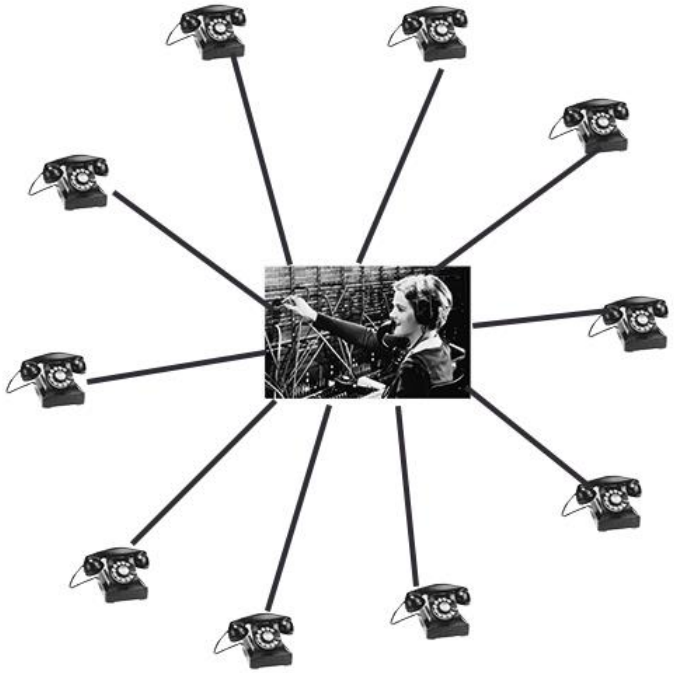




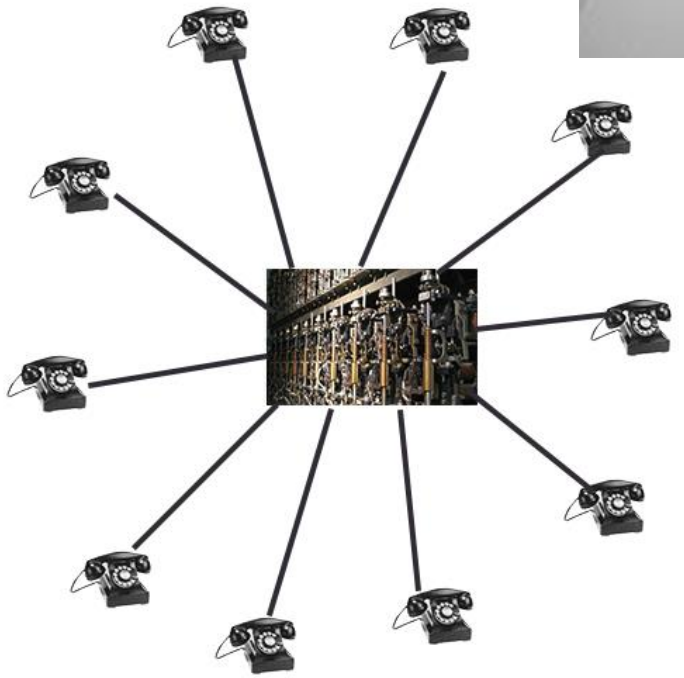
Early telephone system



Telephone switching

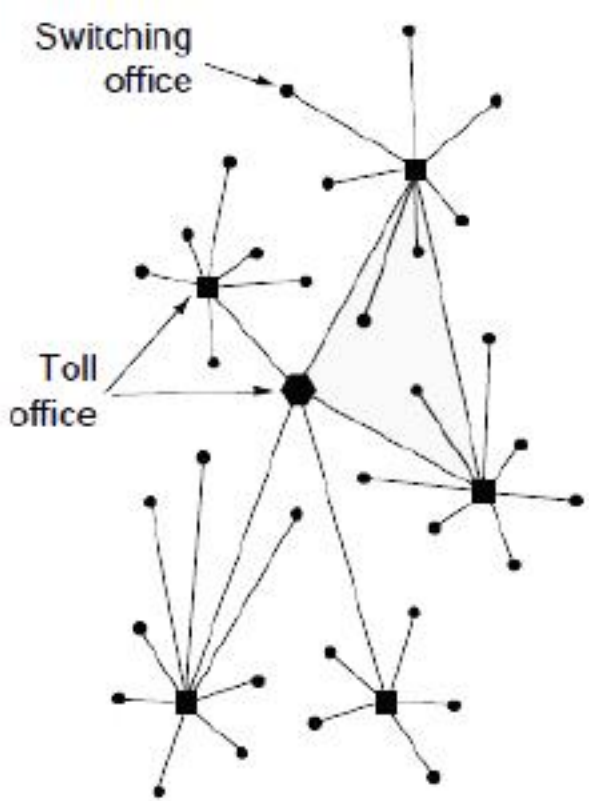


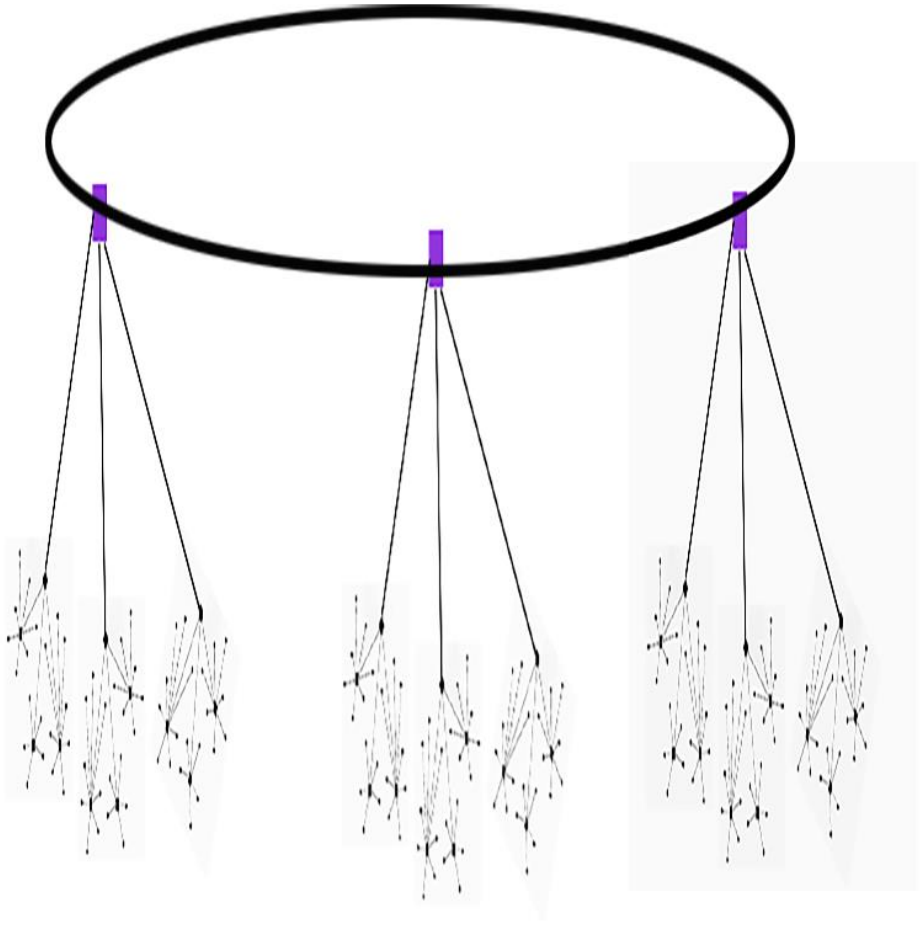
Human operator



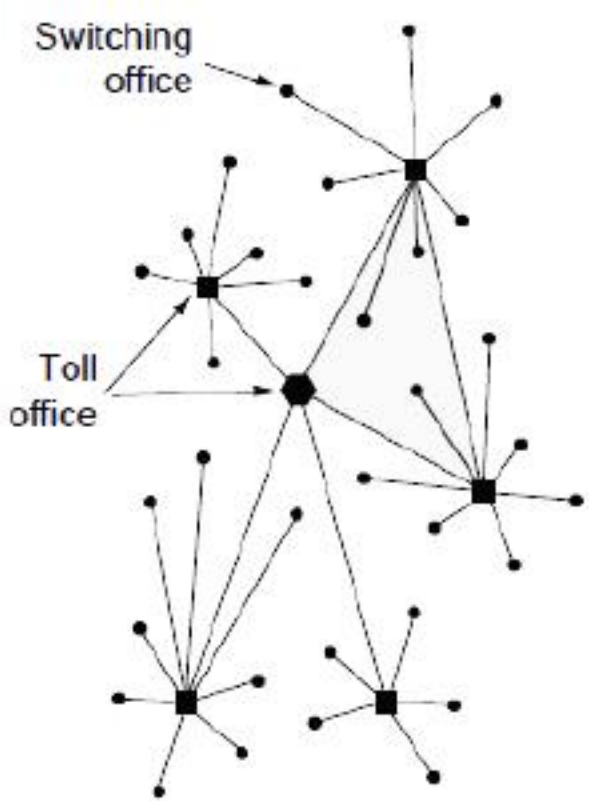
Strowger gear

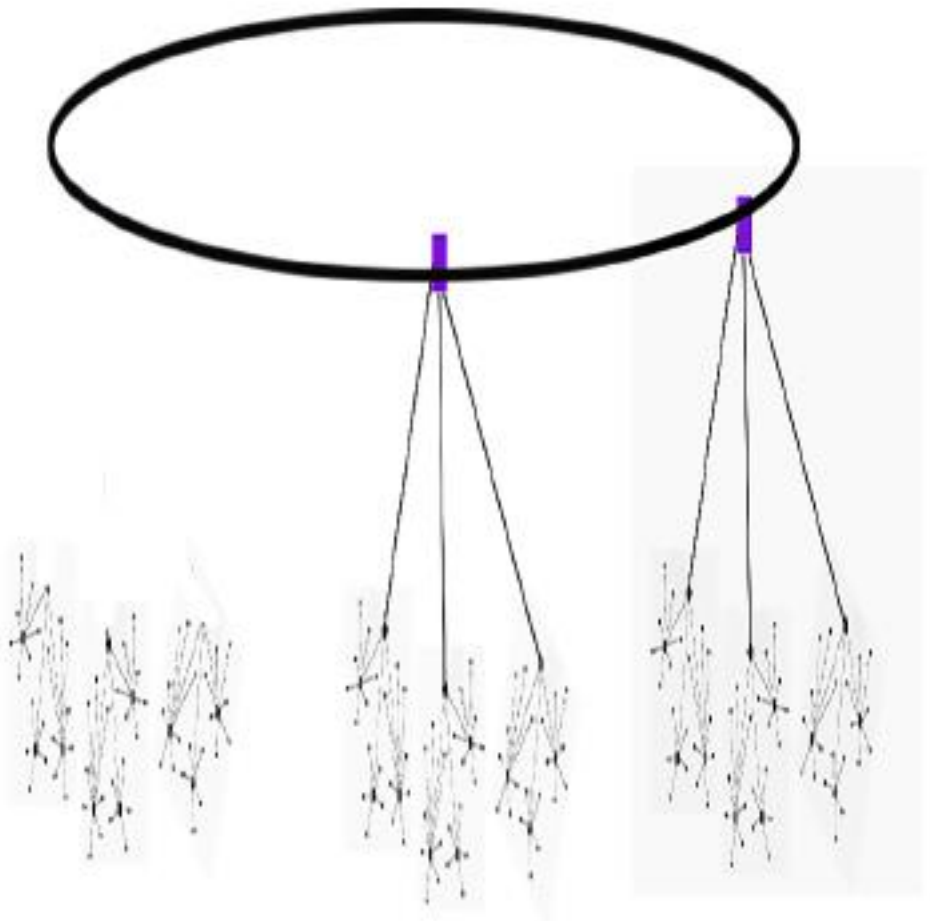
Hierarchical topology





Hierarchical topology



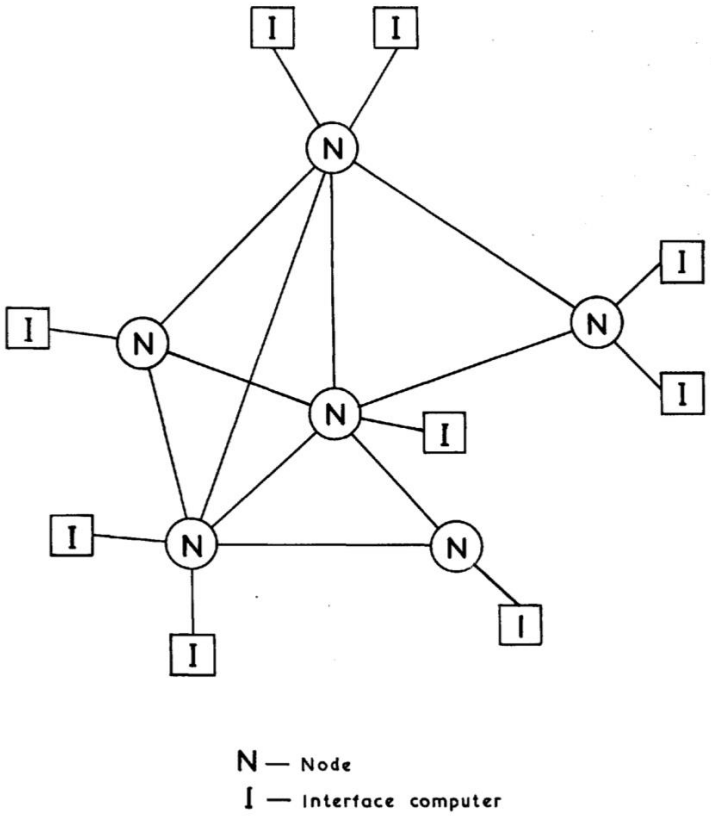


Military is a big fan of resilient systems

- US military asked RAND Corporation to design a better system (in 1960).
- Paul Baran (RAND employee) designed a fault tolerant network.
- Military asked AT&T to build it.
- They refused…
- Baran’s design was forgotten…
- But design improved upon by NPL, built by ARPA.

