KOÇ ÜNİVERSİTESİ
COMPUTER ENGINEERING

COMP416: Computer Networks
Project 3
Network Layer Analysis and Simulations with Cisco Tracer

Due: January 12, 2024, 11:59pm (Late submissions will not be accepted).

Submission of the project deliverables is via Blackboard.

This is an individual project. You are not allowed to share your codes and answers with each other.

This project is about the **Network Layer** of the network protocol stack.

The objectives are to practice with the network layer data, the principles behind network layer services, and designing and simulating a network. Through this project, you will be working with command line tools to analyze your device's properties as well as design a network using the Cisco network simulation tool.

You should read this document carefully before starting your tasks.

Part 1. Network Layer Analysis

Part-1.1 ICMP Analysis

The Internet Control Message Protocol (ICMP) is a supporting protocol in the Internet protocol suite. ICMP is a companion protocol to IP that helps IP to perform its functions by handling various errors and test cases. It is used by network devices, including routers, to send error messages and operational information indicating, for example, that a requested service is not available or that a host or router could not be reached. ICMP differs from transport protocols such as TCP and UDP in that it is not typically used to exchange data between systems, nor is it regularly employed by end-user network applications (with the exception of some diagnostic tools like ping and traceroute).

You are asked to use traceroute in the command line to perform a set of actions described in the following.

Traceroute is implemented in different ways in Unix/Linux/MacOS and Windows. In Unix/Linux, the source sends a series of UDP packets to the target destination using an unlikely destination port number; in Windows, the source sends a series of ICMP packets to the target destination. For both operating systems, the program sends the first packet with TTL=1, the second packet with TTL=2, and so on. Recall that a router will decrement a packet's TTL value as the packet passes through the router. When a packet arrives at a router with TTL=1, the router sends an ICMP error packet back to the source. A shareware version of a much nicer Windows Traceroute program is pingplotter.

The source and destination IP addresses in an IP packet denote the endpoints of an Internet path, not the IP routers on the network path the packet travels from the source to the destination. Traceroute is a utility for discovering this path. It works by eliciting ICMP TTL Exceeded responses from the router 1 hop away from the source towards the destination, then 2 hops away from the source, then 3 hops, and so forth until the destination is reached. The responses will identify the IP address of the router. Since traceroute takes advantage of common router implementations, there is no guarantee that it will work for all routers along the path, and it is usual to see " * " responses when it fails for some portions of the path.

- Perform traceroute with the URL provided to you. (Note that on a Windows machine, the command is "tracert" and not "traceroute".)
- On a Linux machine, you may need to force the traceroute command to send ICMP packets instead of UDP packets. You may look for this information using 'man traceroute' and choose the appropriate flag.
- At the end of the experiment, your Command Prompt Window should show that for each TTL value, the source program sends three probe packets. Traceroute displays the RTTs for each of the probe packets, as well as the IP address (and possibly the name) of the router that returned the ICMP TTL-exceeded message.

Answer the following:

1. Find the minimum TTL less than which the traceroute messages do not reach your particular URL destination. Provide a screenshot satisfying your answer.
2. What is the default number of probes used by the traceroute? Run multiple traceroutes, increasing the number of probes progressively. Explain your observation regarding the resolution of the route to your destination ip address.
3. On a Linux machine, you may need to force the traceroute command to send ICMP packets instead of UDP packets. You may look for this information using 'man traceroute' and choose the appropriate flag.
4. What is a Routing Blackhole? Provide a scenario where Routing Blackholes may be used beneficially. No screenshot is expected.

Part-1.2 Network Interface Analysis

The objective is to conduct a preliminary analysis of the network interfaces of your machine. The most commonly used commands in the Linux environment were 'ifconfig' and 'netstat'. However, both have now been deprecated and replaced with 'ip' and 'ss', which are part of the 'iproute2' utilities set.

