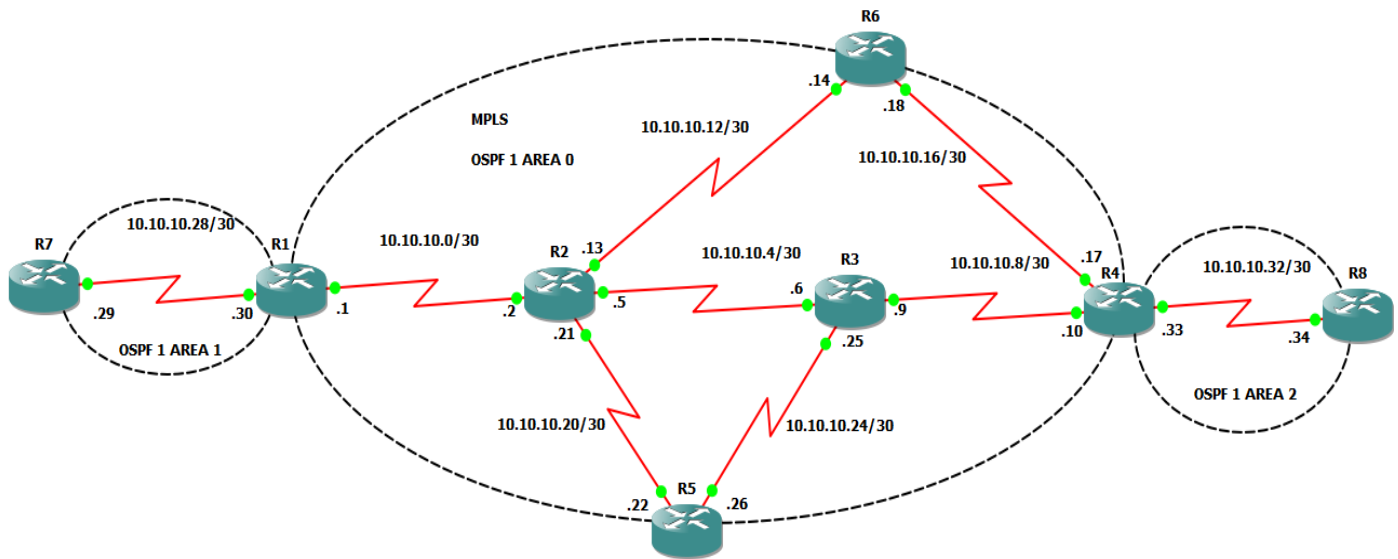


MPLS

- TOPOLOGY



Tunnel Description	Name	Path
Primary Tunnel 1	Tunnel 1000	R1-R2-R3-R4
Primary Tunnel 2	Tunnel 2000	R1-R2-R3-R4
Backup Tunnel 1 (Link Protection)	Tunnel 1	R1-R2-R5-R3-R4
Backup Tunnel 2 (Node Protection)	Tunnel 2	R1-R2-R6-R4

Router	Description
R1	Provider's edge router OR Ingress/Egress LSR
R2	Provider's router OR LSR
R3	Provider's router OR LSR
R4	Provider's edge router OR Ingress/Egress LSR
R5	Provider's router OR LSR
R6	Provider's router OR LSR
R7	Customer's edge router
R8	Customer's edge router

Router	Loopback Address
R1	10.10.10.101
R2	10.10.10.102
R3	10.10.10.103
R4	10.10.10.104
R5	10.10.10.105
R6	10.10.10.106
R7	10.10.10.107
R8	10.10.10.108

TOPOLOGY CONFIGURATION

- ROUTER'S INTERFACE CONFIGURATION

R1

```
en
conf t

int s 1/0
ip address 10.10.10.1 255.255.255.252
no shut
exit

int s 2/0
ip address 10.10.10.30 255.255.255.252
no shut
exit

Int loopback 0
ip add 10.10.10.101 255.255.255.255
exit

exit
wr
```

