Fundamentals of Networks & Security

Markos Vassilis
Mediterranean College

Week 01

A Brief Intro

`sudo echo whoami`

- Vassilis (name) Markos (surname): it also works the other way around.
- My interests include: AI / XAI, Quantum Computing, Data Science, Operator Theory, Statistics, Software Development... (this might be of your interest too in the future, in case you are looking for a **thesis supervisor**).
- I am mostly a Linux / UNIX user, so, please, be kind towards my ignorance regarding MS Windows. :)

What Is This Course?

This course is about many (many) things:

- Networks and Networking.
- Network setup.
- Packet Tracer and other network tools (e.g., wireshark).
- Addressing schemes.
- TCIP/IP
- Protocols (many protocols).

Module(s) Assessment

All coursework will be **submitted directly on UDO** (you will get your credentials soon if you have not yet). This means that:

- Delayed submissions are not possible (including submissions by email etc).
- The only way to get an extension is by formally applying for one **at the University of Derby.**
- All UDO submissions are by default checked by Turnitin.

Module(s) Assessment

So, in order for things to run smoothly:

- You should **work** on coursework sufficiently **prior to the deadline!**
- In case of extension, **make sure you have all necessary documents** available, e.g., doctor's written diagnosis, in case of a medical condition.
- I will be accepting **drafts** which can be discussed during **office hours** to make sure things are okay for submission.
- Do not make (excessive) use of Generative AI!

Module's Coursework

There is a two-part coursework for this module:

- **Coursework 1 (30%):** Continuous assessment (a single try quiz every 4 weeks).
- **Coursework 2 (35%):** Network design proposal in a specific setting (report, 2-3.000 words).
- **Coursework 3 (35%):** The same as above, just with security concerns.

More to be announced soon…

Connecting Things

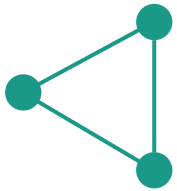
What is “The Internet”?

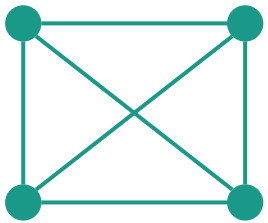
The Internet (or internet) is the **global system of interconnected computer networks** that uses the **Internet protocol** suite (TCP/IP) to communicate between networks and devices. It is a **network of networks** that consists of private, public, academic, business, and government **networks of local to global scope**, linked by a broad array of electronic, wireless, and optical networking technologies. The Internet carries a vast range of information resources and services, such as the **interlinked hypertext documents** and applications of the **World Wide Web** (WWW), electronic mail, telephony, and file sharing.

Source: Wikipedia

How to Connect Things? 1 / n

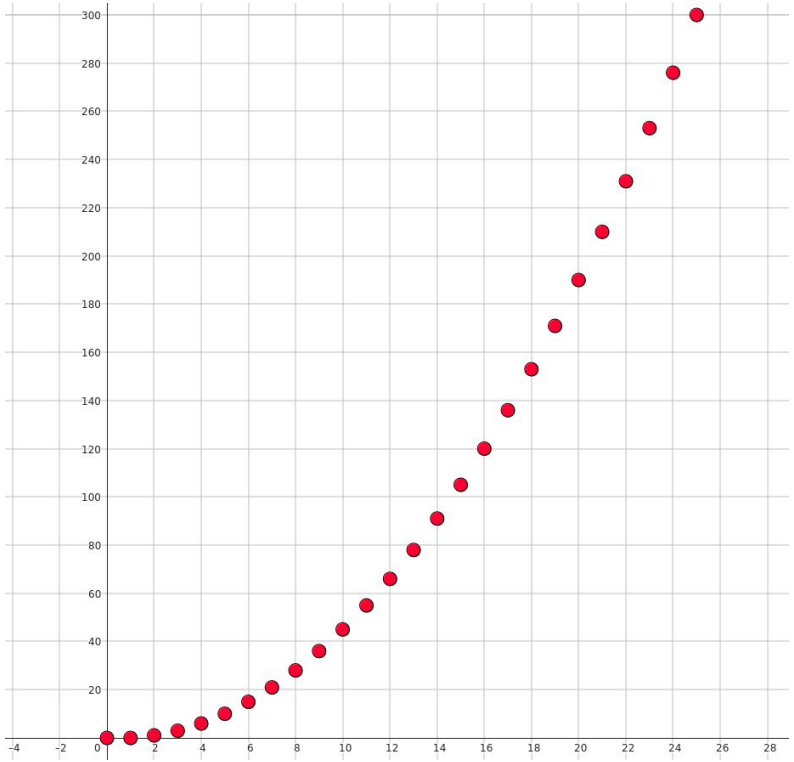
- All-to-all?





