CS335a - Assignment 1

Fall 2025

Main Topics: Packet vs. Circuit Switching,
Delays & Throughput,
Network Measurements & Analysis

Deadline: 17/10 at 10:59 (before the class begins)

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For any questions, send an email to the mailing list: **hy335a-list@csd.uoc.gr**

If your question might reveal part of your answer, send it directly to the TAs mailing list: **hy335a@csd.uoc.gr**

Layers - Encapsulation/Decapsulation

Exercise 1 [6 pts]

Answer the following questions with a brief explanation:

A) If we have **different applications** running simultaneously on a computer, which are sending and receiving data at the same time, is there a possibility that the data between them could get "mixed up"? If not, which layer of the model ensures that the data is kept separate?

B) If you switch from **Ethernet** to **Wi-Fi**, which layer(s) are directly affected?

C) Both the **Network and the Data Link layers** are important for "sending" data. Which is the role of each layer? Hint: you can answer using this prompt: The Network layer is responsible to route packets from ____ to ____ whereas the link layer is responsible for data transfer between ____

D) If two computers use different operating systems (e.g., Windows and Linux), can they still communicate? Why?

Solution:

A) No, data does not get mixed up. The **Transport Layer** (Layer 4) keeps data from different applications separate and ensures it's delivered to the correct one.

B) Switching from Ethernet to Wi-Fi affects the **Data Link Layer** (Layer 2) and **Physical Layer** (Layer 1), since they define how bits are transmitted over a medium. Higher layers remain unchanged.

C) The Network layer is responsible to route packets from **source to destination** whereas the link layer is responsible for data transfer **between neighboring network elements**.

D) Yes. Different operating systems can communicate because they both implement the **same network protocol stack**, which is OS-independent.

Exercise 2 [6 pts]

Select the correct option for the following. There is only one correct answer. Briefly **justify your choice**.

A) What happens during the transmission of a packet from one router to another?

i) The packet is not encapsulated/decapsulated.
ii) Encapsulation/decapsulation occurs, and some fields of the MAC header are changed.
iii) Encapsulation/decapsulation occurs, and the IP addresses of the sender and receiver are changed.

B) During encapsulation, the Transport layer "segment" is converted into a:

i) Frame
ii) Datagram
iii) Message
iv) Bit stream

C) During the encapsulation process, what does the Network layer do with the header of the Transport layer?

i) It removes the header of the Transport layer.
ii) It keeps the header unchanged.
iii) It adds its own header.
iv) It replaces the Transport layer header with a new one.

D) During decapsulation, what does the Data Link layer at the receiver do with the IP header?

i) It removes the IP header.
ii) It keeps the IP header unchanged.
iii) It processes and modifies the IP header.
iv) It removes only the frame header/trailer; the IP header is handled by the Network layer.

Solution:

A) **Correct Answer: (ii) Encapsulation/decapsulation occurs, and some fields of the MAC header are changed.**
Routers work mainly at the Network Layer. When a packet moves from one router to the next, the router checks the Network Layer information to know where the packet should go next. It then creates a new Data Link Layer (MAC) header for the next connection. So, the network information stays the same end-to-end, but the link information (MAC header) changes at each hop.

B) **Correct Anwser: (ii) Datagram**
A segment (Transport Layer) is encapsulated into a datagram (Network Layer).

C) **Correct Anwser: (iii) It adds its own header.**
During encapsulation each layer adds its own header.

D) **Correct Anwser: (iv) It removes only the frame header/trailer; the IP header is handled by the Network layer.**
The Data Link Layer only processes its own data, it does not modify the Network Layer (above layer).

Structure of the Internet

Exercise 3 [12 pts]

Assume a network with the following entities:

- **Access ISP 1:** "AlphaNet" ⟶ Connects Host A (Access Network 1)

- **Access ISP 2:** “BetaLink” ⟶ Connects Host B (Access Network 2)
- **Regional ISP:** “GammaRegional” ⟶ Connects the Access ISPs with the Tier-1 ISPs
- **Tier-1 ISPs:** “TierOneX” and “TierOneY”
- **IXPs: “EuroIX” and “GlobalIX”:** ⟶ Exchange points between Tier-1 ISPs
- **Peering Links:** Links between Tier-1 ISPs and other networks

A) Draw the hierarchical structure of the network.
Note: There is not a single “correct” topology – the diagram should, however, correctly represent the hierarchical levels and connections.

