CO513 - Lab 06
Multiprotocol Label Switching - MPLS

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Multiprotocol Label Switching (MPLS) is data forwarding technology that increases the speed and controls the flow of network traffic. With MPLS, data is directed through a path via labels instead of requiring complex lookups in a routing table at every stop. Scalable and protocol independent, this technique works with Internet Protocol (IP) and Asynchronous Transport Mode (ATM). When data enters a traditional IP network, it moves among network nodes based on long network addresses. With this method, each router on which a data packet lands must make its own decision, based on routing tables, about the packet's next stop on the network. MPLS, on the other hand, assigns a label to each packet to send it along a predetermined path.

Label Switched Paths (LSPs) are predetermined, unidirectional paths between pairs of routers across an MPLS network.

1. When a packet enters the network through a Label Edge Router (also known as an "ingress node"), it is assigned to a Forwarding Equivalence Class (FEC), depending on the type of data and its intended destination. FECs are used to identify packets with similar or identical characteristics.
2. Based on the FEC, the ingress node will apply a label to the packet and encapsulate it inside an LSP.
3. As the packet moves through the network's "transit nodes" (also known as Label Switch Routers), those routers continue to direct the data by the instructions in the packet label. These in-between stops are based on the packet label, not additional IP lookups.
4. At the "egress node," or final router at the end of the LSP, the label is removed and the packet is delivered via normal IP routing.

A label stack is made up of at least four parts:

- Label value: holds the information for routers to determine where the packet should go next.
- Traffic class field: sets Quality of Service priority and Explicit Congestion Notification.
- Bottom of stack flag: indicates the last label in the stack.
- Time-to-live (TTL) field: limits the lifespan of the data, or how many hops it can make before it's discarded.

Labels can also be stacked. The top label controls packet delivery; when it reaches its destination, that label is "popped," and the label underneath takes over for direction.

Setting-up the Environment

For this lab exercise, you would need to set up GNS3 in your environment.

Steps to setup GNS3

1. Go to gns3.com/software/download. Don't download the direct downloading setup for your OS. Select download the GNS3 VM at the end of the list.
2. Download the "VMware Workstation and Fusion" virtual machine from the list.
3. Extract the downloaded file to obtain "GNS3 VM.ova" file
4. Then, download the VMware player from https://www.vmware.com/uk/products/workstation-player/workstation-player-evaluation.html and install.
5. For VMWare to run GNS3 on your computer, nested virtualization should be enabled in the BIOS of your computer.
   Open Bios Menu -> Advanced -> and enable the virtualization technology
   The process to load the BIOS menu can vary according to the brand. Search google for your device.
6. Now, we need to import the GNS3 into VMWare environment. Go to the download directory of the GNS3 VM and open "GNS3 VM.ova" file using VMWare Player.
7. Next, use the ip address shown in the VMWare interface, in a web browser to log in to GNS3 web interface.

NOTE: Follow the youtube video instructions in the following link for more details - https://www.youtube.com/watch?v=g-8fAQHL-Uk

Add CISCO IOS Router to GNS3 space

1. Download a GNS3 CISCO IOS image file using the following link , https://protechgurus.com/download-gns3-ios-images/
2. Follow the instructions below to import the image file to GNS3
   a. Menu -> Go to preferences -> Dynamips -> Add IOS router template

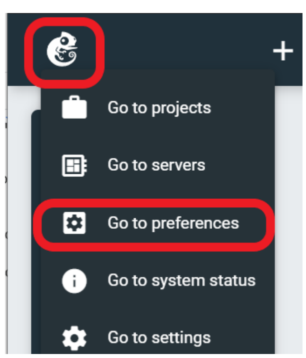

Figure 01

   b. Select "Run this IOS router locally" option from Server type
   c. Add the image file from the download directory to IOS image and select it

