Assignment 1

Thinking in Layers

Assignment Overview

- Getting familiar with Packets and Layers
- Doing some hands-on work with packets on the Internet
- Learning more about different application layer protocols

Question 1 (a)

Compare circuit switching to packet switching with respect to the delays that occur. Which parts / processes contribute to the delay in circuit switching and in packet switching, respectively?

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Circuit Switching

- Propagation delay
- Transmission delay
- Queuing delay
- Nodal processing delay
- Setup delay

Packet Switching

- Propagation delay
- Transmission delay
- Queuing delay
- Nodal processing delay

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Packet Switching

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Question 1 (b)

A link with a bandwidth of 60 Mbit/s is to be shared by several users. Each user needs 1 Mbit/s to send, but is only active in 25 % of the time. How many users can be connected if circuit switching is used? Justify your answer briefly.

Question 1 (b)

A link with a bandwidth of 60 Mbit/s is to be shared by several users. Each user needs 1 Mbit/s to send, but is only active in 25 % of the time. How many users can be connected if circuit switching is used? Justify your answer briefly.

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Question 1 (b)

- The important key is circuit switching: The *no sharing principle* means that bandwidth must be reserved for a circuit/user, regardless of whether it is used!
- Hence: Some information we get is not relevant!
- Instead: $|Users| = \frac{Available\ Bandwidth}{Bandwidth\ per\ User}$ -> $|Users| = \frac{60mbit}{1mbit} = 60$

Question 1 (b)

- The important key is circuit switching: The *no sharing principle* means that bandwidth must be reserved for a circuit/user, regardless of whether it is used!
- Hence: Some information we get is not relevant!
- Instead: $|Users| = \frac{Available\ Bandwidth}{Bandwidth\ per\ User}$ -> $|Users| = \frac{60mbit}{1mbit} = 60$
- **Brief** justification: "Because of the no sharing principle, only the bandwidth users *may* need matters."

Questions?

Question 2 (a)

The lecture introduced the concept of the OSI/ISO layering model.

In 1-2 sentences, explain the functionality associated with each of the four lowest layers.

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- OSI/ISO Layering Model
  - Layer 1:
  - Layer 2:
  - Layer 3:
  - Layer 4:
  - Layer 5:
  - Layer 6:
  - Layer 7:

Question 2 (a)

- OSI/ISO Layering Model
  - Layer 1:
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  - Layer 1: Physical Layer
  - Layer 2:
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- OSI/ISO Layering Model
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- OSI/ISO Layering Model
  - Layer 1: Physical Layer
  - Layer 2: Link Layer
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Question 2 (a)

- OSI/ISO Layering Model
  - Layer 1: Physical Layer
  - Layer 2: Link Layer
  - Layer 3: Network Layer
  - Layer 4: Transport Layer
  - Layer 5:
  - Layer 6:
  - Layer 7:

Question 2 (a)

- OSI/ISO Layering Model
  - Layer 1: Physical Layer
    - moves actual bits from one node to the next.
    - Works over the *physical* connection between two hosts
  - Layer 2: Link Layer
    - node-2-node (directly connected) data transfer.
    - Works *independent* of the underlying physical layer (WiFi, Copper, Optical)
  - Layer 3: Network Layer
    - Allows the exchange of data between hosts that are *not* directly connected.
  - Layer 4: Transport Layer
    - allows *applications* to exchange data
    - Enables transparent client-to-server data exchange.

Questions?

Question 2 (b)

Figure 1 shows the three hosts H1, H2, and H3 that connect to the three switches S1, S2, and S3, respectively. All switches connect to the router R1. Explain the decapsulation performed by every device when H1 sends a packet to H3

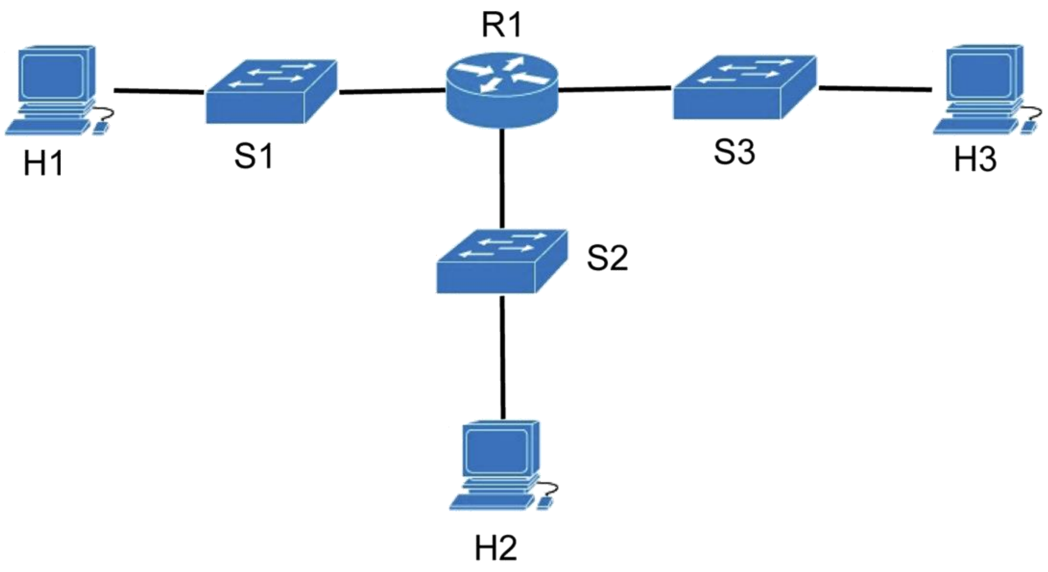

Figure 1: Network topology

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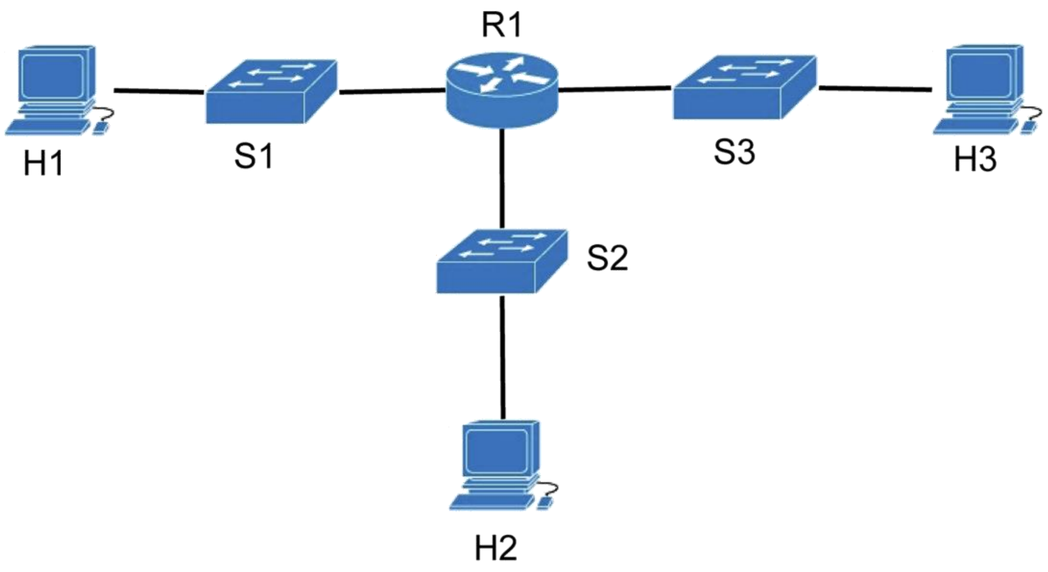

