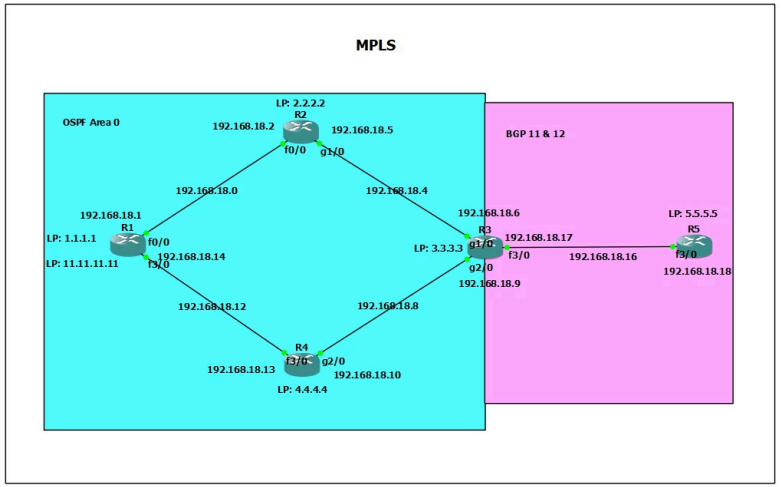

Multi-Router Network with OSPF, BGP, and MPLS

The project successfully demonstrates complete routing and MPLS overlay, integrating OSPF, BGP, and MPLS for network connectivity.

```
R1#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        192.168.18.1    YES manual up                    up
GigabitEthernet1/0     unassigned      YES unset  administratively down down
GigabitEthernet2/0     unassigned      YES unset  administratively down down
FastEthernet3/0        192.168.18.14   YES manual up                    up
FastEthernet3/1        unassigned      YES unset  administratively down down
Loopback0              1.1.1.1         YES manual up                    up
Loopback1              11.11.11.11     YES manual up                    up
R1#
R2#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        192.168.18.2    YES manual up                    up
GigabitEthernet1/0     192.168.18.5    YES manual up                    up
GigabitEthernet2/0     unassigned      YES unset  administratively down down
FastEthernet3/0        unassigned      YES unset  administratively down down
FastEthernet3/1        unassigned      YES unset  administratively down down
Loopback0              2.2.2.2         YES manual up                    up
R2#
R3#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES unset  administratively down down
GigabitEthernet1/0     192.168.18.6    YES manual up                    up
GigabitEthernet2/0     192.168.18.9    YES manual up                    up
FastEthernet3/0        192.168.18.17   YES manual up                    up
FastEthernet3/1        unassigned      YES unset  administratively down down
Loopback0              3.3.3.3         YES manual up                    up
R3#
R4#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES unset  administratively down down
GigabitEthernet1/0     unassigned      YES unset  administratively down down
GigabitEthernet2/0     192.168.18.10   YES manual up                    up
FastEthernet3/0        192.168.18.13   YES manual up                    up
FastEthernet3/1        unassigned      YES unset  administratively down down
Loopback0              4.4.4.4         YES manual up                    up
R4#
R5#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES unset  administratively down down
GigabitEthernet1/0     unassigned      YES unset  administratively down down
GigabitEthernet2/0     unassigned      YES unset  administratively down down
FastEthernet3/0        192.168.18.18   YES manual up                    up
FastEthernet3/1        unassigned      YES unset  administratively down down
Loopback0              5.5.5.5         YES manual up                    up
R5#
```

IP Addressing & Loopbacks

Purpose: Proof of interface and loopback setup

```
R1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
4.4.4.4           1   FULL/BDR        00:00:38    192.168.18.13   FastEthernet3/0
2.2.2.2           1   FULL/BDR        00:00:33    192.168.18.2    FastEthernet0/0
R1#show ip route ospf
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       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, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      2.0.0.0/32 is subnetted, 1 subnets
O        2.2.2.2 [110/11] via 192.168.18.2, 01:15:39, FastEthernet0/0
      3.0.0.0/32 is subnetted, 1 subnets
O        3.3.3.3 [110/12] via 192.168.18.2, 01:15:07, FastEthernet0/0
      4.0.0.0/32 is subnetted, 1 subnets
O        4.4.4.4 [110/13] via 192.168.18.2, 01:14:52, FastEthernet0/0
      5.0.0.0/32 is subnetted, 1 subnets
O E2     5.5.5.5 [110/1] via 192.168.18.2, 00:59:45, FastEthernet0/0
      192.168.18.0/24 is variably subnetted, 7 subnets, 2 masks
O        192.168.18.4/30 [110/11] via 192.168.18.2, 01:15:12, FastEthernet0/0
O        192.168.18.8/30 [110/12] via 192.168.18.2, 01:15:02, FastEthernet0/0
 --More--
```

Network Setup (Interfaces + Loopbacks + OSPF)

1 Interface IP Addresses

Configured on all router interfaces (R1 to R5).

