

Computer Networks X_400487

Lecture 1: Introduction to Computer Networks

Welcome! Lecture starts at 15:30



Lecturer: Jesse Donkervliet



Copyright Jesse Donkervliet 2024

Vrije Universiteit Amsterdam



Copyright Jesse Donkervliet 2024

<https://www.uva.nl/en/computer-networks/lectures/1-introduction-to-computer-networks>

2

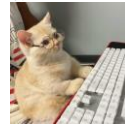
WAN Types	Dynamic IP Static IP PPPoE PPTP L2TP	NAT Forwarding	Port Forwarding DMZ URoP Virtual Server IGMP Proxy
1. After this course, you understand router specifications			
WIRELESS			
Standards	IEEE 802.11a/b/g IEEE 802.11n/ac/ah/5 GHz IEEE 802.11ax/be/bq/2.4 GHz	DHCP	Address Reservation DHCP Client List Server
WiFi Speeds	AXES400 6 GHz: 2402 Mbps (802.11ax) 5 GHz: 2402 Mbps (802.11ax) 2.4 GHz: 574 Mbps (802.11n)	DDNS	TP-Link NO-IP DynDNS
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

Copyright Jesse Donkervliet 2024

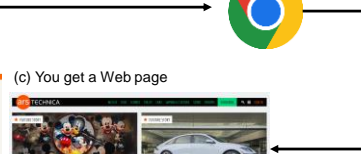
<https://www.tcf.nl.com/en/home-networking/wifi/router/802.11ax/be/bq/2.4ghz>

3

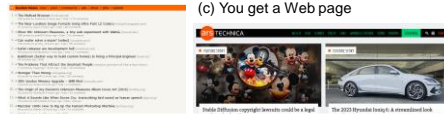
(a) Type address in browser



(b) Browser does magic



(c) You get a Web page



2. After this course, you understand browser magic

Copyright Jesse Donkervliet 2024

4



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

Copyright Jesse Donkervliet 2024

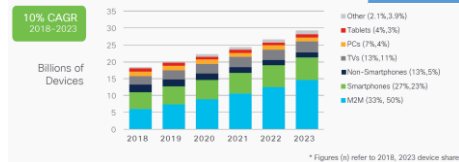
Image source: Nvidia, NASA. <https://www.4mat.com/tech/ai/ai-networks/ai-networks-how-ai-works-what-is-ai-network-what-is-ai-network-what-is-ai-network/>

5

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?



* Figures (a) refer to 2018, 2023 device share

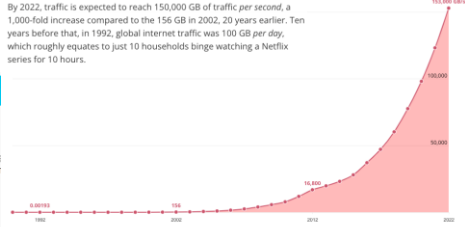
Copyright Jesse Donkervliet 2024

Download Cisco report: <https://www.cisco.com/c/en/us/solutions/collateral/executive-perspectives/annual-internet-report/white-paper/c11741490.html>

6

Global traffic

Growth of global internet traffic in the past 30 years



Figures (t) refer to 2016, 20 Source: Cisco VNI Global #1 Source: WDR 2021 team calculations and Cisco Visual Networking Index: Forecast and Trends, 2017-2022. Copyright: Jesse Darken/Mer 2024 https://www.cisco.com/en/us/solutions/collateral/service-provider/visual-networking-index-vni/vni-hyperconnectivity-ap.html 7

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



Source: Cisco Annual Internet Report, 2018-2023 Copyright: Jesse Darken/Mer 2024 8

THE INTERNET IN 2023 EVERY MINUTE



Google Services Go Down in Some Parts of U.S. People experienced outages of services like Gmail, YouTube and Google Meet.

Facebook's outage likely cost the company over \$60 million Configuration change cascaded down the data centers, bringing systems to a halt.