R2

```
en
conf t

int s 1/0
ip address 10.10.10.2 255.255.255.252
no shut
exit

int s 2/0
ip address 10.10.10.5 255.255.255.252
no shut
exit
```

```
int s 3/0
ip address 10.10.10.13 255.255.255.252
no shut
exit
```

```
int s 4/0
ip address 10.10.10.21 255.255.255.252
no shut
exit
```

```
Int loopback 0
ip add 10.10.10.102 255.255.255.255
exit
```

```
exit
wr
```

R3

```
en
conf t
```

```
int s 1/0
ip address 10.10.10.6 255.255.255.252
no shut
exit
```

```
int s 2/0
ip address 10.10.10.9 255.255.255.252
no shut
exit
```

```
int s 3/0
ip address 10.10.10.25 255.255.255.252
no shut
exit
```

```
Int loopback 0
ip add 10.10.10.103 255.255.255.255
exit
```

```
exit
wr
```

R4

```
en
conf t

int s 1/0
ip address 10.10.10.10 255.255.255.252
no shut
exit

int s 2/0
ip address 10.10.10.17 255.255.255.252
no shut
exit

int s 3/0
ip address 10.10.10.33 255.255.255.252
no shut
exit

Int loopback 0
ip add 10.10.10.104 255.255.255.255
exit

exit
wr
```

R5

```
en
conf t

int s 1/0
ip address 10.10.10.22 255.255.255.252
no shut
exit

int s 2/0
ip address 10.10.10.26 255.255.255.252
no shut
exit

Int loopback 0
ip add 10.10.10.105 255.255.255.255
exit
```

```
exit
wr
```

R6

```
en
conf t

int s 1/0
ip address 10.10.10.14 255.255.255.252
no shut
exit

int s 2/0
ip address 10.10.10.18 255.255.255.252
no shut
exit

Int loopback 0
ip add 10.10.10.106 255.255.255.255
exit

exit
wr
```

R7

```
en
conf t

int s 1/0
ip address 10.10.10.29 255.255.255.252
no shut
exit

Int loopback 0
ip add 10.10.10.107 255.255.255.255
exit

exit
wr
```

R8

```
en
conf t

int s 1/0
ip address 10.10.10.34 255.255.255.252
no shut
exit

Int loopback 0
ip add 10.10.10.108 255.255.255.255
exit

exit
wr
```

- OSPF CONFIGURATION

R1

```
en
conf t

router ospf 1
network 10.10.10.101 0.0.0.0 area 0
network 10.10.10.0 0.0.0.3 area 0
network 10.10.10.28 0.0.0.3 area 0
exit

exit
wr
```

R2

```
en
conf t

router ospf 1
network 10.10.10.102 0.0.0.0 area 0
network 10.10.10.0 0.0.0.3 area 0
network 10.10.10.4 0.0.0.3 area 0
network 10.10.10.12 0.0.0.3 area 0
network 10.10.10.20 0.0.0.3 area 0
exit

exit
wr
```

R3

```
en
conf t

router ospf 1
network 10.10.10.103 0.0.0.0 area 0
network 10.10.10.4 0.0.0.3 area 0
network 10.10.10.8 0.0.0.3 area 0
network 10.10.10.24 0.0.0.3 area 0
exit

exit
wr
```

R4

```
en
conf t

router ospf 1
network 10.10.10.104 0.0.0.0 area 0
network 10.10.10.8 0.0.0.3 area 0
network 10.10.10.16 0.0.0.3 area 0
network 10.10.10.32 0.0.0.3 area 0
exit

exit
wr
```

R5

```
en
conf t

router ospf 1
network 10.10.10.105 0.0.0.0 area 0
network 10.10.10.20 0.0.0.3 area 0
network 10.10.10.24 0.0.0.3 area 0
exit

exit
wr
```

R6

```
en
conf t

router ospf 1
network 10.10.10.106 0.0.0.0 area 0
network 10.10.10.12 0.0.0.3 area 0
network 10.10.10.16 0.0.0.3 area 0
exit

exit
wr
```

R7

```
en
conf t

router ospf 1
network 10.10.10.107 0.0.0.0 area 1
network 10.10.10.28 0.0.0.3 area 0
exit

exit
wr
```