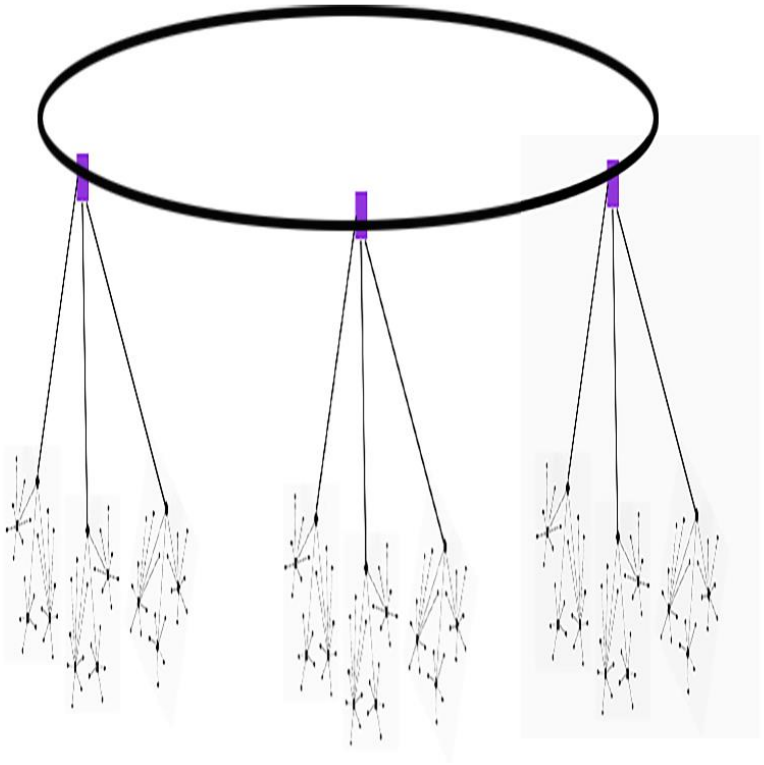
Network designed by the National Physical Laboratory

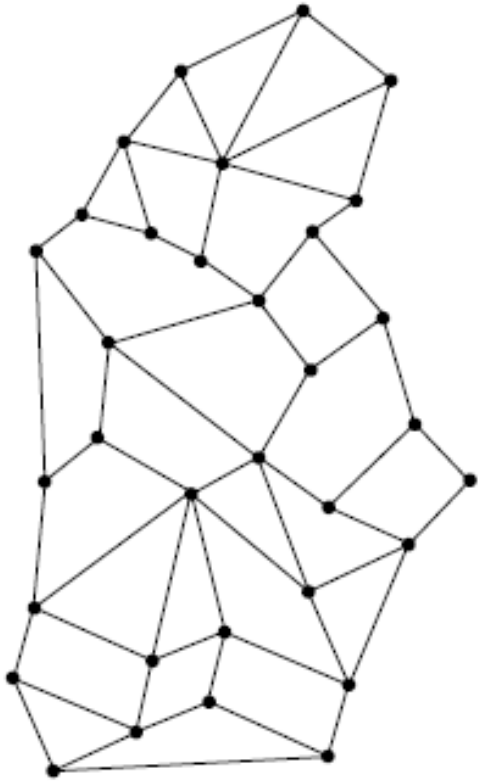
- NPL paper cited Baran but went further
- **Divided files into chunks called packets**
- **Store-and-forward packet switching network**



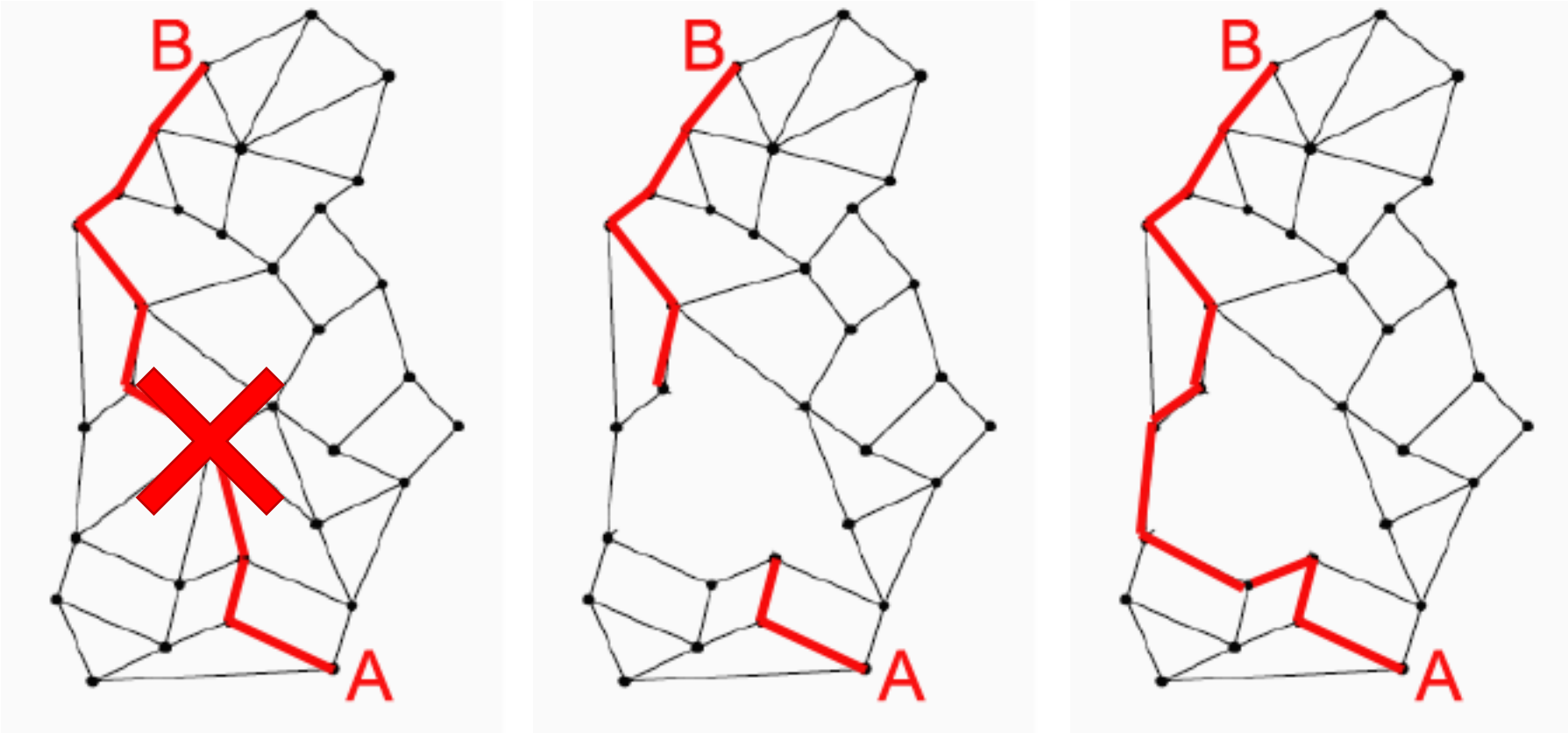
They did not build a prototype, but described its design.

The ARPANET
A mesh-structured network





The ARPANET
Fault tolerance



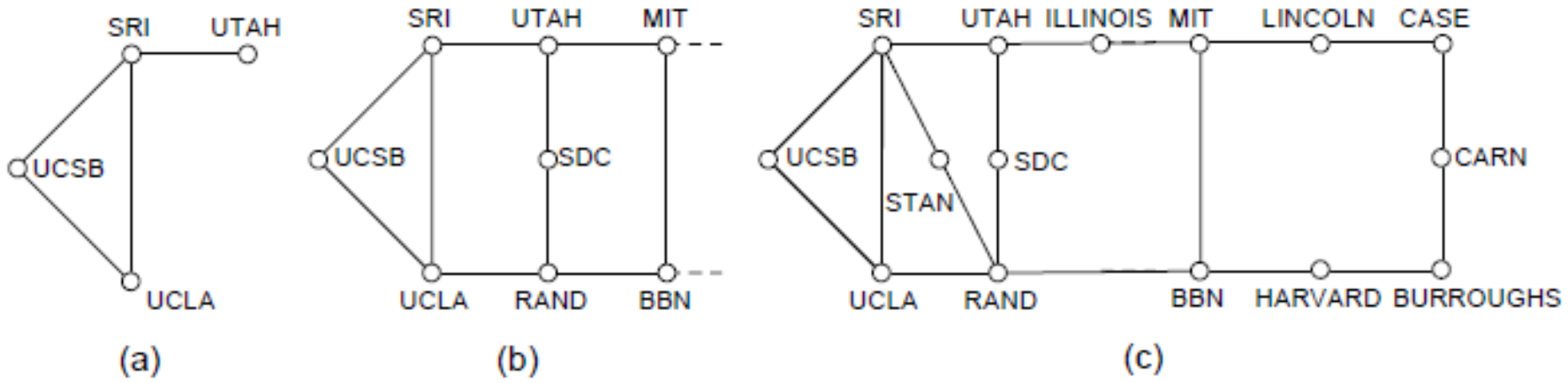
The ARPANET
Growth over time

Growth of the ARPANET.

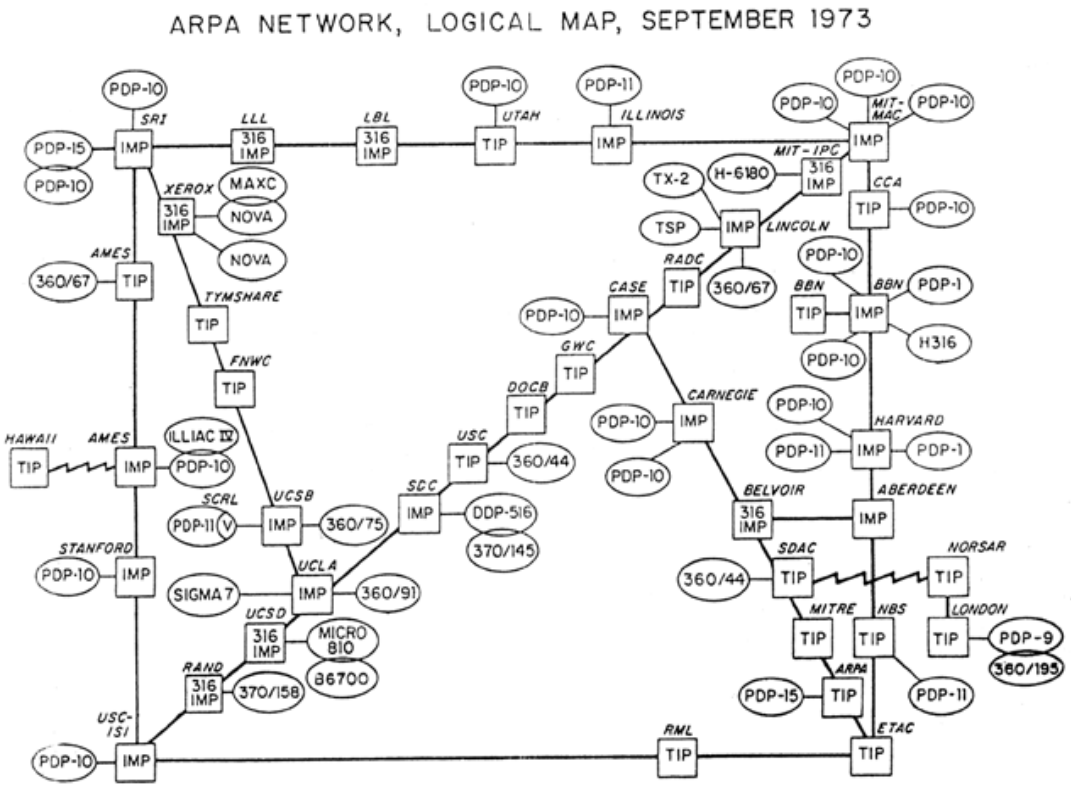
(a) December 1969.

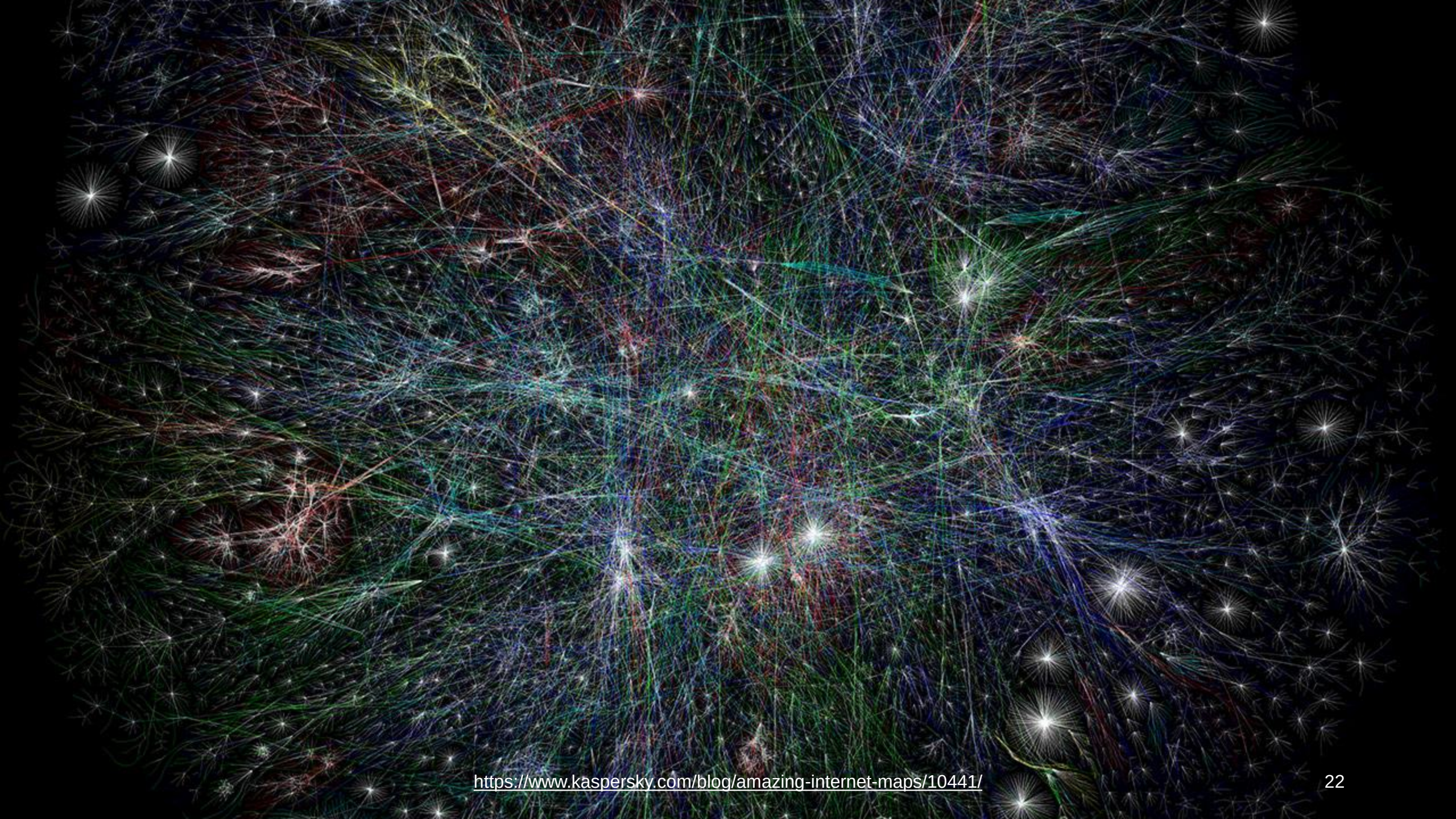
(b) July 1970.