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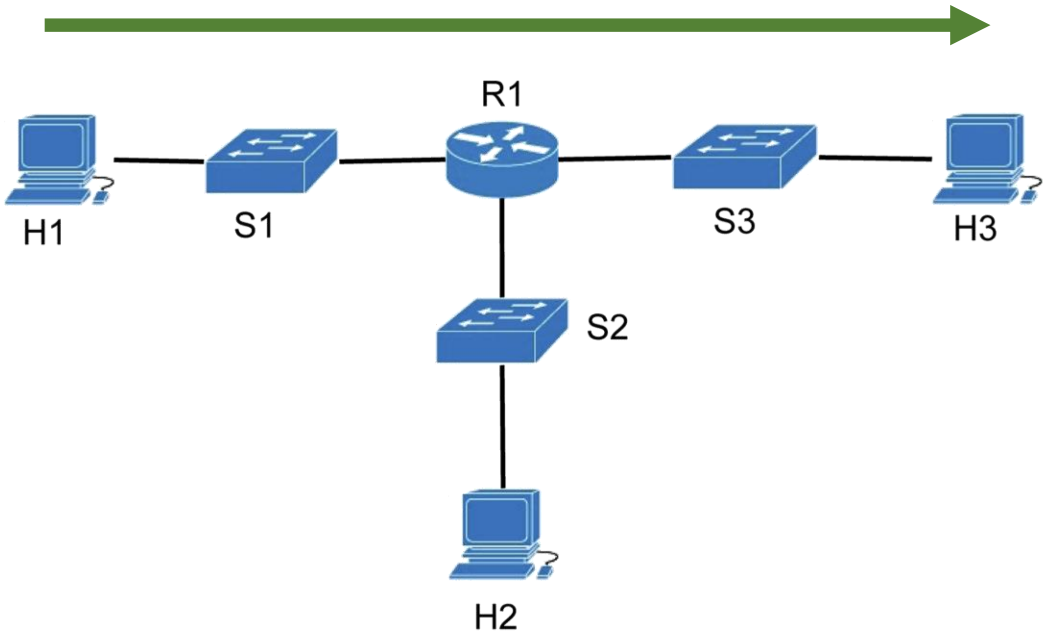

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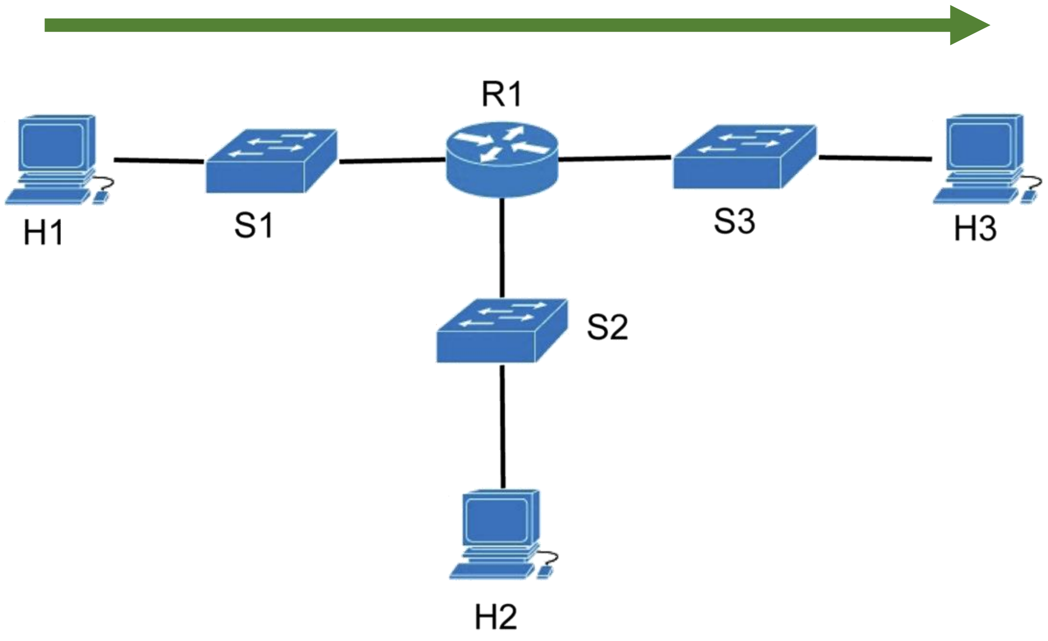

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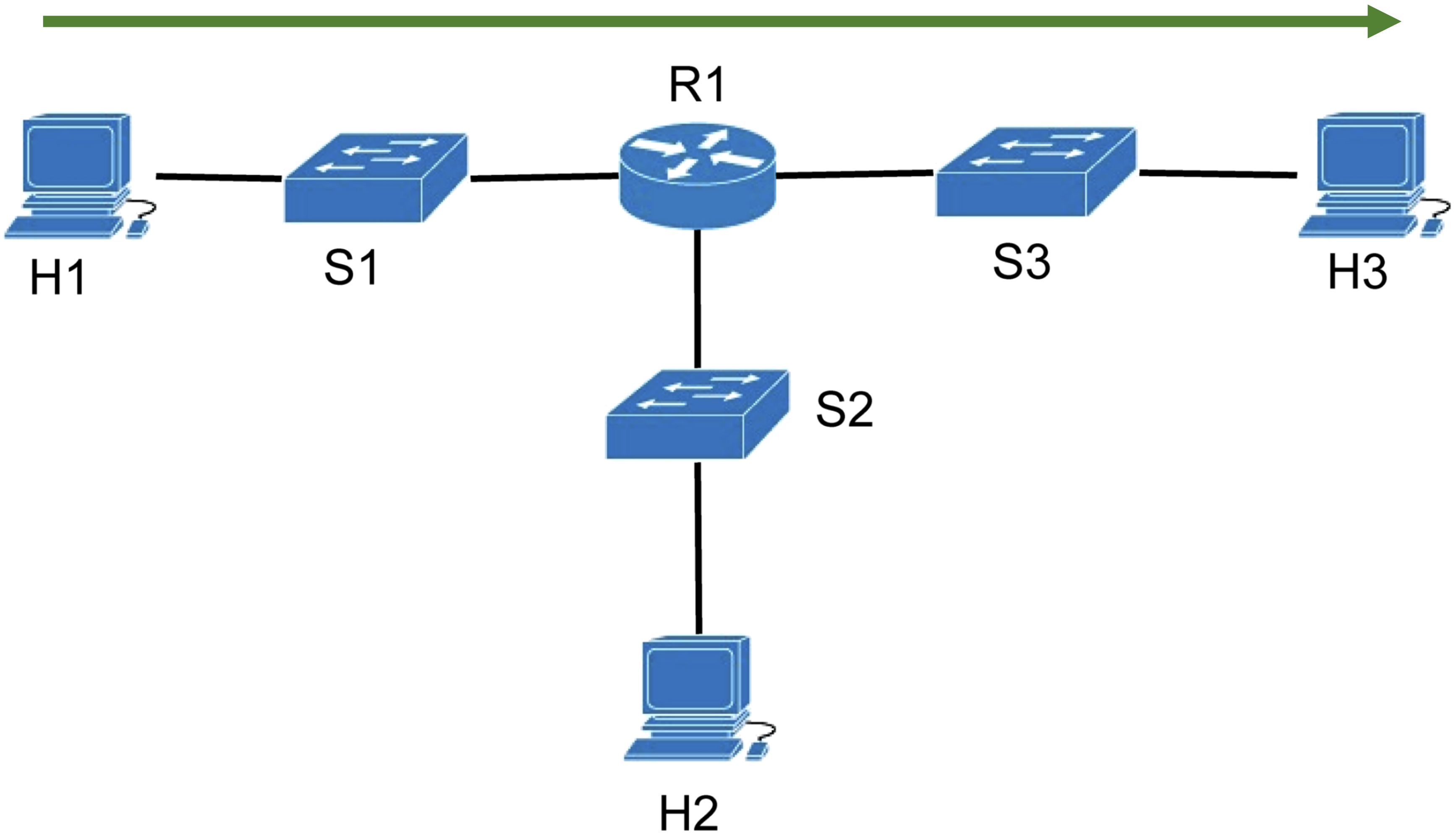