Nodes	Connections
2	1
3	3
4	6
5	10
6	15
20	???
n	???

How to Connect Things? 2 / n



For n nodes there should be n(n-1)/2 connections.

Nodes	Connections
20	190
50	1225
100	4950
1000	499500
10000	49995000

A Proof by Counting

- Imagine you have n nodes and you want to connect every possible pair of these n nodes.
- At first, pick a node, n_1 and connect it to all the rest, i.e., n-1 nodes. This results to n-1 new connections.
- Then, take another node, n_2. How many nodes remain unconnected to n_2? If you guessed n-2 you are write. Of the n nodes, in total, all have been connected to n_1, including n_2. Since we have made no other connections, there are exactly n-2 nodes that remain unconnected to n_2. This results to n-2 new connections.
- Similarly, we get in total (n-1) + (n-2) + (n-3) + … + 3 + 2 + 1 new connections.
- To compute the above sum, observe that you can pair its terms as follows:

$$(n-1) + (n-2) + (n-3) + \ldots + 3 + 2 + 1$$

- This results in exactly (n-1) / 2 pairs, each of which sums up to n. So, in total we get n(n-1)/2, as expected.

A Combinatorial Proof

- Imagine again that you have n nodes that you want to connect in every possible way, and label them by the numbers {1,2,...,n}.
- This, essentially means that you should choose every possible pair of numbers from {1,2,...,n}.
- Observe that in this setting order does not matter. That is, the pair (1,4) is the very same as the pair (4,1) since, if 1 is connected to 4, so is 4 to 1. Essentially, our "pairs" corresponds to all subsets {x,y} of {1,2,...,n} such that $x \neq y$. So, how many choices do you have for such a set?
- For the first element, x, you have exactly n choices, as you can pick any of the numbers in {1,2,...,n}.
- For the second element you have exactly n-1 choices, since you have already picked x.
- So far, you have n(n-1) possible pairs in total. What's wrong?
- Observe now that you have created each possible "pair" exactly twice, since with the above protocol you can first pick 1 and then 3, resulting to {1,3} and then you can also pick 3 and then 1 resulting to {3,1}, which is exactly the same - because, remember, order doesn't matter.
- Hence, the actual number of choices is exactly the half, i.e., n(n-1)/2.