- https://en.wikipedia.org/wiki/Iproute2
- https://wiki.linuxfoundation.org/networking/iproute2
- https://vmware.github.io/photon/assets/files/html/3.0/photon_admin/use-ip-and-ss-commands.html

You will be using the **'ip/ifconfig'** [Linux/Mac only] command to see the status of various network interfaces on your machine. The 'ip' command is a networking tool used for troubleshooting and configuration that can also serve as a monitoring tool for connections over the network. Both incoming and outgoing connections, routing tables, port listening, and usage statistics are common uses for this command.

Note: There are no direct alternative commands for Windows systems. Windows users can install WSL2 (Windows Subsystem for Linux) - a native Windows application for Windows 10 and higher, which enables the usage of Linux on Windows. Using WSL2 will enable the option for official MS-stored Linux installation Windows users, after which they can use Linux commands to answer the above questions. Install WSL

*Run the 'ip' command to observe the command syntax with various Objects and Options. You will get a result similar to Figure 1.

1. Understand how to use the ip command and then execute three different variations (OBJECTs) of it while explaining their usefulness. Provide screenshots of each command executed. In each command, you are going to execute, use at least two OPTIONs you have not used before.

```
Usage: ip [ OPTIONS ] OBJECT { COMMAND | help }
       ip [ -force ] -batch filename
where  OBJECT := { address | addrlabel | fou | help | ila | ioam | l2tp | link |
                   macsec | maddress | monitor | mptcp | mroute | mrule |
                   neighbor | neighbour | netconf | netns | nexthop | ntable |
                   ntbl | route | rule | sr | tap | tcpmetrics |
                   token | tunnel | tuntap | vrf | xfrm }
       OPTIONS := { -V[ersion] | -s[tatistics] | -d[etails] | -r[esolve] |
                    -h[uman-readable] | -iec | -j[son] | -p[retty] |
                    -f[amily] { inet | inet6 | mpls | bridge | link } |
                    -4 | -6 | -M | -B | -0 |
                    -l[oops] { maximum-addr-flush-attempts } | -br[ief] |
                    -o[neline] | -t[imestamp] | -ts[hort] | -b[atch] [filename] |
                    -rc[vbuf] [size] | -n[etns] name | -N[umeric] | -a[ll] |
                    -c[olor]}
```

Figure 1. The ip Command Structure

Part 2. Understanding IP and Subnetting:

Please answer the following questions while providing screenshots when applicable:

1. Using the command line on your computer, what is the IP address of the network you are currently connected to (choose the one that has a default gateway)? Attach a screenshot of the used command showing the IP address as well as the whole interface information.
2. What is the **subnet mask** of the network?
3. What is the **network (subnet) address** that you are connected to?
4. What is the **broadcast** address?
5. Calculate and write down the maximum number of devices that can connect to the identified network. Provide explanations.

Part 3. Simulations with Cisco Packet Tracer

The second part of the project requires you to work with the Cisco Packet Tracer. This is a GUI-based network simulator and analysis tool developed by Cisco. (You will need netcad account to download it from the official website. You can also download it from here.

To get started with the Packet Tracer Application, we suggest you watch the first two tutorials in the video tutorials series available on this link: Video Tutorials.

Packet Tracer offers an effective, interactive environment for learning networking concepts and protocols. It is an educational simulation tool designed to simulate the creation and testing of network architectures based on Cisco networking devices. CISCO Packet Tracer is a cross-platform visual simulation tool designed by Cisco Systems that allows users to create network topologies and imitate modern computer networks. The software allows users to simulate the configuration of Cisco routers and switches using a simulated command line interface. Packet Tracer makes use of a drag-and-drop user interface, allowing users to add and remove simulated network devices as they see fit. Also, you can use it for testing purposes. Suppose you want to deploy any change in your production network, you can use packet tracer to first test the required changes and if everything is working fine, then you can deploy those changes into production. It supports a number of devices, protocols, services routing mechanisms, Quality of Service (QoS) mechanisms and security elements.

