# Arquitetura e Gestão de Redes

## Laboratory Guide

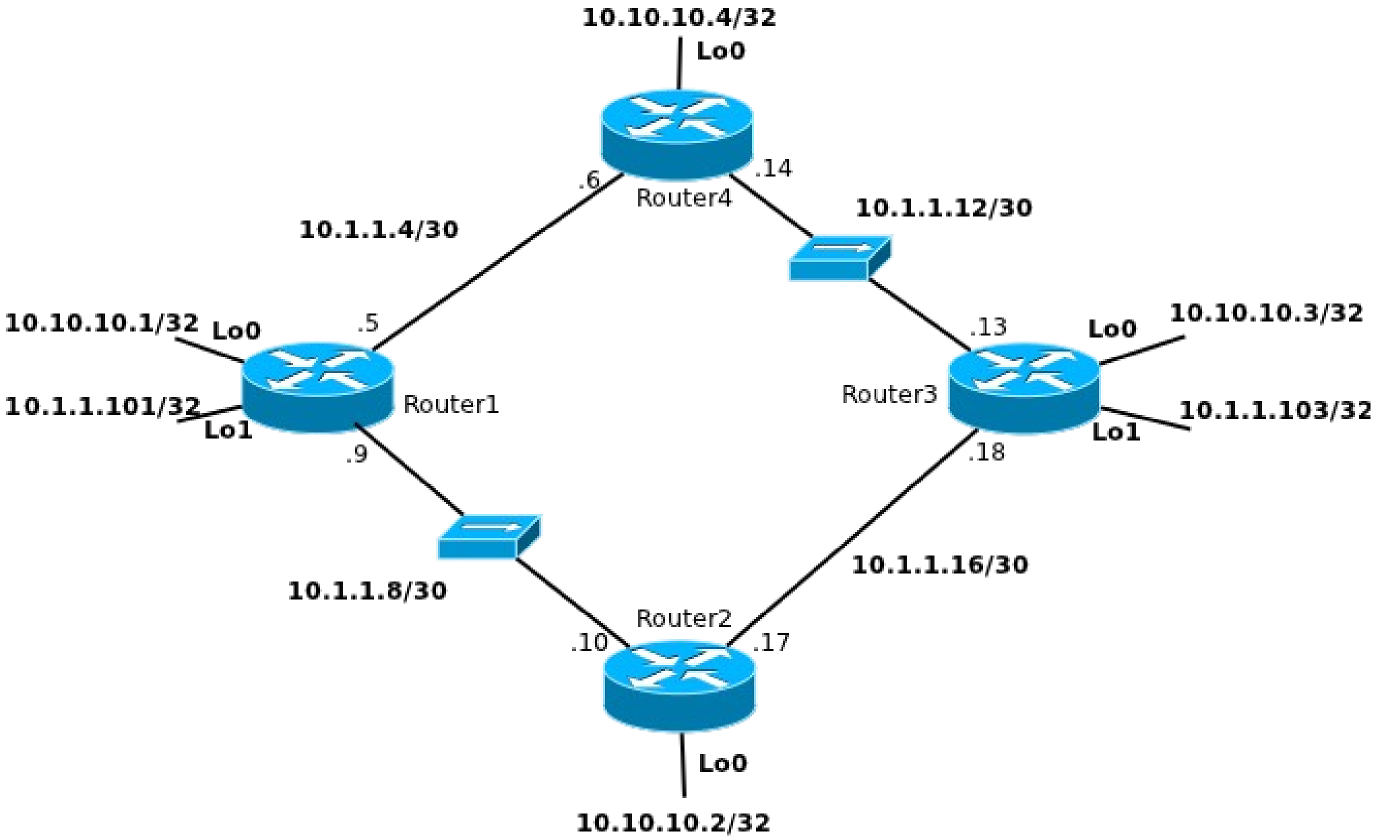
### Objectives

- MPLS basic configuration
- MPLS-TE

**This guide must be executed by two groups simultaneously. One group is responsible for Routers 1 and 2 and the other group is is responsible for Routers 3 and 4.**

## Basic MPLS configuration using OSPF

1. Set up the network specified in the next figure. Configure OSPF routing protocol considering a single area and **including the Loopback interfaces**. Verify the correctness of the IP routing tables to assure total connectivity.