R8

```
en
conf t

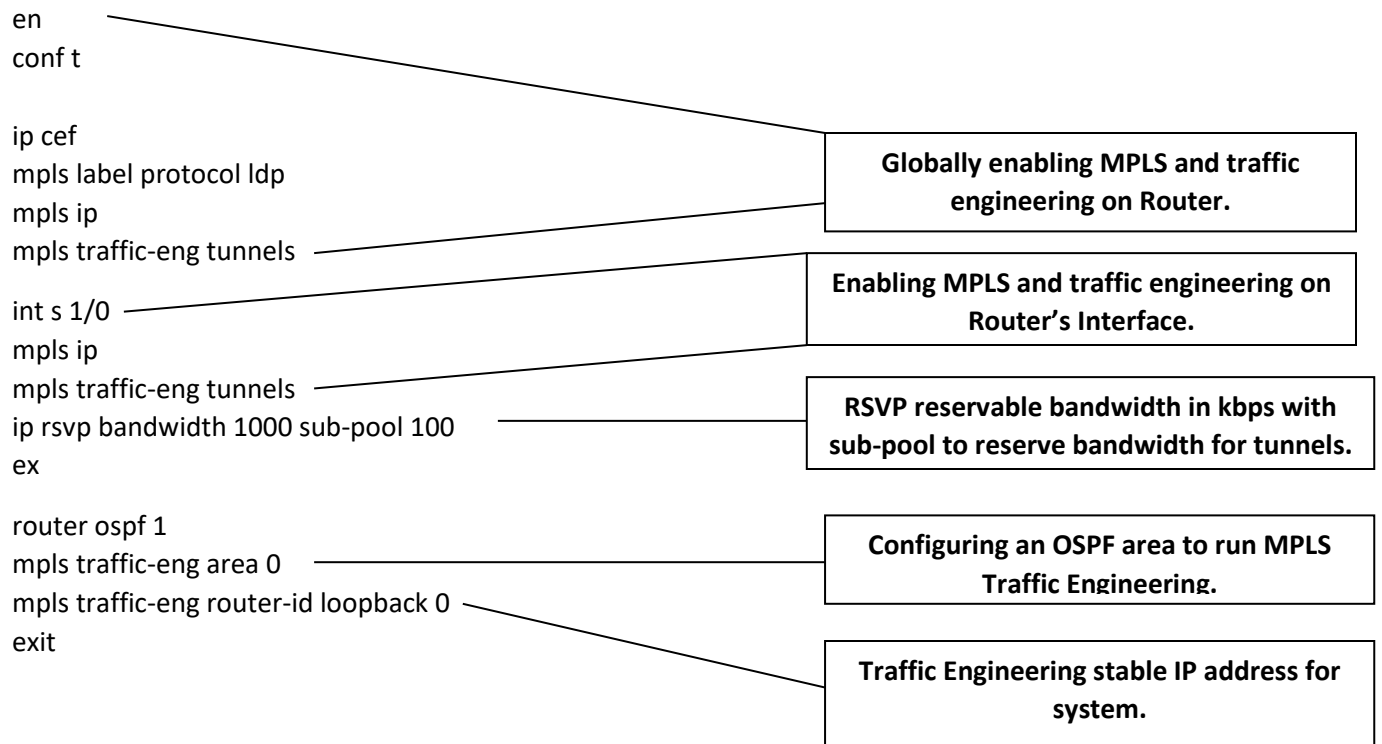
router ospf 1
network 10.10.10.108 0.0.0.0 area 2
network 10.10.10.32 0.0.0.3 area 0
exit

exit
wr
```

