IP Networking Lab Assignment

Configuring Basic Aspects of OSPF Routing Protocol

1 Purpose and Goals

This lab assignment will give you a hands-on experience in configuring and managing routers and particularly in setting up the OSPF IP routing protocol. You will prepare the lab session, perform the practical exercises, and write a lab report, which describes the whole lab, including planning, preparations and results. You will work and hand in the report in groups of two students.

The lab report will be assessed; grading will be added to the total course score - check the course home page for details.

2 Overview

The Assignment is divided into preparation, practical part and documentation.

2.1 Preparations

The preparations are crucial to the successful execution of the main exercise. Without proper study there is no possibility to fulfil the requirements within the specified time; trial-and-error will not work!

The Appendix contains some basic information related to Cisco IOS software, that you should read and understand to follow the instructions provided in this document. However, during this phase it is advised to study the additional Cisco routers documentation available in the Internet if any additional explanations to relevant IOS commands are required. Finally, you should refresh and expand your knowledge on the topic of the lab exercise.

2.2 Lab Access and the Exercise

The main exercise is executed using the virtual lab that is accessible remotely from a computer of your choice via the Internet – you don't need to be present in the Lab room during the exercise. To access the lab you only need a PC with Internet access, an OpenVPN client installed (the app is freely available at: https://openvpn.net/community-downloads/) and a terminal client. For the latter we strongly recommend using MobaXTerm free application, available at https://mobaxterm.mobatek.net/download-home-edition.html, but you can use other similar applications (such as PuTTY), provided that they support the required functions (such as capturing the terminal text to the file in a well-readable format).

The lab environment emulates Cisco routers, and so the router operation system is IOS. The emulated network topology is fixed – changes can be only introduced by opening and closing individual router interfaces.

Before starting the main lab exercise, it is required to reserve the lab resources beforehand using the Resource Reservation system. Please refer to the *Resource Reservation User Guide* accessible at the relevant course home page. The lab can be booked for maximum of 4 hours (this is a total time assigned for completing the lab exercise). If you are well-prepared, this should be enough to execute the main exercise and gather information required to prepare the lab report.

To access the lab remotely, you first need to obtain the relevant OpenVPN certificate and then, at the reserved lab time, open the OpenVPN session. After successful login to the VPN network, the router consoles should be accessible via *telnet* sessions to the terminal server inside the VPN using the terminal client. For detailed instructions, please refer to the *Remote Access User Guide* accessible at the relevant course home page.

The tasks required to pass the exercise are described in detail in Section 3.

In case of any technical problems during the exercise (problems with remote access, access to router consoles, instability etc.) please contact the lab supervisor. The exercise can be repeated in cases justified by the observed technical problems.

Remark: do not use the `reload` command if you want to restore the initial state of the router during the exercise, or you will lose access to the router console. Use the procedure described in the Appendix instead, if necessary.

2.3 FINAL REPORT

The last phase consists of lab report preparation. You should plan the outline of the report in advance, during the preparation phase to be sure what input is necessary before attempting the main part of the exercise.

The report should contain the findings collected during the main practical part. This instruction will provide the questions and remarks (usually marked with different colour) as a guideline for the mandatory content of the report. Please make sure that you paste all required screenshots or text from terminal where asked and provide relevant explanations. The report should be clear, logical, concise, and formatted in a form that is typical for technical documents.

The final archive to be delivered as a result of the exercise should contain:

1. The report (in PDF format – all other formats will be rejected)
2. The file (or files) containing the text from all terminal windows where the router's consoles were accessed (the MobaXTerm software provides a very convenient way to save the content of the terminal window; the procedure is described in the *Remote Access User Guide*). **The archives without these files will be rejected.**

Please deliver the final report before the deadline announced for this exercise.

Note: If you find any errors or inconsistencies in this document and referenced manuals, please report them to the lab exercise supervisor(s). It will help to improve the lab exercise in the future.

3 LAB EXERCISE

The topology of the network emulated in the virtual environment is shown in Figure 1. All emulated routers are Cisco 3600. The experience of configuring the routers running within the virtual environment is indistinguishable from configuration of actual devices via typical ssh console access.