An Amazon server outage caused problems for Alexa, Ring, Disney Plus, and deliveries Amazon says "many" services have already recovered.

Created by: @Discovery Today & LTHG 1. https://blog.cloudflare.com/2021/facebook-outage/ 2. https://www.polygon.com/2021/11/02/amazon-aws-outage-2021/ 3. https://www.polygon.com/2021/11/02/amazon-aws-outage-2021/ Copyright: Jesse Darken/Mer 2024 9

FEATURE

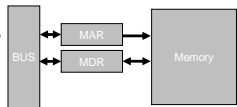
Eve Online is getting crushed by its own success

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."

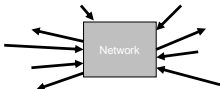
<https://www.polygon.com/2021/11/10/22228832/eve-online-ccp-games-server-problems-2021>
<https://www.polygon.com/2021/11/02/21485296/amazon-aws-outage-2021-11-02>

Why are existing systems not good enough?



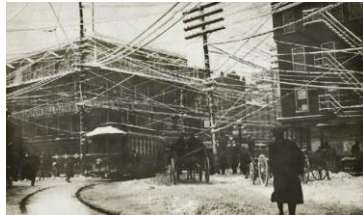
Examples of challenges:

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



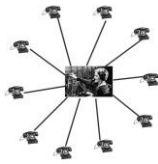
Copyright: Jesse Darken/Mer 2024 11

Early telephone system



Copyright: Jesse Darken/Mer 2024 12

Telephone switching



Human operator



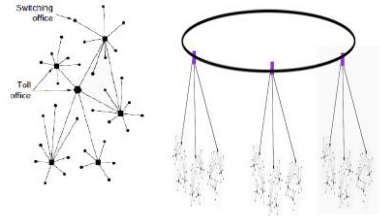
Strowger gear



Copyright Jesse Darken/Net 2024

13

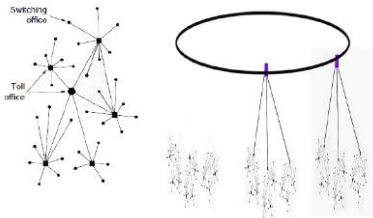
Hierarchical topology



Copyright Jesse Darken/Net 2024

14

Hierarchical topology



Copyright Jesse Darken/Net 2024

15

Military is a big fan of resilient systems

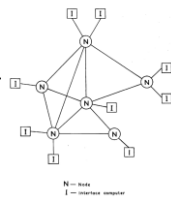
- US military asked RAND Corporation to design a better system (in 1960).
- Paul Baran (RAND employee) designed a fault tolerant network.
- Military asked AT&T to build it.
- They refused...
- Baran's design was forgotten...
- But design improved upon by NPL, built by ARPA.

Copyright Jesse Darken/Net 2024

16

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**

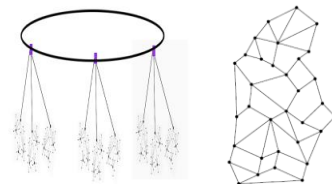


They did not build a prototype, but described its design.

Copyright Jesse Darken/Net 2024

17

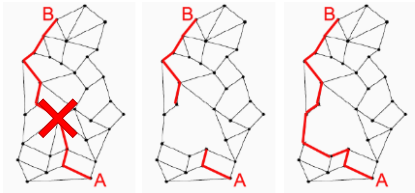
The ARPANET A mesh-structured network



Copyright Jesse Darken/Net 2024

18

The ARPANET Fault tolerance



Copyright Jesse Dorkner 2024

19

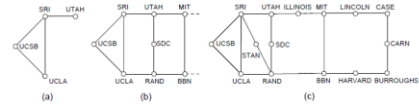
The ARPANET Growth over time

Growth of the ARPANET.

(a) December 1969.

(b) July 1970.

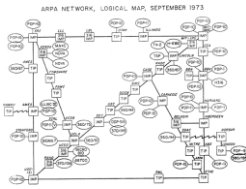
(c) March 1971.