(c) March 1971.



The ARPANET
Network state in 1973





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

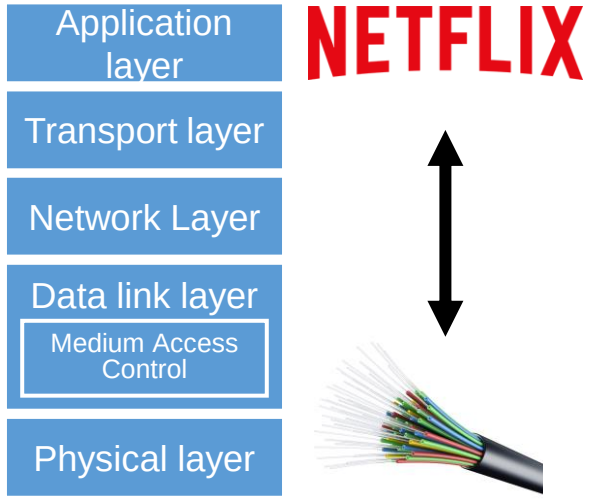
Layered architecture

Q: Why use a layered architecture?

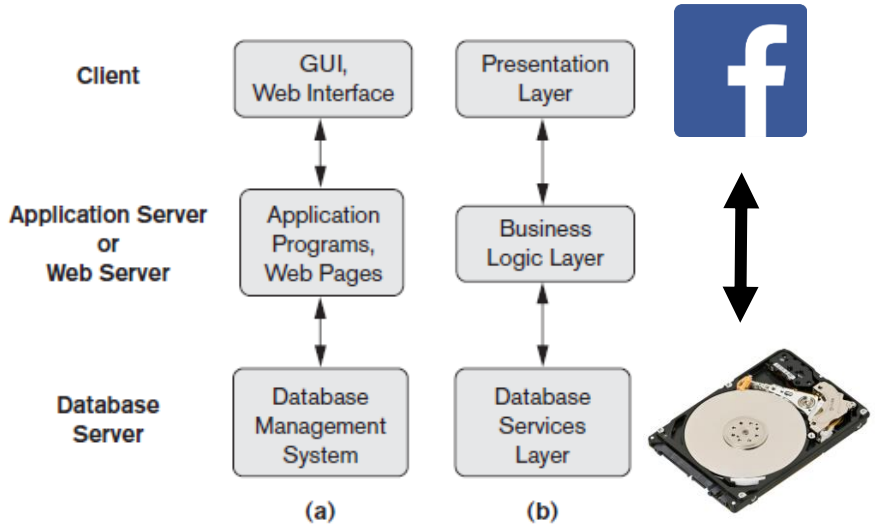
Q: Can you think of another domain that uses layered architectures?

Can be found in…

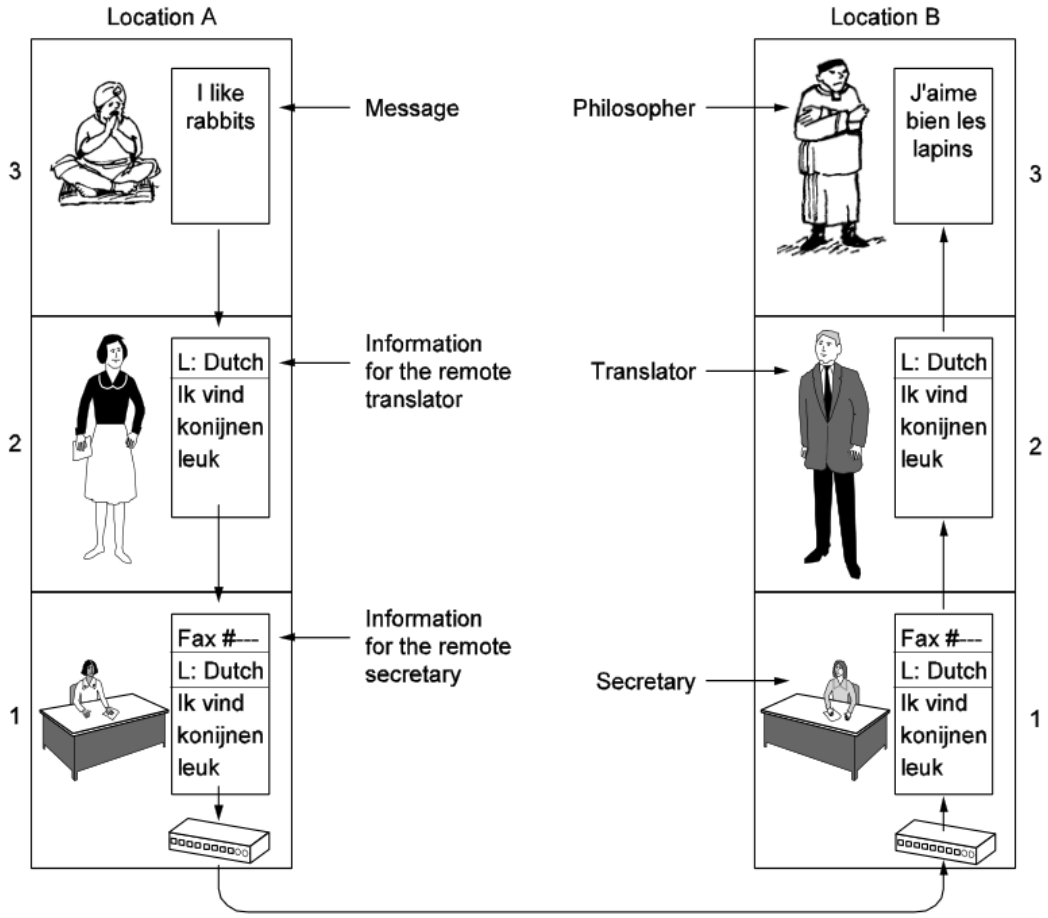
…computer networks…



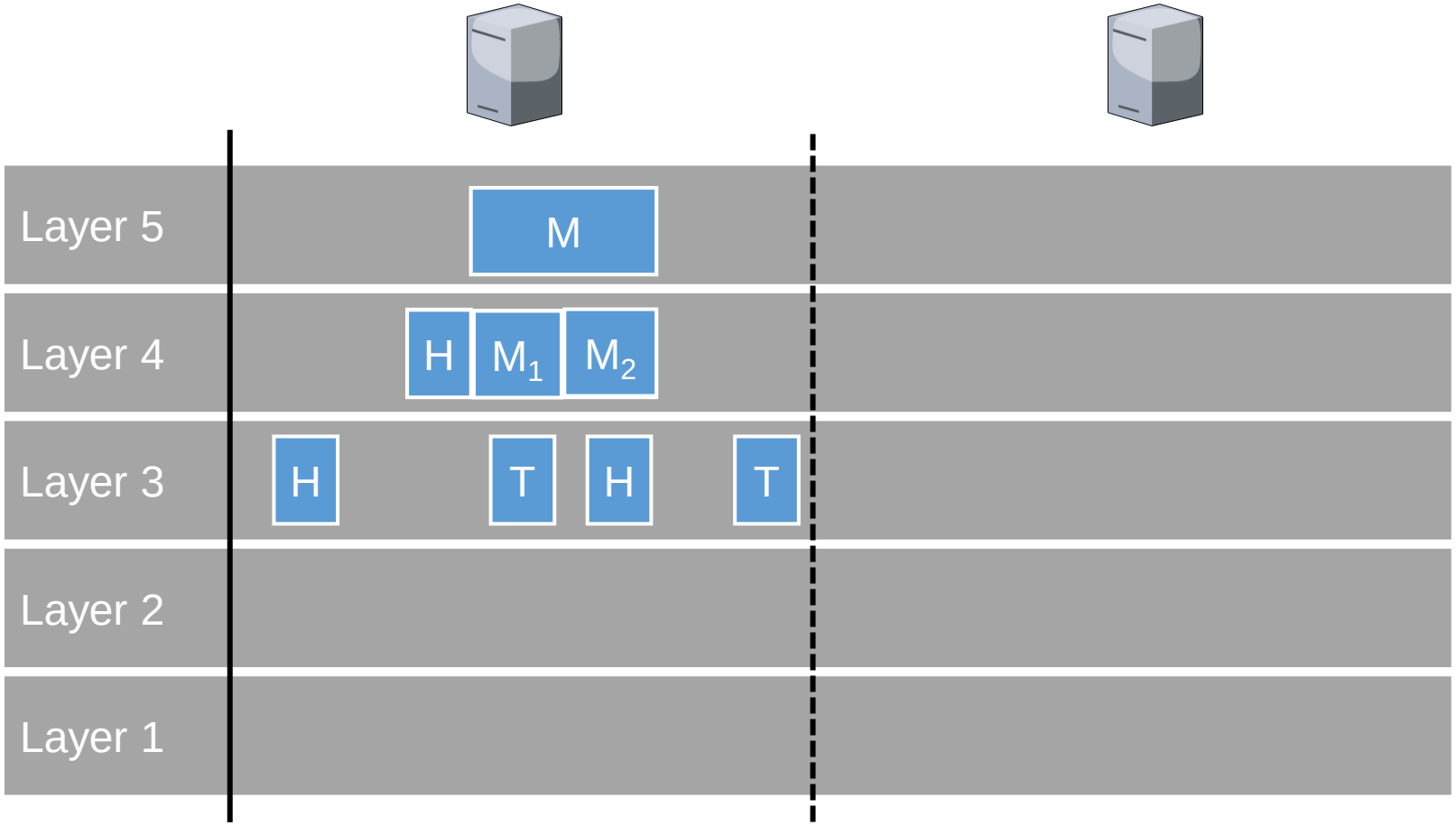
…and other domains



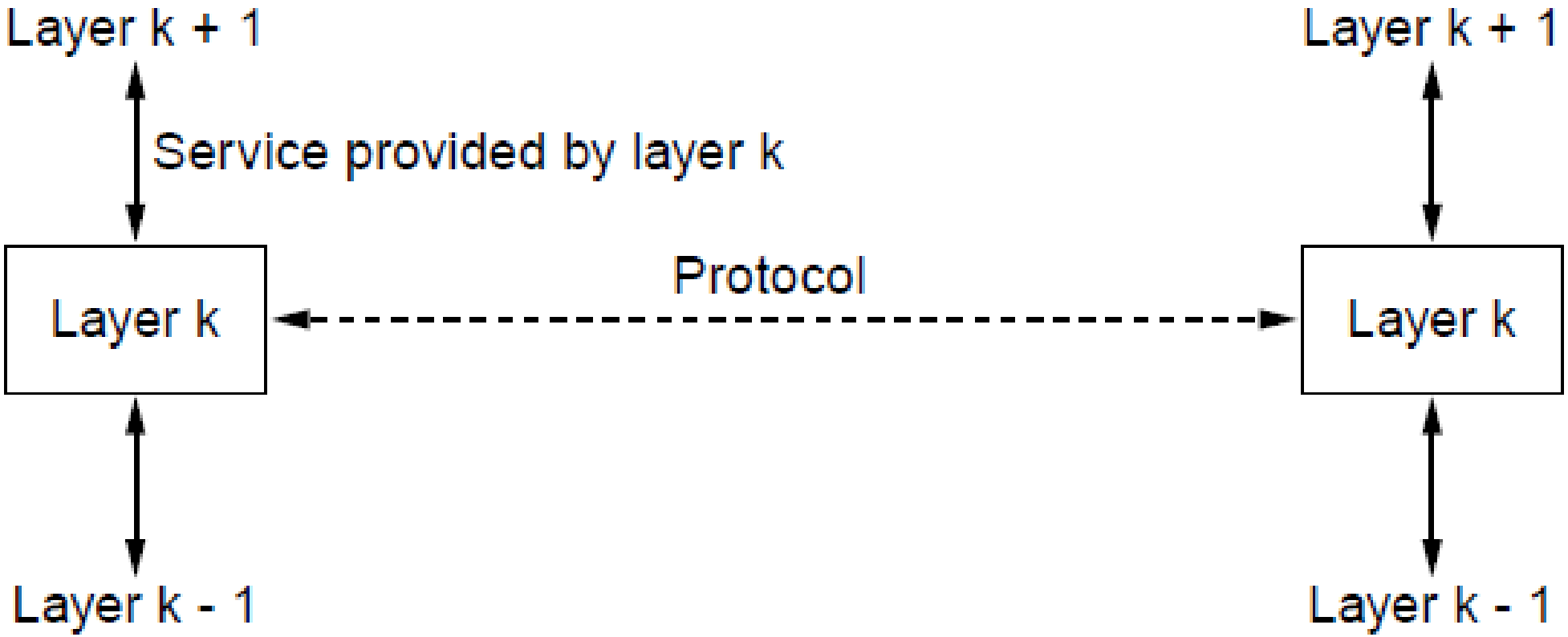
Layered architecture in computer networks: an analogy



Layered architecture in computer networks: an overview



Illusion of direct communication



How scale affects networks design

Personal Area Network (PAN)

- Example: Bluetooth

Local Area Network (LAN)

- Examples: WiFi (802.11)

Metropolitan Area Network (MAN)

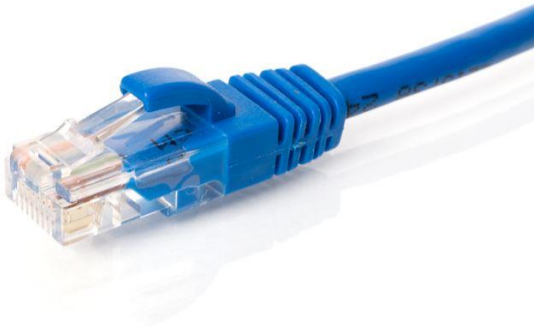
Wide Area Network (WAN)