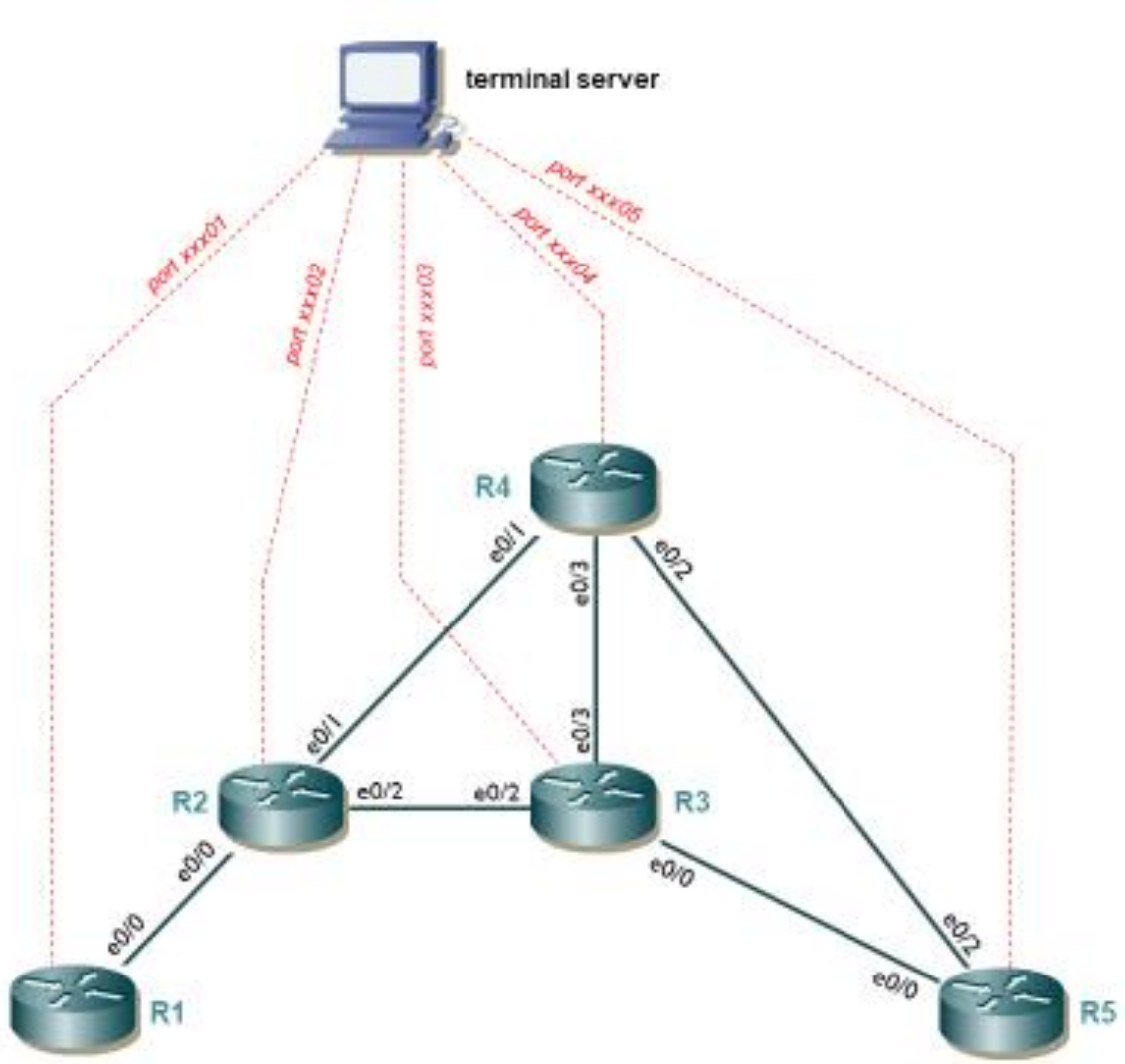

Figure 1. Router Lab topology

The lab exercise is divided into two main parts:

- Basic configuration of network devices
- Configuration and analysis of the OSPF protocol

The remainder of this section covers all practical tasks that constitute the scope of this exercise.