MPLS CONFIGURATION

- ENABLING MPLS AND TRAFFIC-ENG ON ROUTERS, INTERFACES AND OSPF
+
RSVP BANDWIDTH ON INTERFACES

R1



```
exit  
wr
```

R2

```
en  
conf t
```

```
ip cef  
mpls label protocol ldp  
mpls ip  
mpls traffic-eng tunnels
```

```
int s 1/0  
mpls ip  
mpls traffic-eng tunnels  
ip rsvp bandwidth 1000 sub 100  
ex
```

```
int s 2/0  
mpls ip  
mpls traffic-eng tunnels  
ip rsvp bandwidth 1000 sub 100  
ex
```

```
int s 3/0  
mpls ip  
mpls traffic-eng tunnels  
ip rsvp bandwidth 1000 sub 100  
ex
```

```
int s 4/0  
mpls ip  
mpls traffic-eng tunnels  
ip rsvp bandwidth 1000 sub 100  
ex
```

```
router ospf 1  
mpls traffic-eng area 0  
mpls traffic-eng router-id loopback 0  
exit
```

```
exit
wr
```

R3

```
en
conf t
```

```
ip cef
mpls label protocol ldp
mpls ip
mpls traffic-eng tunnels
```

```
int s 1/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 1000 sub 100
ex
```

```
int s 2/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 1000 sub 100
ex
```

```
int s 3/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 1000 sub 100
ex
```

```
router ospf 1
mpls traffic-eng area 0
mpls traffic-eng router-id loopback 0
exit
```

```
exit
wr
```

R4

```
en
conf t

ip cef
mpls label protocol ldp
mpls ip
mpls traffic-eng tunnels

int s 1/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 1000 sub 100
ex

int s 2/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 1000 sub 100
ex

router ospf 1
mpls traffic-eng area 0
mpls traffic-eng router-id loopback 0
exit

exit
wr
```

R5

```
en
conf t

ip cef
mpls label protocol ldp
mpls ip
mpls traffic-eng tunnels

int s 1/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 1000 sub 100
ex
```

```
int s 2/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 1000 sub 100
ex

router ospf 1
mpls traffic-eng area 0
mpls traffic-eng router-id loopback 0
exit

exit
wr
```

R6

```
en
conf t

ip cef
mpls label protocol ldp
mpls ip
mpls traffic-eng tunnels

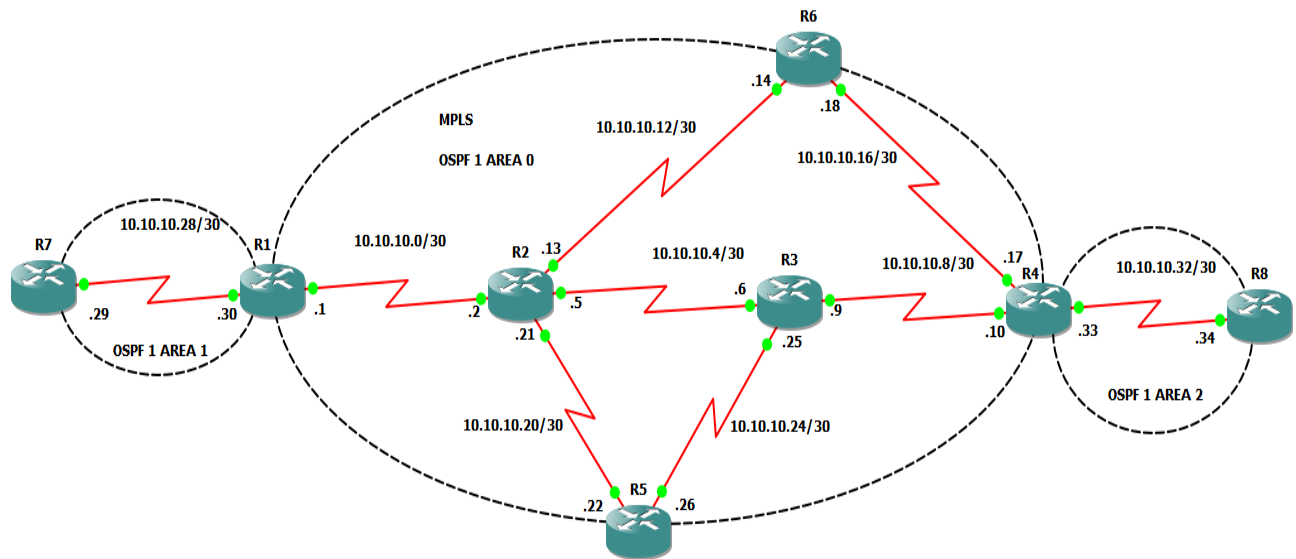
int s 1/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 1000 sub 100
ex

int s 2/0
mpls ip
mpls traffic-eng tunnels
ip rsvp bandwidth 1000 sub 100
ex

router ospf 1
mpls traffic-eng area 0
mpls traffic-eng router-id loopback 0
exit

exit
wr
```