2. Start a capture of IP packets on subnetwork 10.1.1.8/30 (or 10.1.1.12/30). At each router,
Enable (if not already active) ***Cisco Express Forwarding*** in general configuration mode: `ip cef`
Enable **MPLS IP** in general configuration mode and in each physical interface: `mpls ip`
**Note 1:** 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.
**Note 2:** When you activate MPLS, LDP is automatically turned on and labels start being advertised (default mode: downstream unsolicited).
**Note 3:** Cisco's routers have by default MPLS Penultimate Hop Popping (*PHP*) mechanism active.
Analyze the captured packets, particularly those belonging to the LDP protocol, in order to see the label advertising process.
Using the command

```
show mpls ldp neighbor [detail]
```

identify the LDP neighbors and check if all their interfaces are being properly announced.

3. Using the `show ip route` command, check the routing tables at each router.
Use the `show mpls forwarding-table [detail]` command 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.

Use the `show mpls ip binding` and `show mpls ldp bindings` commands to see the label bindings associated to each destination.
Start a capture of IP packets on sub-networks 10.1.1.4/30 or 10.1.1.8/30, 10.1.1.12/30 or 10.1.1.16/30. From Router 3 ping Router 1's Lo1 and Lo0 interfaces and from Router 1 ping Router 3's Lo1 and Lo0 interfaces. Explain the contents of the captured ICMP/IP packets and the eventual additional MPLS headers.

## MPLS traffic engineering (TE) using static and dynamic tunnels

4. Start a new capture of IP packets on subnetwork 10.1.1.8/30 (or 10.1.1.12/30). Remove the *mpls ip* command from the general configuration of each router and from all physical interfaces. Enable traffic engineering features on ***OSPF*** in order to announce Multiprotocol Label Switching (MPLS) traffic engineering (TE) link information by entering the following command on global configuration mode and on each physical interface of area 0 to enable **MPLS TE** on all routers**:**

```
mpls traffic-eng tunnels
```

and the following commands on the OSPF configuration mode of all routers:

```
mpls traffic-eng area 0
mpls traffic-eng router-id Loopback 0
```

Use the command `clear ip ospf process` to reinitialize the OSPF process in each router (one at a time).
**Note that** OSPF floods TE topology and resource information using type 10 Link-State Advertisements (also called Opaque LSAs). Analyze the OSPF packets that were captured.
Using the commands

```
show ip ospf mpls traffic-eng link
show ip ospf database opaque-area
```

verify the TE relevant networks/interfaces being announced and received via OSPF by each router. The *`show ip ospf mpls traffic-eng link`* command shows the links advertised by OSPF at a given router, including the RSVP characteristics. The *`show ip ospf database opaque-area`* command shows the OSPF database restricted part corresponding to Type 10 LSAs, showing the database that is used by the MPLS TE process to calculate TE routes for tunnels.

5. Start a new capture of IP packets on subnetwork 10.1.1.8/30 (or 10.1.1.12/30). Enable RSVP by entering in each physical interface

```
ip rsvp bandwidth 512 512
```

(these are the values of the reservable bandwidth in each interface, total and per flow).
**Note that** RSVP is used to establish and maintain LSP tunnels based on the calculated path using PATH and RSVP RESV messages. The RSVP protocol specification has been extended so that the RESV messages also distribute label information.