3A. BASIC DEVICE CONFIGURATION

You should start with configuring the IP addressing of the lab devices (note that the lab topology indicated in Figure 1 should not be changed). Allocate appropriate network and host IP addresses to the routers. Remember that each router interface must have a unique IP address on the subnet that it belongs to.

- All IP addresses used for network interfaces, except the interface between routers R1 and R2, should be taken from the following address pool: **192.168.10.0/27.** This pool should be further subneted according to network addressing requirements.
- The R1-R2 interface should be addressed using the range **192.168.11.0/30.**
- All IP addresses used for loopback interfaces should be taken from the following address pool: **192.168.0.0/29**. *Hint: It's a good practice to use mask /32 (255.255.255.255) for loopback addresses to efficiently use the available address pool.*

Place the addressing scheme at the beginning of the report (preferably in a form of table or picture). You should plan the addressing scheme during preparation phase.

- Configure IP addressing on all routers and interfaces according to the plan. Use the following command (in configuration mode for a given interface) to configure the IP address of an interface:

  `ip address <ip address> <mask>`

  After assigning the IP address to the interface bring the line protocol up using the **`no shutdown`** command. You should end this step with IP addresses configured on all your routers' interfaces.

- On all routers, check if the data link protocol is up on all configured connections using the Cisco CDP protocol (use the **`show cdp neighbors`** command). Verify and correct the addressing in case when there is no connectivity on a given interface. *Remark*: you can observe some delay between the configuration of the interface and its visibility in the output of the CDP command.
- Check the routing table on all routers using the **`show ip route`** command. Copy the output of this command from all routers to the report and explain the meaning of entries observed in these routing tables.

3B. INITIAL OSPF PROTOCOL CONFIGURATION

At this stage it is not possible to send IP packets via the network, for example from R1 to R5. To do this, a routing protocol such as OSPF is needed. Your task is now to configure the OSPF protocol in order to enable packet forwarding between routers in your network.

OSPF is a link state routing protocol. In OSPF each router has a unique identity. Cisco routers can use the loopback interface address or the largest IP address assigned to any interface on the router as the router id. However, Cisco IOS gives precedence to loopback interfaces in the selection of router id. If there is a loopback interface configured on the router, and this interface has an IP address, this IP address will be used as the router id. If no loopback interface exists then the largest IP address of the routers' interface will be used. The router id can be also configured explicitly by the network administrator.

- Start with configuring loopback 0 interface on all routers. Give each loopback interface a unique IP address.

- Initiate OSPF on the routers using **`router ospf`** command. *Hint: OSPF needs a process ID. Pick a number from 1 to 65535 of your choice.*

- Add router interfaces to OSPF. The OSPF process needs to know the networks that will be advertised to other routers (i.e. the interfaces on which the OSPF protocol will run), and the area to which they belong (the backbone area 0 is the default one; all additional areas, if created, will communicate through the default one). The command to advertise the network in OSPF has the following syntax:

  `network <prefix> <wildcard-mask> area <area-id>`

  The prefix can denote network address, subnet, or a given interface. The wildcard mask is the one that complements a subnet mask. Any bit set in the wildcard mask indicates a position in the network id that has no significance (e.g. if the subnet mask is 255.255.255.0, the corresponding wildcard mask is 0.0.0.255).

  Please note, that in some cases you can use a single command to cover all router interfaces that you want to add to OSPF process. However, this is not always correct – there are cases when individual interfaces should be specified.

- Optionally you can configure the router id using the **`router-id`** command. This option requires the restart of the OSFP process with the **`clear ip ospf process`** command to be effective.

- After adding all required router interfaces to OSPF check the ospf configuration with the **`show ip ospf`** command and next check the content of routing tables with **`show ip route`** command on all routers and place the output of the commands in the report.