- TUNNELS CONFIGURATION + AUTOROUTE + BANDWIDTH RESERVATION + RSVP



R1

conf t

```
int tunnel 1000
ip unnumbered loopback 0
tunnel mode mpls traffic-eng
tunnel destination 10.10.10.104
tunnel mpls traffic-eng bandwidth sub-pool 10
tunnel mpls traffic-eng path-option 1 explicit name PRI_LSP
tunnel mpls traffic-eng autoroute announce
exit
```

Tunnel 1000 will use 10 kbps from sub-pool.

Explicit path for the tunnel.

```
int tunnel 2000
ip unnumbered loopback 0
tunnel mode mpls traffic-eng
tunnel destination 10.10.10.104
tunnel mpls traffic-eng bandwidth 5
tunnel mpls traffic-eng path-option 1 explicit name PRI_LSP
tunnel mpls traffic-eng autoroute announce
exit
```

Tunnel 2000 will use 5 Kbps from global pool.

```
ip explicit-path name PRI_LSP
next-address 10.10.10.2
next-address 10.10.10.6
next-address 10.10.10.10
next-address 10.10.10.104
exit
```

Configuring the path. Defining the next IP to go to.

Line protocol on Interface Tunnel1000 changed state to up

Line protocol on Interface Tunnel2000 changed state to up

```
int tunnel 1000
tunnel mpls traffic-eng fast-reroute
exit
```

Enabling Fast-Reroute FRR on tunnels

```
int tunnel 2000
tunnel mpls traffic-eng fast-reroute bw-protect
exit
```

When a router maps LSPs to backup tunnels, “bw-protect” option ensures that an LSP uses a given backup tunnel only if there is sufficient backup bandwidth.

```
exit
wr
```

R2

conf t

First backup tunnel (Tunnel 1) will protect the link between R2 and R3.

Backup tunnel that bypass only a single link of the LSP’s path provide link protection. They protect LSPs if a link along their path fails by rerouting the LSP’s traffic to the next hop (bypassing the failed link).

```
int tunnel 1
ip unnumbered loopback 0
tunnel mode mpls traffic-eng
tunnel destination 10.10.10.103
tunnel mpls traffic-eng path-option 1 explicit name AVOID_LINK
tunnel mpls traffic-eng autoroute announce
exit
```

```
ip explicit-path name AVOID_LINK
exclude-address 10.10.10.6
exit
```

Backup tunnel must avoid the protected link, it is convenient to use the exclude-address command.

Second backup tunnel (Tunnel 2) will protect the node R3.

Tunnel 2 terminates at the node following the next-hop node of the LSP paths.

```
int tunnel 2
ip unnumbered loopback 0
tunnel mode mpls traffic-eng
tunnel destination 10.10.10.104
tunnel mpls traffic-eng path-option 1 explicit name AVOID_NODE
tunnel mpls traffic-eng autoroute announce
exit

ip explicit-path name AVOID_NODE
exclude-address 10.10.10.103
exit
```

Backup tunnel must avoid the protected node, it is convenient to use the `exclude-address` command.