The Internet

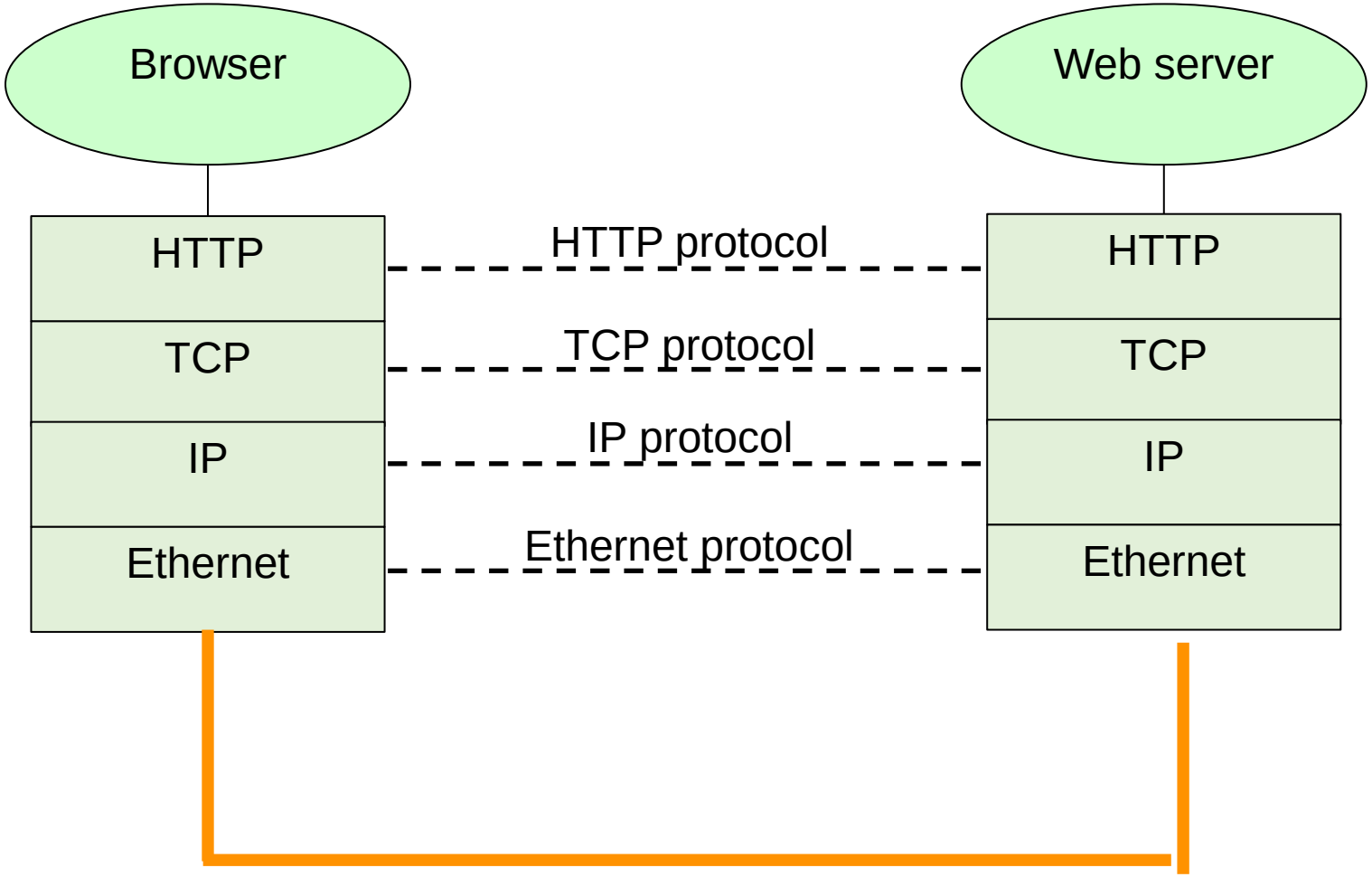
Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

How the medium affects network design

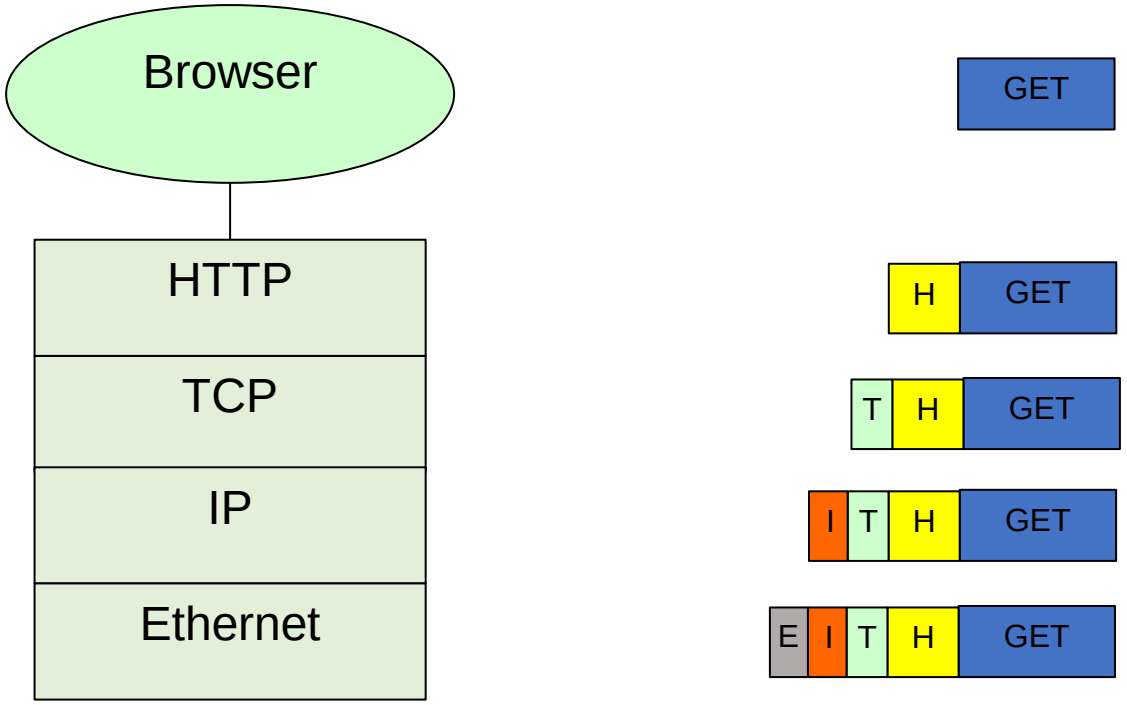
Different frequencies have different physical properties!



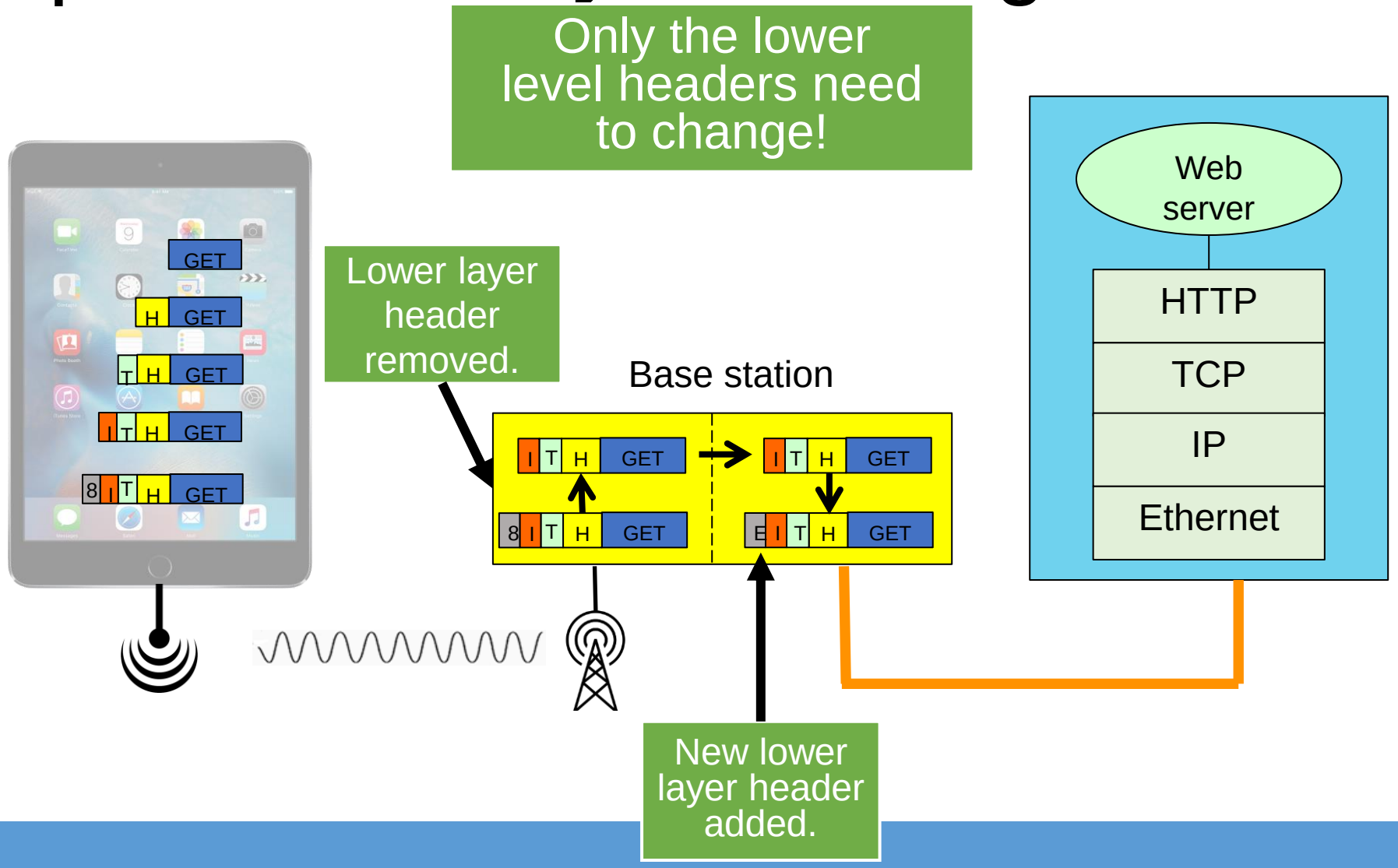
An example protocol



Encapsulation in a protocol stack



The power of a layered design



Multiple reference models for computer networks

Each models has both advantages and disadvantages.