B) Which possible paths can the packets take from Host A to Host B? Describe at least two different paths through Tier-1 ISPs and IXPs.

C) Suppose there is also a Content Provider Network (CPN) named “StreamPlus.”

i) How does the existence of the CPN change the network topology?

ii) How does it affect the possible paths?

Solution:

A) An example topology that follows a hierarchical structure.

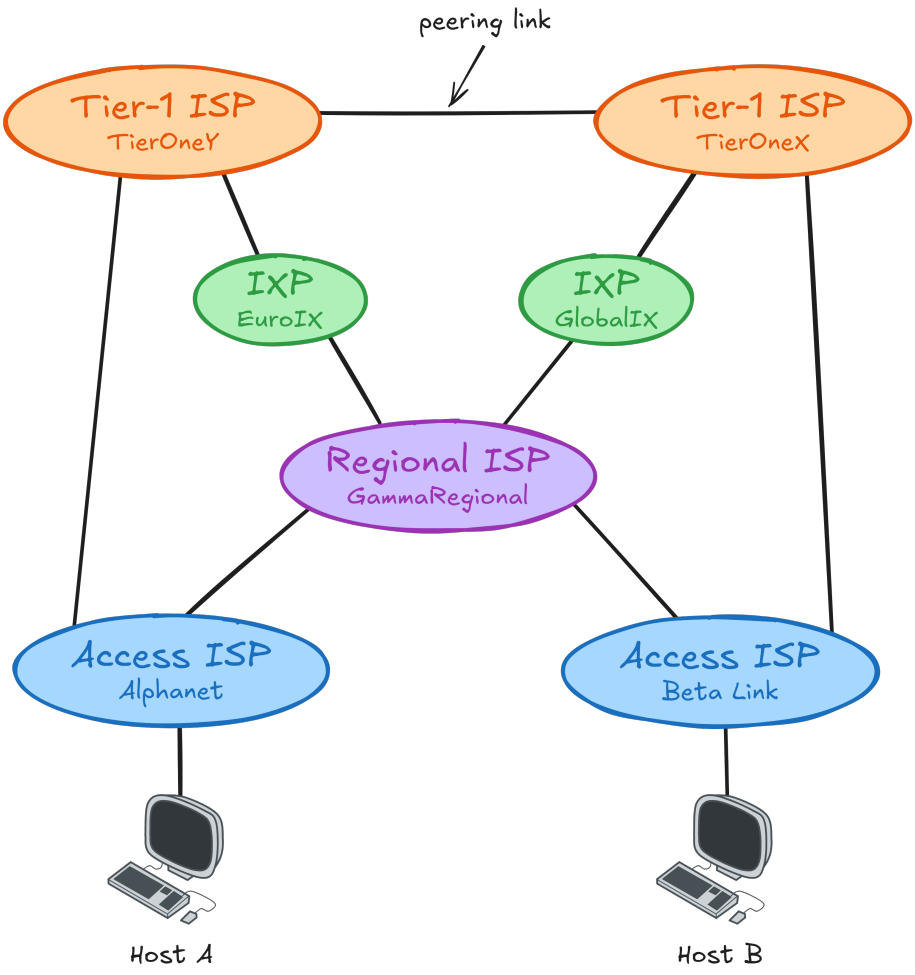


Figure 1: Hierarchical structure of the network

B) **Possible Path 1**
Host A → Alphanet → TierOneY → TierOneX → BetaLink → Host B

Possible Path 2
Host A → Alphanet → GammaRegional → GlobalIX → TierOneX → BetaLink → Host B

C) i) By adding the Content Provider we get the following (possible) topology:

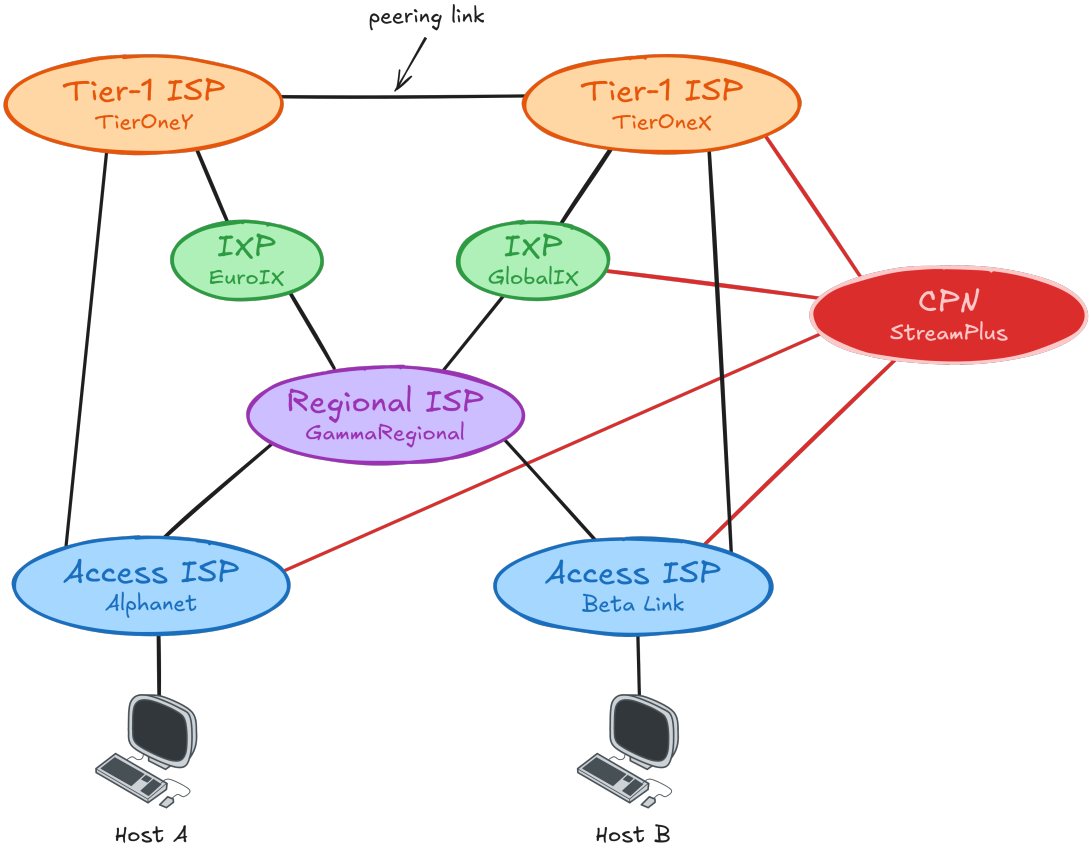


Figure 2: Structure of the network with a CPN

The CPN "breaks" the hierarchical structure of the network and tries to be as close to the clients as possible so as to serve them faster.

ii) With the existence of the CPN, packets from Host A to Host B do not always need to pass solely through the Tier-1 ISPs to reach the other ISP: The route can bypass intermediate Tier-1s to provide better access to the content.

Possible Path: Host A → StramPlus → Host B

Packet vs. Circuit Switching

Exercise 4 [10 pts]

Consider an application that transmits data at a constant rate. Also, once such an application starts it runs for a relatively long time. Answer the following questions with a brief explanation:

A) For this application, would a packet-switched network or a circuit-switched network be more appropriate? Why?

B) Assume a packet-switched network is used and the only traffic in the network comes from applications like this one. Further assume the sum of the data rates of the applications is less than the capacity of every link. Is any form of congestion control needed? Why?

Solution:

A) A **circuit-switched** network would be more appropriate.

- The application transmits data at a **constant rate**: allocate a fixed amount of bandwidth → consistent performance, no chance of congestion
- The application runs for a **long time**: the reserved circuit will be well utilized rather than remaining idle

B) No, congestion control is **not needed**.

The sum of the data rates of all applications is **less than the capacity of every link**, so the network will never become overloaded. Even if all applications transmit simultaneously, the available bandwidth is sufficient for all flows, so congestion will not occur.

Exercise 5 [9 pts]

Consider the following circuit-switched network. It consists of 4 switches and 4 links, each link has 4 circuits.