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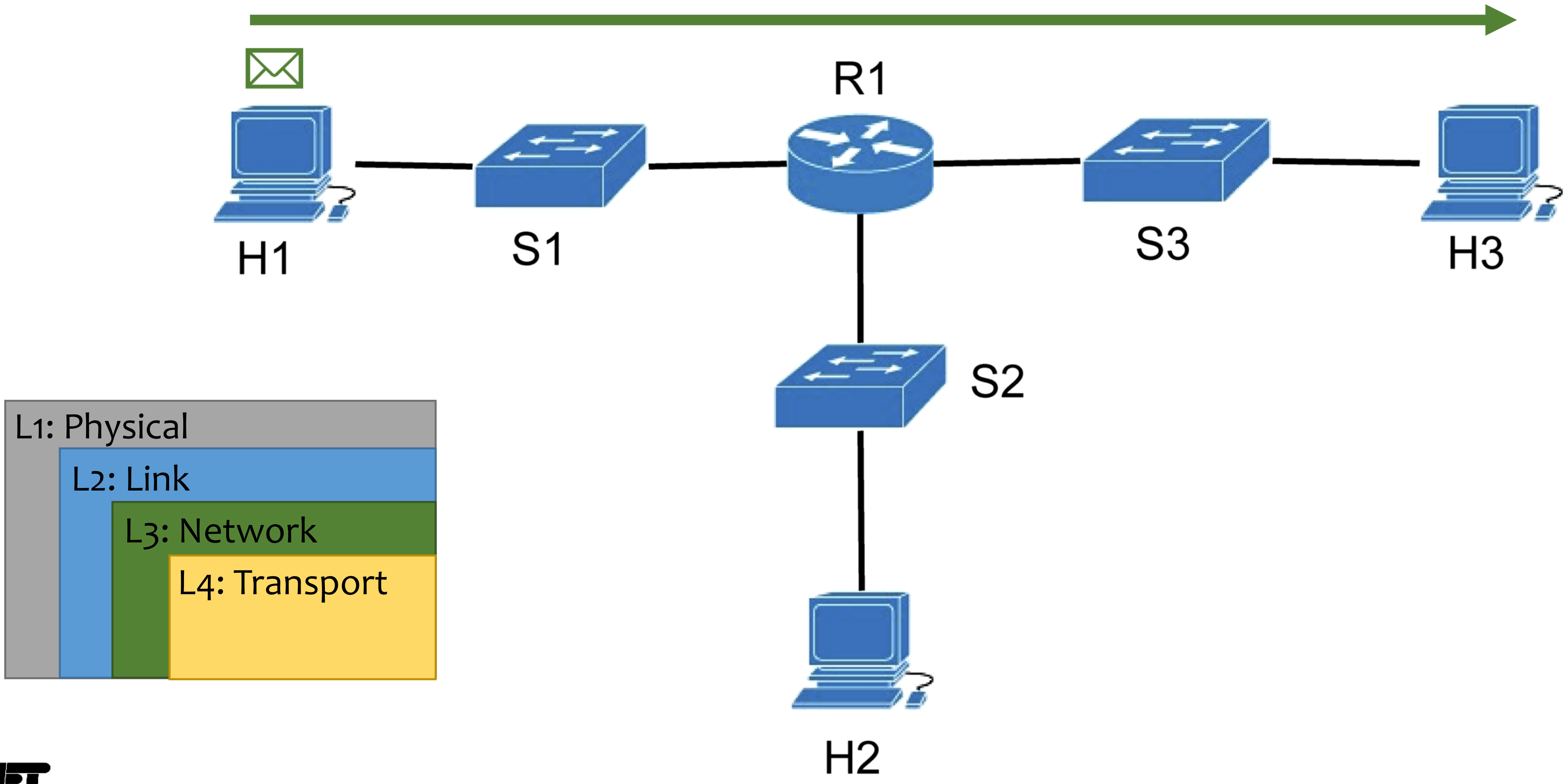
R1
H1
S1
S3
H3
S2
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L1: Physical
L2: Link
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L4: Transport

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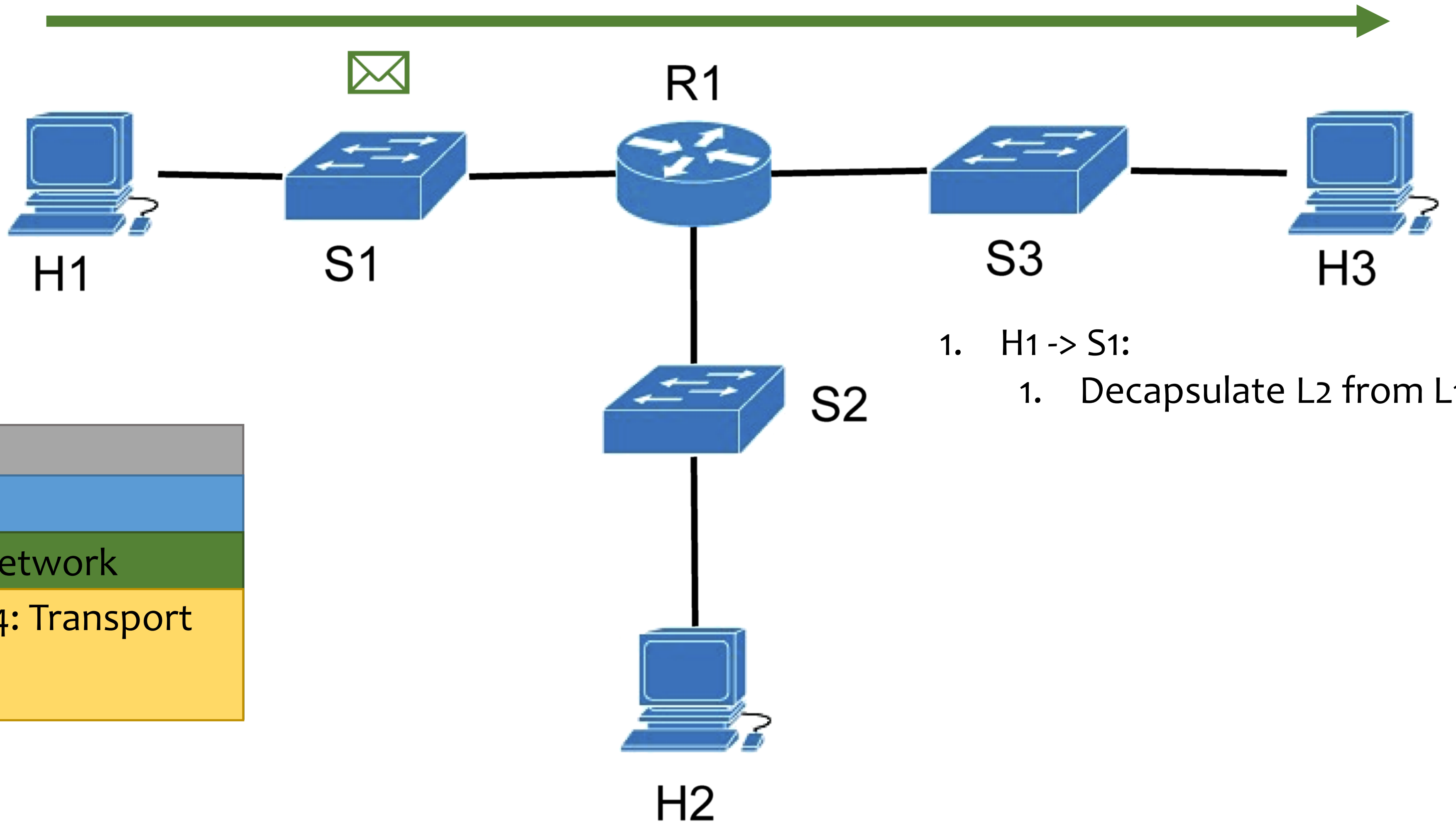