3C. OSPF DATABASE

By default, the OSPF links in a lab network are of broadcast type. However, they are actually point-to-point, so you can configure OSPF to treat them this way, to avoid unnecessary election of the DR/BDR, only needed in broadcast network type. To explicitly set the point-to-point network type for OSPF, you need to use the following command: **`ip ospf network point-to-point`**

- Execute this command on interfaces between the following routers: R2-R3, R2-R4, R4-R5, and R3-R5 (you need to do it in the context of each respective interface).
- After finishing the above task, check the routing information on router R5 using the following commands:
  - **`show ip ospf database`**
  - **`show ip ospf database router`**
  - **`show ip ospf database network`**
- Copy/paste the output of the above commands to the report and explain:
  a. why there are exactly 5 router LSAs and 2 network LSAs in OSPF database?
  b. the content of the router LSA advertised by router R3 (check if the obtained output agrees with the network topology you have),
  c. the content of the network LSAs (check if the obtained output agrees with the network topology you have),
  d. which routers were elected as DRs and why?
  e. how router R5 can discover network topology using information from LSAs?

3D. MULTI-AREA OSPF

- Modify the current network configuration in such a way that R1-R2 interface belongs to different area (area 1), and so the R2 is now an ABR (Area Border Router). You must redefine the network R1-R2 in the ospf configuration (in routers R1 and R2) to area 1.

  `network <prefix> <wildcard-mask> area 1`

- Next on routers R1 and R5:
  - Execute **`show ip ospf database`** command. Copy/paste the output of this command to the report and explain the obtained output (note any observed difference from the expected result).
  - Execute the **`show ip ospf database summary`** command. Copy/paste the output of this command to the report and explain the provided information (what type of information can be obtained from summary LSAs?). Compare the content of the output observed for routers R1 and R5, explain the differences etc.
  - Execute **`show ip route`** command on each router and copy/paste the output to the report.

3E. OSPF LINK COSTS

Check if packets are forwarded via the expected paths using the **`traceroute`** command. Make yourself familiar with IOS **`ping`** and **`traceroute`** commands. Both commands come in two versions normal and extended. We are only examining the normal version.

- From router R4, ping the interface e0/0 of router R1. Add the result to the report and explain the interpretation of the information you get from the ping command.
- Do a traceroute to the same interface. Add the output from this command to the report and explain.

The command **`show ip ospf interface`** can be used to find more information about costs (weights) of the links (try this command on R2). The default reference bandwidth used to set the cost of network interfaces automatically is 100M.

- Check the routing table on the router R1 and explain the displayed paths' costs.
- Check the bandwidth of the link between R2 and R4 and compare it with the respective link cost. Note the output in the report and explain the obtained values. To find the interface cost for the above task you can use **`show ip ospf interface brief`**. To find the interface bandwidth use **`show interface`** command.

  Hint: you can use more advanced constructs to filter only the relevant information from the command output:

```
show ip ospf interface | include protocol|Cost
show interface | include protocol|BW
```

- Set cost of the link between R2 and R4 to 100 using command:

  `ip ospf cost 100`

  Hint: the command must be issued in the configuration context of the interface e0/1 on router R2, and, symmetrically, interface e0/1 on router R4.

- Check if the new costs are set. Copy -paste the proof to the report.
- From router R4, ping again the interface e0/0 of router R1. Add the result to the report and explain.
- Do a traceroute to the same interface. Add the output from this command to the report and explain.

3F. ROUTE REDISTRIBUTION (OPTIONAL PART)

Configure routers R1 and R2 such that they exchange routing information using RIP protocol, not OSPF.

- Switch off the OSPF process on R1. Next, configure RIP on R1 using the following commands and a proper interface address:
  - enable rip protocol: **`router rip`**
  - set the rip version using the following command: **`version 2`**
  - add R1-R2 network to RIP using the following command: **`network`** ...

- On R2 you need to configure both OSPF and RIP. Use the following commands, assigning proper interfaces to respective processes:
  - enter the ospf configuration mode: **`router ospf 1`**
  - delete the R1-R2 network from ospf: **`no network`** ...
  - set the metric for redistributed routes: **`default-metric 100`**
  - enable redistribution from rip: **`redistribute rip subnets`**
  - enable rip protocol (in OSPF configuration mode): **`router rip`**
  - set the rip version: **`version 2`**
  - add R1-R2 network to RIP: **`network`** ...
  - enable redistribution from OSPF: **`redistribute ospf 1`**
  - set the metric for redistributed routes: **`default-metric 2`**

Verify route redistribution.