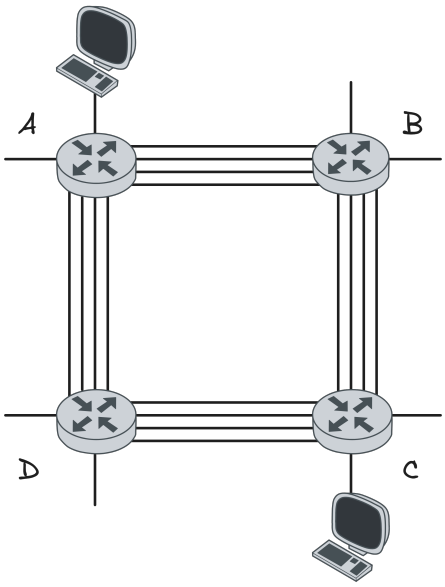


Figure 3: Circuit-Switched Network

A) What is the maximum number of simultaneous connections that can be in progress at any given time within this network?

B) Suppose that all connections are between switches A and C. What is the maximum number of simultaneous connections that can be in progress?

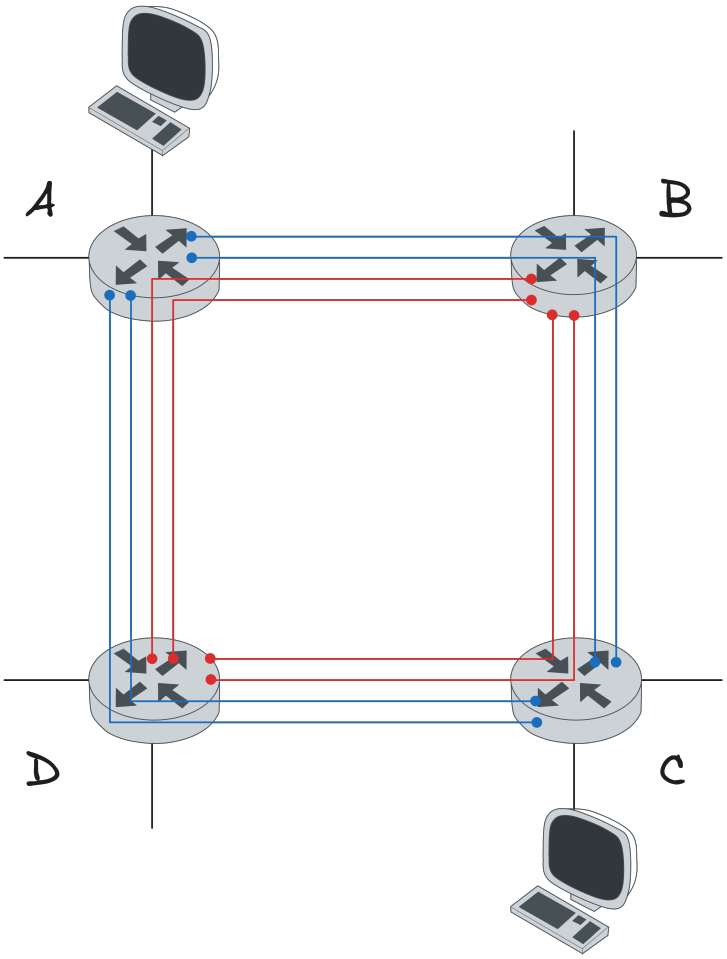
C) Suppose we want to establish four connections between switches A and C, and another four connections between switches B and D. Can we route these calls through the four links so as to serve all eight connections?

Solution:

A) 16 possible simultaneous connections: 4 between A-B, 4 between B-C, 4 between C-D and 4 between A-D

B) 8 possible simultaneous connections: 4 between A-B-C and 4 between A-D-C

C) Yes, it is possible: for A-C we use 2 connections between A-B-C and 2 between A-D-C (blue) and for B-D we use 2 connections between B-A-D and 2 between B-C-D (red)



Delays & Throughput

Exercise 6 [9 pts]

Consider two computers, A and B, connected by a single link with a rate of R bps. Assume the two computers are m meters apart, and the propagation speed on the link is s meters per second. Host A is going to send a packet of size L to host B.

A) Express the propagation delay d_{prop} as a function of m and s.

