

Advanced Networking Architectures and Wireless Systems

Carlo Vallati

Assistant Professor@ University of Pisa

c.vallati@iet.unipi.it

MPLS TE

Carlo Vallati

PostDoc Researcher@ University of Pisa

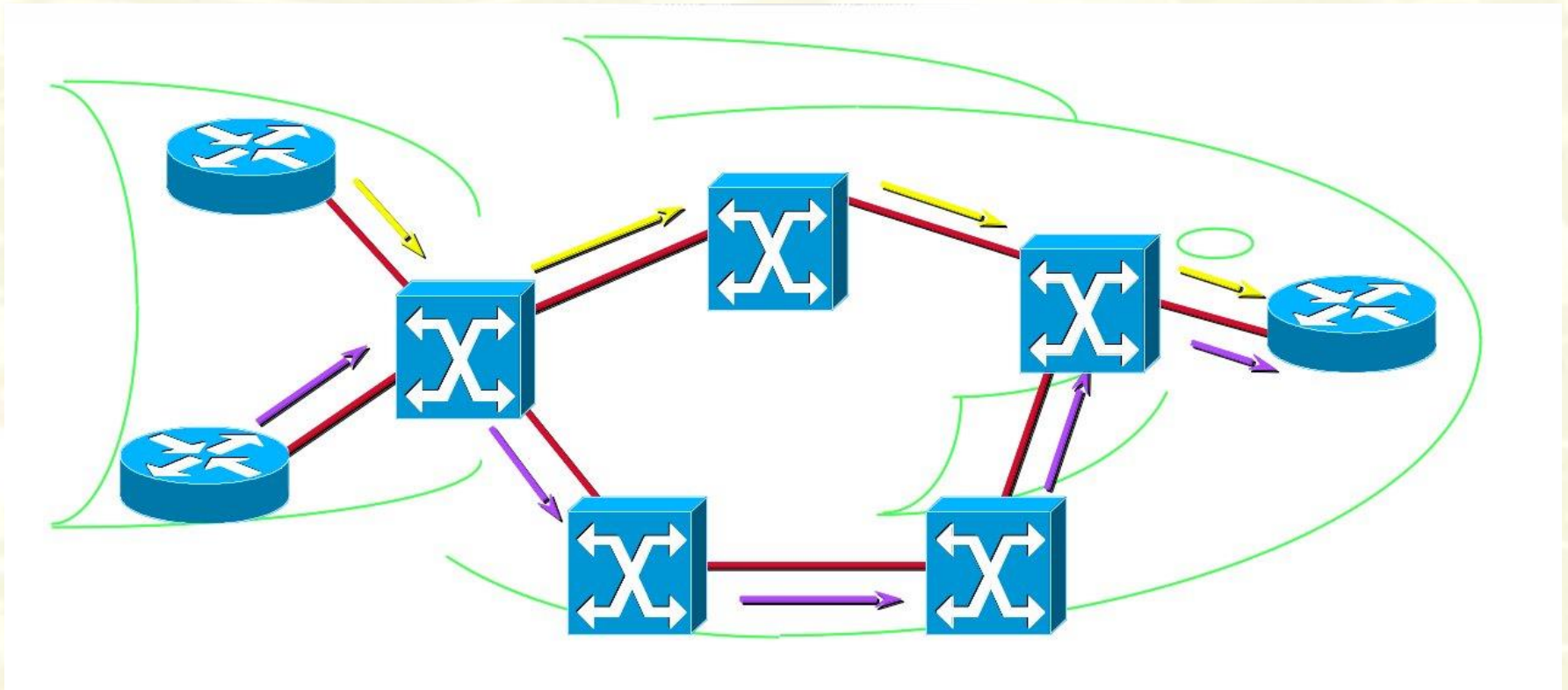
c.vallati@iet.unipi.it

MPLS TE

- Traditional IP networks uses **destination-based routing**
- **Explicit routing** (e.g. source based routing) is not supported
- MPLS networks can support **destination-based and explicit routing simultaneously**
- **MPLS TE** uses extensions to RSVP and MPLS forwarding to support constrained-based routing (taking into account more information on network constraints and policy requirements)

MPLS TE

- Resource optimization, avoid over- and under- utilization of network parts, traffic not being aggregated on the shortest path



OSPF configuration

- RIP is a distance vector routing protocol, only link-state routing protocols that provide constant updates on the link state can be used
- For this reason we need to configure OSPF (already done in the MPLS scenario)
 - `router ospf 100`
 - `network 10.1.1.0 0.0.0.3 area 1`
 - `network 10.2.2.0 0.0.0.3 area 1`
 - `network 192.168.1.0 0.0.0.255 area 1`
 - `network 192.168.2.0 0.0.0.255 area 1`
 - `network 192.168.3.0 0.0.0.255 area 1`

