COMPUTER NETWORKS

2024-2025 SUMMER SEMESTER

PROJECT

INTRODUCTION

For this project we intend to build a computer network. We will start by creating a webserver, then we will create a LAN for two PCs using a switch, and afterwards we will evolve to connect our LAN to others and create a typical corporate network.

During this project, we expect that you deliver 4 written reports that will summarize your efforts on reaching the objective. These reports are the following:

Phase	Due Date
Phase 1	Check dates on moodle
Phase 2	
Phase 3	
Phase 4	

(25%) PHASE 1 – WEB SERVER

On this first phase, you will install a Web Server on your PC and test the connection. A free web server is available on https://www.apachefriends.org/index.html. In order to test if it is working you can open a web browser and point it to your own PC using the address http://127.0.0.1/.

After testing the web server is running you can access it from a browser in another PC, tablet or mobile phone connected to the same network. Just replace the IP address **`127.0.0.1`** in the URL above with the IP address of the PC running the web server.

Use Wireshark to capture the web access from another host and compare the HTTP headers sent by the client and the server. If you have trouble connecting to the server check if the firewall is disabled on the PC running the server.

Now, you will develop a Web client (that will replace your browser) using a programming language of your choice where you should establish a TCP connection to the server and request the base webpage from your previously installed webserver. You should also try using your client with a different webserver, from the Internet. The requirements are that:

- you CANNOT use an HTTP library;

- you are supposed to establish the TCP connection by yourself using the available sockets library, send the HTTP request and receive the HTTP reply;
- the HTTP reply should then be presented to the user;
- extra points will be given if you prepare your client to proactively act to the different HTTP replies;
- you do not need to develop a graphic application, a text-only application is enough.

Use Wireshark to capture the interaction from your application to the webserver and compare it to the one obtained previously when using the web browser.

WHAT TO INCLUDE ON THE REPORT?

- Screenshots of your application, browser and Wireshark captures;
- Source code of your application, with line-by-line explanation;
- List of headers sent by the client (browser and application) and server, and their meanings;
- Report on what was performed to achieve the objectives for this part (includes the installation and configuration process of web server).

INTRODUCTION TO PHASES 2, 3 AND 4

In this phase we start working on a virtual environment. Virtual environments allow us to build a much larger network without access to physical devices. For this project, we will use Cisco Packet Tracer as a virtual environment to build our topology and run some experiments. Cisco Packet Tracer is a free educational simulator developed by Cisco that allows us to create network topologies composed of different types of devices, configure them and run simple test applications.