Copyright Jesse Dorkner 2024

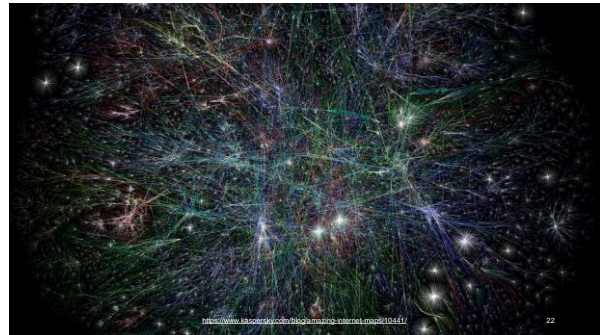
20

The ARPANET Network state in 1973



Copyright Jesse Dorkner 2024

21



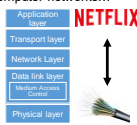
<https://www.kitsofsky.com/blog/visualizing-internet-topology/1044/>

22

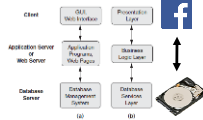
Layered architecture

Can be found in...

...computer networks...



...and other domains



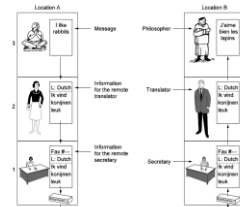
Q: Why use a layered architecture?

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

Copyright Jesse Dorkner 2024

23

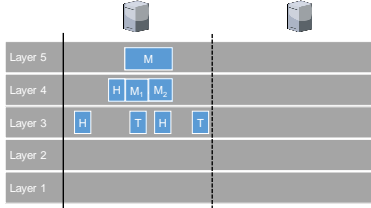
Layered architecture in computer networks: an analogy



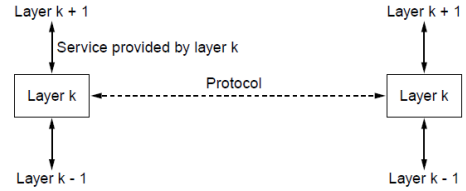
Copyright Jesse Dorkner 2024

24

Layered architecture in computer networks: an overview



Illusion of direct communication

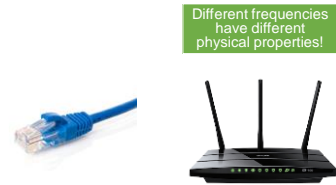


How scale affects networks design

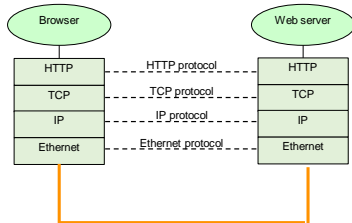
- Personal Area Network (PAN)
 - Example: Bluetooth
- Local Area Network (LAN)
 - Examples: WiFi (802.11)
- Metropolitan Area Network (MAN)
- Wide Area Network (WAN)
- The Internet

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	Metropolitan area network
10 km	City	
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

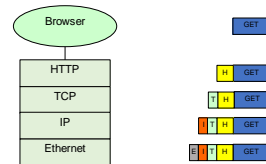
How the medium affects network design



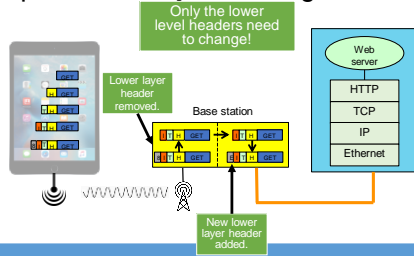
An example protocol



Encapsulation in a protocol stack



The power of a layered design



Multiple reference models for computer networks

Each model has both advantages and disadvantages.

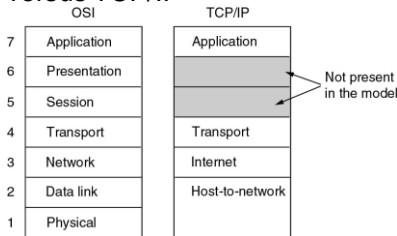
OSI model

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.