1. H1 -> S1:
    1. Decapsulate L2 from L1

L1: Physical
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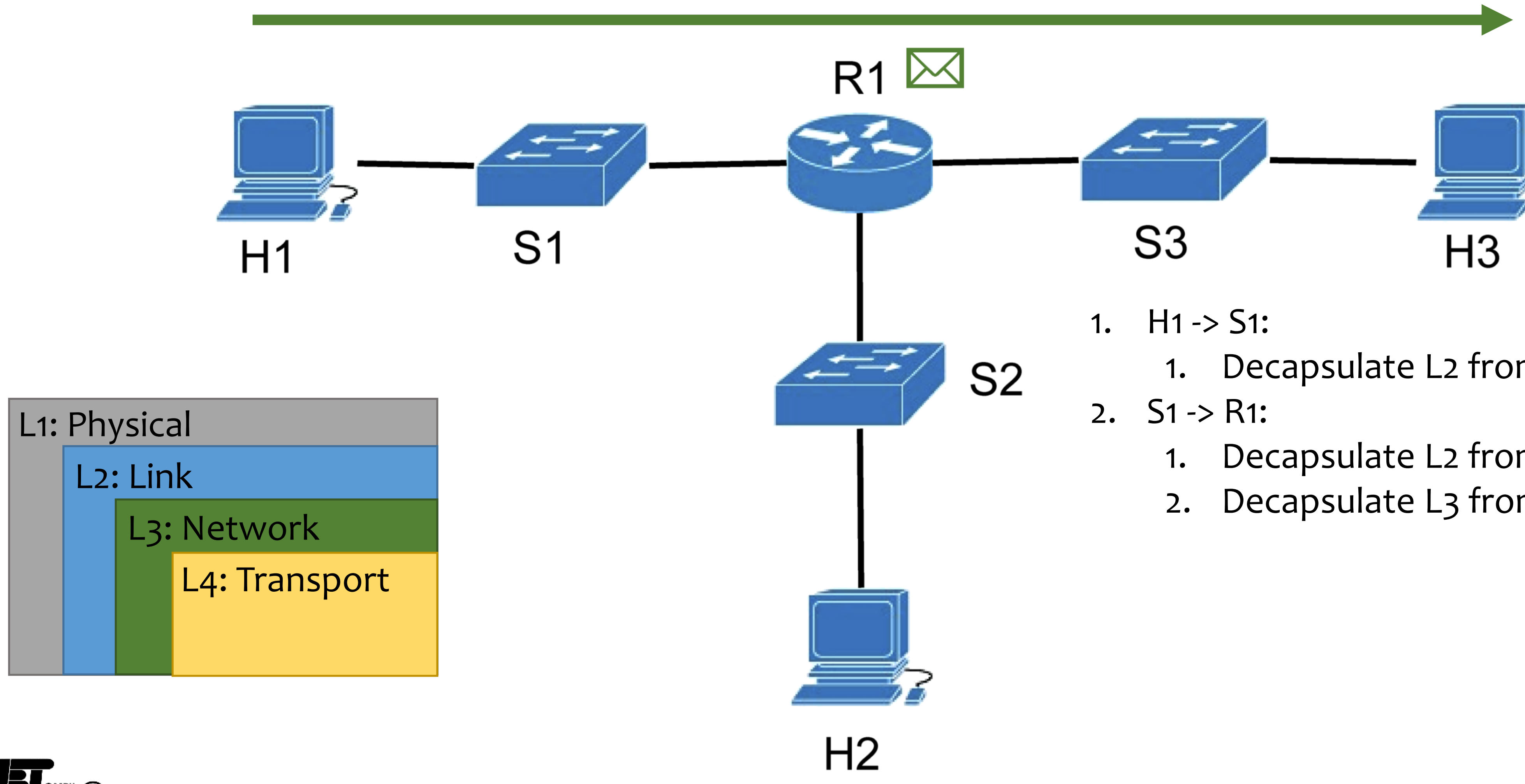

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    2. Decapsulate L3 from L2

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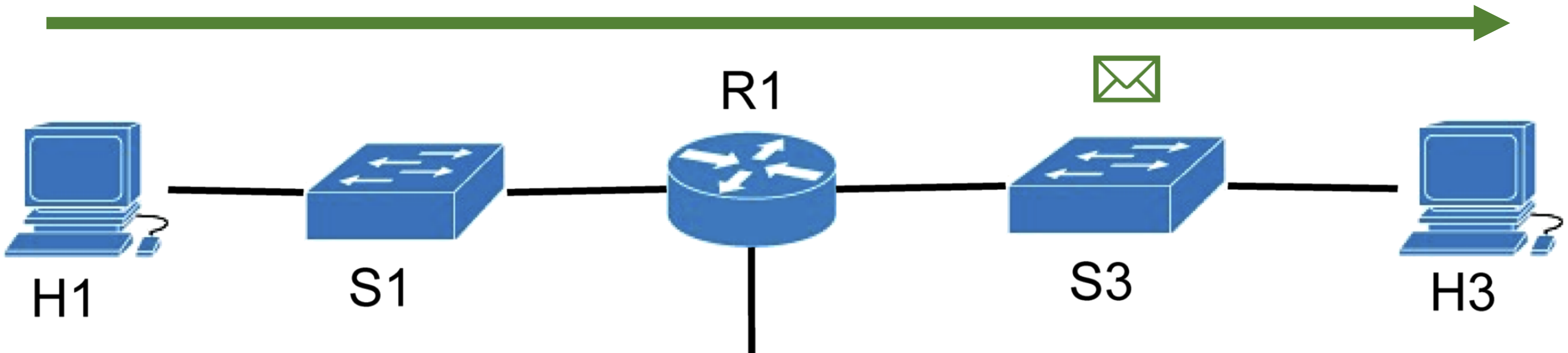