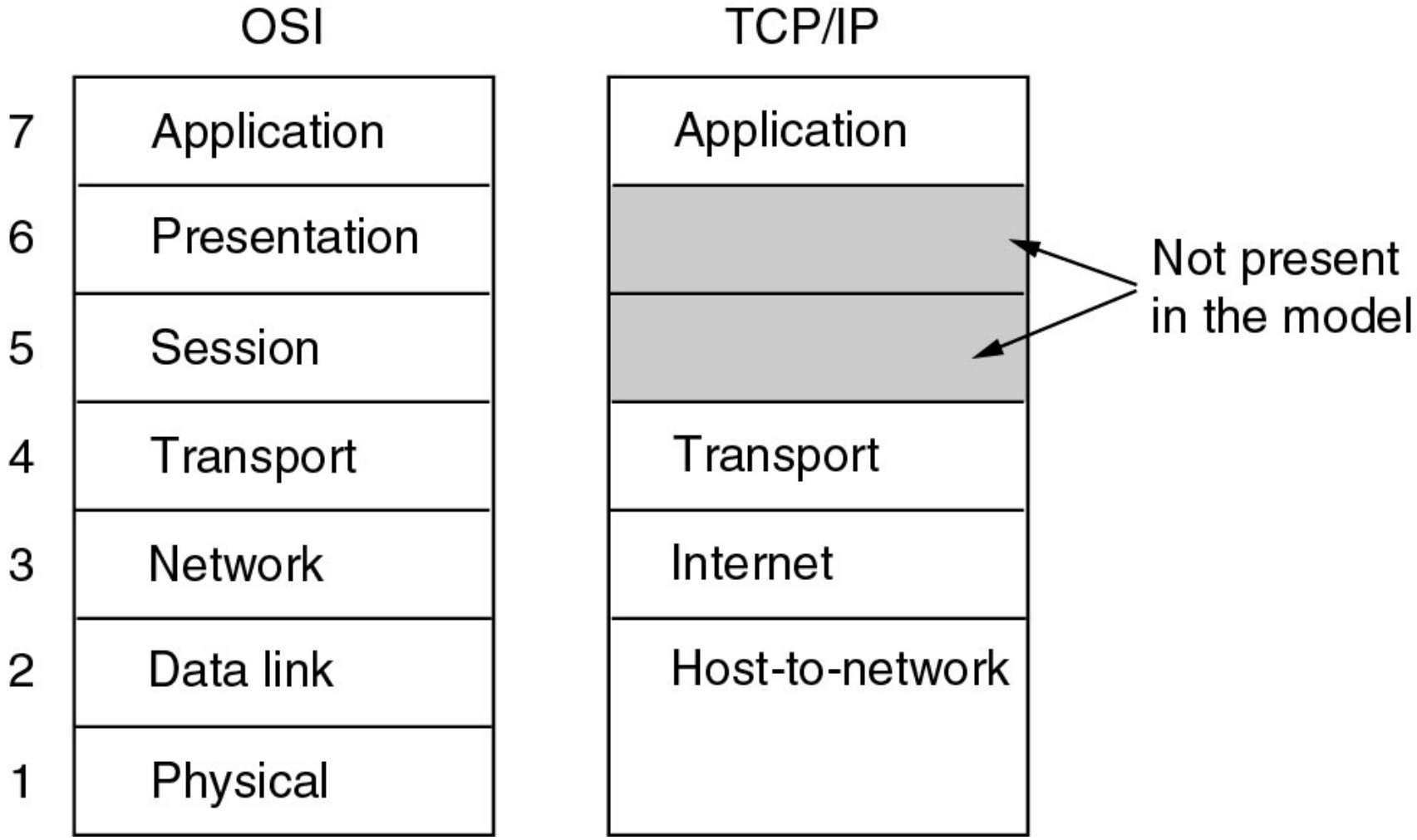
OSI model

1. Design by committee.
2. Strictly separated layers.

TCP/IP model

1. Widely used in practice.
2. Low generality.
3. Poor separation of concerns and interface design.

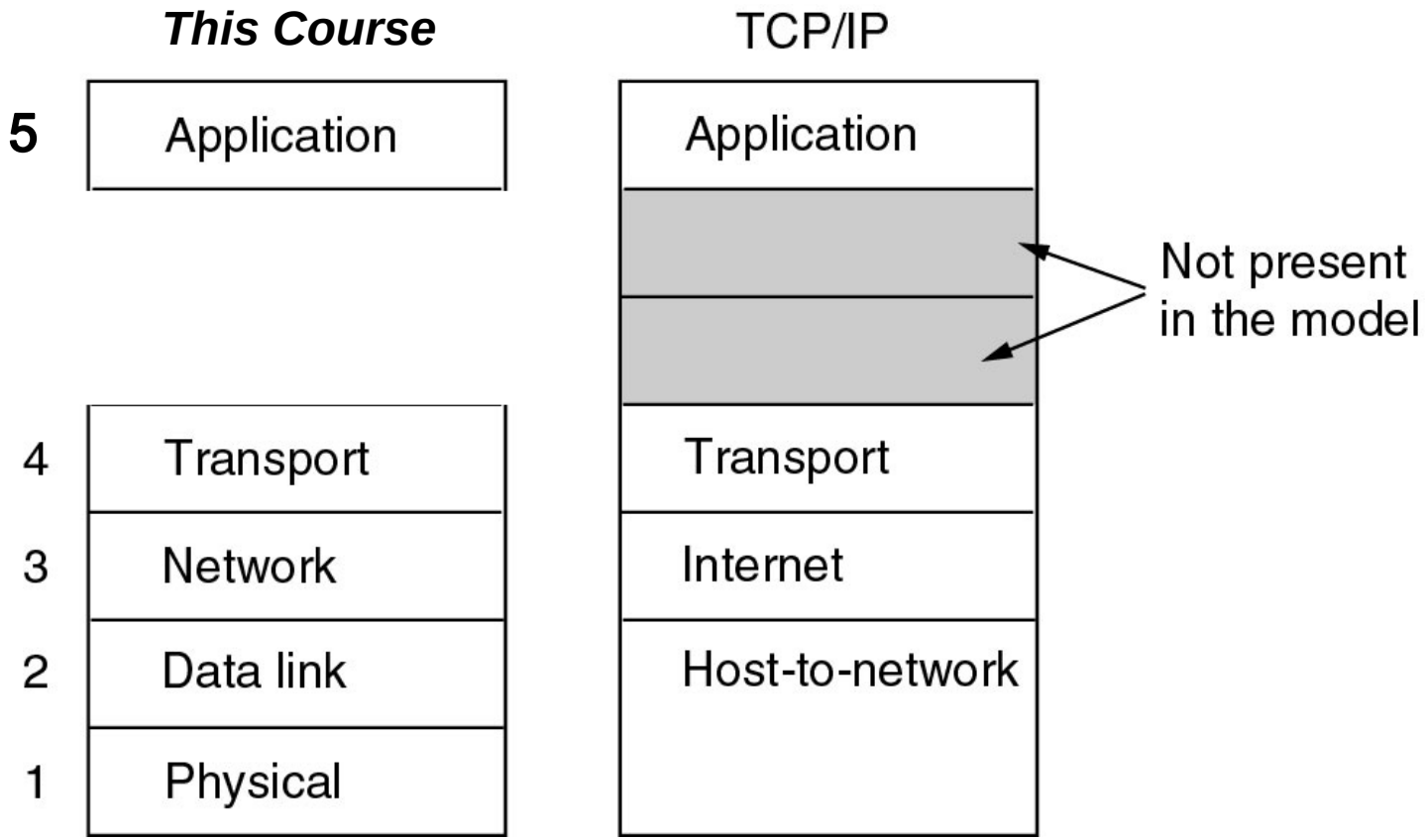
OSI versus TCP/IP



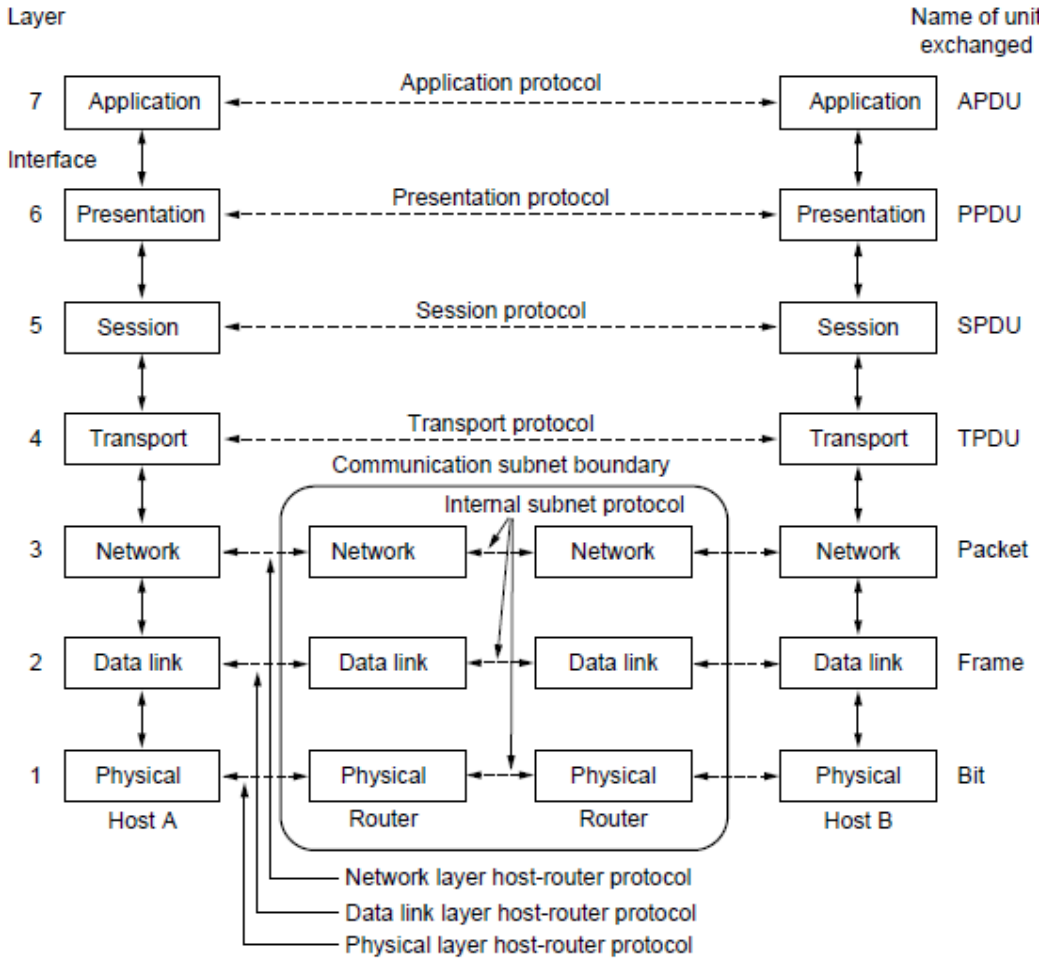
The model used in this course

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

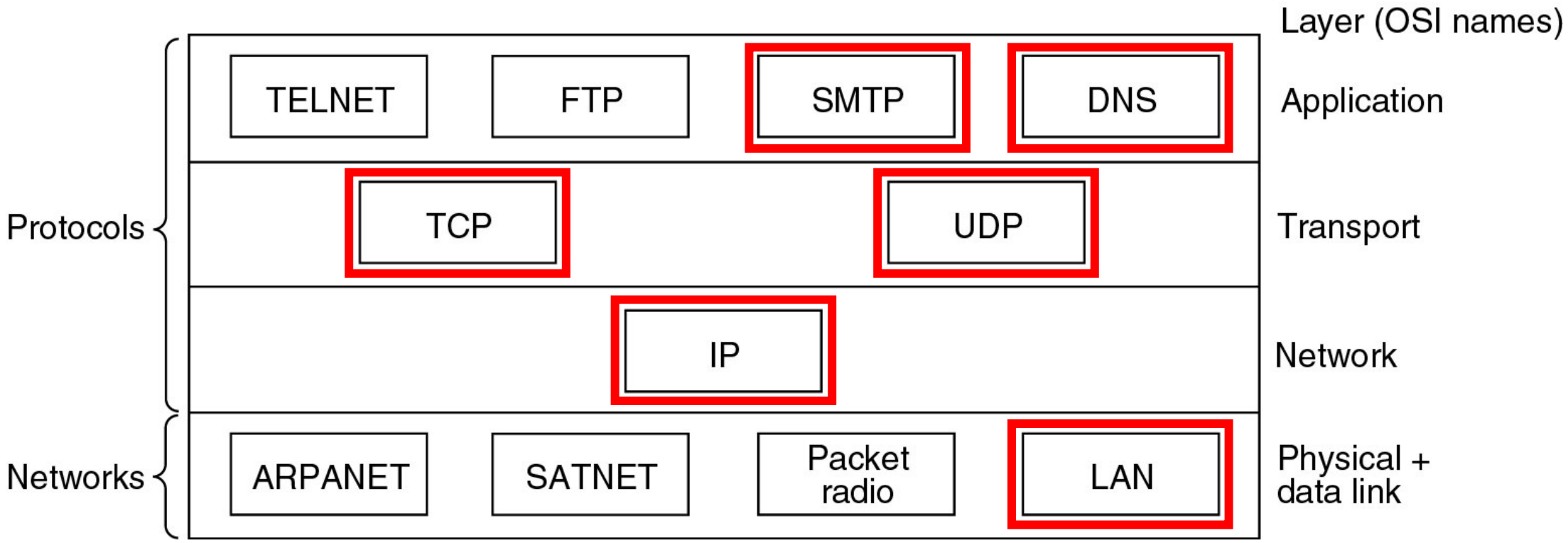
So we skip them!



The OSI reference model



Protocols and Networks from the TCP/IP model



Roadmap of the Computer Networks Course

Lets distributed applications communicate

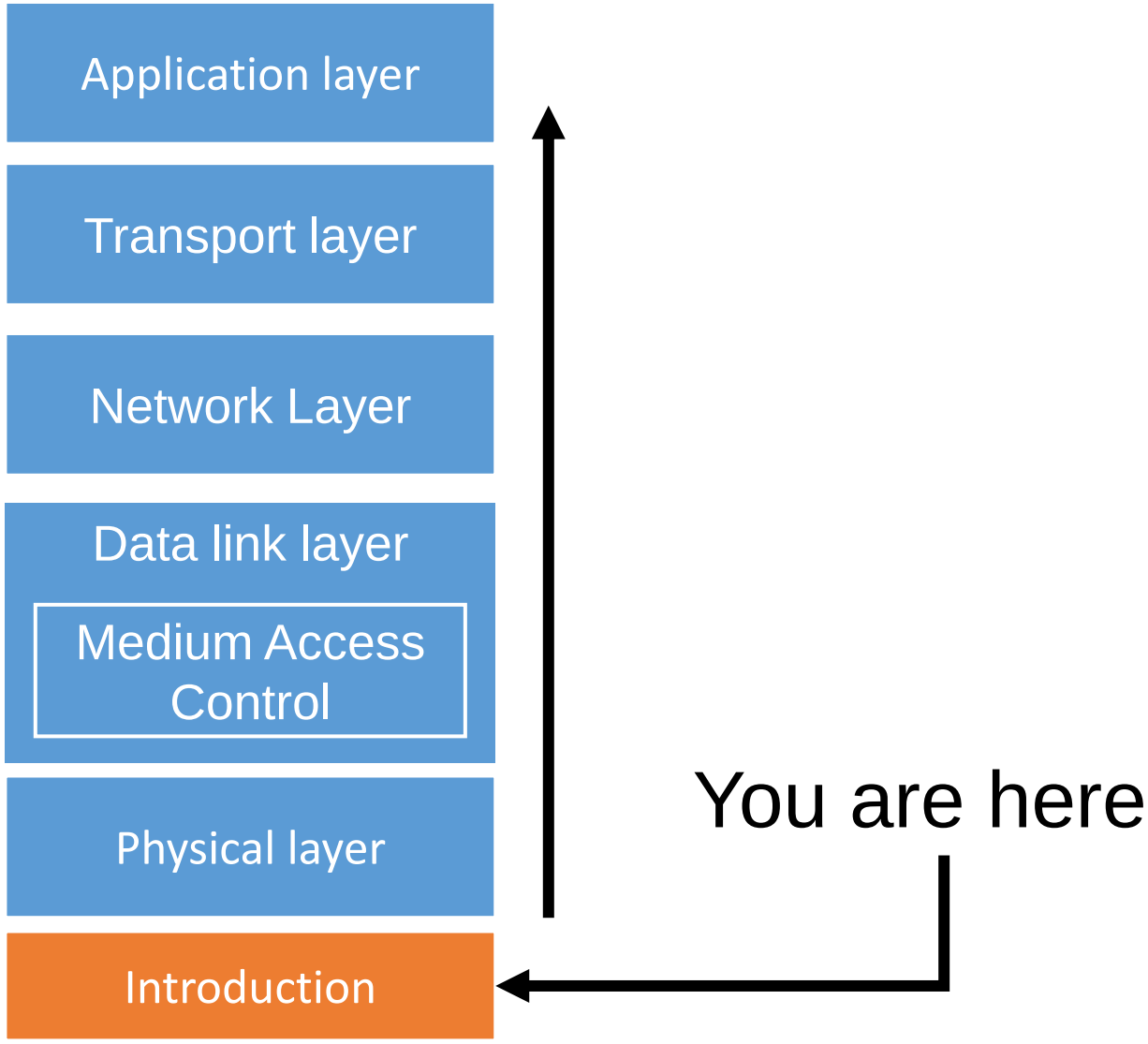
Sends segments from one **process** to another (over a network)

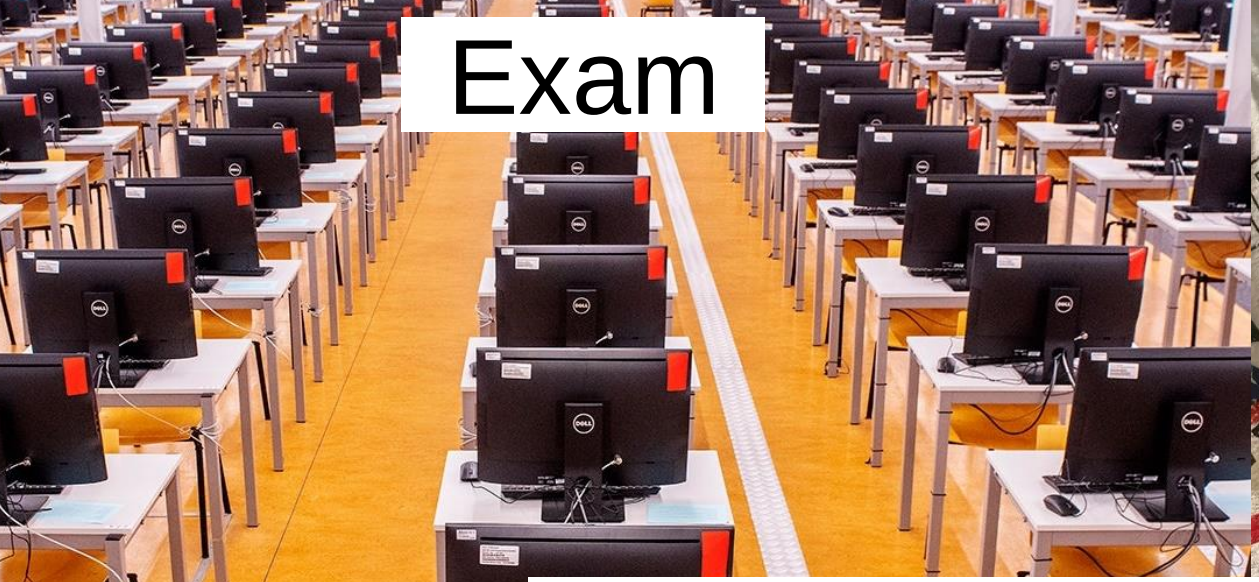
Sends packets from one **machine** to another over a network