B) Express the transmission delay d_{trans} as a function of L and R.

C) Ignoring processing delay and queueing delay, find an expression for the end-to-end delay.

D) Suppose computer A starts transmitting the packet at time $t = 0$. At time $t = d_{trans}$, where is the **last bit** of the packet?

E) Suppose the propagation delay is greater than the transmission delay. At time $t = d_{trans}$, where is the **first bit** of the packet?

F) Suppose the propagation delay is less than the transmission delay. At time $t = d_{trans}$, where is the **first bit** of the packet?

G) Suppose $s = 2{,}5 \cdot 10^8$ m/s, $L = 1500$ Bytes, and $R = 10$ Mbps. Find the distance m such that d_{prop} *is equal to* d_{trans}.

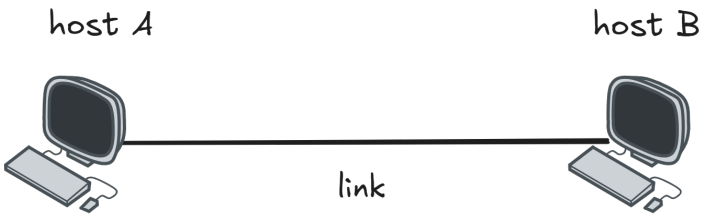


Figure 5: Topology 1

Solution:

A) $d_{prop} = m/s$

B) $d_{trans} = L/R$

C) $d_{e2e} = d_{prop} + d_{trans} = m/s + L/R$

D) At the end of the transmission delay the last bit will have **just left host A** and is at the start of the wire.

E) By the time the transmission finishes the first bit will NOT have reached host B yet. So the first bit is **somewhere on the wire**.

F) By the time the transmission finishes the first bit will have **reached host B**.

G) Notice that we need to convert L from bytes to bits.

$$d_{prop} = d_{trans} \Leftrightarrow \frac{m}{s} = \frac{L}{R} \Leftrightarrow \frac{m}{2,5 \cdot 10^8} = \frac{1500 \cdot 8}{10 \cdot 10^6} \Leftrightarrow m = 300.000\ m.$$

Exercise 7 [10 pts]

Host A wants to send a single packet of size 1500 Bytes to host B. The links between these nodes have different transmission rates and distances: the first link has a rate of 10 Mbps and a length of 100 km, the second link has a rate of 5 Mbps and a length of 200 km, and the third link has a rate of 20 Mbps and a length of 50 km. The propagation speed along all links is 2×10^8 m/s.

Each router introduces a processing delay of 1 ms, and queuing delays at R1 and R2 are 2 ms and 4 ms, respectively. Hosts A and B are assumed to have zero processing or queuing delays.

Your task is to compute the end-to-end delay for this packet. Show your calculations for each link and explain how the total delay is obtained.

Figure 6: Topology 2

Solution:

Notice that we need to convert L from bytes to bits.

$$d_{trans,1} = \frac{L}{R_1} = \frac{1500 \cdot 8}{100 \cdot 10^6} = 0.0012\ s = 1.2\ ms$$

$$d_{prop,1} = \frac{d_1}{s} = \frac{100 \cdot 1000}{2 \cdot 10^8} = 0.0005\ m = 0.5\ ms$$

Similarly:

$$d_{trans,2} = 2.4\ ms, d_{prop,2} = 1\ ms$$

$$d_{trans,3} = 0.6\ ms, d_{prop,3} = 0.25\ ms$$

We know that:

$$d_{proc,1} = 0\ ms, d_{queue,1} = 0\ ms$$

$$d_{proc,2} = 1\ ms, d_{queue,2} = 2\ ms$$

$$d_{proc,3} = 1\ ms, d_{queue,3} = 4\ ms$$

For each node/link:

$$d_{nodal,1} = d_{trans,1} + d_{prop,1} + d_{proc,1} + d_{queue,1} = 1.7\ ms$$

$$d_{nodal,2} = 6.4\ ms$$

$$d_{nodal,3} = 5.85\ ms$$

Finally:

$$d_{e2e} = d_{nodal,1} + d_{nodal,2} + d_{nodal,3} = 13.95\ ms$$

Exercise 8 [8 pts]

Suppose Host A wants to send a large file to Host B. The path from Host A to Host B consists of three links with the following transmission rates: R_1 = 1 Mbps, R_2 = 3 Mbps, and R_3 = 500 kbps. (see Topology 2)

A) Assuming there is no other traffic in the network, what is the throughput for transferring the file?