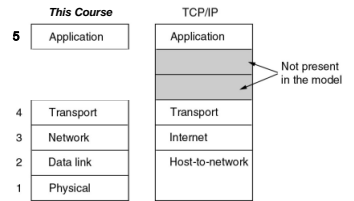
OSI versus TCP/IP



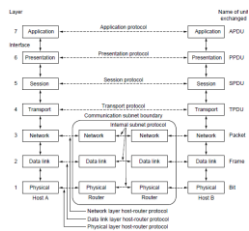
The model used in this course

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

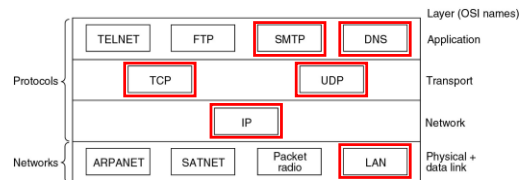
So we skip them!



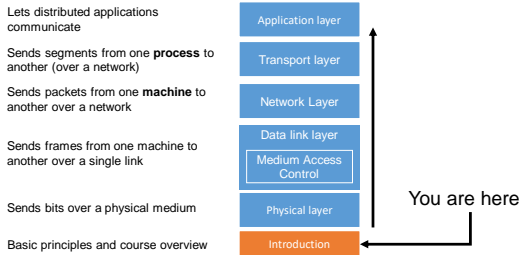
The OSI reference model



Protocols and Networks from the TCP/IP model



Roadmap of the Computer Networks Course



Copyright: Jesse Donkervliet 2024 37

Exam Lab

```

1 import socket
2 sock = socket.socket(socket.AF_INET)
3 sock_port = ("127.0.0.1", 4321)
4 sock.connect(sock_port)
5
6
7 string_bytes = "Sockets are great!".encode()
8 bytes_len = len(string_bytes)
9 num_bytes_to_send = bytes_len
10 while num_bytes_to_send > 0:
11     k = string_bytes[:num_bytes_to_send]
12     num_bytes_to_send -= sock.send(k)
    
```

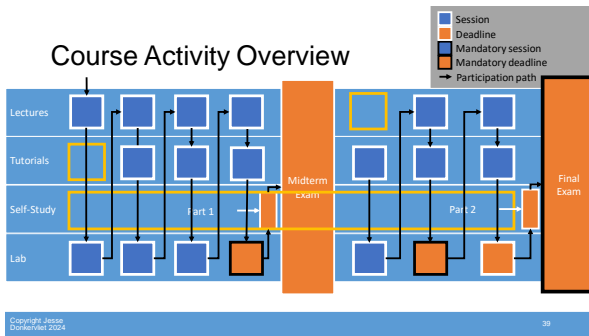
Computer Networks

Lectures+Tutorials Self-Study CO-OP WORKS

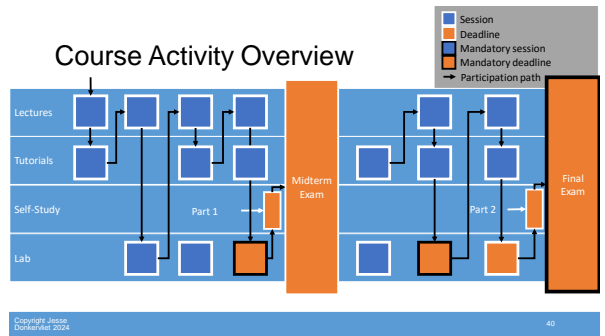
28. Suppose there is a change in the service (set o does this impact services at layers k-1 and k+1?

29. Provide a list of reasons for why the response becomes delay.

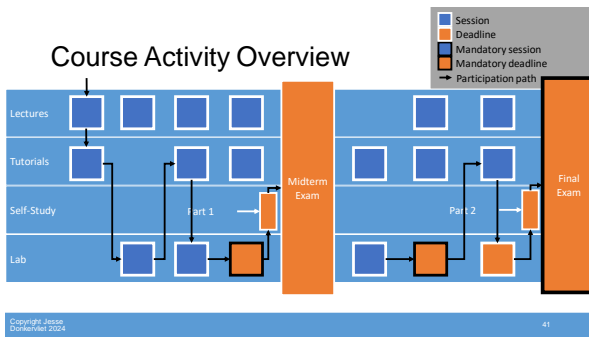
Course Activity Overview



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.