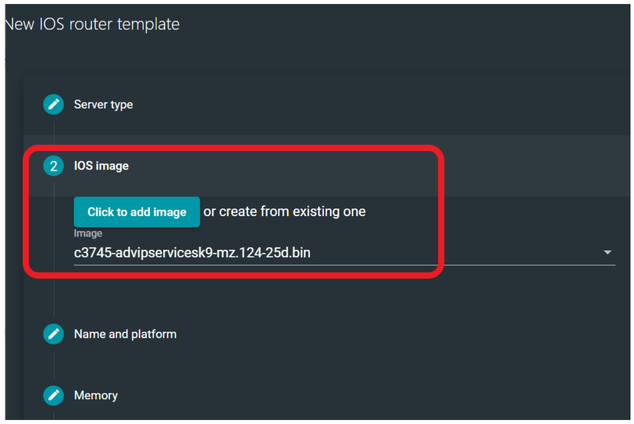

Figure 02

d. Add WIC-1T to all WIC Modules

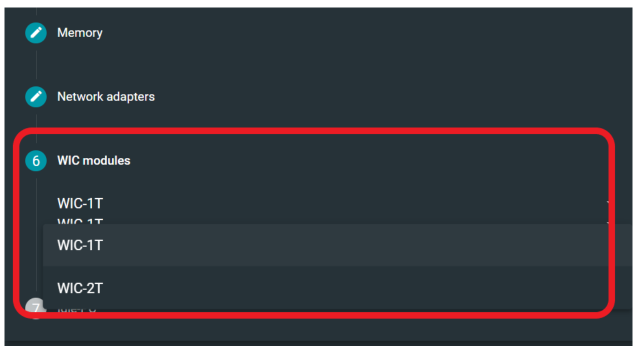

Figure 03

e. After configuring all the settings, click the "Add template" option to add the template and go back to the project.

Lab Exercise

An MPLS network is commonly a backbone network composed of MPLS-enabled routers called Label Switch Routers (LSR). Generally, the network consists of a core LSR with an edge LSR that applies labels to packets.

This is the setup mechanism of an MPLS network:

1. Routing tables of the different LSRs are computed with an Interior Gateway Protocol (IGP). A link-state protocol, such as Open Shortest Path First (OSPF) or Intermediate System-to-Intermediate System (IS-IS), is required if you plan to deploy MPLS TE.
2. A label distribution protocol (LDP) advertises the bindings between routes and labels. These bindings are checked against the routing table. If the route (prefix/mask and next

hop) learned from the LDP matches the route learned from IGP in the routing table, an entry is created in the label that forwards information bases (LFIB) on the LSR.

The LSR uses this forwarding mechanism:

1. Once an edge LSR receives an unlabelled packet, the Cisco Express Forwarding table is checked and a label is imposed on the packet if needed. This LSR is called the ingress LSR.
2. Upon the arrival of a labelled packet at the inbound interface of a core LSR, the LFIB provides the outbound interface and the new label that is associated with the outbound packet.
3. The router before the last LSR (the penultimate hop) pops the label and transmits the packet without the label. The last hop is called the egress LSR.

This diagram illustrates this network setup:

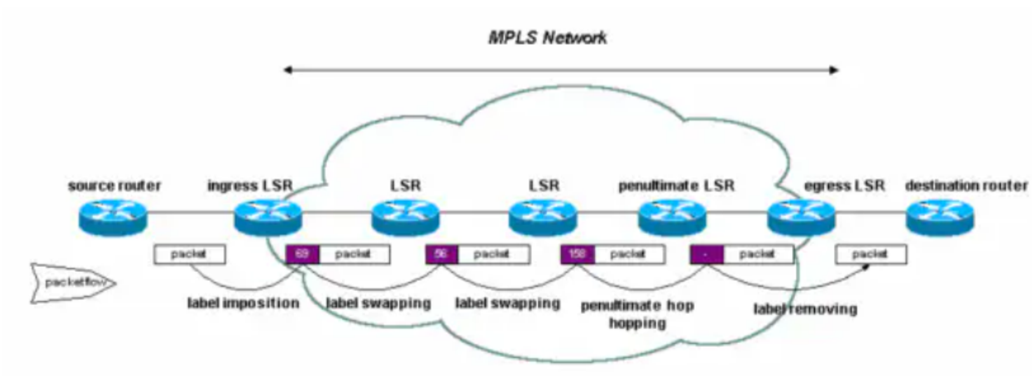

Figure 04

Quick Guide to Configure

1. Set up your network as usual. MPLS needs a standard IP connection in order to establish forwarding bases.
2. Ensure that the routing protocol (OSPF or IS-IS) works correctly. These commands are italicized in the configurations in the next section.
3. Enable **ip cef**, for better performances use ip cef distributed when available, in the general configuration mode. This is shown in bold in the configurations in the next section.
4. Enable **mpls ip**, or tag-switching ip on older Cisco IOS software releases, in the general configuration mode and in each interface, as shown in bold in the configurations in the next section. Even when the mpls ip command is used, the show running output can still show the command as tag-switching ip in some Cisco IOS software releases, as shown in the configurations in the next section.
   Note: The LSRs must have (up) Loopback interfaces with an address mask of 32 bits and these interfaces must be reachable with the global IP routing table.