B) Suppose the file size is 6 million bytes. How long will it take to transfer the file from Host A to Host B? (Ignore all propagation, processing, and queuing delays.)

Solution:

A)

$$\text{throughput} = \min\{R_1, R_2, R_3\} = 500\ \text{kbps}$$

B)

$$\text{time} = \frac{\text{file size}}{\text{throughput}} = \frac{6 \cdot 10^6 \cdot 8}{500 \cdot 1000} = 96\ s$$

Network Measurements & Analysis

Exercise 9 - Ping [10 pts]

Use the ping command with destination “www.physics.uoc.gr”

A) Attach a screenshot of the result

B) Analyze the fields from the command's output

Solution:

A)

```
pavlos@50MBR4:~$ ping www.physics.uoc.gr
PING prodigy.physics.uoc.gr (147.52.190.13) 56(84) bytes of data.
64 bytes from prodigy.physics.uoc.gr (147.52.190.13): icmp_seq=1 ttl=53 time=27.3 ms
64 bytes from prodigy.physics.uoc.gr (147.52.190.13): icmp_seq=2 ttl=53 time=27.1 ms
64 bytes from prodigy.physics.uoc.gr (147.52.190.13): icmp_seq=3 ttl=53 time=28.0 ms
64 bytes from prodigy.physics.uoc.gr (147.52.190.13): icmp_seq=4 ttl=53 time=27.2 ms
64 bytes from prodigy.physics.uoc.gr (147.52.190.13): icmp_seq=5 ttl=53 time=27.1 ms
^C
--- prodigy.physics.uoc.gr ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4006ms
rtt min/avg/max/mdev = 27.062/27.335/27.962/0.325 ms
```

B) In the image we can see that the IP of the destination is "147.52.190.13", there is no packets loss and average RTT being 27.335ms. Also 5 packets were sent.

Exercise 10 - Traceroute [20 pts]

A) Describe how the traceroute from host A to host B will work in the diagram below.

- Refer to all the packets that will be sent during the process (requests and responses).
- For each packet report the values of their fields TTL, source IP and destination IP.

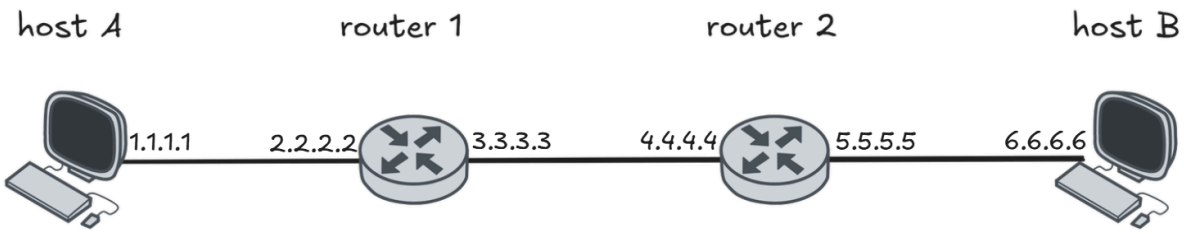


Figure 8: Topology 2

B) Run a traceroute with destination "www.math.uoc.gr" while you are on a network outside of the university.

- Attach a screenshot of the outcome.
- If "*" appear, try to provide possible reasons why they show up.
- After connecting to the university's VPN, run traceroute to "www.math.uoc.gr" again and attach the screenshot. What do you observe compared to the previous traceroute?

Solution:

A) Traceroute starts from host A with destination host B. These are the packets:

IP source	IP destination	TTL
1.1.1.1	6.6.6.6	1
2.2.2.2	1.1.1.1	x
1.1.1.1	6.6.6.6	2
4.4.4.4	1.1.1.1	x
1.1.1.1	6.6.6.6	3

IP source	IP destination	TTL
6.6.6.6	1.1.1.1	x

Το TTL της επιστροφής δεν είναι το σημαντικό της άσκησης (συνήθως κάποια default τιμή).