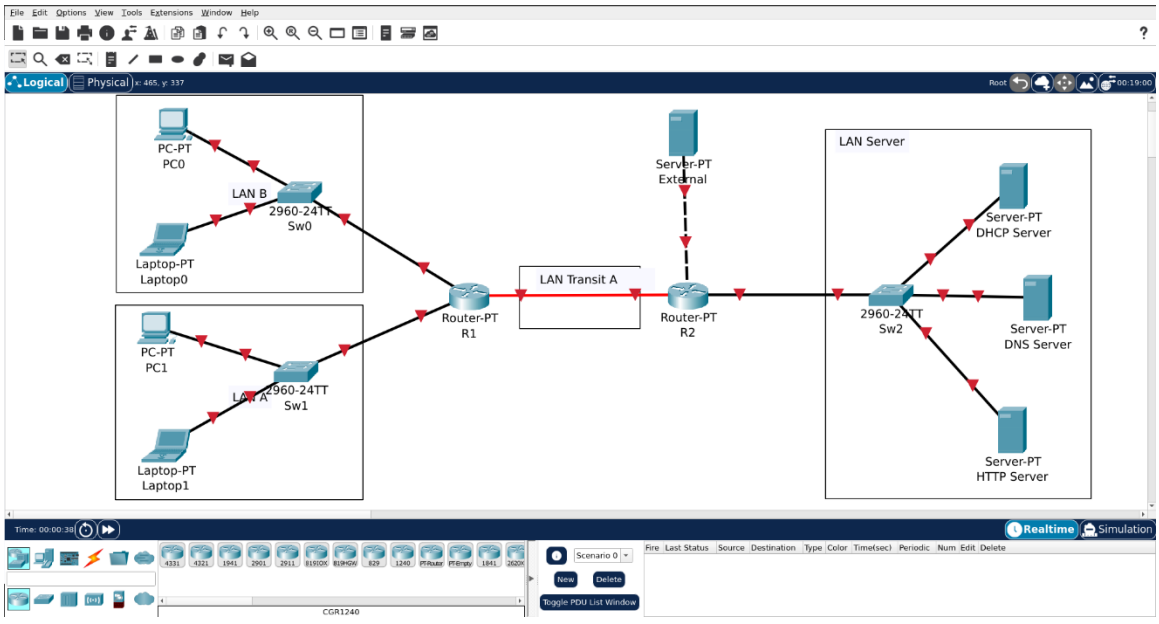

FIGURE 1: CISCO PACKET TRACER INTERFACE.

Figure 1 shows what the network topology will look like in Cisco Packet Tracer, as well as its main menu and controls. This network topology is already provided to you in the form of a PKA file – a Cisco Packet Tracer Activity. You can download this file from Moodle (`Projeto2425v.pka`). **This means that you do not need to change the topology, you only need to start the devices and configure them.**

Cisco Packet Tracer is an application that runs locally on your computer. So, before using it, you need to download it and install it. Even though the program is free, Cisco requires users to register and enroll in one of its courses to download the installer. Start by accessing the *Getting Started with Cisco Packet Tracer* course web page: https://skillsforall.com/pt/course/getting-started-cisco-packet-tracer. You should see a page as shown in Figure 2. Click on *Get Started*. That should take you to a login page where you can either use an existing Cisco Network Academy Account, sign-up for one or login using a Google Account (choose whatever option is more convenient to you).

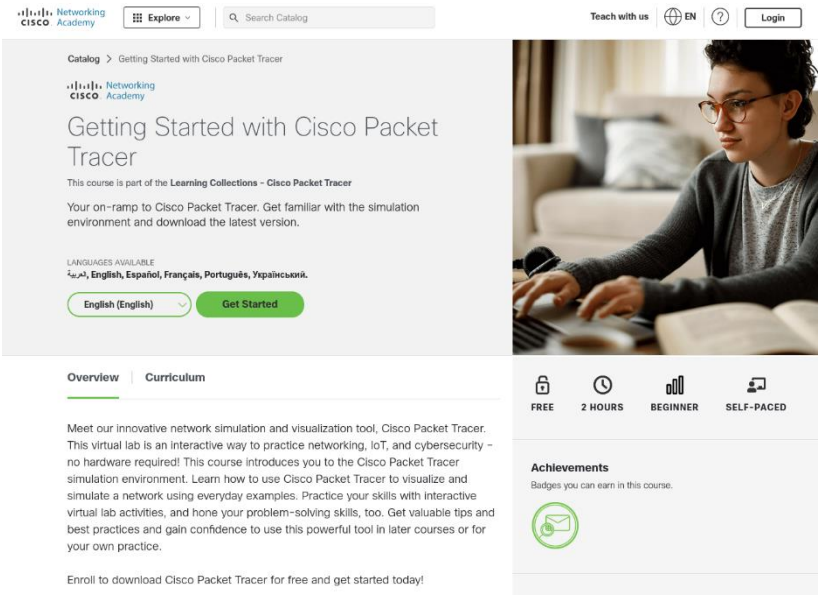

FIGURE 2: WEB PAGE FOR THE *GETTING STARTED WITH CISCO PACKET TRACER* COURSE.

After logging-in and accepting the terms and conditions, you will be redirected to the course material itself, as illustrated in Figure 3. While taking the course is not mandatory for this project, it provides a nice introduction to Cisco Packet Tracer, so it might be interesting to follow it to the end. In Section 1.0.3 of the course, you will find a link to the download page, as shown in Figure 4. You will notice that there are versions available for Windows, Ubuntu and MacOS: choose the one that is suitable for your computer. Also notice that there is a PDF file with additional download and installation instructions available on this page.