Interface	IP-Address	OK?	Method	Status	Prot
FastEthernet0/0	unassigned	YES	NVRAM	administratively down	down
Serial1/0	10.10.10.2	YES	NVRAM	up	up
Serial1/1	10.10.10.5	YES	NVRAM	up	up
Serial1/2	10.10.10.13	YES	NVRAM	up	up
Serial1/3	10.10.10.21	YES	NVRAM	up	up
Loopback0	10.10.10.102	YES	NVRAM	up	up
Tunnel1	10.10.10.102	YES	TFTP	up	up
Tunnel2	10.10.10.102	YES	TFTP	up	up

Tunnel 1 and Tunnel 2 are up

```
int s 1/1
mpls traffic-eng backup-path tunnel 1
mpls traffic-eng backup-path tunnel 2
ex
```

We need to backup tunnels to the protected interface.


```
R2#sh ip rsvp sender
```

To	From	Pro	DPort	Sport	Prev Hop	I/F	BPS
10.10.10.103	10.10.10.102	0	1	2	none	none	0
10.10.10.104	10.10.10.102	0	2	2	none	none	0
10.10.10.104	10.10.10.101	0	1000	6	10.10.10.1	Se1/0	10K
10.10.10.104	10.10.10.101	0	2000	6	10.10.10.1	Se1/0	5K

The first two are the backup tunnels and the last two are the primary tunnels.

```
R2#sh ip rsvp reservation
```

To	From	Pro	DPort	Sport	Next Hop	I/F	Fi	Serv	BPS
10.10.10.103	10.10.10.102	0	1	2	10.10.10.22	Se1/3	SE	LOAD	0
10.10.10.104	10.10.10.102	0	2	2	10.10.10.14	Se1/2	SE	LOAD	0
10.10.10.104	10.10.10.101	0	1000	6	10.10.10.6	Se1/1	SE	RATE	10K
10.10.10.104	10.10.10.101	0	2000	6	10.10.10.6	Se1/1	SE	LOAD	5K

```
R2#sh mpls traffic-eng fast-reroute data
```

Headend frr information:

Protected tunnel	In-label	Out	intf/label	FRR	intf/label	Status
LSP midpoint frr information:						
LSP identifier	In-label	Out	intf/label	FRR	intf/label	Status
10.10.10.101 1000 [6]	26		Se1/1:27	Tu2:implicit-nul		ready
10.10.10.101 2000 [6]	27		Se1/1:28	Tu2:implicit-nul		ready

R2#

```
R2#sh mpls traffic-eng fast-reroute data det
R2#sh mpls traffic-eng fast-reroute data detail
```

FRR Database Summary:

- Number of protected interfaces: 1
- Number of protected tunnels: 2
- Number of backup tunnels: 2
- Number of active interfaces: 0

LSP identifier 10.10.10.101 1000 [6], ready

Input label 26, Output label Se1/1:27, FRR label Tu2:implicit-null

Role Mid Head Hop 10.10.10.101 Tail Hop 10.10.10.104

LSP identifier 10.10.10.101 2000 [6], ready

Input label 27, Output label Se1/1:28, FRR label Tu2:implicit-null

Role Mid Head Hop 10.10.10.101 Tail Hop 10.10.10.104

```

R2#sh mpls traffic-eng tunnels br
Signalling Summary:
  LSP Tunnels Process:      running
  Passive LSP Listener:     running
  RSVP Process:             running
  Forwarding:               enabled
  Periodic reoptimization:  every 3600 seconds, next in 2087 seconds
  Periodic FRR Promotion:   Not Running
  Periodic auto-bw collection: every 300 seconds, next in 287 seconds
TUNNEL NAME                DESTINATION    UP IF    DOWN IF    STATE/PROT
R2_t1                      10.10.10.103   -        Se1/3      up/up
R2_t2                      10.10.10.104   -        Se1/2      up/up
R1_t1000                   10.10.10.104   Se1/0     Se1/1      up/up
R1_t2000                   10.10.10.104   Se1/0     Se1/1      up/up
Displayed 2 (of 2) heads, 2 (of 2) midpoints, 0 (of 0) tails

```

```

int tunnel 1
 tunnel mpls traffic-eng backup-bw global-pool unlimited
 exit

int tunnel 2
 tunnel mpls traffic-eng backup-bw sub-pool 1000
 exit

```

Associating pool types with backup tunnels so that backup tunnel 1 is to be used only by LSP which uses global pool (tunnel 2000) and backup tunnel 2 is to be used only by LSP which uses sub-pool (tunnel 1000)

```

ip rsvp signalling hello

int s 1/1
ip rsvp signalling hello
exit

exit
wr

```

RSVP Hello enables RSVP nodes to detect when a neighboring node is not reachable. This provides node to node failure detection. RSVP can be used by FRR when notification of link-layer failures is not available or when the failure detection mechanism provided by the link layer are not sufficient for the timely detection of node failure. Hello must be configured both globally on the router and on specific interface on which you need FRR protection.