Lab Task - Using GNS3

Use the following diagram to setup the lab

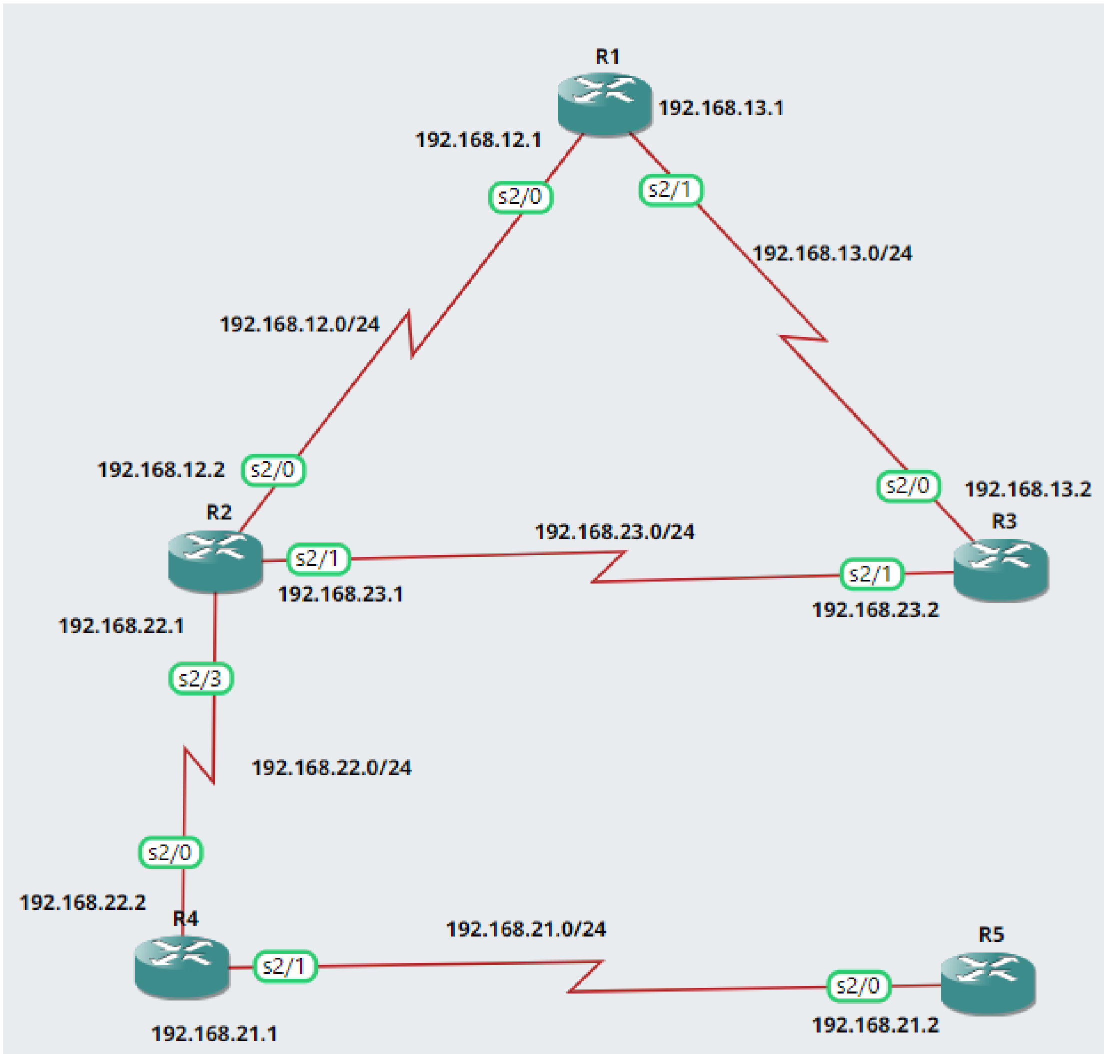

Figure 05

STEPS

1. Open GNS3 VM using VMWare Workstation
2. Use the IP address shown in the GNS3 VM to open it in the web browser

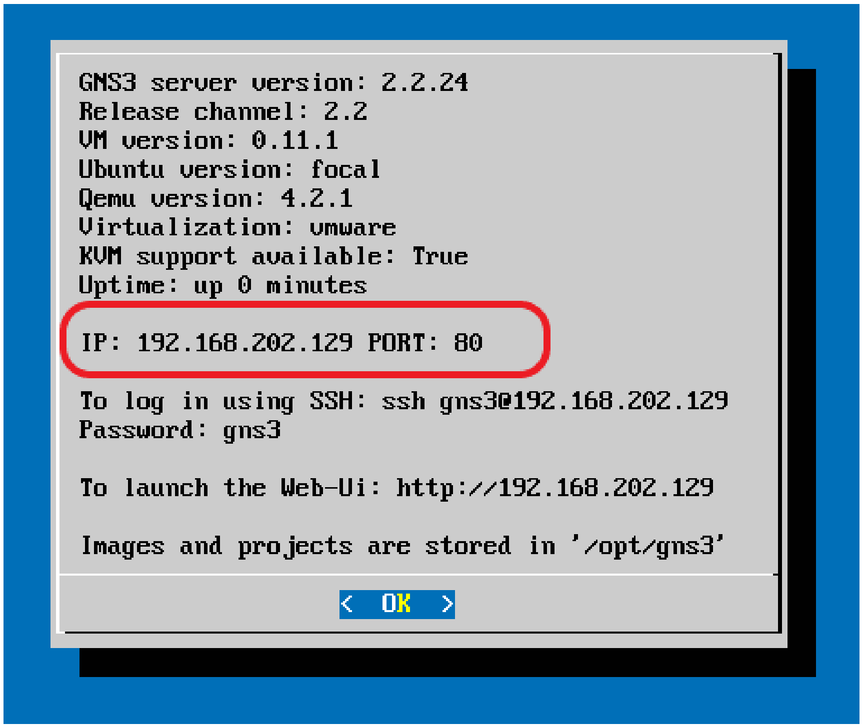

Figure 06

3. Create a new project using "Add blank project" -> type a name -> "Add Project"

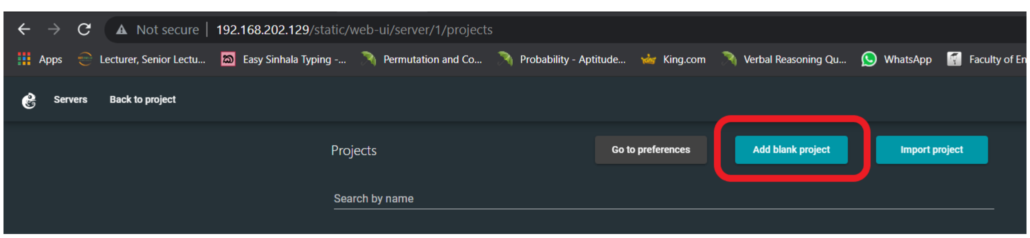

Figure 07

4. Click on + mark in the menu bar to open the available list of devices. The router you added previously, while setting up the environment will appear at the end of the list.