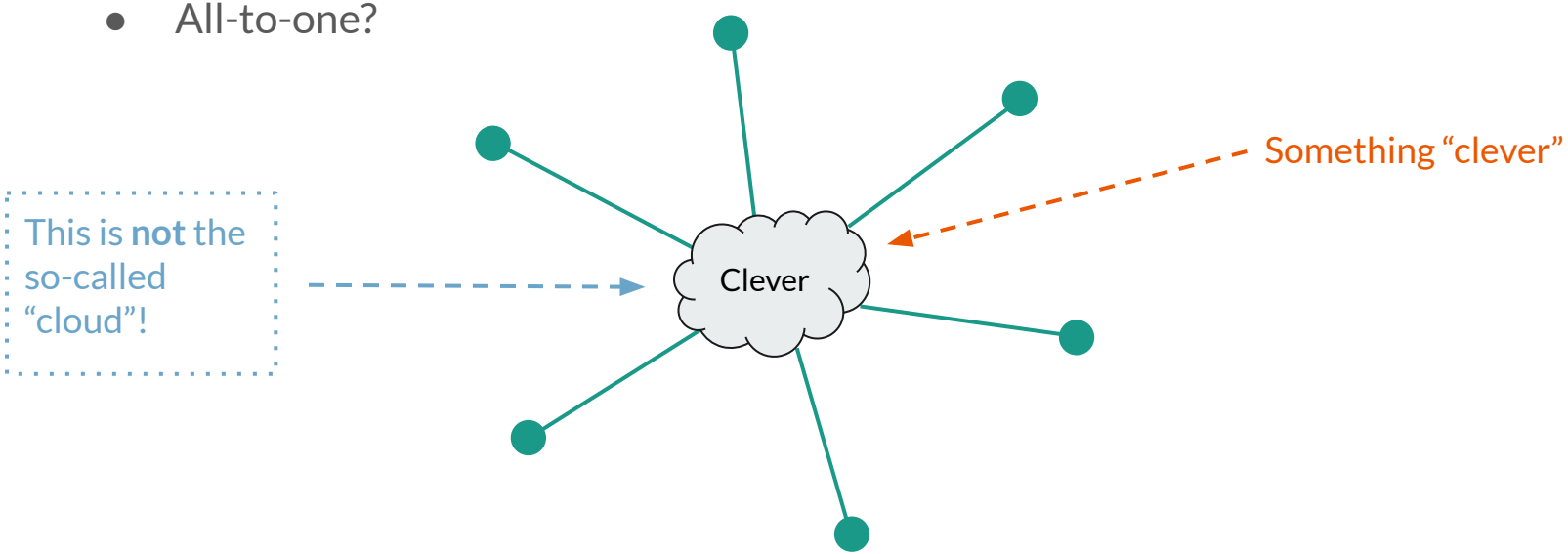
How to Connect Things? 3 / n

Problems with the all-to-all approach:

- Immense load of connections.
- Really (really) complex networks.
- Having many connections means **remembering** many connections (node names, cables etc).
- Even wireless connections suffer from the above (except for cabling).

How to Connect Things? 4 / n

- All-to-one?



How to Connect Things? 5 / n

Benefits of all-to-one connection:

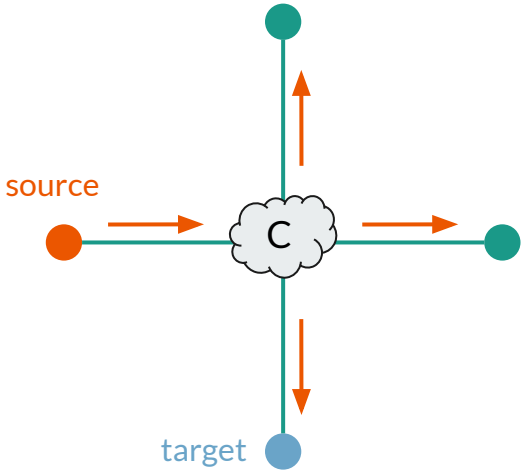
- Only n connections for n nodes (e.g., 5 connections for 5 nodes, 1000 connections for 1000 nodes).
- Assuming the “clever” middleware can properly distinguish between the nodes, then access to each node is performed instantly through that middleware.

Where’s the **catch**?

- Each node should have a **unique name**, to facilitate distinguishing between them!
- The “clever” middleware has to be “really clever”.

How to Connect Things? 6 / n

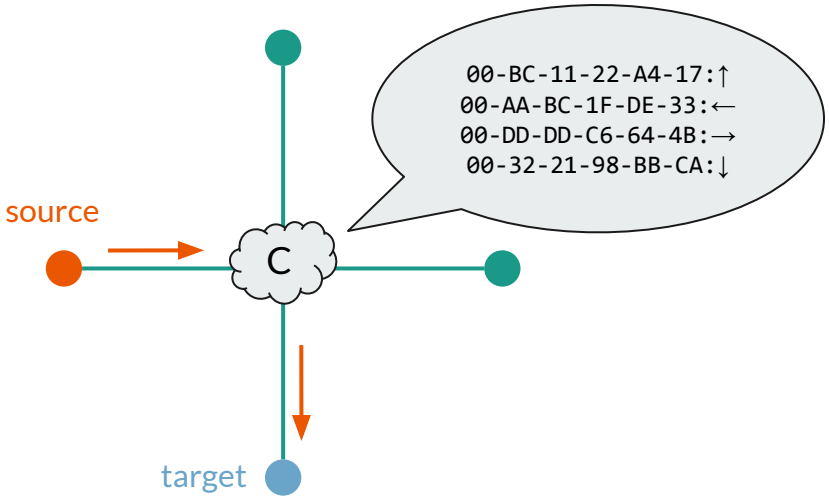
- Unique name -> (Media Access Control) **MAC Address**: 12-character alphanumeric code, unique for each device in a network, e.g., 00-A1-D2-C4-55-4A.
- A simply “clever” middleware could be as follows:



- Simply “clever” middleware -> **Hub**.
- Information flows towards all directions (the hub is oblivious to which is the target port / device).
- Can you see the problem here?
- Too many **collisions** (we shall cover this extensively throughout the course).
- Hubs are not used anymore (really problematic).