Sends frames from one machine to another over a single link

Sends bits over a physical medium

Basic principles and course overview





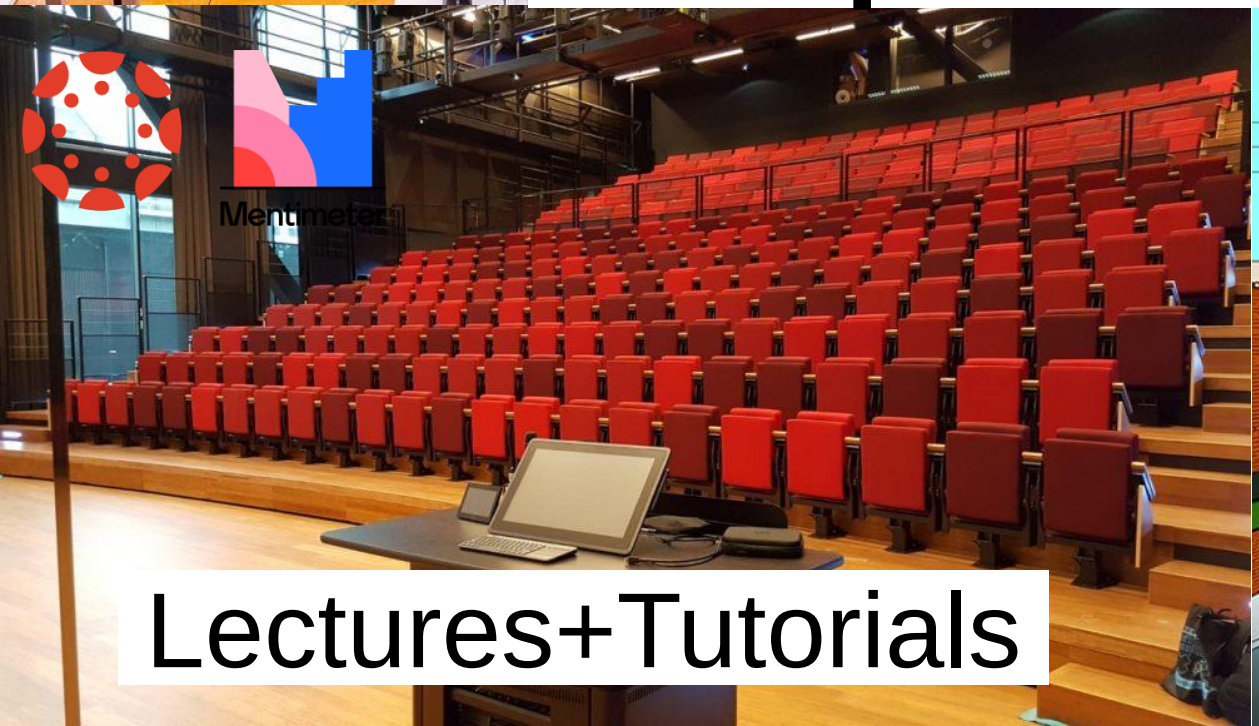
Exam

Lab

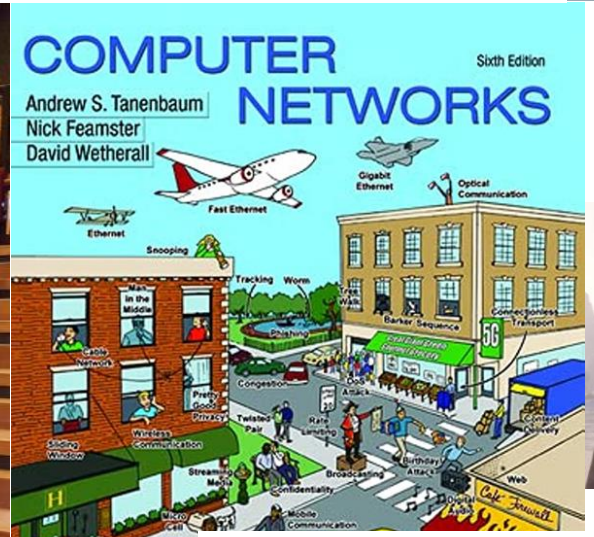
```python
import socket
sock = socket.socket(socket.AF_INET
host_port = ("127.0.0.1", 4321)
sock.connect(host_port)

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

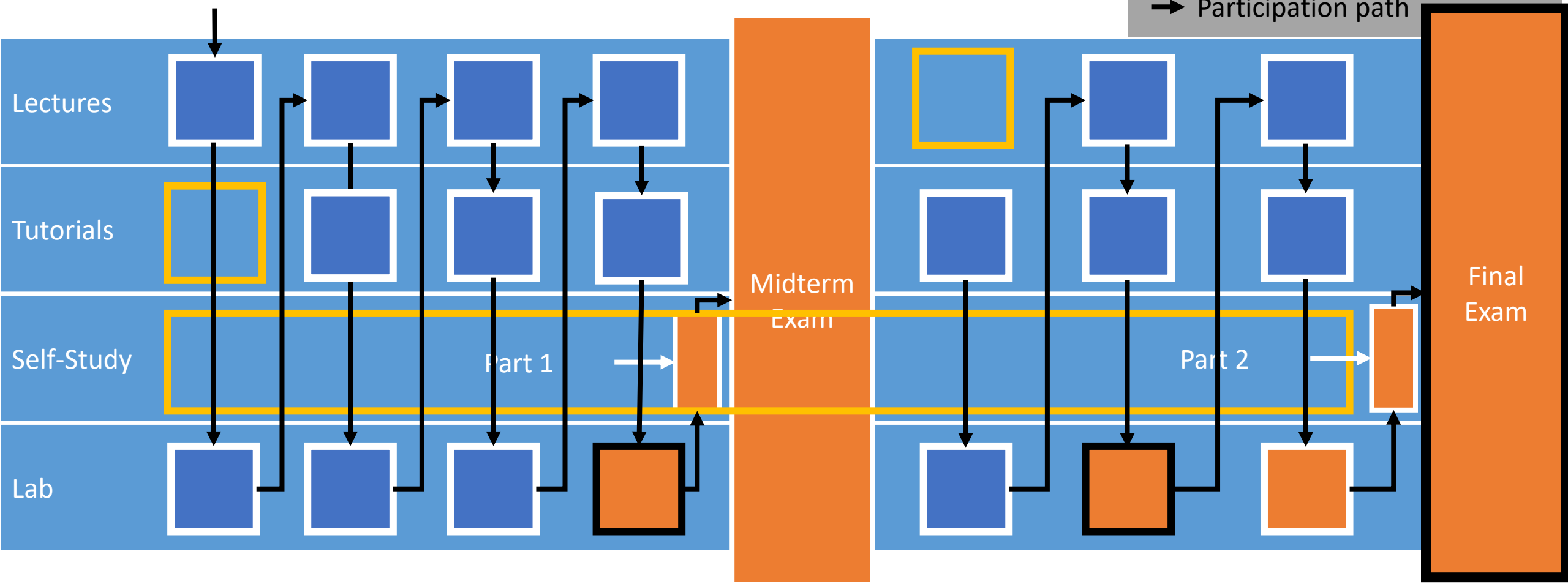


Self-Study

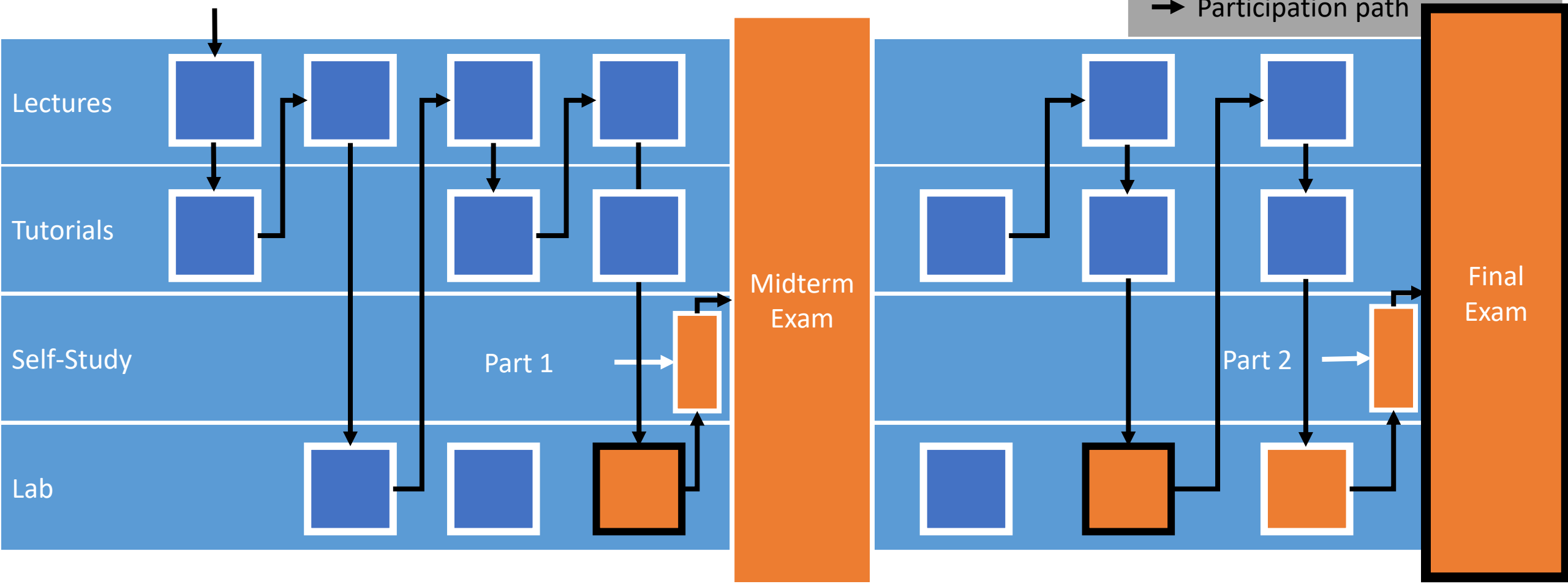
28. Suppose there is a change in the service (set o
does this impact services at layers k-1 and k+1

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

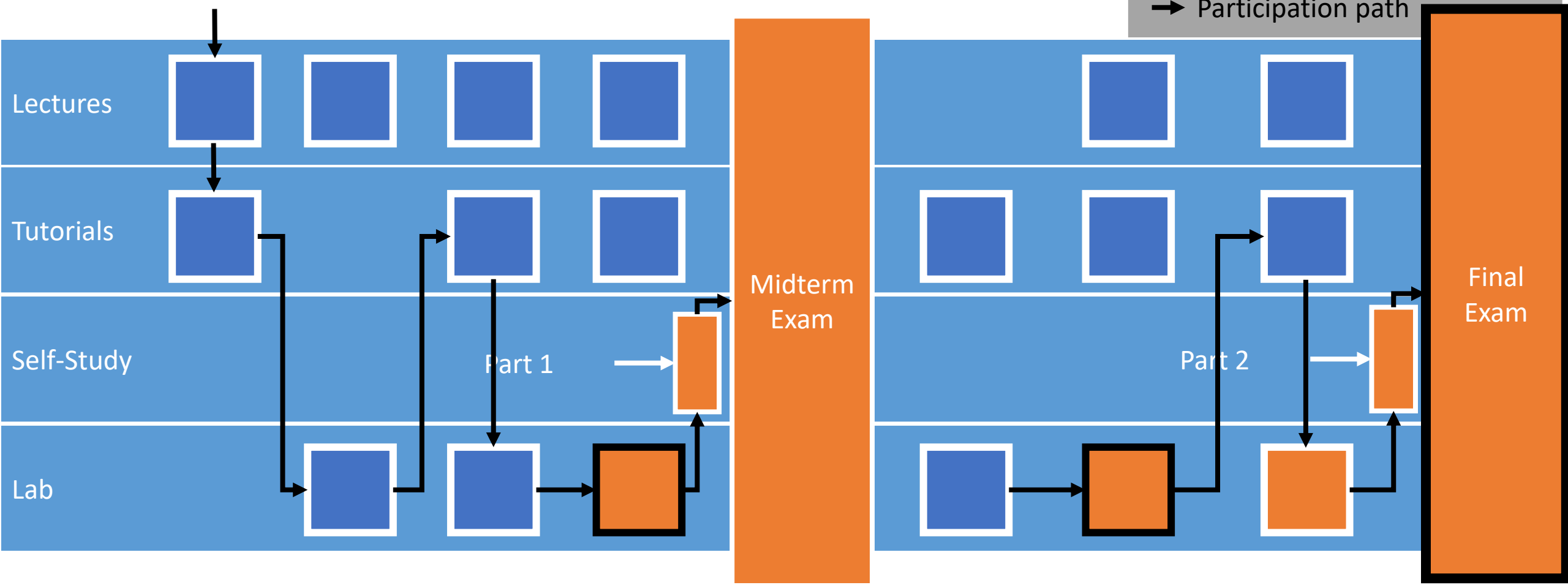
Course Activity Overview



Course Activity Overview



Course Activity Overview



How Am I Graded?

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

* You cannot pass the course without passing the mandatory lab assignment.

Lectures

Collect points by:

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

First quiz is today!

Tutorials: Plenary Practice Sessions

Please use:

- Pen
- Paper

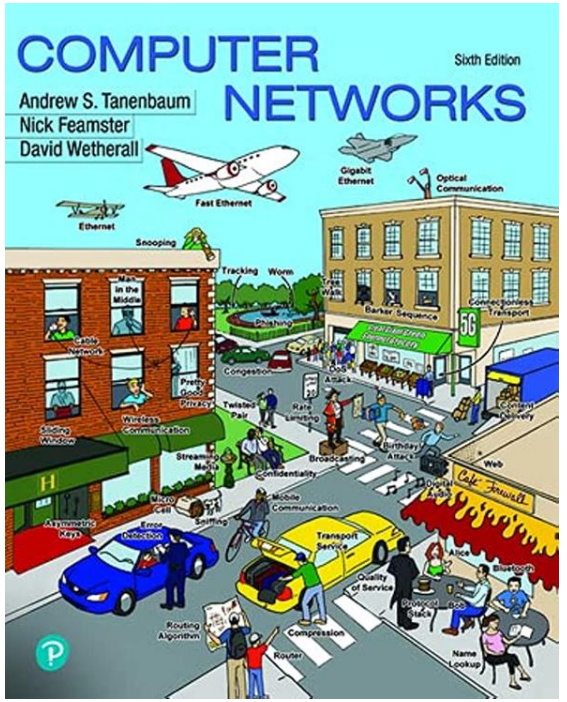
Do not use:

- 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:

- If you successfully completed 2 chapters, you receive +500 points.

Part 2:

- If you complete 2 more chapters, you receive +500 points.
- If you complete 4 more chapters, you receive +1000 points.

How to Participate in the Self-Study?

Join a Self-Study group on Canvas.
Deadline: 12 April.

Submit your Self-Study Plan.
Deadline: 12 April.

We recommend starting as soon as possible, and not wait for this deadline

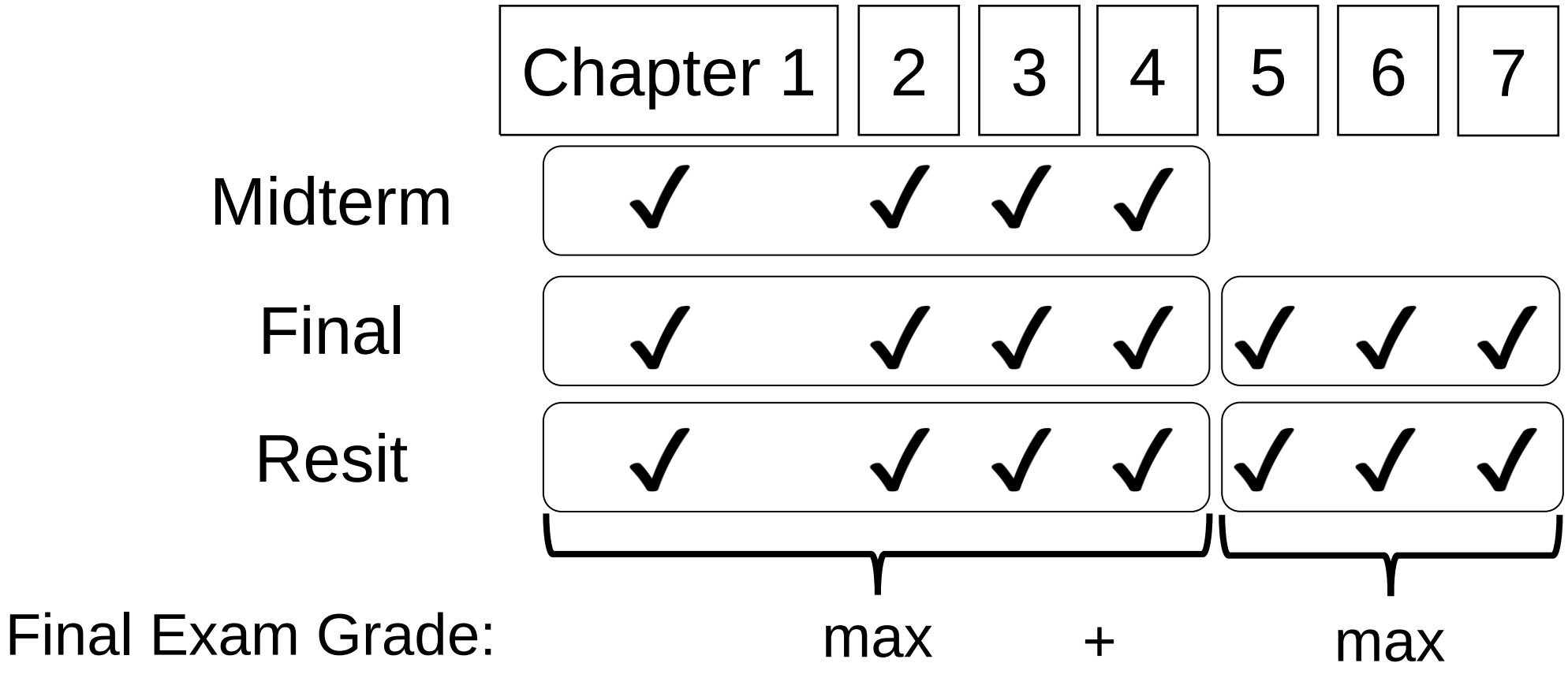
Exams

- Midterm (April 22) and Final (May 31)
- 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 Wednesdays and Fridays.

Use the Canvas groups page to enroll for the one of the sessions.

Lab

Lab Guide specifies several optional assignments

Assignment 1 and 2 are mandatory

For assignment descriptions,
see the ***Lab Guide*** on Canvas.

Lab

Collect points by Completing Lab assignments.