   Click on the device and drag it to the workspace and drop to place it on the canvas.

   HINT: you can use  mark on the menu bar to create the connections between devices.

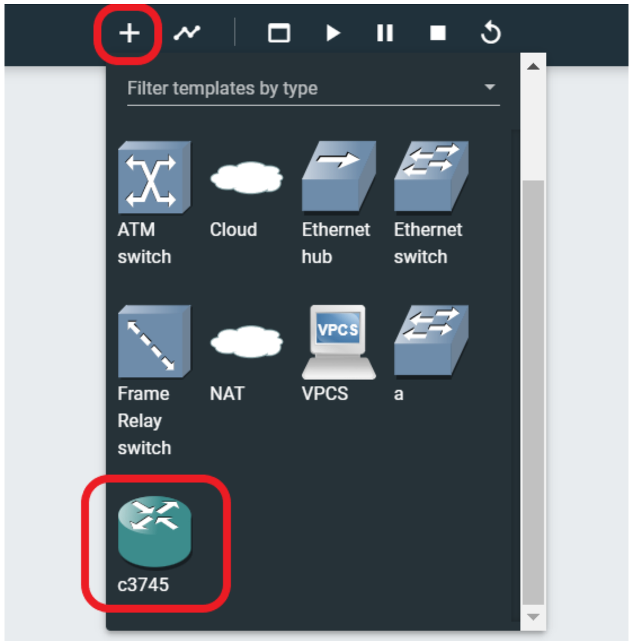

Figure 08

5. Implement the following network in GNS3

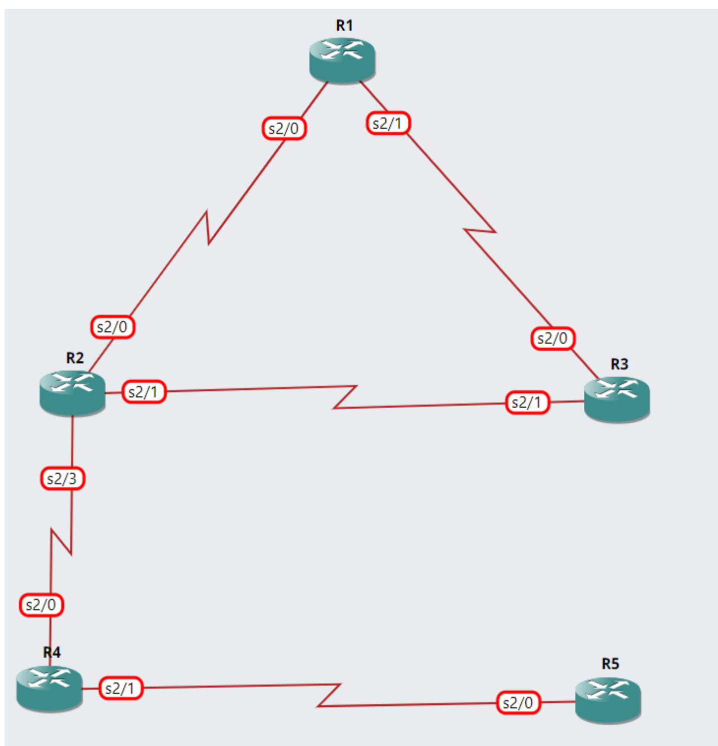

Figure 09

6. Once the network diagram is created, you have to run all the nodes to configure them.
   Click on the “Start/Resume all Nodes” button in the menu bar to start the nodes.