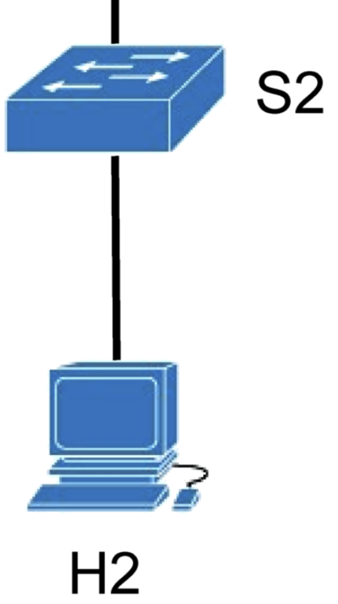

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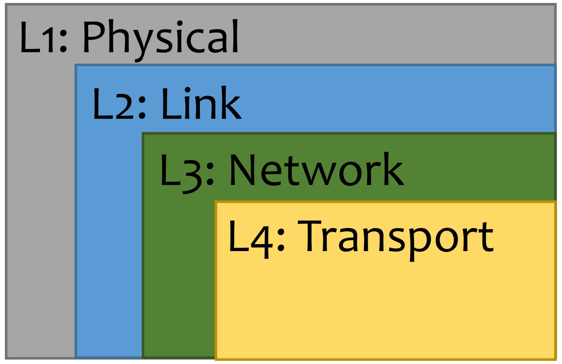

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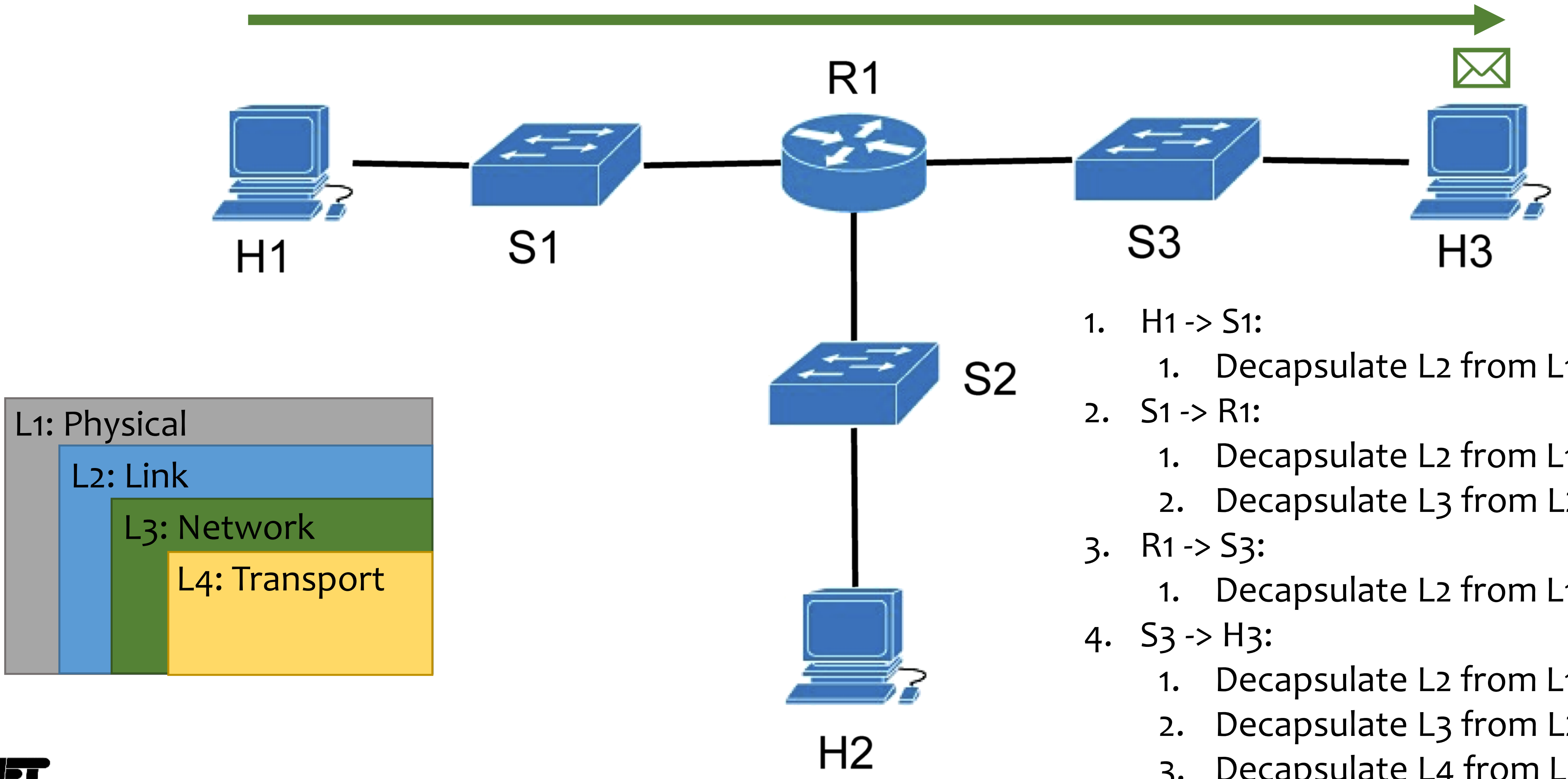

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3. R1 -> S3:
   1. Decapsulate L2 from L1
4. S3 -> H3:
   1. Decapsulate L2 from L1
   2. Decapsulate L3 from L2
   3. Decapsulate L4 from L3

Questions?

Question 3 (a)

Select four universities in Germany, four universities in different European countries and four universities in different countries outside of Europe (12 in total). Ensure that they are pingable and record the average time it takes to get a reply from each target (i.e., the RTT).

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Stockholm	su.se	
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Question 3 (a)

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› ~$ ping -c 4 uni-saarland.de
› PING uni-saarland.de (134.96.7.179) 56(84) bytes of data.
› 64 bytes from webuni...land.de (134.96.7.179): icmp_seq=1
  ttl=55 time=36.7 ms
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  ttl=55 time=37.2 ms
› 64 bytes from webuni...land.de (134.96.7.179): icmp_seq=4
  ttl=55 time=37.8 ms

› --- uni-saarland.de ping statistics ---
› 4 packets transmitted, 4 received, 0% packet loss, time
  3003ms
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TU Munich	tum.de	
TU Berlin	tu.berlin	
Oxford	ox.ac.uk	
Porto	up.pt	
Athens	uoa.gr	
Stockholm	su.se	
MIT	mit.edu	
Sao Paulo	usp.br	
Melbourne	unimelb.edu.au	
Singapore	nus.edu.sg	

Question 3 (a)

```
› ping -c 4  uni-wuerzburg.de
› PING wrz1114.rz.uni-wuerzburg.de (132.187.1.114) 56(84)
  bytes of data.

› --- wrz1114.rz.uni-wuerzburg.de ping statistics ---
› 4 packets transmitted, 0 received, 100% packet loss, time
  3008ms
```

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TU Munich	tum.de	38.279
TU Berlin	tu.berlin	29.655
Oxford	ox.ac.uk	15.416
Porto	up.pt	61.082
Athens	uoa.gr	52.542
Stockholm	su.se	46.888
MIT	mit.edu	16.251
Sao Paulo	usp.br	235.717
Melbourne	unimelb.edu.au	15.458
Singapore	nus.edu.sg	15.675

Question 3 (b)

Determine your geographical distance (in kilometers) from the target. Can you find targets that have a smaller RTT but a larger distance than other targets? Why can this happen? (Give at least 2 reasons)