Loopback configuration

- It is mandatory to setup a Loopback interface with IP mask of 32 bits on each router to be used as router-id
 - `interface Loopback0`
 - `ip address 172.16.1.5 255.255.255.255`
 - `router ospf 100`
 - `network 172.16.1.5 0.0.0.0 area 1`

MPLS



- Cisco MPLS implementation requires CEF – Cisco Express Forwarding
- CEF is an advanced layer 3 switching technology adopted in cisco routers to increase packet switching speed
- CEF keeps track of adjacencies to build the Forwarding Information Base (FIB)

MPLS Configuration

- **Enable**
 - `ip cef`
 - Enable CEF
 - `interface Ethernet 0/0`
 - `tag-switching ip`
 - Enable tag switching on this interface
- **Check**
 - `show tag-switching forwarding-table`

Test



- Open Wireshark and try to ping Console3 from Console 1

347 173.573702000 10.2.2.1 10.4.4.1 ICMP 118 Echo (ping) request id=0x0437, seq=1571/8966, ttl=255 (no response found!)

- > Frame 347: 118 bytes on wire (944 bits), 118 bytes captured (944 bits) on interface 0
- > Ethernet II, Src: c8:01:0b:2b:00:10 (c8:01:0b:2b:00:10), Dst: c8:02:0b:3e:00:10 (c8:02:0b:3e:00:10)
- ✓ MultiProtocol Label Switching Header, Label: 18, Exp: 0, S: 1, TTL: 255
 - 0000 0000 0000 0001 0010 = MPLS Label: 18
 - 000. = MPLS Experimental Bits: 0
 - 1 = MPLS Bottom Of Label Stack: 1
 - 1111 1111 = MPLS TTL: 255
- ✓ Internet Protocol Version 4, Src: 10.2.2.1 (10.2.2.1), Dst: 10.4.4.1 (10.4.4.1)
 - Version: 4
 - Header Length: 20 bytes
 - >— Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00: Not-ECT (Not ECN-Capable Transport))
 - Total Length: 100
 - Identification: 0x000c (12)
 - >— Flags: 0x00
 - Fragment offset: 0
 - Time to live: 255


0000	c8 02 0b 3e 00 10 c8 01 0b 2b 00 10 88 47 00 01	...>.... .+...G..
0010	21 ff 45 00 00 64 00 0c 00 00 ff 01 a1 85 0a 02	!.E..d..
0020	02 01 0a 04 04 01 08 00 9f 6d 04 37 06 23 00 00m.7.#..
0030	00 00 00 03 d4 7f ab cd ab cd ab cd ab cd ab cd

MPLS - TE

- Unlike conventional IP routing MPLS traffic engineering (TE) uses the implicit MPLS characteristic of separation between the forwarding plane and the control plane to allow routing decisions to be made on criteria other than the destination address
- Label switched paths (LSPs), referred as “traffic engineering tunnels” are setup to steer traffic through the network allowing links not included in the shortest path to be used

MPLS TE - Tunnels

- Enable the creation of mpls tunnels for TE:
 - mpls traffic-eng tunnels
 - Enable tunnels creation on the router
 - Interface Ethernet 0/0
 - mpls traffic-eng tunnels
 - ip rsvp bandwidth 512 512
 - Enable MPLS tunnel creation on the interface specifying the reservable bandwidth and the largest reservable flow on the interface
 - router ospf 100
 - mpls traffic-eng area 1
 - mpls traffic-eng router-id Loopback0
 - Enable TE extension on OSPF



RSVP adopted
also as admission
control

MPLS TE - Tunnels

- Define a new tunnel:
 - interface Tunnel0
 - ip unnumbered Loopback0
 - tunnel destination 172.16.1.5
 - tunnel mode mpls traffic-eng
 - tunnel mpls traffic-eng autoroute announce
 - tunnel mpls traffic-eng priority 2 2
 - tunnel mpls traffic-eng bandwidth 400
 - tunnel mpls traffic-eng path-option 1 dynamic
 - The path of the tunnel will be dynamically selected
- Check the status:
 - show mpls traffic-eng tunnels