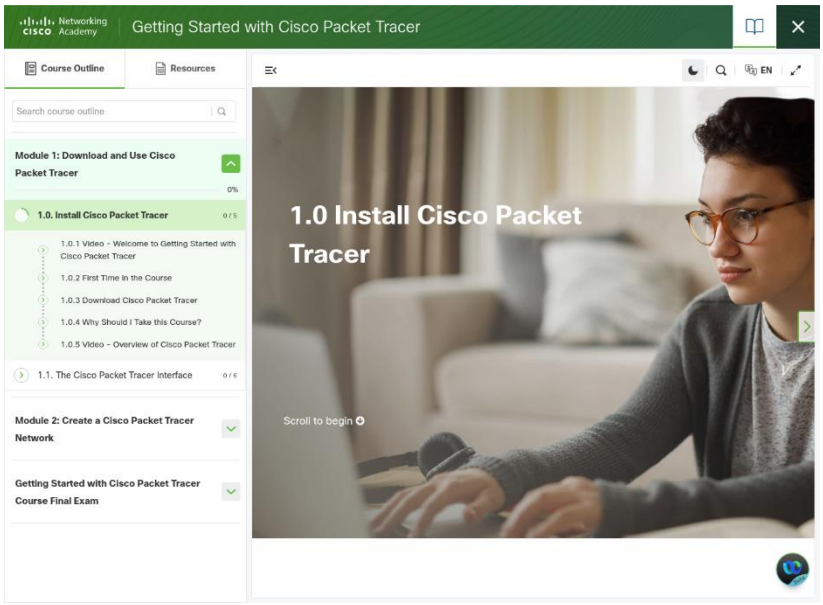

FIGURE 3: COURSE MATERIAL FOR THE *GETTING STARTED WITH CISCO PACKET TRACER* COURSE.

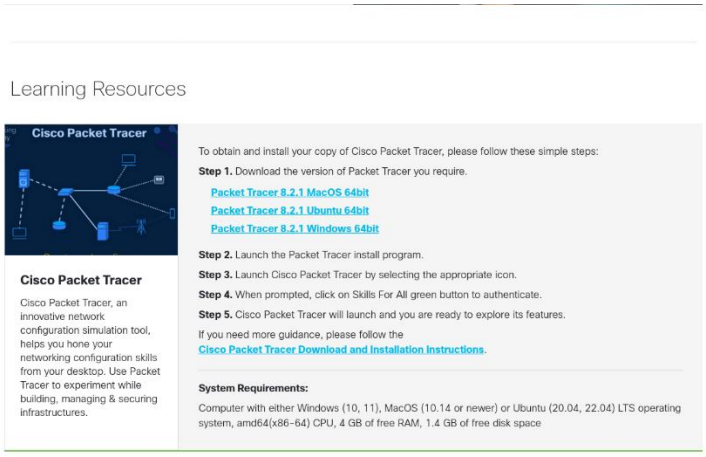

FIGURE 4: CISCO PACKET TRACER DOWNLOAD PAGE.

After downloading the installer, proceed with the installation and launch Cisco Packet Tracer. You will be greeted with a window as the one shown in Figure 5. It requires you to login with either a Cisco Network Academy or a Cisco Skills For All account to use the software. If you used the sign-up option or logged-in with your Google Account while initially accessing the *Getting Started with Cisco Packet Tracer* course web page, you should choose the Cisco Skills For All option. That will open a tab or window in your browser for you to log-in. It is likely that at this point your browser is still logged-in with your credentials and, therefore, the process will be automatically completed (otherwise, just log-in again on your browser window).