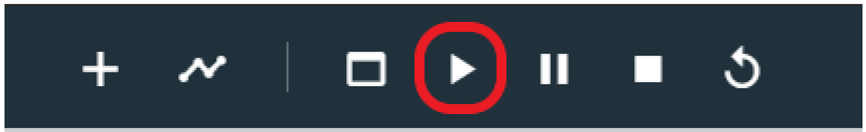

Figure 10

Network Configuration

7. When all the nodes are started, now you have to configure each of the router using its terminal and IOS commands.

8. Open the console terminal of the router R1,
   Right click on R1 -> “Web Console” / “Web Console in new tab”

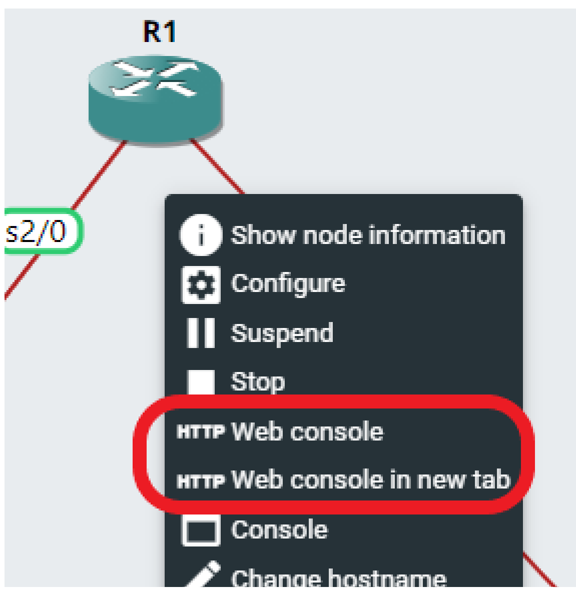

Figure 11

9. Wait for the router to boot and start its configurations.
   NOTE: These devices run same as the original physical devices. Therefore at the initial start, it will ask whether you want to launch the initial configuration dialog. Select NO and proceed until “Router>” appears. (We don’t want to configure all the interfaces for the lab)

10. Configure all the routers. Configuration commands for Routers R1 and R2 are given below.

Use the given commands to configure those two routers and configure the other routers R3,R4 and R5 with the given ip addresses in the figure 05 using the given configuration commands as examples. Enable mpls in in all the interfaces and configure OSPF in all the routers

R1

```
Router>enable

Router#configure terminal

Router(config)#hostname R1
R1(config)#ip cef

R1(config)#interface serial 2/0
R1(config-if)#ip address 192.168.12.1 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#mpls ip

R1(config)#interface serial 2/1
R1(config-if)#ip address 192.168.13.1 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#mpls ip

R1(config-if)#router ospf 10
R1(config-router)#network  192.168.12.0  255.255.255.0  area
1
R1(config-router)#network  192.168.13.0  255.255.255.0  area
1
R1(config-router)#end

R1#
```

R2

```
Router>enable

Router#configure terminal

Router(config)#hostname R2
R2(config)#ip cef

R2(config)#interface serial 2/0
R2(config-if)#ip address 192.168.12.2 255.255.255.0
R2(config-if)#no shutdown
```

```
R2(config-if)#mpls ip

R2(config)#interface serial 2/1
R2(config-if)#ip address 192.168.23.1 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#mpls ip

R2(config)#interface serial 2/0
R2(config-if)#ip address 192.168.22.2 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#mpls ip

R2(config-if)#router ospf 10
R2(config-router)#network 192.168.12.0 255.255.255.0 area 1
R2(config-router)#network 192.168.23.0 255.255.255.0 area 1
R2(config-router)#network 192.168.22.0 255.255.255.0 area 1
R2(config-router)#end

R2#
```

NOTE: After configuring use "Show Running-Config" command to check whether you have done the configurations correctly.
Make sure that you copy the running configurations to the startup configuration to avoid the loss of configurations after switching off the nodes.