How to Connect Things? 7 / n

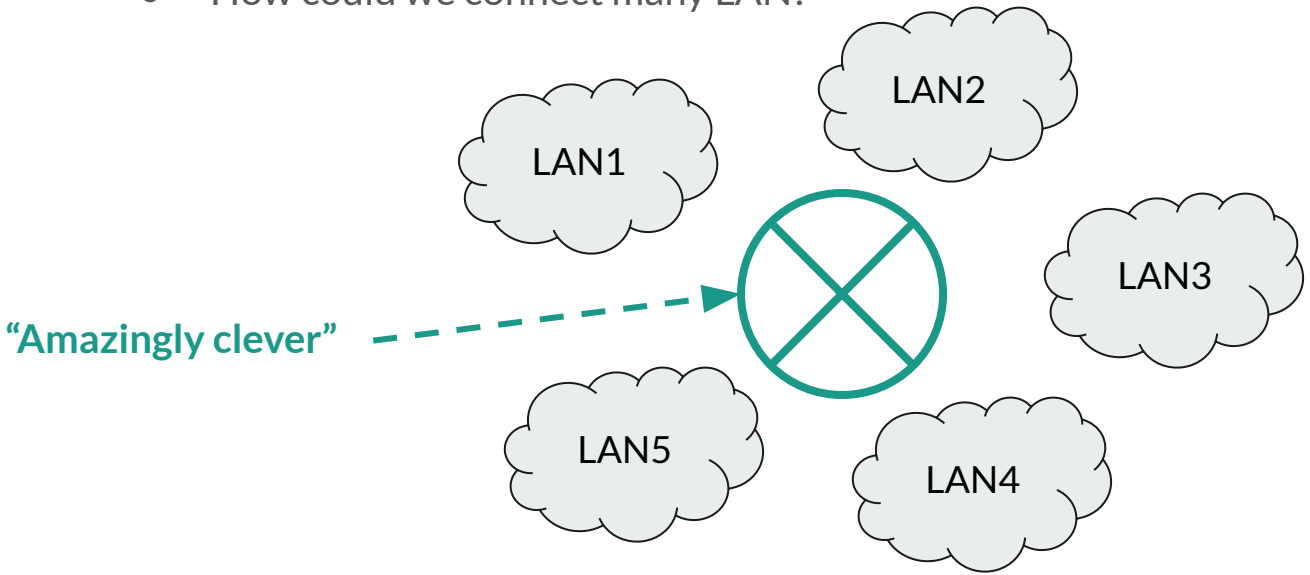
- But, why not take advantage of local connectivity?
- A “really clever” middleware could take advantage of the local **physical connections** to direct information properly:



- “Really clever” middleware -> **Layer 2 switch**.
- Keep track of which devices (i.e., MAC addresses) are connected to which ports of C.
- Essentially, memory is what makes a Layer 2 switch “really clever”.
- But, what is Layer 2?
- Stay tuned…

How to Connect LAN? 1 / n

- All networks as the above fall under the broader category of **Local Area Networks (LAN)**.
- How could we connect many LAN?



How to Connect LAN? 2 / n

- Networks of LAN, or of Layer 2 networks, in general, are often referred to as **Layer 3 networks**.
- Interlinking multiple networks as above comes under the name of **Internetworking** (could you think of an abbreviation for that?).
- “Amazingly clever” -> Router.
- As with Layer 2 switches, Routers should somehow know the names of the corresponding LAN (which, as you would expect, should be **unique**).
- How does a Router work?
- It has its own protocol, the **Internetwork Protocol** (aka IP).

Protocol: One’s way of doing things.