In this project, you are required to use Packet Tracer to simulate a network with the appropriate devices to ensure that all network entities can communicate with each other and perform an analysis of the underlying networking elements.

Network Details:

A company with three branches and a headquarters asked you to design their network architecture. You are required to design the network and select the suitable hardware needed. The number of devices in each branch and the headquarters will be as follows:

- Headquarters: 30 devices
- Branch A: 20 devices
- Branch B: 15 devices
- Branch A: 25 devices

In addition, you are required to select a suitable IP address from the following choices and divide it as needed. Please take into consideration the number of devices at each location and **the need for future scalability to add more branches and/or more devices with minimum to no changes needed.**

- Option I: 192.168.1.0/24
- Option II: 10.0.0.0/16
- Option III: 172.16.0.0/20

  Please consider the following while designing the network:

  - The headquarters and each branch will be assigned a different subnet. Note: The connection between two routers needs a subnet of its own and the connected ports should be from the same subnet.
  - In your Cisco Packet Tracer design, you can put 3 devices in each branch and the headquarters, no need to add all of the devices. However, your design should allow connecting at least the number of devices required without changes to the created subnets, subnet masks, or gateways.
  - An appropriate number of routers and switches should be used.
  - Use automatic cable connecting while connecting between the devices.
  - All interfaces and devices should be configured with appropriate static IP addresses, subnet masks, and gateways. You can do the configurations using the Graphical User Interface at each node.
  - Make sure that every PC in each branch can establish communication with any PC in the same and other branches (headquarters is considered as a branch).

Answer the following questions in your report. Make sure to attach a screenshot with each answer supporting your arguments.

1. Attach a screenshot of the designed network with a label beside each port indicating its IP address, subnet mask, and gateway (if exists).
2. Which IP address you have selected from Options I, II, and III, and why?
3. How many branches does your network architecture support? What is the maximum number of devices that could be connected in each branch? Provide explanations. Include the calculations in your report (images of handwritten calculations are acceptable).
4. While configuring your network, you probably configured the routers using the Graphical User Interface. However, in real life, a command line is probably used. Make a table having two columns. The first column is the process, and the second one is the command. You can notice the commands written automatically when selecting an option in the GUI.
5. You can display the routing table using the command line at each router. Search for the command that displays the routing table and attach a screenshot for the routing table at each router.
6. Your network should be working, it means any two devices can communicate. Attach screenshots of using the ping command to test connectivity between a device from each branch with a device from other branches.

Project deliverables

Important Note:

You are expected to submit a project report, in PDF format that documents all the steps and instructions (for reproducibility) for this project. Use screenshots to illustrate the steps and provide clear textual descriptions as well. All reports/codes/works would be analyzed for plagiarism. Please be aware of the KU Statement on Academic Honesty. DEMO is a mandatory part of your project and MUST be attended to obtain credit for this project.

The name of your project .zip file must be <surname>-<KUSIS-id>.zip

You should turn in a single .zip file including

- Project Report named <surname>-<KUSIS-id>.pdf.
- You must provide screenshots with each answer, when applicable. Please also note that screenshots themselves are not explanations, and you are required to provide a description where mentioned in the question.
- The network simulation file (.pkt)

Figures in your report should be scaled to be visible and clear enough. All figures should have captions, should be numbered according to their order of appearance in the report, and should be referenced and described clearly in your text. All pages should be numbered and have headers the same as your file naming criteria.

If you employ any (online) resources in this project, you must reference them in your report. There is no page limit for your report.

Demonstration

In the demo session, you are expected to answer questions on the concepts of Network Layer. You may also be asked about the commands with the relevant options you may have used in answering the questions from Part 1. You will be required to demonstrate the working of your Part 3. implementation. Note that the demo is a must for evaluation, i.e. your project will not be graded in case you don't show up at your demo session.

Good Luck!