6. Set up tunnels two **static tunnels** between R3 and R1 to be used for TE: Tunnel 1 and Tunnel 2 with explicit paths (next figure).
In order to configure these tunnels, enter the following commands on Router3:

```
Router3(config)#interface Tunnel 1
Router3(config-if)#ip unnumbered Loopback0
Router3(config-if)#tunnel destination 10.10.10.1
Router3(config-if)#tunnel mode mpls traffic-eng
 Router3(config-if)#tunnel mpls traffic-eng bandwidth 150
           ! Specification of the tunnel bandwidth (Kbit/s)
Router3(config-if)#tunnel mpls traffic-eng path-option 1 explicit name path1
Router3(config)#interface Tunnel 2
Router3(config-if)#ip unnumbered Loopback0
Router3(config-if)#tunnel destination 10.10.10.1
Router3(config-if)#tunnel mode mpls traffic-eng
Router3(config-if)#tunnel mpls traffic-eng bandwidth 150
Router3(config-if)#tunnel mpls traffic-eng path-option 1 explicit name path2
```

```
Router3(config)#ip explicit-path name path1 enable
Router3(cfg-ip-expl-path)#next-address 10.1.1.14
Router3(cfg-ip-expl-path)#next-address 10.1.1.5
Router3(config)#ip explicit-path name path2 enable
Router3(cfg-ip-expl-path)#next-address 10.1.1.17
Router3(cfg-ip-expl-path)#next-address 10.1.1.9
```

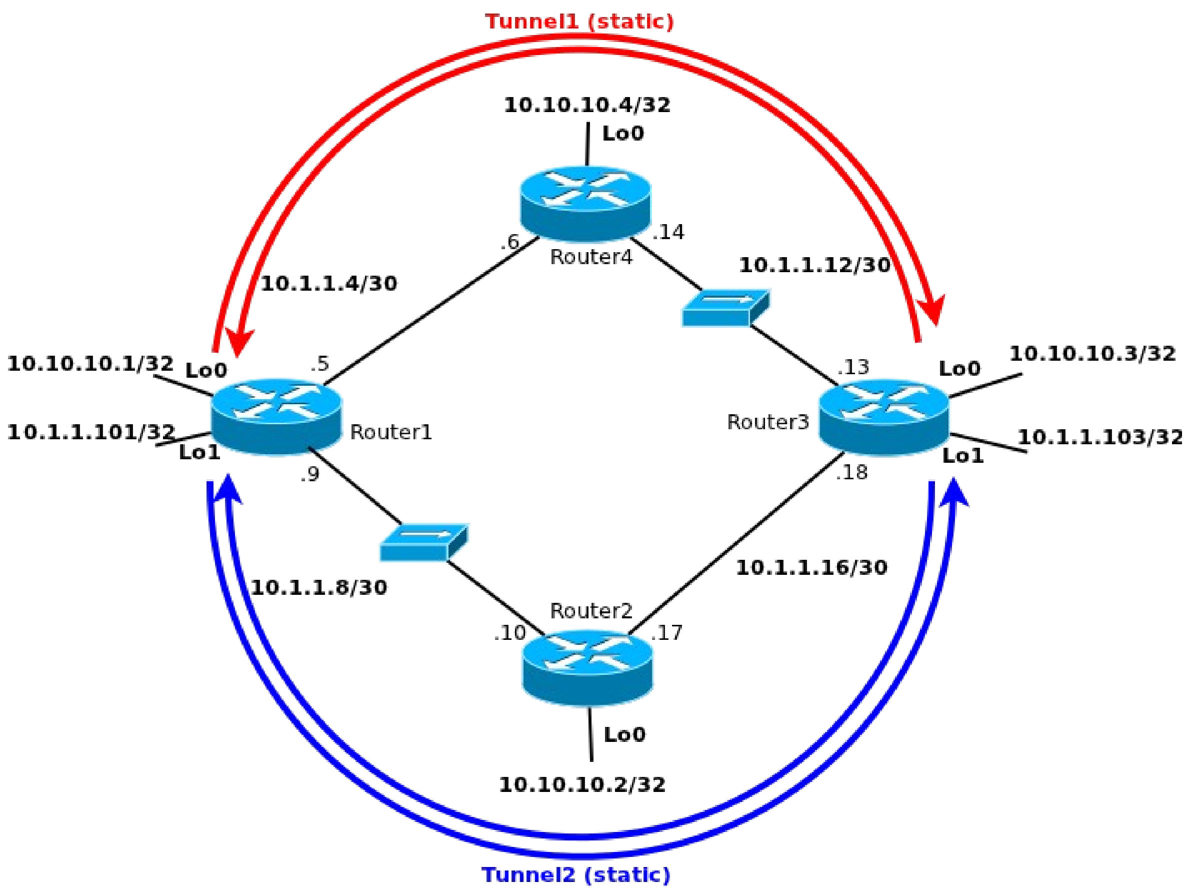
Make similar (symmetric) configurations on Router1.