- On R1 and R5 execute **`show ip route`** command. Paste the results to the report. On R5, explain the meaning of the E2 tag (see example below).

  O E2 192.168.11.0 [110/100] via 192.168.10.21, 05:02:49, Ethernet0/0)

- On R5, execute the following commands and paste the results to the report:
  - **`show ip ospf database`**
  - **`show ip ospf database external`** (explain also which network is advertised and the metric of the external route)
  - **`show ip ospf database router`** (note the ID of the ASBR router in the report – you will need to analyze the R2 LSA to get it).

3G. CLOSING REMARKS

Before exiting the lab environment, you are required to do the following:

1. Run "show running-config" command on each router console
2. Save the terminal text for each router console and attach the saved files to the zip archive containing the report.

The reports that do not fulfill the above requirements will be rejected.

Do not forget to list the authors' names on the first page of the report and use the following template for archive naming: **COURSE_Semester_FirstAuthorSurname.zip** (example: TD_2020L_Kowalski.zip).

There is no need to restore the router initial configuration after the exercise. The basic configs are loaded automatically at the beginning of each reserved timeslot.

4 DOCUMENTATION

At the course page you should have access to the following two complementary documents:

- *Resource Reservation User Guide*
- *Remote Access User Guide*

APPENDIX – INTRODUCTION TO CISCO IOS

The routers used in the lab exercise run Cisco IOS. There is an abundance of in-depth information related to the IOS in the Internet, so here only a very brief introduction is given.

IOS is the Cisco routers' operating system. You control IOS, and thereby the router, using IOS command line interface, in short – the CLI.

A. Command Completion and Help

In most cases it is not necessary to write the IOS commands in full. As soon as there are enough characters so that the CLI can differentiate between commands available in the specific context, you can stop entering characters.

If you are not sure which commands are available, you can always enter a "**?**" sign for help. This is also true if you want to check subcommands.

You can also use the TAB key for command completion.

B. Modes

IOS has several command levels or modes. Depending on mode you can use different commands. When you connect to a router you enter the EXEC mode. The command you will use most in this mode is the **show** command. In EXEC mode the command prompt ends with a >

```
R1>
```

To be able to control the router you must change the mode to PRIVILEGED. You can do this by entering the **enable** command in EXEC mode. In the PRIVILEGED mode the command prompt ends with a #:

```
R1#
```

You can return to EXEC mode from PRIVILEGED mode with the command ***exit***.

Another mode is the CONFIG mode (see subsection D).

C. Configuration

The router has two configuration storages. The first one is the **startup-config**. This configuration is stored in non-volatile memory and is read into **running-config** memory when the router starts up or reboots.

The **running-config** memory contains the configuration that is used when the router is up and running. When you are in CONFIG mode and enter configuration commands you change the **running-config** immediately, thereby changing the behavior of the router. You can copy the **running-config** to **startup-config** memory by using

```
copy running-config startup-config
```

Doing so at the beginning of the exercise will create the **startup-config** and allow reverting to the initial state by typing:

```
configure replace nvram:startup-config
```

The following should also work:

```
copy startup-config running-config
```

Note! *Do not use the* ***reload*** *command to revert to the default configuration as you will lose access to the router console afterwards.*

D. The „configure" command

To enter CONFIG mode, you issue the **config** command. This command takes parameters, and in our case, you want to enter configuration commands from the terminal. So, the command should be **configure terminal** or in short just **conf t.**

Once in CONFIG mode remember that each configuration command you enter is activated immediately. It is easy to cut off the branch you are sitting on, then. In our lab, though, you are accessing the router via the console port which is very hard to shut down.