2 Loopback Creation

Defined loopback interfaces for each router.

3 OSPF Enablement

Enabled OSPF on all routers and advertised interfaces.

4 OSPF Adjacency Verification

Verified full OSPF adjacency using show ip ospf neighbor.

```
R3#show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol
FastEthernet0/0        unassigned      YES unset  administratively down down
GigabitEthernet1/0     192.168.18.6    YES manual up                    up
GigabitEthernet2/0     192.168.18.9    YES manual up                    up
FastEthernet3/0        192.168.18.17   YES manual up                    up
FastEthernet3/1        unassigned      YES unset  administratively down down
Loopback0              3.3.3.3         YES manual up                    up
R3#show ip bgp
BGP table version is 68, local router ID is 192.168.18.17
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal,
              r RIB-failure, S Stale, m multipath, b backup-path, f RT-Filter,
              x best-external, a additional-path, c RIB-compressed,
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI validation codes: V valid, I invalid, N Not found

     Network          Next Hop            Metric LocPrf Weight Path
 *>  1.1.1.1/32       192.168.18.5             3         32768 ?
 *>  2.2.2.2/32       192.168.18.5             2         32768 ?
 *>  3.3.3.3/32       0.0.0.0                  0         32768 ?
 *>  4.4.4.4/32       192.168.18.10            2         32768 ?
 *>  5.5.5.5/32       192.168.18.18            0             0 12 i
 *>  11.11.11.11/32   192.168.18.5             3         32768 ?
 *>  192.168.18.0/30  192.168.18.5             2         32768 ?
 *>  192.168.18.4/30  0.0.0.0                  0         32768 ?
 *>  192.168.18.8/30  0.0.0.0                  0         32768 ?
 *>  192.168.18.12/30 192.168.18.10            2         32768 ?
 *>  192.168.18.16/30 0.0.0.0                  0         32768 ?
 *                    192.168.18.18            0             0 12 i
R3#show ip route 5.5.5.5
Routing entry for 5.5.5.5/32
  Known via "bgp 11", distance 20, metric 0
  Tag 12, type external
  Redistributing via ospf 1
  Advertised by ospf 1 subnets
  Last update from 192.168.18.18 03:37:52 ago
  Routing Descriptor Blocks:
  * 192.168.18.18, from 192.168.18.18, 03:37:52 ago
      Route metric is 0, traffic share count is 1
      AS Hops 1
      Route tag 12
      MPLS label: none
```

BGP Setup + Integration with OSPF

BGP Config

Between R3 (AS 11) and R5 (AS 12).

Loopback Advertise

R5 advertised loopback 5.5.5.5 via BGP.

Redistribute Routes

R3 redistributed BGP routes into OSPF.

Route Learning

R1 learned 5.5.5.5 through OSPF.

```
R1#show ip ospf interface
Loopback0 is up, line protocol is up
  Internet Address 1.1.1.1/32, Area 0, Attached via Network Statement
  Process ID 1, Router ID 1.1.1.1, Network Type LOOPBACK, Cost: 1
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           1         no          no            Base
  Loopback interface is treated as a stub Host
Loopback1 is up, line protocol is up
  Internet Address 11.11.11.11/32, Area 0, Attached via Network Statement
  Process ID 1, Router ID 1.1.1.1, Network Type LOOPBACK, Cost: 1
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           1         no          no            Base
  Loopback interface is treated as a stub Host
FastEthernet3/0 is up, line protocol is up
  Internet Address 192.168.18.14/30, Area 0, Attached via Network Statement
  Process ID 1, Router ID 1.1.1.1, Network Type BROADCAST, Cost: 100
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           100       no          no            Base
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 1.1.1.1, Interface address 192.168.18.14
  Backup Designated router (ID) 4.4.4.4, Interface address 192.168.18.13
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:02
  Supports Link-local Signaling (LLS)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
```

Redundancy via OSPF Cost + Virtual Link Attempt

OSPF Cost Adjustment

- Lower cost via R2 (primary).
- Higher cost via R4 (backup).

Failover Verification

Shutdown of R1-R2 to test failover.