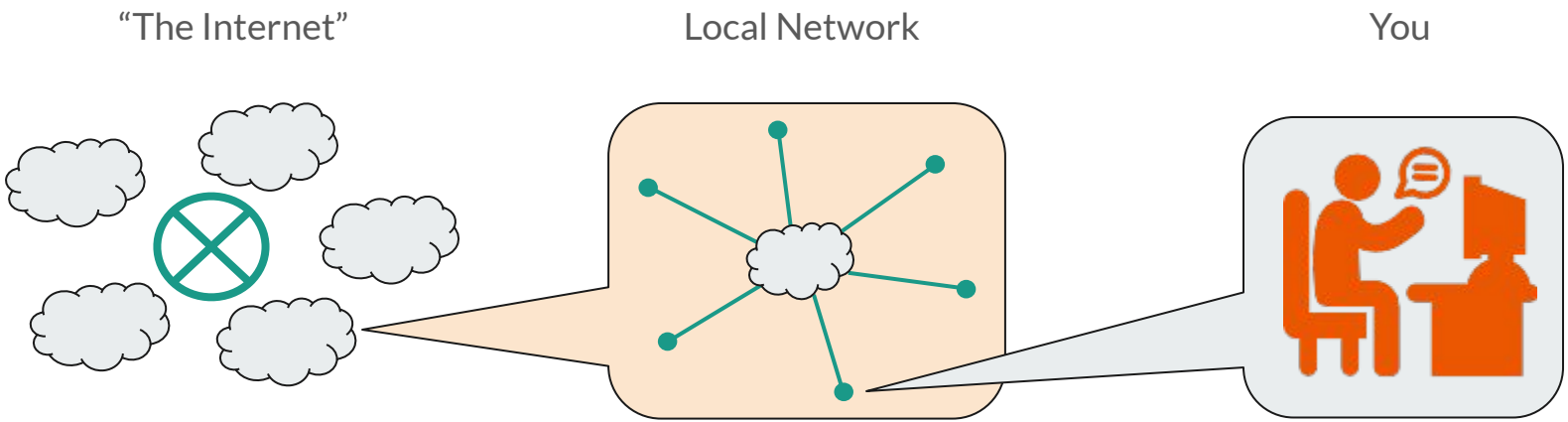
Could you define Layer 4, Layer 5, or Layer n, in the spirit of the definitions of Layers 2 and 3?

Layer 2 vs Layer 3

- What's the main difference between Layer 2 and Layer 3 connections?
- **Layer 2** is mostly implemented at the **physical level,** i.e., at the level of cables, wireless signal etc. That is, any networking is done at the level of the hardware and **is not amenable to changes!**
  Remember how the Layer 2 switch is implemented?
- **Layer 3** is implemented at the **logical level,** i.e., based on our "opinion" of what is meaningful and, hence, **is amenable to changes**.

What is “The Internet”? (revisited)

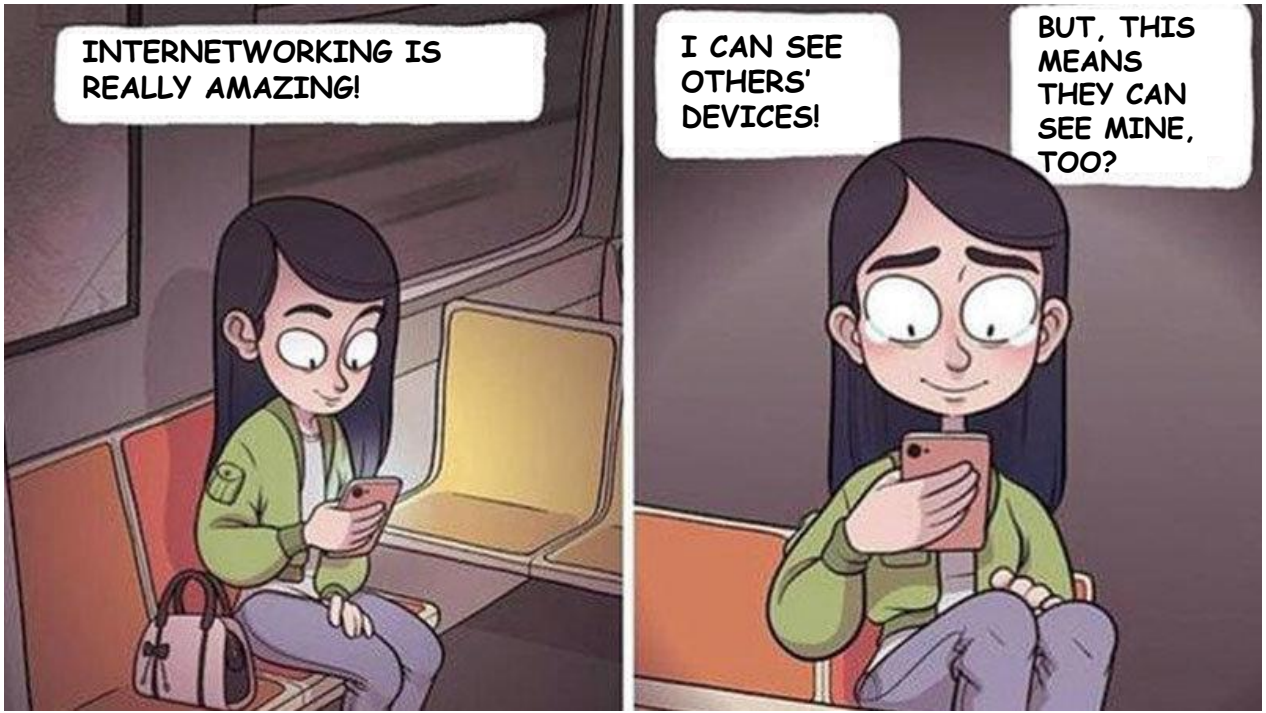
- A network of networks or, in technical terms, a **Wide Area Network (WAN)**.
- Each device and sub-network uses **unique addresses** to identify itself (How do we call them?).
- **Routers** are used to connect local networks to the rest of the world.