Use the

```
show mpls traffic-eng tunnels [brief]
```

command to see the tunnels status. Check the routing tables of the different routers and explain their contents. Analyze the RSVP packets that were captured, paying special attention to the TE extensions of the RSVP messages.

**Troubleshooting:** If the tunnel status is down due to an error finding a node on the path, use the command `clear ip ospf process` to reinitialize the OSPF process in each router (one at a time).




7. Configure two static routes in Router 3 to forward traffic to Router 1's Lo1 interface via Tunnel 1 and traffic to Router 1's Lo0 interface via Tunnel 2:

```
ip route 10.1.1.101 255.255.255.255 Tunnel1
ip route 10.10.10.1 255.255.255.255 Tunnel2
```

Configure two static routes in Router 1 to forward traffic to Router 3's Lo1 interface via Tunnel 1 and traffic to Router 3's Lo0 interface via Tunnel 2:

```
ip route 10.1.1.103 255.255.255.255 Tunnel1
ip route 10.10.10.3 255.255.255.255 Tunnel2
```

Start a capture of IP packets on sub-networks 10.1.1.4/30, 10.1.1.8/30, 10.1.1.12/30 and/or 10.1.1.16/30 (if necessary repeat the experiment). From Router 3 ping Router 1's Lo1 and Lo0 interfaces and from Router 1 ping Router 3's Lo1 and Lo0 interfaces. Explain the contents of captured ICMP/IP packets and eventual additional MPLS headers.

8. In Routers 1 and 3, <u>remove all static routes</u> and include the following commands in the MPLS tunnels configurations:

```
Router(config)#interface Tunnel 1
Router(config-if)# tunnel mpls traffic-eng autoroute announce
Router(config)#interface Tunnel 2
Router(config-if)# tunnel mpls traffic-eng autoroute announce
```

Analyze and explain Router3 and Router1 routing tables.

**<u>Note that</u>** the `tunnel mpls traffic-eng autoroute announce` command announces the presence of a tunnel via routing protocol.

From Router 3 ping Router 1's Lo1 and Lo0 interfaces and from Router 1 ping Router 3's Lo1 and Lo0 interfaces. Repeat, defining as source interface Lo0 (or Lo1) interface. Verify that both tunnels are being used to transmit data between Routers 3 and 1. Why?

9. Now, at Router 3 (or Router 1) enter the following command in Tunnel 2:

```
tunnel mpls traffic-eng autoroute metric 5
```

Justify the changes on the routing table of Router 3 (or Router 1).

Now, at Router 3 enter the following command in Tunnel 1 and Tunnel 2:

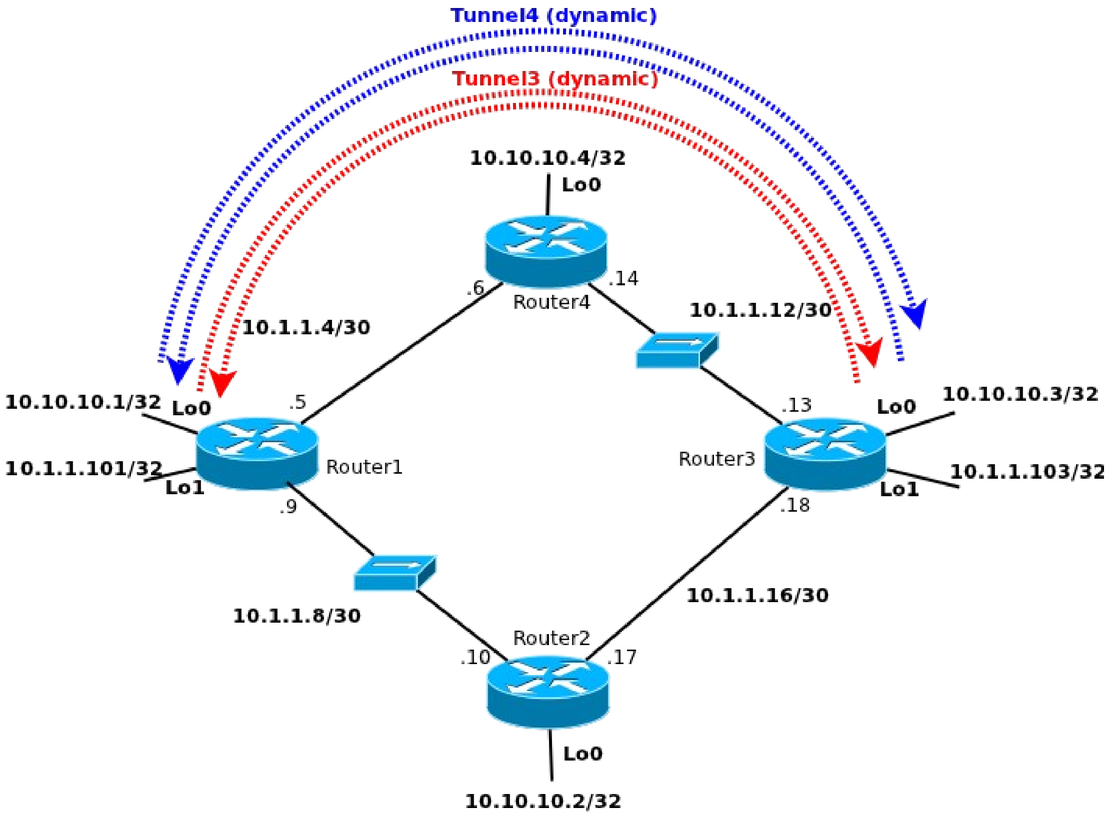
```
tunnel mpls traffic-eng autoroute metric 20
```

Justify the changes on the routing table of Router 3.

10. Now, we want to set up two **dynamic tunnels** to be used for TE between Router 1 and Router 3 (next figure):

```
Router1(config)#interface Tunnel 3
Router1(config-if)#ip unnumbered Loopback0
Router1(config-if)#tunnel destination 10.10.10.3
Router1(config-if)#tunnel mode mpls traffic-eng
Router1(config-if)#tunnel mpls traffic-eng autoroute announce
Router1(config-if)#tunnel mpls traffic-eng bandwidth 100
Router1(config-if)#tunnel mpls traffic-eng path-option 1 dynamic
...
Router1(config)#interface Tunnel 4
Router1(config-if)#ip unnumbered Loopback0
Router1(config-if)#tunnel destination 10.10.10.3
Router1(config-if)#tunnel mode mpls traffic-eng
Router1(config-if)#tunnel mpls traffic-eng autoroute announce
Router1(config-if)#tunnel mpls traffic-eng auto-bw
                                              !bandwidth is automatically adjusted
Router1(config-if)#tunnel mpls traffic-eng path-option 1 dynamic
```

Make similar (symmetric) configurations on Router3. Check if the dynamic tunnels have been set up through the shortest path between Routers 1 and 3 or not.