Reservation
priority for the
tunnel

MPLS TE - Tunnels

- Define a tunnel with explicit path:
 - interface Tunnel1
 - ip unnumbered Loopback0
 - tunnel destination 172.16.1.5
 - tunnel mode mpls traffic-eng
 - tunnel mpls traffic-eng autoroute announce
 - tunnel mpls traffic-eng priority 2 2
 - tunnel mpls traffic-eng bandwidth 400
 - tunnel mpls traffic-eng path-option 1 explicit name longpath
 - tunnel mpls traffic-eng path-option 2 dynamic
- Define the path:
 - ip explicit-path name longpath enable
 - next-address 10.2.2.2
 - next-address 10.3.3.2
 - next-address 10.4.4.2

Test



- show ip route

```
R1
o - ODR, P - periodic downloaded static route
Gateway of last resort is not set

172.16.0.0/32 is subnetted, 5 subnets
O   172.16.1.5 [110/21] via 0.0.0.0, 00:08:13, Tunnel1
O   172.16.1.4 [110/21] via 10.2.2.2, 00:08:13, Ethernet1/1
C   172.16.1.1 is directly connected, Loopback0
O   172.16.1.3 [110/11] via 10.2.2.2, 00:08:13, Ethernet1/1
O   172.16.1.2 [110/11] via 10.1.1.2, 00:08:13, Ethernet1/0
10.0.0.0/30 is subnetted, 5 subnets
O   10.4.4.0 [110/30] via 0.0.0.0, 00:08:13, Tunnel1
    [110/30] via 10.2.2.2, 00:08:13, Ethernet1/1
O   10.5.5.0 [110/20] via 10.1.1.2, 00:08:14, Ethernet1/0
O   10.3.3.0 [110/20] via 10.2.2.2, 00:08:14, Ethernet1/1
C   10.1.1.0 is directly connected, Ethernet1/0
C   10.2.2.0 is directly connected, Ethernet1/1
O   192.168.102.0/24 [110/30] via 0.0.0.0, 00:08:15, Tunnel1
C   192.168.1.0/24 is directly connected, Ethernet0/0
O   192.168.103.0/24 [110/30] via 0.0.0.0, 00:08:15, Tunnel1
C   192.168.2.0/24 is directly connected, Ethernet1/2
C   192.168.3.0/24 is directly connected, Ethernet1/3
O   192.168.101.0/24 [110/30] via 0.0.0.0, 00:08:15, Tunnel1
R1#
```

Test



- RSVP messages can be seen

```
4429 7026.570716000 172.16.1.1 172.16.1.5 RSVP 290 P...ATE: IPv4-LSP, Tunnel Source: 172.16.1.1, LSP ID: 11.
> Frame 4429: 290 bytes on wire (2320 bits), 290 bytes captured (2320 bits) on interface 0
> Ethernet II, Src: c8:01:0b:2b:00:11 (c8:01:0b:2b:00:11), Dst: c8:03:0b:4e:00:11 (c8:03:0b:
> Internet Protocol Version 4, Src: 172.16.1.1 (172.16.1.1), Dst: 172.16.1.5 (172.16.1.5)
v Resource ReserVation Protocol (RSVP): PATH Message. SESSION: IPv4-LSP, Destination 172.16.
  >- RSVP Header. PATH Message.
  >- SESSION: IPv4-LSP, Destination 172.16.1.5, Tunnel ID 1, Ext ID ac100101.
  >- HOP: IPv4, 10.2.2.1
  >- TIME VALUES: 30000 ms
  v- EXPLICIT ROUTE: IPv4 10.2.2.2, IPv4 10.3.3.1, IPv4 10.3.3.2, ...
    - Length: 52
    - Object class: EXPLICIT ROUTE object (20)
    - C-type: 1
    >- IPv4 Subobject - 10.2.2.2, Strict
    >- IPv4 Subobject - 10.3.3.1, Strict
    >- IPv4 Subobject - 10.3.3.2, Strict
    >- IPv4 Subobject - 10.4.4.1, Strict
    >- IPv4 Subobject - 10.4.4.2, Strict
    >- IPv4 Subobject - 172.16.1.5, Strict
  >- LABEL REQUEST: Basic: L3PID: IP (0x0800)
  >- SESSION ATTRIBUTE: SetupPrio 2, HoldPrio 2, SE Style, [R1_t1]
  >- SENDER TEMPLATE: IPv4-LSP, Tunnel Source: 172.16.1.1, LSP ID: 11.
  >- SENDER TSPEC: IntServ_Token_Bucket 50000 bytes/sec.
0000 c8 03 0b 4e 00 11 c8 01 0b 2b 00 11 08 00 46 c0 ...N.... .+....F.
0010 01 14 01 00 00 00 fe 2e ca d0 ac 10 01 01 ac 10 .....
0020 01 05 94 04 00 00 10 01 8f d1 fe 00 00 fc 00 10 .....
0030 01 07 ac 10 01 05 00 00 00 01 ac 10 01 01 00 0c .....
0040 01 07 ac 10 01 05 00 00 00 01 ac 10 01 01 00 0c .....
```