Internet vs WWW

- What does WWW stand for?
- **WWW = World Wide Web.**
- Are “The Internet” and the WWW the same thing?
- Internet -> Network of networks.
- WWW -> The information available on the internet.
  - Documents
  - Audio / Video
  - Control Signals
  - Instrument readings
  - ...

What about this?



Adapted from Adam Ellis.

Networks and Security

- As described so far, networks allow free access to and flow of information (**to anyone**).
- But, there is **stuff we don't want to share** (e.g., personal / private information).
- Ways of network protection:
  - Firewalls
  - Network segmentation
  - Remote access VPN
  - Many more **Layer 4 techniques**

What we saw today… 1 / n

- **What is “The Internet”?**

  A network of networks: a Layer 3 network where local networks are interlinked to each other, using appropriate addressing for each local network. Often referred to as a WAN (Wide Area Network).

- **Why not connect all devices with one another in a device network?**

  Because this would result in an immense number of connections, leading to increased setup, running and maintenance costs.

- **What is a prerequisite for the utilisation of a Layer 2 switch?**

  Each device should have a **unique** name in order to be recognized by the switch.

What we saw today… 2 / n

- **What is a MAC (Media Access Control) Address?**

  A MAC address is a unique address assigned to any device connected to a Local Area Network (LAN).

- **What is the difference between a “Hub” and a “Layer 2 switch”?**

  The hub does not distinguish between the devices connected to it, letting information flow towards all devices in a network and, thus, increasing the chance of collision. Layer 2 switches avoid that by remembering which port is (physically) connected to which device (through the devices’ MAC addresses).

- **What is the plural of LAN?**

  The plural of LAN is still LAN, since acronyms are both singular and plural number.

What we saw today... 3 / n

- **What is a Router?**

  A Router is a device which interlinks many different LAN in a way similar to which a Layer 2 switch does with devices within a LAN (similarities appear just at the abstract level, though!).

- **What is an IP (Internetwork Protocol)?**

  An IP is essentially “the way” in which a Router manages to properly handle the flow of signals (information) throughout an interlinked network of LAN.

- **Right or Wrong? Networking done through a Layer 2 switch is subject to changes.**

  Wrong. Layer 2 switches rely on **physical** connectivity, thus they are not amenable to changes, but for the case when / where the physical connections between network devices change.

What we saw today… 4 / n

- **Right or Wrong? Layer 3 networking is amenable to changes.**

  Right. Layer 3 is implemented at the **logical level**, i.e., based on our views on how things "should" be, and does not rely on the physical connections between networks and / or network devices.

- **What's the difference between "The Internet" and the WWW?**

  The term "Internet" refers to interlinked local networks that build up a wider network, while "WWW" refers to the information that is kept in and flows through that network.

- **Mention some ways of network protection.**

  Some network security techniques include but don't restrict to: Firewalls, Network Segmentation, Remote access VPN and other techniques that mostly rely on Layer 4.