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Saarland University	uni-saarland.de	37.277	
Lübeck	uni-luebeck.de	30.095	
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Lübeck	uni-luebeck.de	30.095	575
TU Munich	tum.de	38.279	357
TU Berlin	tu.berlin	29.655	578
Oxford	ox.ac.uk	15.416	647
Porto	up.pt	61.082	1513
Athens	uoa.gr	52.542	1830
Stockholm	su.se	46.888	1329
MIT	mit.edu	16.251	5828
Sao Paulo	usp.br	235.717	9671
Melbourne	unimelb.edu.au	15.458	16450
Singapore	nus.edu.sg	15.675	10395

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Lübeck	uni-luebeck.de	30.095	575
TU Munich	tum.de	38.279	357
TU Berlin	tu.berlin	29.655	578
Oxford	ox.ac.uk	15.416	647
Porto	up.pt	61.082	1513
Athens	uoa.gr	52.542	1830
Stockholm	su.se	46.888	1329
MIT	mit.edu	16.251	5828
Sao Paulo	usp.br	235.717	9671
Melbourne	unimelb.edu.au	15.458	16450
Singapore	nus.edu.sg	15.675	10395

Question 3 (b)

Determine your geographical distance (in kilometers) from the target. Can you find targets that have a smaller RTT but a larger distance than other targets? Why can this happen? (Give at least 2 reasons)

- Technology: Faster Servers, Cold-Starts, Better Cables, Routing Quirks, …
- Global distribution: The **responding** server can be geographically closer than the city (e.g. when using CDNs)
- Measurement: Average time distorted by outliers (e.g. random, queuing delays)

Question 3 (c)

As the last thing to do, use your favorite tool to visualize the data and plot the RTT measured in (a) against the distance determined in part (b), showing the distance on the x-axis and the RTT on the y-axis. Make sure that you label the axes and use a legend.

Question 3 (c)

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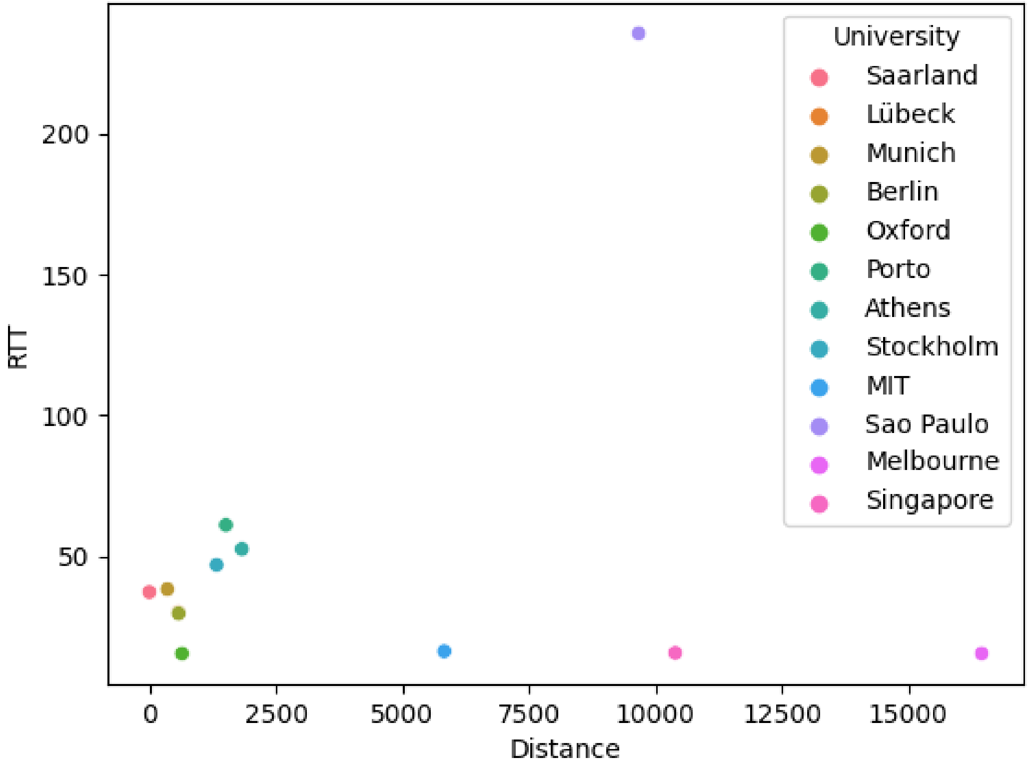
Question 3 (c)

```python
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

df = pd.read_csv('ping.csv')

fig, ax = plt.subplots()
sns.scatterplot(data=df, x='Distance',
y='RTT', hue='University')
plt.show()
```



Question 3 (c)

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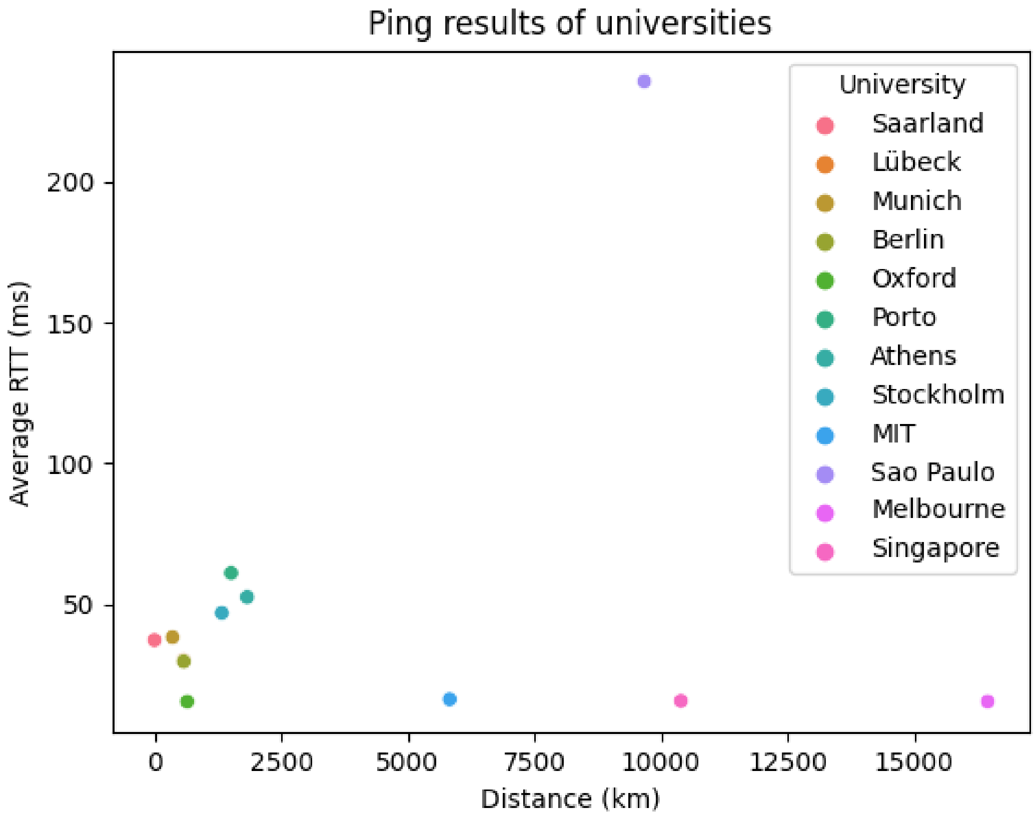
df = pd.read_csv('ping.csv')