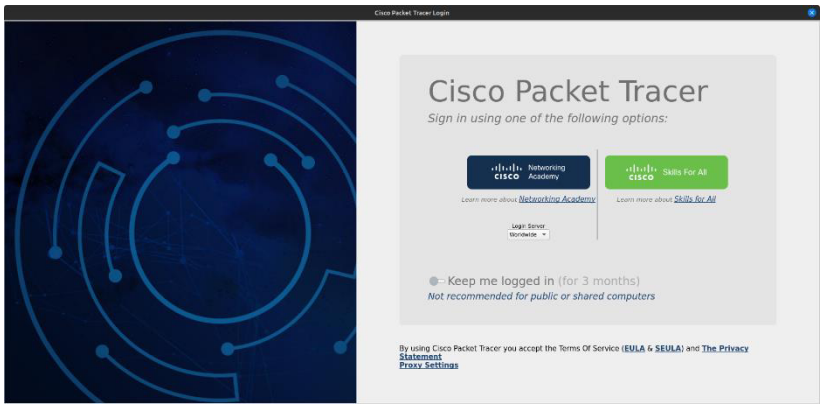

FIGURE 5: CISCO PACKET TRACER LOGIN WINDOW.

After all those steps, you should now see the main window on Cisco Packet Tracer with an empty canvas. At this point, if you haven't done it yet, download the `Projeto2425v.pka` file from Moodle. Now, in Cisco Packet Tracer window, choose **`File > Open…`** and open the file. You should see the topology (Logical View) loaded on the main window (as shown in Figure 1) as well as a second window containing instructions to the activity.

For this project, you will mostly interact with the Logical View and the Device Window. You can open the Device Window for a certain device by clicking on it on the Logical View. For instance, if you click on router *R1*, you should see a window like the one on Figure 6.

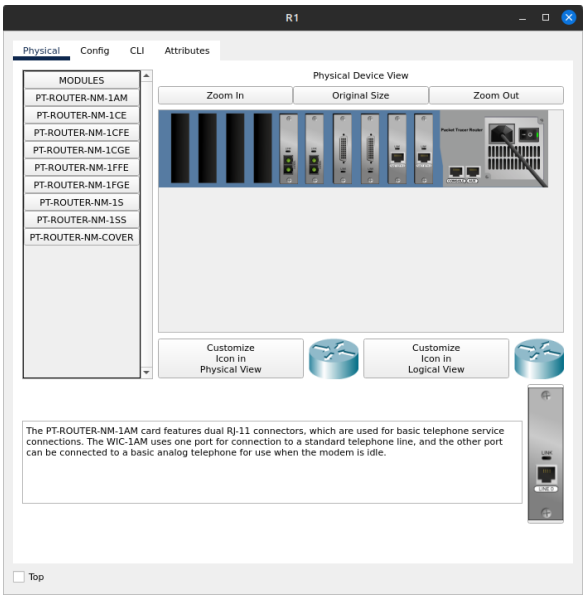

FIGURE 6: DEVICE WINDOW.

This window allows you to see and change several device settings, as well as interact with it in different ways. It is organized in tabs, such as *Physical* (you can see and change physical properties of the device, such as power it on and off and add or remove hardware modules) and *Config* (basic device configurations).

For network devices (*e.g.*, routers and switches), there is a *CLI* tab, which emulates a command line interface for that device, allowing you to enter Cisco CLI commands. You will likely need to use the CLI for more advanced configurations.

For end-devices (PCs, laptops, servers), there is a *Desktop* tab. It contains different applications that can be used on that device. The *Command Prompt* app is particularly useful, as it provides a Windows-like prompt allowing you to use basic commands such as `ping`, `tracert` and `ipconfig`.

Finally, for servers, there is a *Services* tab that lists some classical network services that can be enabled on those hosts (*e.g.*, DHCP, HTTP, DNS). Selecting one of those services on this tab, you will be presented with a simplified configuration interface which can be used to change some settings.

Note that any configuration you make to routers will be lost if you power the device off without saving it to its NVRAM (or exporting it to a file for importing it back later).