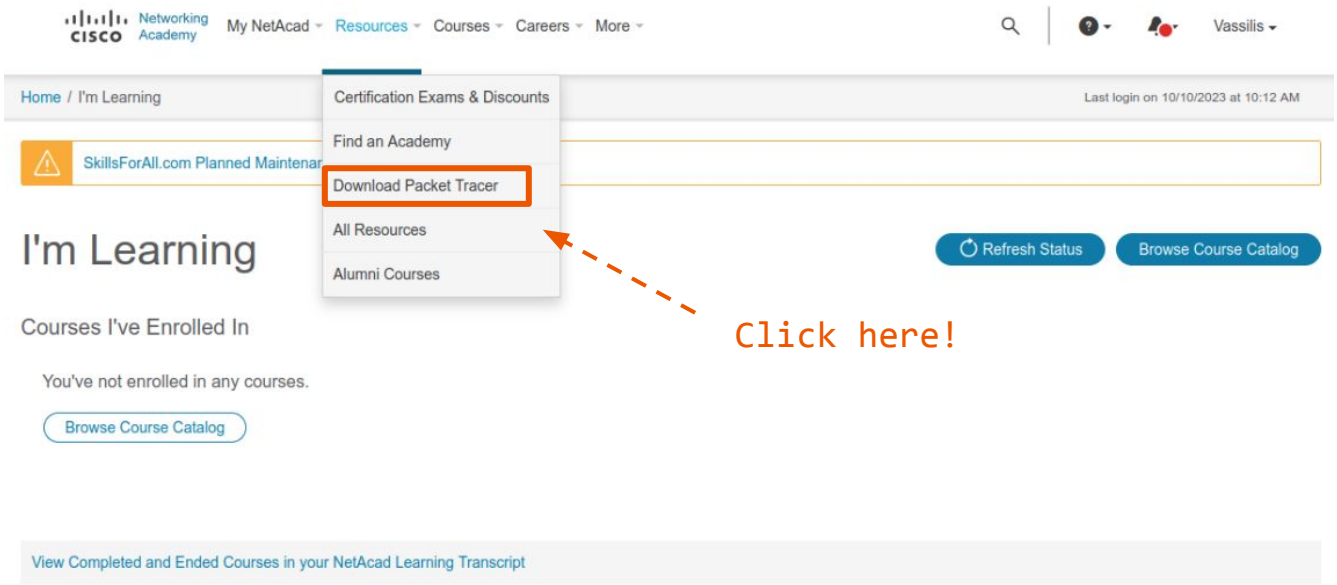
Cisco Packet Tracer

What is Packet Tracer?

- A tool developed by Cisco to facilitate the virtual design and understanding of networks.
- You can download Packet Tracer **for free** provided that you sign up for a Cisco Network Academy (NetAcad) account (which is also free).
- Web Page: https://www.netacad.com/courses/packet-tracer
- With a NetAcad account you can also get access to some of the courses offered, which is highly recommended.
- To make it more clear, homework and classroom activities will often rely on NetAcad materials, so…

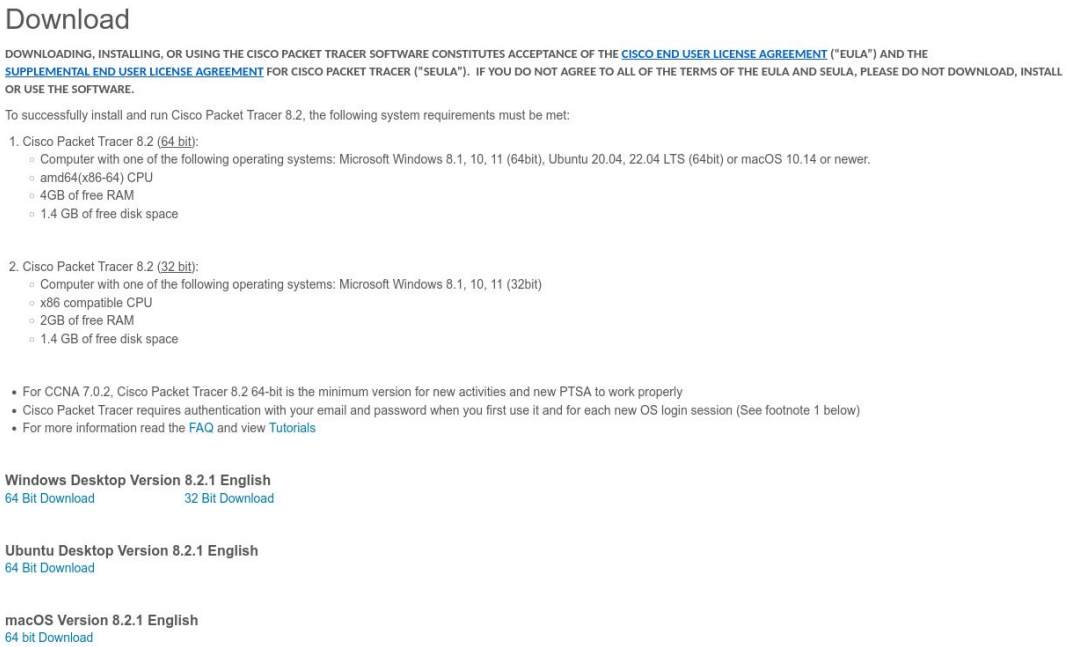
Downloading Packet Tracer 1 / n

Log in to your account and then click to **“Resources”** -> **“Download Packet Tracer”**:



Downloading Packet Tracer 2 / n

Scroll down to the **Download** section and pick the appropriate distribution for you:



Download

DOWNLOADING, INSTALLING, OR USING THE CISCO PACKET TRACER SOFTWARE CONSTITUTES ACCEPTANCE OF THE CISCO END USER LICENSE AGREEMENT ("EULA") AND THE SUPPLEMENTAL END USER LICENSE AGREEMENT FOR CISCO PACKET TRACER ("SEULA"). IF YOU DO NOT AGREE TO ALL OF THE TERMS OF THE EULA AND SEULA, PLEASE DO NOT DOWNLOAD, INSTALL OR USE THE SOFTWARE.

To successfully install and run Cisco Packet Tracer 8.2, the following system requirements must be met:

1. Cisco Packet Tracer 8.2 (64 bit):
   - Computer with one of the following operating systems: Microsoft Windows 8.1, 10, 11 (64bit), Ubuntu 20.04, 22.04 LTS (64bit) or macOS 10.14 or newer.
   - amd64(x86-64) CPU
   - 4GB of free RAM
   - 1.4 GB of free disk space

2. Cisco Packet Tracer 8.2 (32 bit):
   - Computer with one of the following operating systems: Microsoft Windows 8.1, 10, 11 (32bit)
   - x86 compatible CPU
   - 2GB of free RAM
   - 1.4 GB of free disk space

- For CCNA 7.0.2, Cisco Packet Tracer 8.2 64-bit is the minimum version for new activities and new PTSA to work properly
- Cisco Packet Tracer requires authentication with your email and password when you first use it and for each new OS login session (See footnote 1 below)
- For more information read the FAQ and view Tutorials

Windows Desktop Version 8.2.1 English
64 Bit Download 32 Bit Download

Ubuntu Desktop Version 8.2.1 English
64 Bit Download

macOS Version 8.2.1 English
64 bit Download

NetAcad Courses

In the “Download Packet Tracer” page, above the “Download” section, you can find **three interesting courses** (*interesting course: a course is characterised as “interesting” to inform someone that they should take it, without telling them to do so directly*):

- Getting Started with Cisco Packet Tracer
- Exploring Networking with Cisco Packet Tracer
- Exploring IoT with Cisco Packet Tracer

Also interesting is the following NetAcad course:

- Network Technician

Time for Group-work! 1 / n

- Group together in groups of 2 or 3.
- Open a shared document (or use a blank sheet of paper).
- Have a look at the classroom around you and spot any devices that are connected to the classroom network (please, stay seated, if possible).
- Fill in a Table like the following one, containing all devices you have spotted above:

Manufacturer	Device	Location	Connection	Media
Apple	iPhone	Mobile	Wireless	WiFi & cell phone
Cisco	Cable Modem	Home Office	Wired	Cable TV coaxial cable, Ethernet cable
HP	Printer / Scanner	Home Office	Wireless	WiFi
Beats by Dre	Headphones	My Room	Wireless	Bluetooth

Time for Group-work! 2 / n

Write down brief answers to the following questions:

1. Are there other electronic devices that are not connected to the local network to share information or resources? What would be the benefit of having these devices online?
2. Which type of connectivity is used most frequently in your local network, wired or wireless?
3. Draw a diagram of your local network depicting your network's **topology**. Label each device with a name and location.

Network Topology: The physical and logical arrangement of nodes and connections in a network

A bit of hands on work before we go…

1. For what follows you should resume working on your own computer.
2. Open NetAcad's tutorial **`3.3.3 Packet Tracer - Deploy Devices.pdf`** and follow the instructions found there to complete the tutorial.
3. Then open NetAcad's tutorial **`3.3.4 Packet Tracer - Deploy and Cable Devices.pdf`** and follow the instructions found there.

Homework!

1. Download and install Packet Tracer on your own machine following the instructions presented in class.
2. Enrol for the “Getting Started With Packet Tracer” Course.
3. Complete the “Getting Started With Packet Tracer” Course.
4. Don’t forget to email me for any questions at: v.markos@mc-class.gr

Any Questions?

Don’t forget to fill-in the questionnaire! (look right)

https://forms.gle/bjt37WkTNQKkwbDX8