Copyright: Jesse Donkervliet 2024 41

Copyright: Jesse Donkervliet 2024 42

Lectures

Collect points by:

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

First quiz is today!

Copyright, Jesse
Dordevet 2024

43

Tutorials: Plenary Practice Sessions

Please use:

- Pen
- Paper

Do not use:

- Calculators
- AI Chatbots
- Other external tools

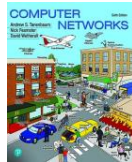
Copyright, Jesse
Dordevet 2024

44

Self-Study: Completing Book Exercises

Complete exercises from the book in a group.

Earn more points by
completing more chapters.



Copyright, Jesse
Dordevet 2024

45

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.

Copyright, Jesse
Dordevet 2024

46

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

Copyright, Jesse
Dordevet 2024

47

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

Copyright, Jesse
Dordevet 2024

48

Exam Content and Grades

	Chapter 1	2	3	4	5	6	7
Midterm	✓	✓	✓	✓			
Final	✓	✓	✓	✓	✓	✓	✓
Resit	✓	✓	✓	✓	✓	✓	✓

Final Exam Grade: max + max

Copyright, Jesse
Dankert 2024

49

Lab

Logistics

Copyright, Jesse
Dankert 2024

50

Lab

Labs on Wednesdays and Fridays.

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

Copyright, Jesse
Dankert 2024

51

Lab

Lab Guide specifies several optional assignments

Assignment 1 and 2 are mandatory

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

Copyright, Jesse
Dankert 2024

52

Lab

Collect points by Completing Lab assignments.

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

Copyright, Jesse
Dankert 2024

53

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

Copyright, Jesse
Dankert 2024

54

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.

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://canvas.lanl.gov/courses/13968/assignments/12112028/queue>

*** 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

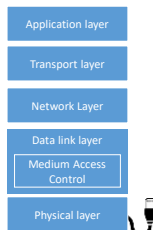
Network layer services

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

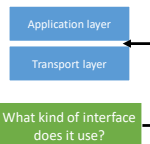


Network layer services

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?

Send – send data to the other application.

Receive – receive data from the other application.

Close – close the connection.

Used to allow incoming connections

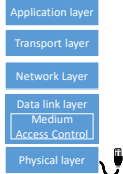
Bind – assign a *local address* to the socket.

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()
```



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)
HELLO - F R O M J E S
s.recv(2048)
S E \n W H O \n
s.recv(2048)
S E N D E C H O B O T H
s.recv(2048)
E L L O W O R L D \n
```

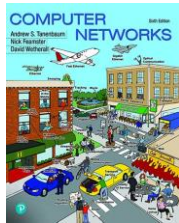
Threading Python

```
# 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)
```

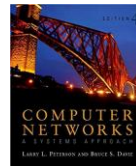
Course Material

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

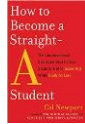
Available for free at <https://book.systemsapproach.org>



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

Copyright: Jesse Donker/Mart 2024

<https://unspibeb.com/photos/CompNet2024>

67

Meet the Team!



Copyright: Jesse Donker/Mart 2024

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

68

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*

Copyright: Jesse Donker/Mart 2024

69

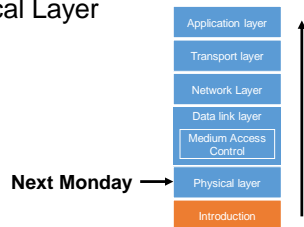
Next steps

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

Copyright: Jesse Donker/Mart 2024

70

Next step: Physical Layer



Next Monday →

Copyright: Jesse Donker/Mart 2024

71