Another feature that is important to this project is identifying the names of the interfaces connected to each link – you will need that to know which router interface to configure for a certain purpose. One way of doing this is by going back to the Logic View on the main window and hovering over the line that represents the link: after a few moments, identifiers of the interfaces connected to that physical link should be shown.

You should also keep an eye on the small icons that are shown above the links, near each device. They show the status of the respective network interface. For instance, a green upward triangle indicates that the interface is up, while a red downward triangle indicates that the interface is down (maybe the interface is disabled, or the device is off).

(25%) Phase 2 – Connecting Devices (using LAN A and B only)

This phase is currently divided into 2 sub-phases. First, we will consider only LAN A, and then we will consider both LANs A and B.

We will start by configuring LAN A, as illustrated in Figure 2. To connect more than 2 computers we need to use a switch.

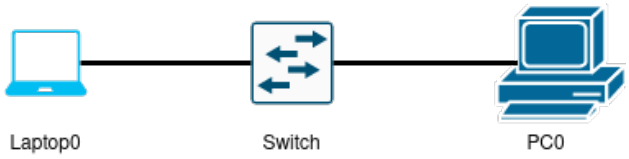

Figure 7: LAN A Topology.

Since we are building our own LAN we should start by defining our own IP address range. The range attributed to your group, for this phase and the remaining ones, is **`10.0.N.0/24`** where N is your group number.

Configure *Laptop0* and *PC0* with IP addresses. *Laptop0* should have the IP address **`10.0.N.1`** and *PC0* should have the IP address **`10.0.N.2`**. For now, no gateway is going to be defined.

Now test the connectivity between the 2 computers using the command **`ping`**.

WHAT TO INCLUDE ON THE REPORT?

- Screenshots of the configuration screens;
- Outputs of the commands;
- Report on what was performed to achieve the objectives for this part, including answers to the questions.

CONNECTING TWO LANS WITH A ROUTER

Let us continue by connecting multiple LANs (LAN A and LAN B) using a single Router. To do so we will connect two network interfaces on the router to the switch of each LAN. Figure 3 shows the expected topology. Note that this topology corresponds to the left part of the topology you received in the Packet Trace Activity file. Therefore, the physical connections are already made for you and require no changes.

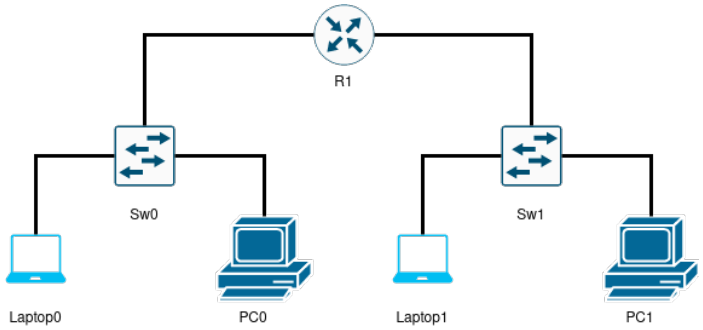

FIGURE 8: TWO LANS CONNECTED.

Since now there is a second LAN, you should have a different address space allocated for it. To do so you should subnet the address space given to your group (the `10.0.N.0/24` above). You should also check if the previous configurations on *Laptop0* and *PC0* must be changed.

Aside from the hosts, for this phase, you will only need to configure router *R1* (add IP addresses to the interfaces and check that they are online).

Router interfaces should use the last available address of the subnet address range for each interface. Do not forget to also configure the default gateway on the different hosts.

Test all configurations using the previously mentioned commands, testing connectivity between all the devices in the network. Check ARP caches again and explain the results. Also, check the routing table on the router with the CLI command **`show ip route`**. Explain the results.

WHAT TO INCLUDE ON THE REPORT?

- Updated screenshots of the hosts configuration screens;
- Outputs of the commands;
- Router configuration;
- What was performed to achieve the objectives for this phase, including answers to the questions.