- Small reward for the mandatory assignments
- Larger rewards for the optional assignments

How to Participate in the Lab?

1. On Canvas, create a CodeGrade group for each assignment

Resit students: please team up with another resit student or work by yourself

2. Complete the assignment(s)
3. Submit the assignment(s) on Canvas
4. Enqueue **during** the lab to discuss your solution with a TA

Show and explain your solution for the two mandatory assignments during a lab session in ***week 4*** and ***week 7*** at the latest, respectively

Show and explain your solution for other assignments during a lab session during or in ***week 8*** at the latest

Assignments uploaded to Canvas are not accepted without without TA approval obtained during the lab

Lab Logistics

Important:

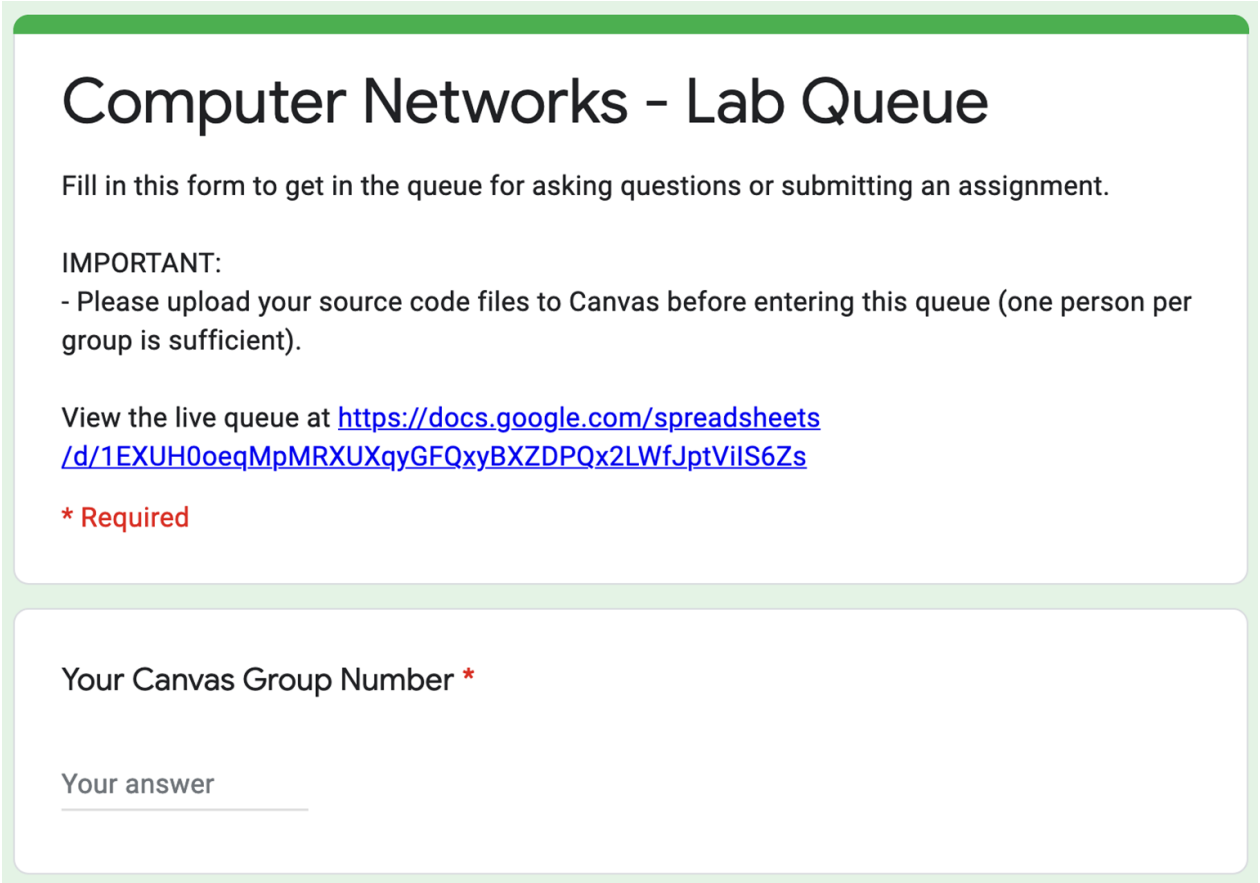
1. The assignments may take more than 4 hours to complete.
2. Getting your assignment approved takes time.

Complete the assignments before the day of their deadline!

How to Hand in Lab Assignments

Submission System:

1. Complete assignment.
2. Upload code/report to Canvas.
3. Enter Queue ➡
4. Wait for, and discuss with, TA.
5. ✅ Assignment approved.
   -or-
   ❌ Go to step 1.



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

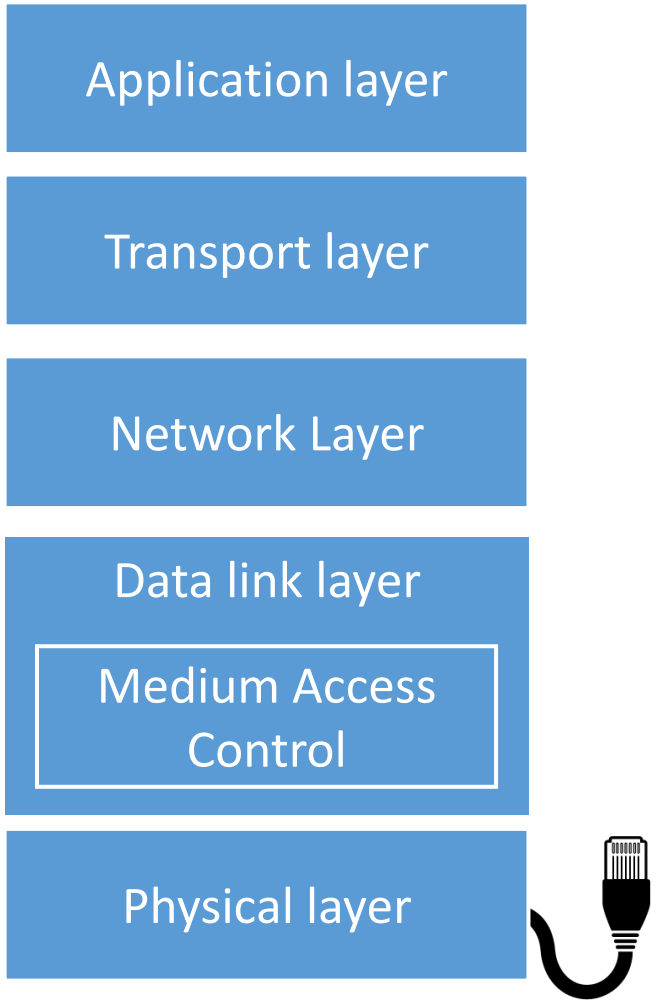
Network layer services

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

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

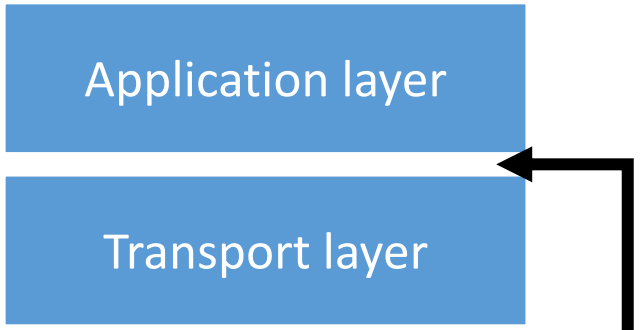
Sends frames from one machine to another over a single link

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?

Send – send data to the other application.

Receive – receive data from the other application.

Close – close the connection.

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*.

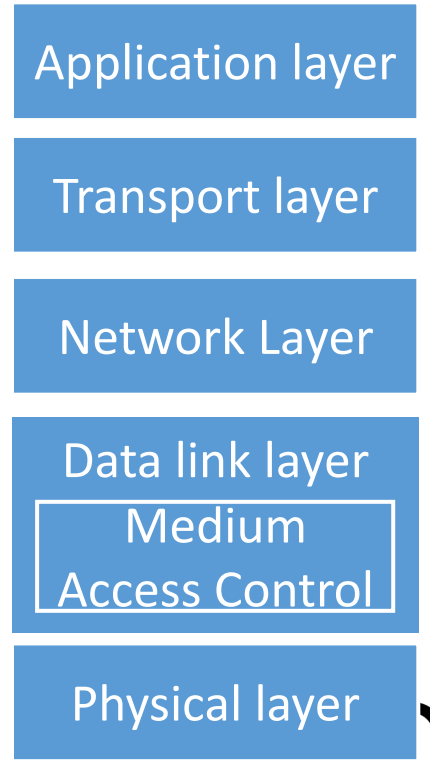
TCP Sockets in Python

```
# 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)

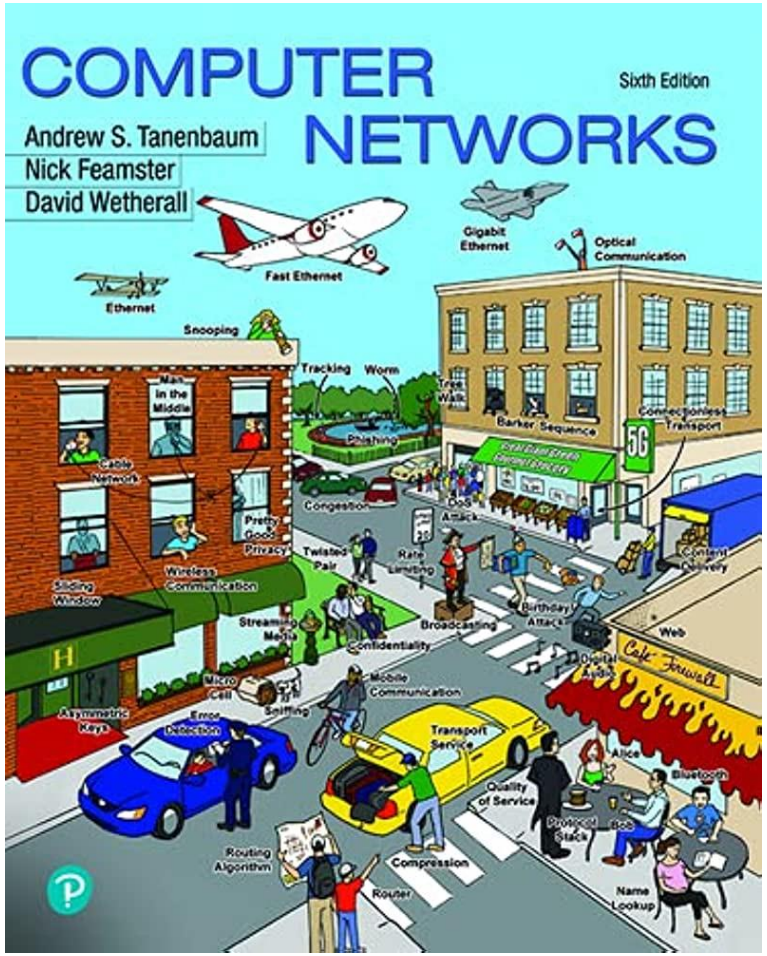
Threading Python

```
# 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)
```