B) •

```
PS C:\Users\user\Desktop> tracert www.math.uoc.gr

Tracing route to www.math.uoc.gr [147.52.205.205]
over a maximum of 30 hops:

  1     2 ms     2 ms     2 ms  vodafone.station [192.168.2.1]
  2    17 ms    18 ms    18 ms  loopback2004.med01.dsl.hol.gr [62.38.0.170]
  3     *        *        *     Request timed out.
  4    17 ms    18 ms    18 ms  grnet-2.gr-ix.gr [176.126.38.31]
  5    19 ms    19 ms    19 ms  eier-kolettir-AE.backbone.grnet.gr [62.217.100.63]
  6    19 ms    19 ms    19 ms  62.217.101.121
  7     *        *        *     Request timed out.
  8     *        *        *     Request timed out.
  9     *        *        *     Request timed out.
 10    28 ms    28 ms    28 ms  pollux.ict.uoc.gr [147.52.205.205]
```

- The "*" can appear because of firewalls that drop unknown traffic, security setups that do not respond to traceroute…
-

```
PS C:\Users\user\Desktop> tracert www.math.uoc.gr

Tracing route to www.math.uoc.gr [147.52.205.205]
over a maximum of 30 hops:

  1    27 ms    26 ms    28 ms  vpn.uoc.gr [147.52.193.2]
  2    27 ms    27 ms    27 ms  147.52.193.1
  3     *        *        *     Request timed out.
  4    30 ms    29 ms    28 ms  pollux.ict.uoc.gr [147.52.205.205]
```

We see that in order to reach the server using the VPN it needs less steps. That has to do with the fact that the VPN gives us an IP inside the university network (like we are on the premises), which are much closer to the server.

Exercise 11 - Wireshark [20 pts]

A) Ping the CSD website "www.csd.uoc.gr". While doing this, have Wireshark running to capture the traffic.

- Attach a screenshot with the output of ping.
- Attach another screenshot from Wireshark showing only the replies received from the CSD server. How did you achieve this?

B) On the course's website you will find a CSV file ("capture.csv") containing packet captures from Wireshark. Using Python load the CSV file (hint: pandas library) and answer the following:

- Calculate the total amount of data sent, both in Bytes and in Megabytes (MB).
- Find all the packets related with the ping command. Find to which IP addresses they were sent, and how many bytes were sent to each address respectively.
- Create a piechart that showcases the number of packets belonging to the protocols TCP, DNS, ARP and ICMP. Make it so that each slice shows the percentages of the slice (hint: matplotlib library).

Solution:

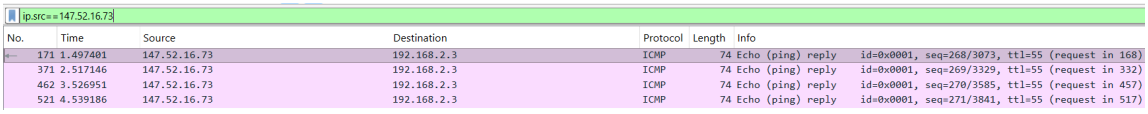
A) •

```
PS C:\Users\user\Desktop> ping www.csd.uoc.gr

Pinging csd.uoc.gr [147.52.16.73] with 32 bytes of data:
Reply from 147.52.16.73: bytes=32 time=26ms TTL=55
Reply from 147.52.16.73: bytes=32 time=27ms TTL=55
Reply from 147.52.16.73: bytes=32 time=26ms TTL=55
Reply from 147.52.16.73: bytes=32 time=26ms TTL=55

Ping statistics for 147.52.16.73:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 26ms, Maximum = 27ms, Average = 26ms
```

•



In order to just see the replies from the server, we filtered the packets based on the source IP with the server's IP (which can be seen from the ping above 147.52.16.73).

B) Inside the "packet_statistics.py" file.

Submission Guidelines

- Compile your report into a **single** PDF file. Include there all the answers to the theoretical exercises and any screenshots.
- Create a `.zip` file that includes your report and the `.py` file.
- Use the elearn-page to submit your `.zip` file.
- Reports that are not in PDF format will not be accepted.
- To prevent plagiarism, in each assignment series a random sample of students will be selected for further oral examination.