Verification

11. To check whether your network configuration works properly, you can use the following commands.
    a. **show ip route** : Used to check the IP route for this destination in the IP routing table

```
R1#show ip route 192.168.22.2
Routing entry for 192.168.22.0/24
  Known via "ospf 10", distance 110, metric 128, type intra area
  Last update from 192.168.12.2 on Serial2/0, 00:38:39 ago
  Routing Descriptor Blocks:
  * 192.168.12.2, from 192.168.23.1, 00:38:39 ago, via Serial2/0
      Route metric is 128, traffic share count is 1

R1#
```

Figure 11

    b. **show mpls forwarding-table** : Used to check the MPLS forwarding table, which is the label switching equivalent of the IP routing table for standard IP routing. It contains inbound and outbound labels and descriptions of the packets.

```
R1#show mpls forwarding-table
Local  Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag    tag or VC   or Tunnel Id      switched   interface
16     17          192.168.21.0/24   0          Se2/0      point2point
17     Pop tag     192.168.22.0/24   0          Se2/0      point2point
18     Pop tag     192.168.23.0/24   0          Se2/1      point2point
       Pop tag     192.168.23.0/24   0          Se2/0      point2point
R1#
```

.Figure 12

c. **show mpls forwarding-table detail** : Used to see MPLS forwarding table details
d. **show mpls ldp bindings** or **show tag-switching tdp bindings** (based on which Cisco IOS software release you use) : Used to see the label bindings associated with a particular destination. Both the local as well as the remote bindings can be seen.
e. **show ip cef detail** : Used to check that Cisco Express Forwarding works properly and that tags are swapped correctly

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Submission

Create a report renamed as **E16XXX_report.pdf** (XXX is your E Number).

The report should include,

- All the screenshots for the lab task from step 01 to 11
- Necessary explanations for the observations for the verification step (11)

Submit a zip file **E16XXX_Lab06.zip** (XXX is your E Number) which contains the following.

- **E16XXX_report.pdf**
- **GNS project file**

Note: Make sure that you have copied your running configuration to startup configurations before exporting

Steps t o export

- Stop all the nodes
- Go to Menu -> Project settings -> Export portable project

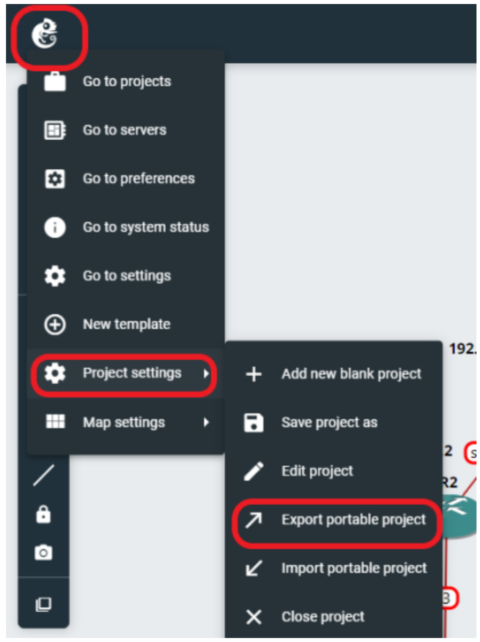

Figure 13

References

- What is MPLS? Multiprotocol Label Switching Defined | Forcepoint
- https://www.youtube.com/watch?v=g-8fAQHL-Uk
- https://www.cisco.com/c/en/us/support/docs/multiprotocol-label-switching-mpls/mpls/13736-mplsospf.html