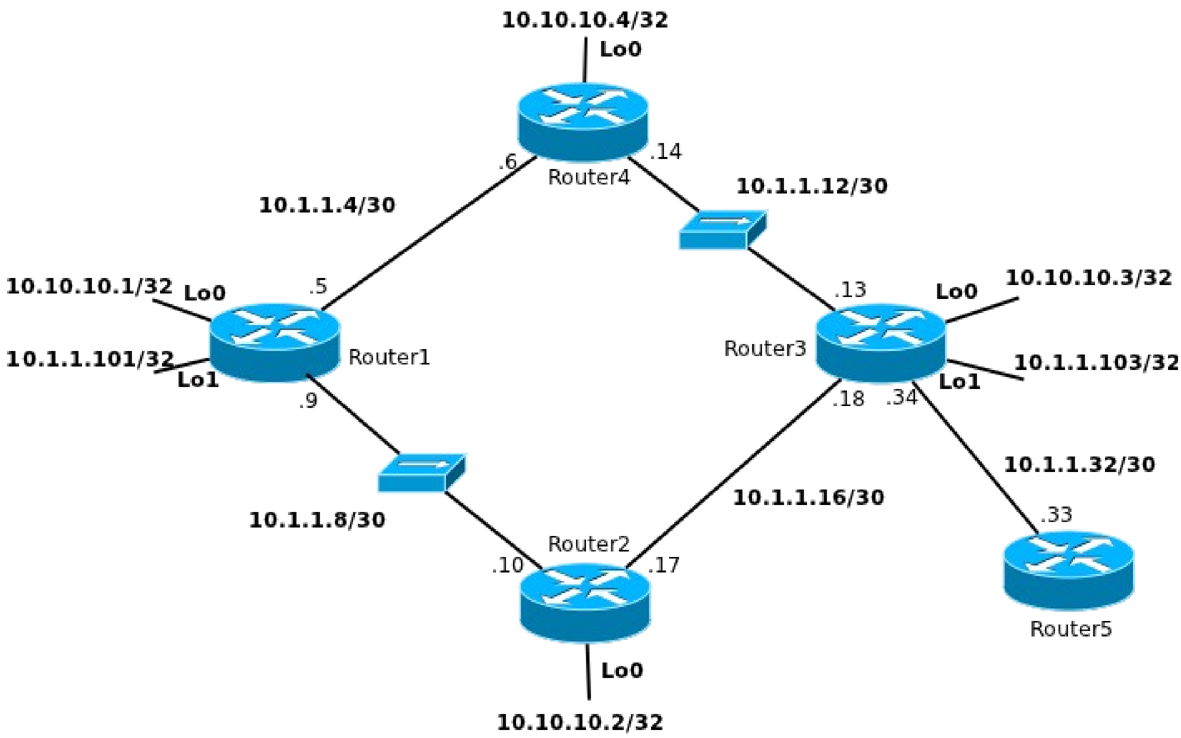

11. Disconnect (by entering the `shutdown` command) the direct connection between Routers 1 and 4 and check again the settings of the different tunnels. What happened to the static and dynamic tunnels?

## Policy-based routing

12. Now add Router 5 according to the following figure and configure OSPF at Router 5.
In order to use **policy-based routing** (PBR) to force ICMP packets from Router 5 destined to 10.10.10.1 to be routed through Tunnel 2, enter the following commands at the interface of Router 3 connecting to Router 4:

```
Router3(config-if)#ip policy route-map trafficTOtunnel2
Router3(config-if)#route-map trafficTOtunnel2
Router3(config-route-map)#match ip address 101
Router3(config-route-map)#set interface Tunnel2
Router3(config-route-map)#exit
Router3(config-if)#access-list 101 permit icmp host 10.1.1.33 host 10.10.10.1
```

By executing the ping commando from Router 5 to 10.10.10.1, verify the correct operation of the PBR method.


10.10.10.4/32
Lo0
.6
.14
Router4
10.1.1.4/30
10.1.1.12/30
10.10.10.1/32
Lo0
.5
.13
Lo0
10.10.10.3/32
10.1.1.101/32
Lo1
Router1
Router3
10.1.1.103/32
Lo1
.9
.18
.34
10.1.1.32/30
10.1.1.16/30
.33
10.1.1.8/30
Router2
.10
.17
Router5
Lo0
10.10.10.2/32