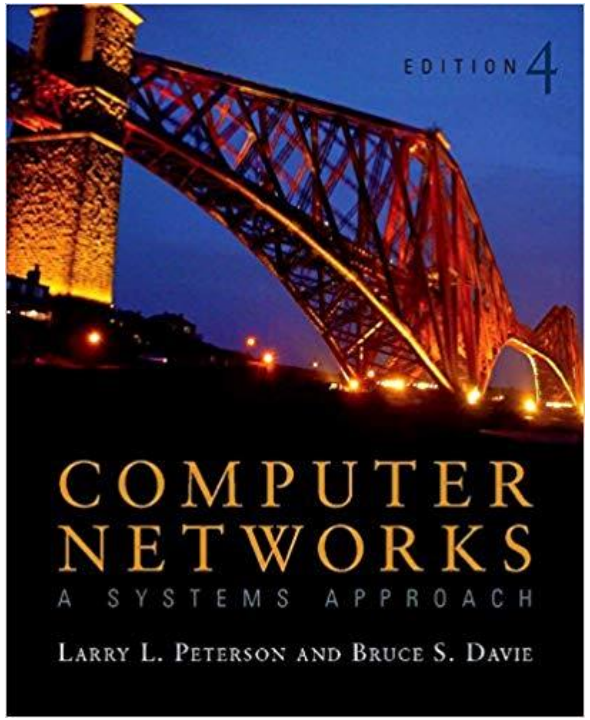
Course Material

Course Material:

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

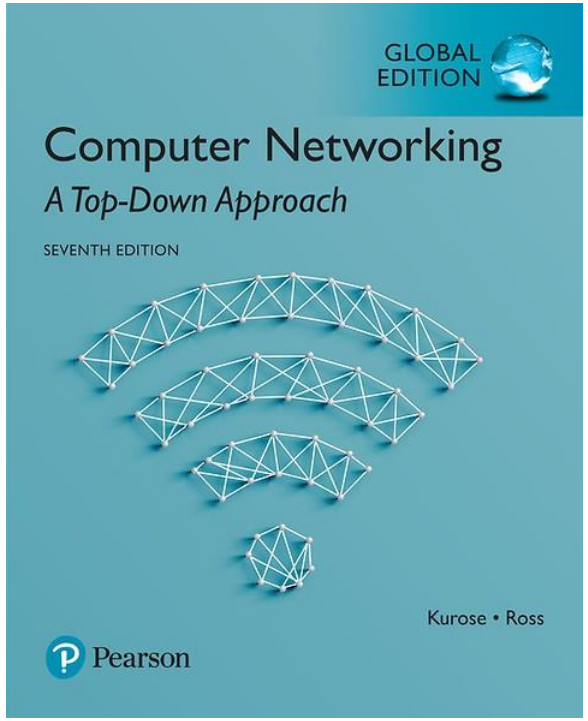


Other Computer Networks Books



Peterson and Davie

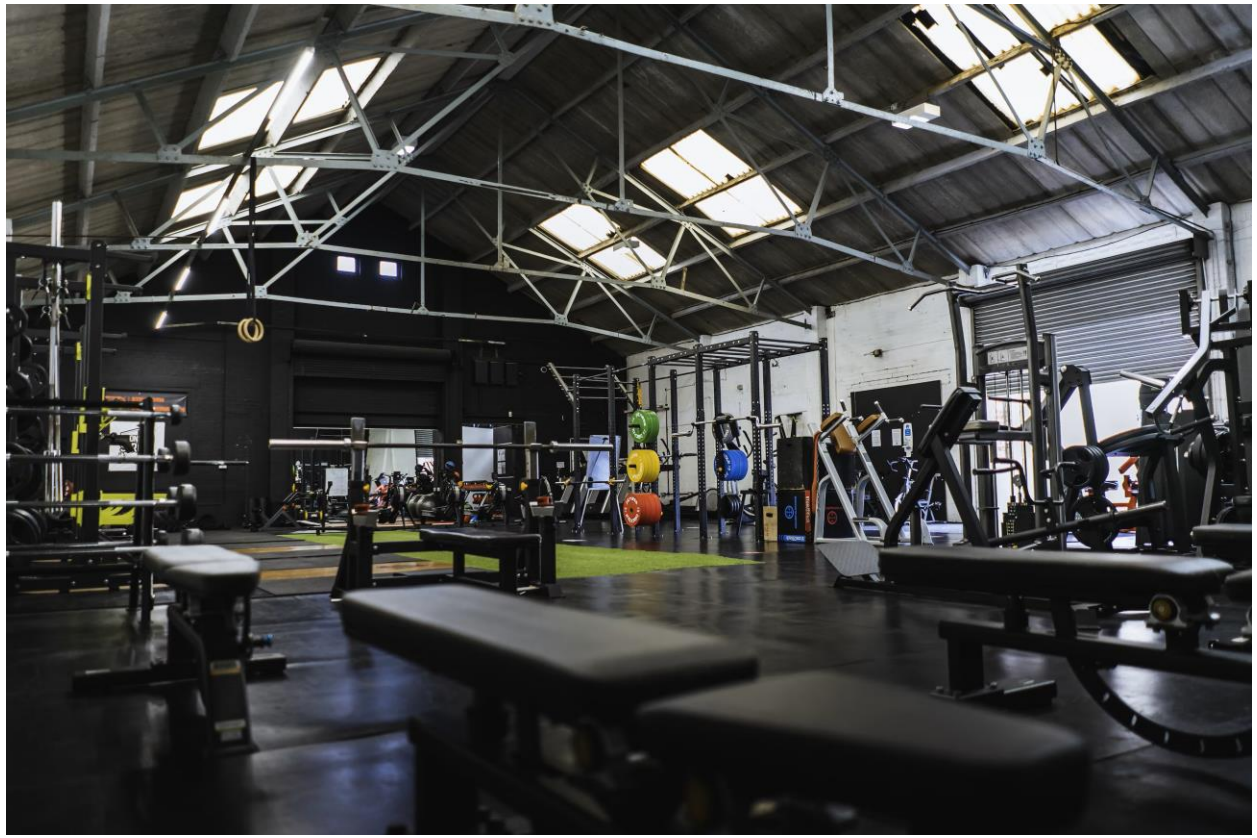
Available for free at
https://book.systemsapproach.org

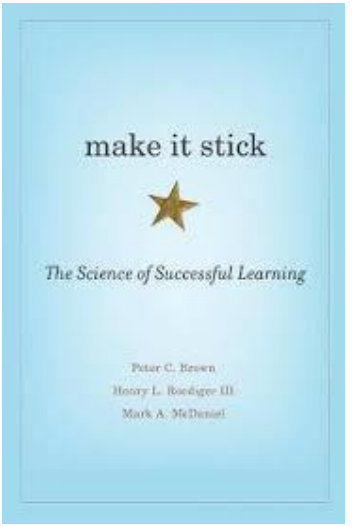


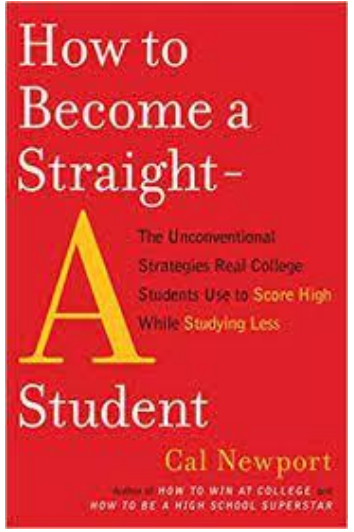
Kurose and Ross

How to Study (for this Course)

Or: how we view our own course







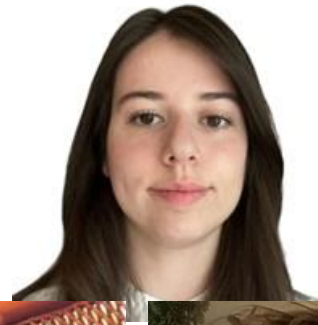
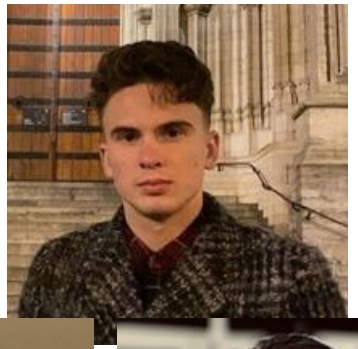
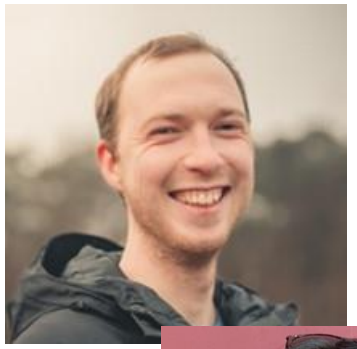
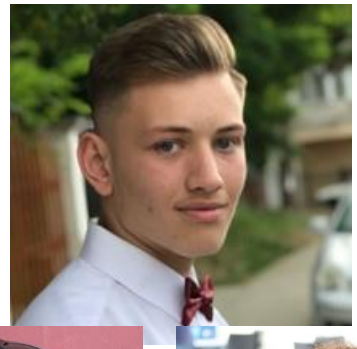
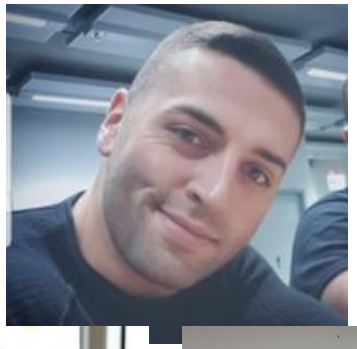
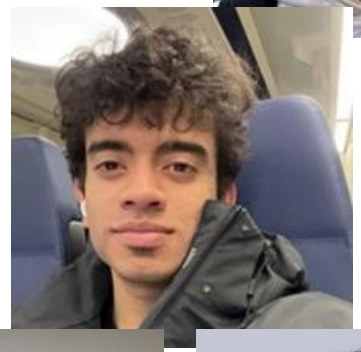
Teaching (us) and learning (you)

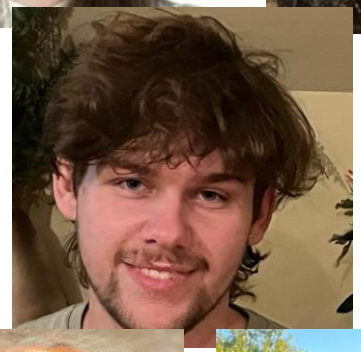
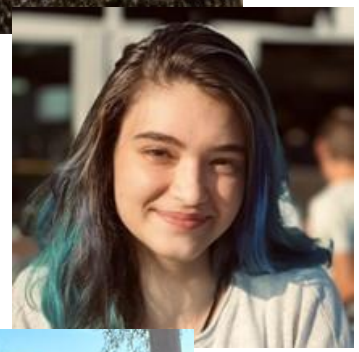
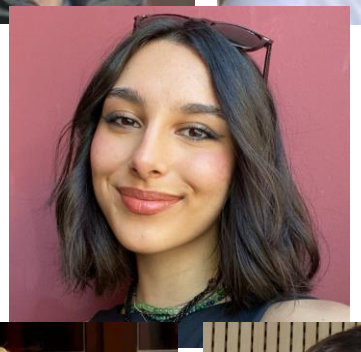
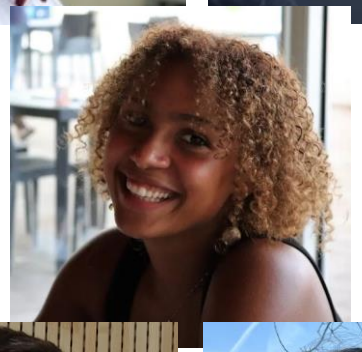
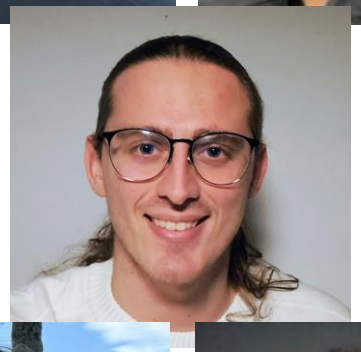
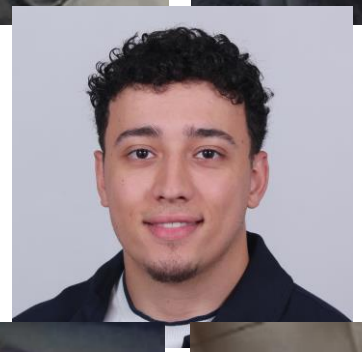
Our recommendations:

- Producing is better than consuming (Do exercises, write programs, quiz yourself, etc.)
- Learn how to study effectively
  - Example books: Make It Stick, How to Become a Straight-A Student

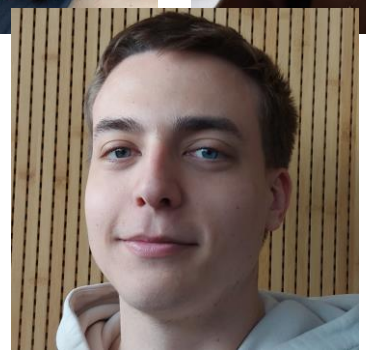
https://unsplash.com/photos/CmGkazPyiKQ

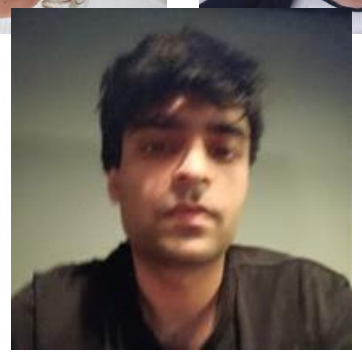
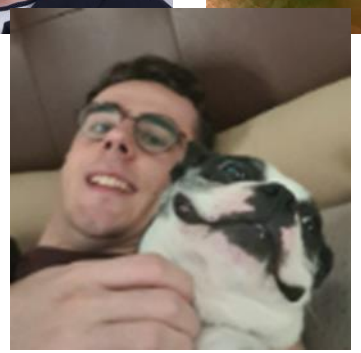
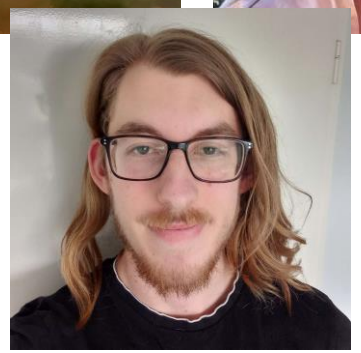
Meet the Team!






+11 others whose picture I could not get in time (sorry!)

How to Contact the Team?

Talk to us at the lab/lecture/tutorial

• Expected response time: *minutes*

Canvas discussion board

• Expected response time: *hours*

Mail us at compnet2024.beta@vu.nl

• Expected response time: *days*

Next steps

1. Participate in the Entry Quiz! Earn your first points!
2. Read the course syllabus (10 pages)
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

Next stop: Physical Layer