(25%) PHASE 3 – CONNECTING MULTIPLE NETWORKS

Now that you understand subnetting, it is easier to expand our network. In this phase, we will connect our two LANs (A and B) to Server LAN using a Transit Network. LAN Transit A will be a transit network between routers *R1* and *R2*. From this point on, we will assume that LAN A is a network for users of department A and LAN B for the users of department B. We also have LAN Server which connects several servers. Moreover, router *R2* is an edge router connecting our corporate network to the rest of the Internet. Figure 9 shows an abstract overview of the network topology.

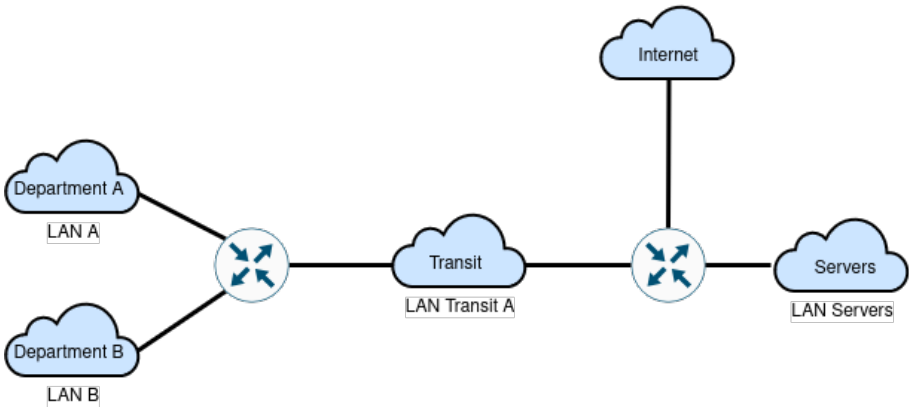

FIGURE 9: NETWORK TOPOLOGY WITH MULTIPLE ROUTERS.

Because now you have more LANs, you will have to change, again, the subnetting. To obtain the number of clients connected to LANs A and B you should use the following formulae:

$$\text{Clients}_{LAN_A} = \max\left(20, \left(\sum_{k=0}^{n} studentnumber_k\right) mod\ 100\right)$$

$$\text{Clients}_{LAN_B} = \frac{\text{Clients}_{LAN_A}}{2}$$

The summation in the first formula represents the sum of the student numbers for all group members (*n* represents the total number of students in your group). Then, you should take the result of the summation modulo 100 (select only the last two digits of this value). If this number is lower than 20, you should use the value 20. The number of clients at LAN B should be half of the ones from LAN A.

LAN transit A should use /30 subnets each.

LAN Server should have the largest remaining contiguous block of your address space.

Additionally, to *simulate* the connectivity with the Internet, router *R0* should be configured with the IP address 8.8.8.2/30 on the FastEthernet0/0 interface.

Moreover, you will need to configure routing tables on the routers to ensure proper packet forwarding. Your configuration should fulfill the following requirements:

1. all hosts must be able to reach each other;
2. hosts on LANs A and B must be able to reach **any** address external to the corporate network;
3. hosts on the LAN Server must be able to reach **any** address external to the corporate network; and
4. the routing tables on R1 and R2 must include the minimum number of entries required to achieve the previous requirements.

Test the connectivity between networks and routers. If the configuration has been done properly, you should be able to *ping* all the network devices from any other device, *i.e. Laptop0* should be able to ping *Laptop1*, *PC0*, *PC1*, R0, R1, R2, the servers in LAN Server, and the address 8.8.8.1. The same goes for Laptop B, and so on…

Do not forget to adjust routing tables and default gateways on the PCs, Laptops, Routers and Servers. Test if everything is working as expected, use the previous knowledge to test everything.

WHAT TO INCLUDE ON THE REPORT?

- IP Address distribution, including max number of devices and network and broadcast addresses per subnet;
- Command outputs in order to test connectivity and routing;
- Configuration of different devices and networks (including the address space used on each LAN);
- What was performed to achieve the objectives for this phase.