fig, ax = plt.subplots()
sns.scatterplot(data=df, x='Distance'
y='RTT', hue='University')
ax.set_xlabel('Distance (km)')
ax.set_ylabel('Average RTT (ms)')
ax.set_title('Ping results of
universities')
plt.show()
```



Question 3 (c)

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df = pd.read_csv('ping.csv')

fig, ax = plt.subplots()
sns.scatterplot(data=df, x='Distance'
y='RTT', hue='University')
ax.set_xlabel('Distance (km)')
ax.set_ylabel('Average RTT (ms)')
ax.set_title('Ping results of
universities')
ax.yaxis.grid(color='gray',
linestyle='dashed')
ax.xaxis.grid(color='gray',
linestyle='dashed')
plt.show()
```
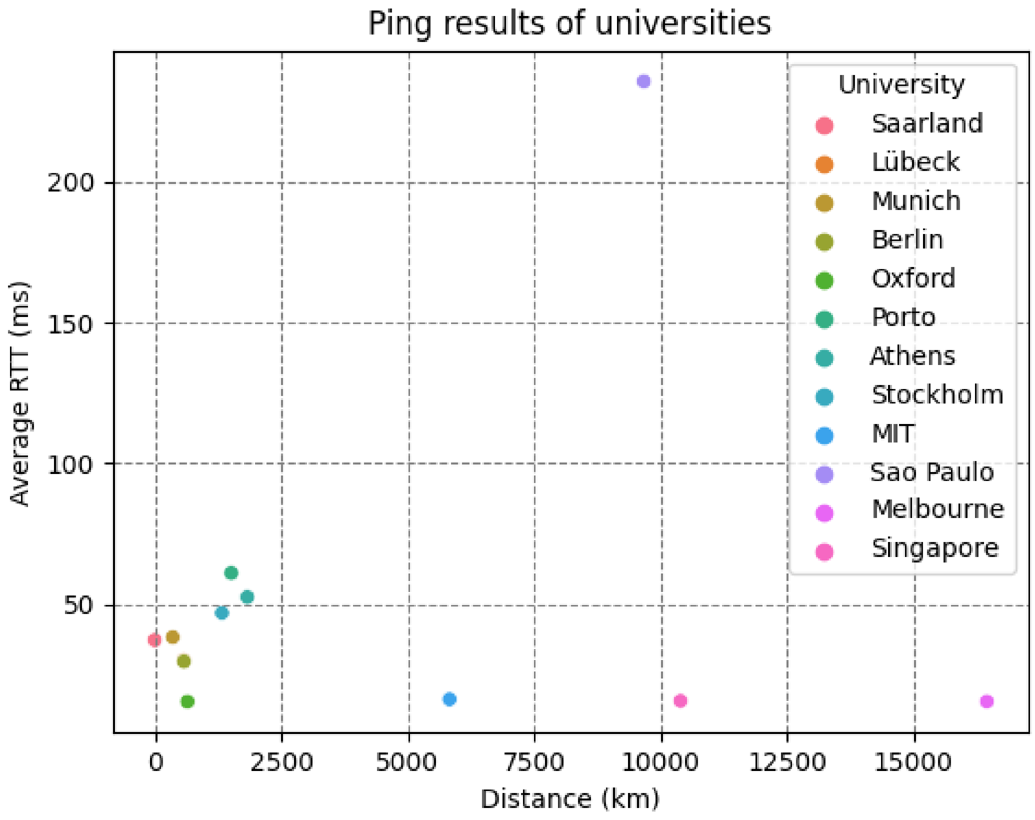
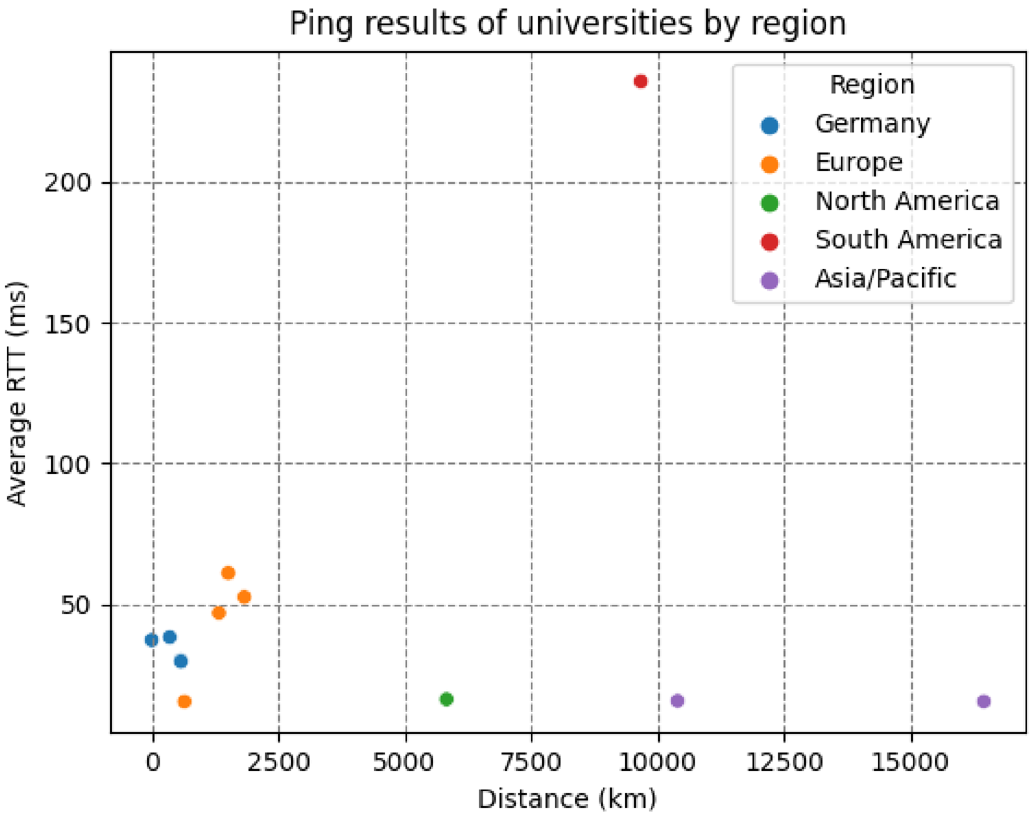



Question 3 (c)

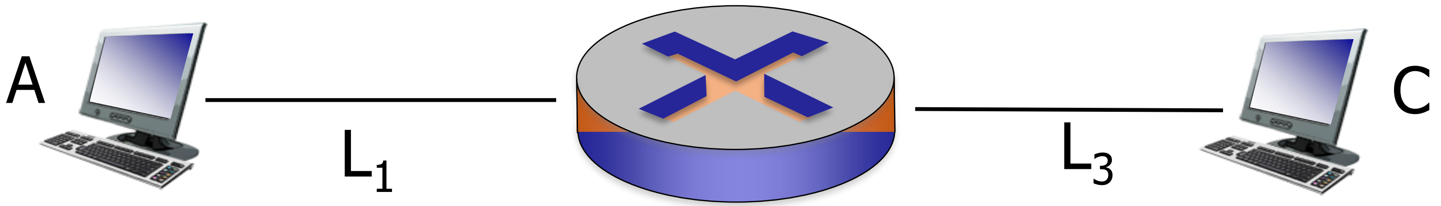
```python
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

df = pd.read_csv('ping.csv')

fig, ax = plt.subplots()
sns.scatterplot(data=df, x='Distance'
y='RTT', hue='Region’)
ax.set_xlabel('Distance (km)')
ax.set_ylabel('Average RTT (ms)')
ax.set_title('Ping results of
universities by region')
ax.yaxis.grid(color='gray',
linestyle='dashed')
ax.xaxis.grid(color='gray',
linestyle='dashed')
plt.show()
```



Questions?