Each function in the router can be set or unset. To set a function you just use the specific configuration command. To unset a function, you write **no** in front of the same command. All functions have a default status, for most of them this state is unset. The default state is not printed in the configuration listing. So those few commands that have the state set as the default state, you will not see in the configuration print out. They will only be listed if you have unset them, that is they will show in the listing with a no in front of them and will be unseen again if you activate that function.

CONFIG mode has several sub modes, for instance the interface configuration sub mode. You enter this mode by typing the interface configuration command:

```
(config)# interface ethernet 0/0
```

or in short just

```
(config)# in e0/0
```

In configure interface sub mode you can assign the interface an IP address. Use the command **ip address <ip address> <mask>.** In this sub mode you can also open and close individual interfaces. To close an interface, use the **shutdown** command. And in consequence of what was said above, you open an interface with the command **no shutdown**. You can also create and delete virtual interfaces, so called loopback interfaces, in the configure interface sub mode. To create a new loopback interface just type the configure command **interface loopback <interface-number>.** You can exit from CONFIG mode or any sub mode to PRIVILEGED mode by typing ***ctrl'Z***. To exit from a sub mode or from the CONFIG mode use the **exit** command.

E. The „debug" command

Another nifty command is the **debug** command. In general, it is dangerous to use, since by issuing this command you might end up in a situation where all packets going through the router are displayed on the console terminal. This may have severe impact on the router throughput. Do not use this command in the lab until it is explicitly stated in the lab manual or it is absolutely necessary for troubleshooting. You can debug nearly anything you want, from each single IP-packet to routing announcements sent between the routers. To see the output from the debugging you must direct it to the terminal console

that you are connected to. Use the **terminal monitor** command. To turn on debugging you issue command **debug <parameter ...>.** To turn it off it is often best to use **no debug all**.

F. The "show" command

The **show** command is the one that you will use the most. All parameters of the router can be inspected with this command. Here are some typical uses of this command that you will need.

show running-config	With this command you inspect the running-configuration. It must be given in PRIVILEGED mode.
show interface	With this command you inspect the status of an interface. You can enter an interface name if you don't want to list them all.
show IP int brief	With this command you get a list of all the router's interfaces with IP addresses.
show IP protocol	This command gives you information on parameters and status of routing processes running on the router.
show IP route	You show the router's current forwarding table with this command. If you want to see a routing table for the one of perhaps several routing protocols, use the command **show ip route <routing protocol>.**
show CDP neighbor	Cisco Discovery Protocol is Cisco's proprietary protocol used to exchange information between Cisco equipment. It allows retrieving information on which neighbors are connected to a device, and some basic information about them. This command is a good way to check your connections. If you add the parameter **detailed** as a suffix to this command, you will get a lot of information.

G. The "ping" and "traceroute" commands

Both **ping** and **traceroute** are available tools in IOS. In their normal form they take the remote host as parameter. Example:

```
ping 192.168.101.10

traceroute 192.168.7.17
```

Since a router has several interfaces, i.e. more than one, there is a minor issue here: Which of the several addresses of a router should be used as a source address?

All functions that make use of IP packets, including **ping** and **traceroute**, use the interface closest to the remote host, and therefore the IP address of this interface is used as source address. In our lab we will meet situations where this is not what we want. We might want to check connection with a router loopback interface as source.

In PRIVILEGED mode you can use the extended version of **ping** and **traceroute**. Just enter the **ping** or **traceroute** command without any parameters, and you will have several ways to control

these commands, like number of packets sent, packet size, and more. Answer **`yes`** to Extended commands question and you will have the possibility to declare source interface or source IP address. In the latter case the IP address must be one of the router's own IP addresses.

H. Additional hints

- Router interfaces are inactive by default. After proper configuration they must be activated using **`no shutdown`** command.
- Command lines starting from **`show`** (and **`debug`**) work properly only in the PRIVILEGED mode (indicated by the **#** sign next to the router name). However, you can issue these command from CONFIG mode using the ***do*** prefix (e.g. **`do show ip bgp`**)
- After configuring a router and routing protocol it is advised to check the validity of configuration by reviewing the config file (**`show running-config`**) and router's routing table (**`show ip route`**).