(25%) PHASE 4 – DEPLOY SERVICES

In this phase we will upgrade our network to a more realistic one by using DHCP and DNS to provide an easier experience to our users. Additionally, we will also add a webserver. Notice that the provided Cisco Packet Tracer Activity file already has three servers connected to LAN Server with the corresponding labels. The respective services are already enabled on those servers, but they may require additional configuration. It is your task for this phase to perform such configurations as well as any additional settings[1] required on the remaining network devices to achieve the objectives stated here.

Users of LANs A and B should be able to receive a network configuration automatically (from the DHCP server) and to access the web server by the name www.company.com. Figure 10 shows the expected network diagram. You can test the DNS using **`nslookup`**, and DHCP on the clients using **`ipconfig /release`** or **`ipconfig /renew.`**

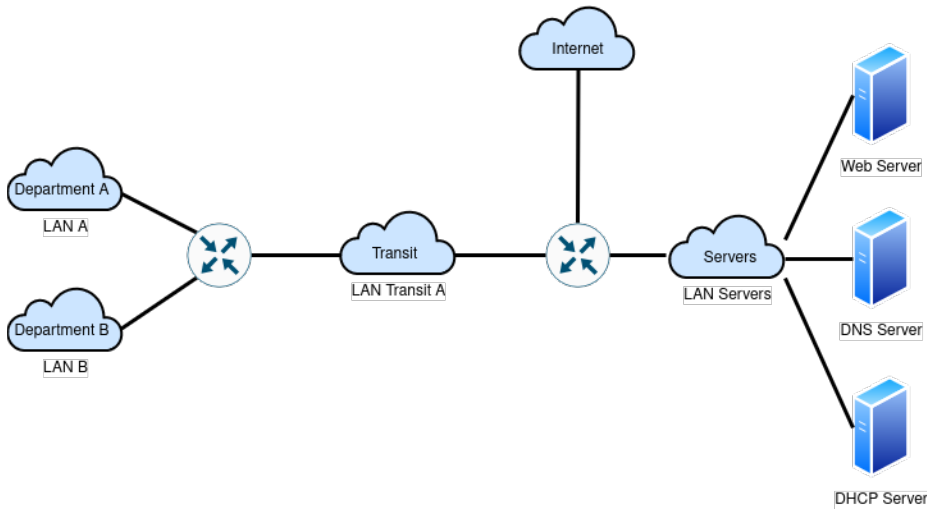

FIGURE 10: NETWORK WITH SERVICES.

To further test the DNS configuration, perform a ping using the correct name of the Webserver. To test the DHCP configuration, show the outputs of **`ipconfig`** commands on the clients. To test the Webserver, use the *Web Browser* app on the hosts of LAN A to try to access the URL http://www.company.com/ (an *index.html* file is already available in the web server).

Additionally, perform the following experiment:

1. Go into the configuration of the DHCP server and turn its network interface off.
2. After that, turn it on again.
3. Now, open a command prompt at the DHCP server and check the status of its ARP table. Write down the results.

[1] Particularly, you may need some additional configurations on some routers. The graphical configuration dialog on the routers' Device Windows may not be sufficient for this purpose. For some potentially useful CLI commands, please refer to https://www.cisco.com/en/US/docs/ios/12_4t/ip_addr/configuration/guide/htdhcpre.html#wp1095442

4. After the link between the DHCP server and its switch is operational, start a ping from PC1 to the DHCP server.
5. Go back to the command prompt at the DHCP server and check again the contents of its ARP table. Write down the results.

Now, look again at the contents of the ARP table you obtained from steps 3 and 5 above. Did the contents change? Why? Explain what happened.

WHAT TO INCLUDE ON THE REPORT?

- Configuration of different devices and networks (including the address space used on each LAN);
- Command outputs in order to test connectivity, routing, DNS, DHCP and Web access;
- What was performed in order to achieve the objectives for this phase.
- The contents of the ARP table of the DHCP server at steps 3 and 5 above, as well as an explanation of what happened.

This is your last phase. By this time, you should be able to understand all the concepts and protocols related with building a simple corporate network.