Virtual Link Attempt

- Attempted between R3 and R5.
- Unsuccessful due to BGP.

```
R3#show mpls ldp neighbor
    Peer LDP Ident: 2.2.2.2:0; Local LDP Ident 3.3.3.3:0
        TCP connection: 2.2.2.2.646 - 3.3.3.3.37738
        State: Oper; Msgs sent/rcvd: 107/108; Downstream
        Up time: 01:22:15
        LDP discovery sources:
          GigabitEthernet1/0, Src IP addr: 192.168.18.5
        Addresses bound to peer LDP Ident:
          192.168.18.2    192.168.18.5    2.2.2.2
    Peer LDP Ident: 4.4.4.4:0; Local LDP Ident 3.3.3.3:0
        TCP connection: 4.4.4.4.47186 - 3.3.3.3.646
        State: Oper; Msgs sent/rcvd: 108/107; Downstream
        Up time: 01:21:35
        LDP discovery sources:
          GigabitEthernet2/0, Src IP addr: 192.168.18.10
        Addresses bound to peer LDP Ident:
          192.168.18.10   192.168.18.13   4.4.4.4
    Peer LDP Ident: 5.5.5.5:0; Local LDP Ident 3.3.3.3:0
        TCP connection: 5.5.5.5.32420 - 3.3.3.3.646
        State: Oper; Msgs sent/rcvd: 106/96; Downstream
        Up time: 01:20:57
        LDP discovery sources:
          FastEthernet3/0, Src IP addr: 192.168.18.18
        Addresses bound to peer LDP Ident:
          192.168.18.18   5.5.5.5
R3#
R3#show mpls forwarding-table
Local      Outgoing   Prefix           Bytes Label   Outgoing    Next Hop
Label      Label      or Tunnel Id     Switched      interface
16         16         1.1.1.1/32       0             Gi1/0       192.168.18.5
           16         1.1.1.1/32       0             Gi2/0       192.168.18.10
17         Pop Label  2.2.2.2/32       0             Gi1/0       192.168.18.5
18         Pop Label  4.4.4.4/32       12430         Gi2/0       192.168.18.10
19         20         11.11.11.11/32   0             Gi1/0       192.168.18.5
           20         11.11.11.11/32   0             Gi2/0       192.168.18.10
20         Pop Label  192.168.18.0/30  0             Gi1/0       192.168.18.5
21         Pop Label  192.168.18.12/30 0             Gi2/0       192.168.18.10
22         No Label   5.5.5.5/32       1938          Fa3/0       192.168.18.18
```

MPLS Integration

MPLS Enablement

Globally and on router interfaces.

Loopback Reachability

Via OSPF Area 0.

LDP Router IDs

Loopbacks used for label exchange.

Neighbor Verification

LDP neighbors and label assignments verified.

```
VRF info: (vrf in name/id, vrf out name/id)
  1 192.168.18.2 [MPLS: Label 19 Exp 0] 108 msec 92 msec 96 msec
  2 192.168.18.6 [MPLS: Label 22 Exp 0] 60 msec 68 msec 56 msec
  3 192.168.18.18 88 msec 84 msec 96 msec
R1#ping 5.5.5.5
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 5.5.5.5, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 76/89/104 ms
R5#ping 1.1.1.1 source loopback0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 1.1.1.1, timeout is 2 seconds:
Packet sent with a source address of 5.5.5.5
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 80/90/100 ms
R1(config)#interface f0/0
R1(config-if)#shutdown
R1(config-if)#exit
R1(config)#
*Apr 19 06:33:19.291: %OSPF-5-ADJCHG: Process 1, Nbr 2.2.2.2 on FastEthe
hbor Down: Interface down or detached
R1(config)#
*Apr 19 06:33:21.263: %LINK-5-CHANGED: Interface FastEthernet0/0, change
n
*Apr 19 06:33:22.263: %LINEPROTO-5-UPDOWN: Line protocol on Interface Fa
 down
R1(config)#exit
R1#tra
*Apr 19 06:33:26.047: %SYS-5-CONFIG_I: Configured from console by consol
R1#traceroute 5.5.5.5
Type escape sequence to abort.
Tracing the route to 5.5.5.5
VRF info: (vrf in name/id, vrf out name/id)
  1 192.168.18.13 20 msec 32 msec 16 msec
  2 192.168.18.9 72 msec 52 msec 68 msec
  3 192.168.18.18 92 msec 80 msec 100 msec
```

Final Results (MPLS + Routing Validation)

End-to-End Ping

Successful ping from R1 to R5 (5.5.5.5).

MPLS Label Switching

Traceroute showed label switching between hops.

OSPF + BGP Path

Confirmed path logic.

Thank You !!

Any questions?