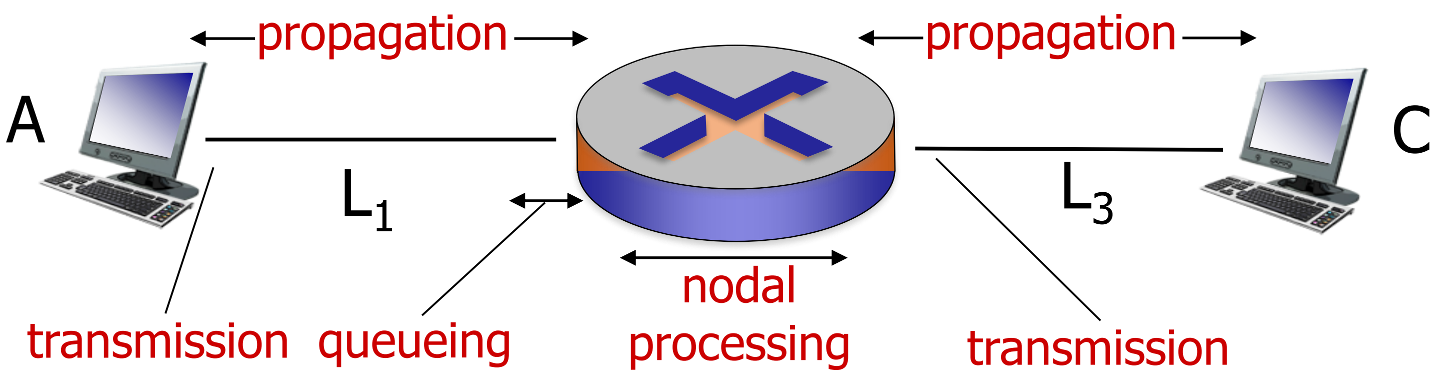
Question 4 (a)

- A sends a packet of 250 $bytes$ to C, measuring an RTT of 20 ms. How many milliseconds of the RTT are made up of queueing delays?



Question 4 (a)

- A sends a packet of 250 $bytes$ to C, measuring an RTT of 20 ms. How many milliseconds of the RTT are made up of queueing delays?



$$d_{total} = d_{proc} + 2d_{trans} + d_{queue} + d_{prop}$$

Question 4 (a)

- A sends a packet of $250\ bytes$ to C, measuring an RTT of $20\ ms$.
- Assume a nodal processing delay of $0\ ms$
- Assume a bandwidth of $2\ \text{Mbit/s} = 2 * 10^6\ bit/s$
- Link lengths of $1\ km$ for L_1 and $300\ km$ for L_3
- Assume a signal propagation speed of $10^8 m/s$
- All replies have the same size as the outgoing packet

$$d_{total} = d_{proc} + 2d_{trans} + d_{queue} + d_{prop}$$

$$d_{queue} = d_{total} - d_{proc} - 2d_{trans} - d_{prop}$$

$$d_{total} = \frac{1}{2} RTT = \frac{1}{2} * 20ms = 10ms$$

$$d_{proc} = 0ms$$

$$d_{trans} = \frac{Size}{Bandwidth} = \frac{8 * 250\ bit}{2 * 10^6 \frac{bit}{s}} = 1ms$$

$$d_{prop} = \frac{L_1 + L_3}{Speed} = \frac{301km}{10^8 m/s} \approx 3ms$$

$$d_{queue} = 10ms - 0ms - 2ms - 3ms = 5ms$$

$\rightarrow$ **$2 * d_{queue} = 10ms$ are made up of queuing delays**

Questions?

Question 4 (b)

- C sends a packet to A, measuring an RTT of 65 ms.
- What was the approximate size of the packet assuming empty queues this time?

$$d_{trans} = \frac{Size}{Bandwidth}$$

$$d_{total} = d_{proc} + 2d_{trans} + d_{queue} + d_{prop}$$

$$d_{trans} = \frac{(d_{total} - d_{proc} - d_{queue} - d_{prop})}{2}$$

Question 4 (b)

- C sends a packet to A, measuring an RTT of $65\ ms$.
- What was the approximate size of the packet assuming empty queues this time?
- Assume a nodal processing delay of $0\ ms$
- The propagation delay stays unchanged $3\ ms$
- Assume a bandwidth of $2\ \text{Mbit/s} = 2 * 10^6\ bit/s$

$$d_{trans} = \frac{Size}{Bandwidth} = \frac{Size}{2 * 10^6\ bit/s}$$

$$d_{total} = d_{proc} + 2d_{trans} + d_{queue} + d_{prop}$$

$$d_{trans} = \frac{(d_{total} - d_{proc} - d_{queue} - d_{prop})}{2}$$

$$d_{trans} = \frac{(32.5ms - 0ms - 0ms - 3ms)}{2}$$

$$d_{trans} = 14.75ms = \frac{size}{2 * 10^6\ bit/s}$$

$$size = 29500\ bit \approx 3{,}687\ byte$$

$\rightarrow$ ***The packet size is 3687 byte***

Question 4 (c)

- B sends a packet of 1000 bytes to C and measures an RTT of 32 ms.
- Calculate a theoretical upper bound for the length of the line L_2.

$$d_{prop} = \frac{L_2 + L_3}{Speed}$$

$$d_{total} = d_{proc} + 2d_{trans} + d_{queue} + d_{prop}$$

$$d_{prop} = d_{total} - d_{proc} - 2d_{trans} - d_{queue}$$

Question 4 (c)

- B sends a packet of 1000 bytes to C and measures an RTT of $32\ ms$.
- Calculate a theoretical upper bound for the length of the line L_2.
- Assume a nodal processing delay of $0\ ms$
- Assume a queueing delay of $0\ ms$
- Assume a signal propagation speed of $10^8 m/s$
- Link lengths of $1\ km$ for L_1 and $300\ km$ for L_3

$$d_{prop} = \frac{L_2 + L_3}{Speed}$$

$$d_{total} = d_{proc} + 2d_{trans} + d_{queue} + d_{prop}$$

$$d_{prop} = d_{total} - d_{proc} - 2d_{trans} - d_{queue}$$

$$d_{prop} = 16ms - 0ms - \frac{8 * 1000\ bit}{2 * 10^6\ bit/s} - 0ms$$

$$d_{prop} = 8ms$$

$$L_2 = 500km$$

→ ***L_2 can be up to 500 km long***

Questions?

Question 5 (a)

Choose an application layer protocol that is NOT listed below:
SMTP, POP3, IMAP, SSH, FTP(S), HTTP(S), DNS.

Start some research on the chosen protocol and try to briefly discuss it along the following lines:

a) In 3-4 sentences, summarize its purpose and basic functionality

NTP is a protocol that allows the synchronization of system clocks in a network.

NTP Servers sync to a reference clock or other servers, NTP clients sync their internal clocks to servers.

NTP also specifies a format to exchange messages containing the times and algorithms on how to adjust the internal clock.

Question 5 (b)

Choose an application layer protocol that is NOT listed below:

SMTP, POP3, IMAP, SSH, FTP(S), HTTP(S), DNS.

Start some research on the chosen protocol and try to briefly discuss it along the following lines:

b) Which transport layer protocol does it use? Is the application layer protocol standardized? Can you find the standard?

NTP uses UDP

NTPv4 (RFC5905) is a proposed standard

NTPv3 (RFC1305) is a draft standard

Questions?

Feedback?