Test



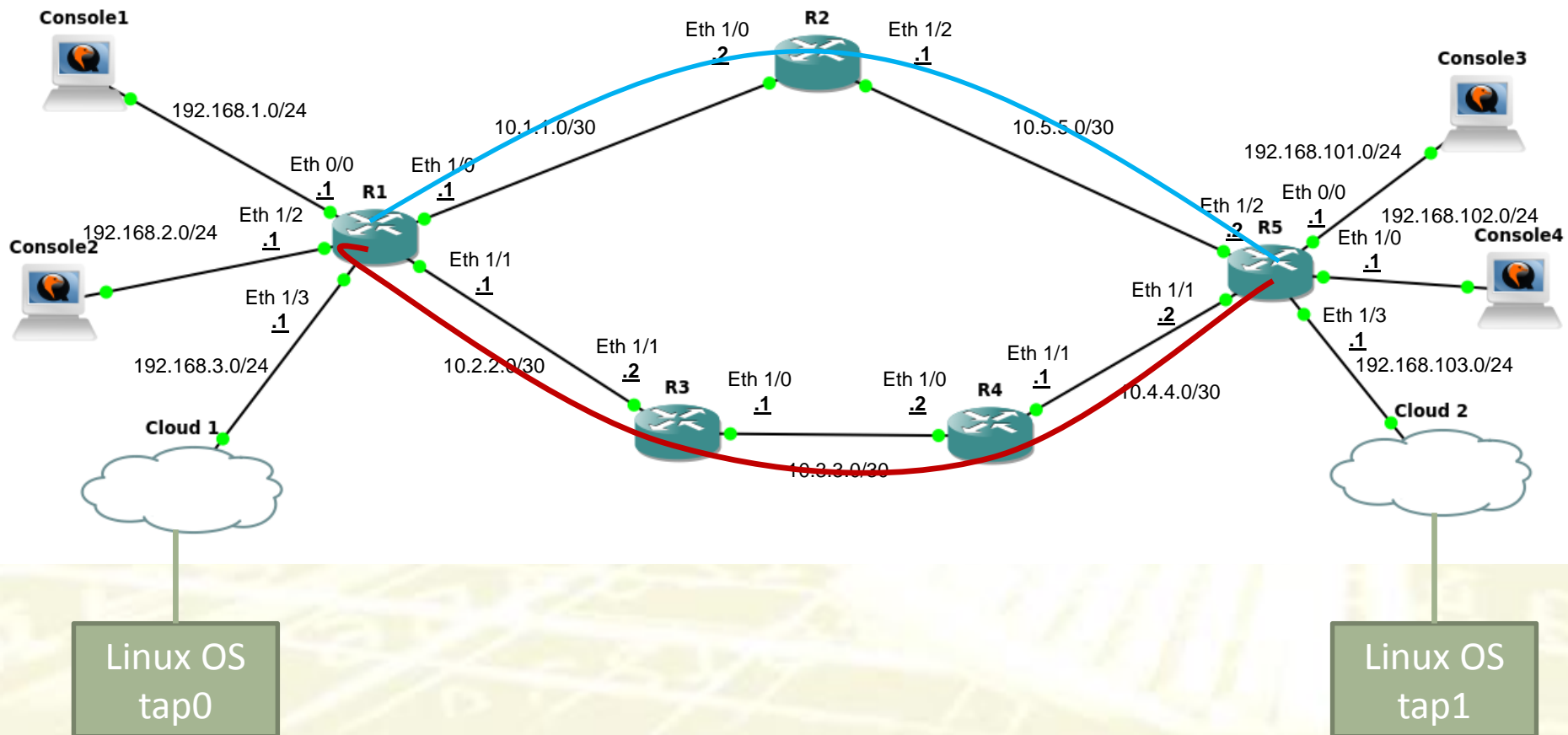
- Open Wireshark on one of the links in the long path and try to ping Console3 from Console 1

```
4435 7029.188930000 192.168.1.2 192.168.101.2 ICMP 102 Echo 1 request id=0x1207, seq=1/256, ttl=63 (no response found!)
> Frame 4435: 102 bytes on wire (816 bits), 102 bytes captured (816 bits) on interface 0
> Ethernet II, Src: c8:01:0b:2b:00:11 (c8:01:0b:2b:00:11), Dst: c8:03:0b:4e:00:11 (c8:03:0b:4e:00:11)
v MultiProtocol Label Switching Header, Label: 16, Exp: 0, S: 1, TTL: 63
  - 0000 0000 0000 0001 0000 .... = MPLS Label: 16
  - .... 000. .... = MPLS Experimental Bits: 0
  - .... 1 .... = MPLS Bottom Of Label Stack: 1
  - .... 0011 1111 = MPLS TTL: 63
> Internet Protocol Version 4, Src: 192.168.1.2 (192.168.1.2), Dst: 192.168.101.2 (192.168.101.2)
v Internet Control Message Protocol
  - Type: 8 (Echo (ping) request)
  - Code: 0
  - Checksum: 0x278b [correct]
  - Identifier (BE): 4615 (0x1207)
  - Identifier (LE): 1810 (0x0712)
  - Sequence number (BE): 1 (0x0001)
  - Sequence number (LE): 256 (0x0100)
  > [No response seen]
  > Data (56 bytes)

0000 c8 03 0b 4e 00 11 c8 01 0b 2b 00 11 88 47 00 01 ...N.... .+...G..
0010 01 3f 45 00 00 54 00 00 40 00 3f 01 54 54 c0 a8 .?E..T.. @.?.TT..
0020 01 02 c0 a8 65 02 08 00 27 8b 12 07 00 01 81 cb ....e... '.....
0030 3c a1 00 00 00 00 00 00 00 00 00 00 00 00 00 00 <..... .....
```