R3

```

ip rsvp signalling hello

int s 1/0
ip rsvp signalling hello refresh
exit

```

TESTING

- SHUTTING DOWN THE LINK BETWEEN R2 AND R3

R3

en
conf t
ints 1/0
shut

The link between R2 and R3 is down, but we didn't see any notification (on any router) indicating that tunnel 1000 or 2000 is down. Because our tunnels now use backup LSPs.

```
R2#sh mpls forwarding-table
Local  Outgoing    Prefix      Bytes Label  Outgoing  Next Hop
Label  Label or VC  or Tunnel Id Switched      interface
16     Pop Label    10.10.10.101/32  0           Se1/0      point2point
17     Pop Label [T] 10.10.10.103/32  0           Tu1        point2point
18     Pop Label    10.10.10.24/30   0           Se1/3      point2point
19     No Label [T] 10.10.10.8/30    0           Tu1        point2point
       No Label [T] 10.10.10.8/30    0           Tu2        point2point
20     Pop Label [T] 10.10.10.104/32  0           Tu2        point2point
21     Pop Label    10.10.10.16/30   0           Se1/2      point2point
22     Pop Label    10.10.10.105/32  0           Se1/3      point2point
23     Pop Label    10.10.10.106/32  0           Se1/2      point2point
25     30          [T] 10.10.10.101 2000 [15]  \
                                0           Tu1        point2point
26     Pop Label [T] 10.10.10.101 1000 [17]  \
                                0           Tu2        point2point

[T] Forwarding through a LSP tunnel.
    View additional labelling info with the 'detail' option
```

```
R2#sh mpls traffic-eng fast-reroute database
Headend frr information:
Protected tunnel      In-label Out intf/label    FRR intf/label    Status
LSP midpoint frr information:
LSP identifier      In-label Out intf/label    FRR intf/label    Status
10.10.10.101 1000 [17]    26       Se1/1:25          Tu2:implicit-nul active
10.10.10.101 2000 [15]    25       Se1/1:30          Tu1:30            active
```

```

R2#sh mpls traffic-eng fast-reroute database detail
FRR Database Summary:
  Number of protected interfaces: 1
  Number of protected tunnels: 2
  Number of backup tunnels: 2
  Number of active interfaces: 1
LSP identifier 10.10.10.101 1000 [17], active
  Input label 26, Output label Se1/1:25, FRR label Tu2:implicit-null
  Role Mid  Head Hop 10.10.10.101 Tail Hop 10.10.10.104
LSP identifier 10.10.10.101 2000 [15], active
  Input label 25, Output label Se1/1:30, FRR label Tu1:30
  Role Mid  Head Hop 10.10.10.101 Tail Hop 10.10.10.104

```

- SHUTTING DOWN R3

Let's stop R3. After we stop it, Backup Tunnel 1 (which goes through R3) should be down. Because of that, Tunnel 2000 (which uses Tunnel 1 as a backup) should also be down.

```

R2#sh mpls traffic-eng fast-reroute database detail
FRR Database Summary:
  Number of protected interfaces: 1
  Number of protected tunnels: 1
  Number of backup tunnels: 1
  Number of active interfaces: 1
LSP identifier 10.10.10.101 1000 [17], active
  Input label 26, Output label Se1/1:25, FRR label Tu2:implicit-null
  Role Mid  Head Hop 10.10.10.101 Tail Hop 10.10.10.104

```

```

R2#sh mpls traffic-eng fast-reroute database
Headend frr information:
Protected tunnel          In-label Out intf/label  FRR intf/label  Status

LSP midpoint frr information:
LSP identifier          In-label Out intf/label  FRR intf/label  Status
10.10.10.101 1000 [17]  26       Se1/1:25       Tu2:implicit-nul active

```