Response is
sent on the
short path!

Create two tunnels



Test



- show ip route

```
R1
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
ia - IS-IS inter area, * - candidate default, U - per-user static route
o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

172.16.0.0/32 is subnetted, 5 subnets
O   172.16.1.5 [110/31] via 0.0.0.0, 00:00:02, Tunnel0
    [110/31] via 0.0.0.0, 00:00:02, Tunnel1
O   172.16.1.4 [110/21] via 10.2.2.2, 00:00:02, Ethernet1/1
C   172.16.1.1 is directly connected, Loopback0
O   172.16.1.3 [110/11] via 10.2.2.2, 00:00:02, Ethernet1/1
O   172.16.1.2 [110/41] via 0.0.0.0, 00:00:02, Tunnel0
    [110/41] via 0.0.0.0, 00:00:02, Tunnel1
10.0.0.0/30 is subnetted, 5 subnets
O   10.5.5.0 [110/40] via 0.0.0.0, 00:00:04, Tunnel0
    [110/40] via 0.0.0.0, 00:00:04, Tunnel1
O   10.4.4.0 [110/30] via 10.2.2.2, 00:00:04, Ethernet1/1
O   10.3.3.0 [110/20] via 10.2.2.2, 00:00:04, Ethernet1/1
C   10.2.2.0 is directly connected, Ethernet1/1
C   10.1.1.0 is directly connected, Ethernet1/0
O   192.168.102.0/24 [110/30] via 0.0.0.0, 00:00:00, Tunnel0
    [110/30] via 0.0.0.0, 00:00:00, Tunnel1
C   192.168.1.0/24 is directly connected, Ethernet0/0
O   192.168.103.0/24 [110/30] via 0.0.0.0, 00:00:00, Tunnel0
    [110/30] via 0.0.0.0, 00:00:00, Tunnel1
C   192.168.2.0/24 is directly connected, Ethernet1/2
C   192.168.3.0/24 is directly connected, Ethernet1/3
O   192.168.101.0/24 [110/30] via 0.0.0.0, 00:00:00, Tunnel0
    [110/30] via 0.0.0.0, 00:00:00, Tunnel1

R1#
R1#
R1#
R1#
```


Differentiate routing



- To differentiate routing you can set static routes (e.g. for load balancing):
 - `ip route 192.168.101.0 0.0.0.255 Tunnel0`
 - `ip route 192.168.102.0 0.0.0.255 Tunnel1`

Policy Based Routing and MPLS-TE

- Define Classification

- `access-list 1 permit 192.168.1.2 0.0.0.0`

- Define Marking:

- `interface Ethernet 0/0`
 - `ip policy route-map prio`
 - `route-map prio permit 10`
 - `match ip address 1`
 - `set interface Tunnel 0`

References



- MPLS TE:
http://www.cisco.com/c/en/us/td/docs/ios/12_0s/feature/guide/TE_1208S.html