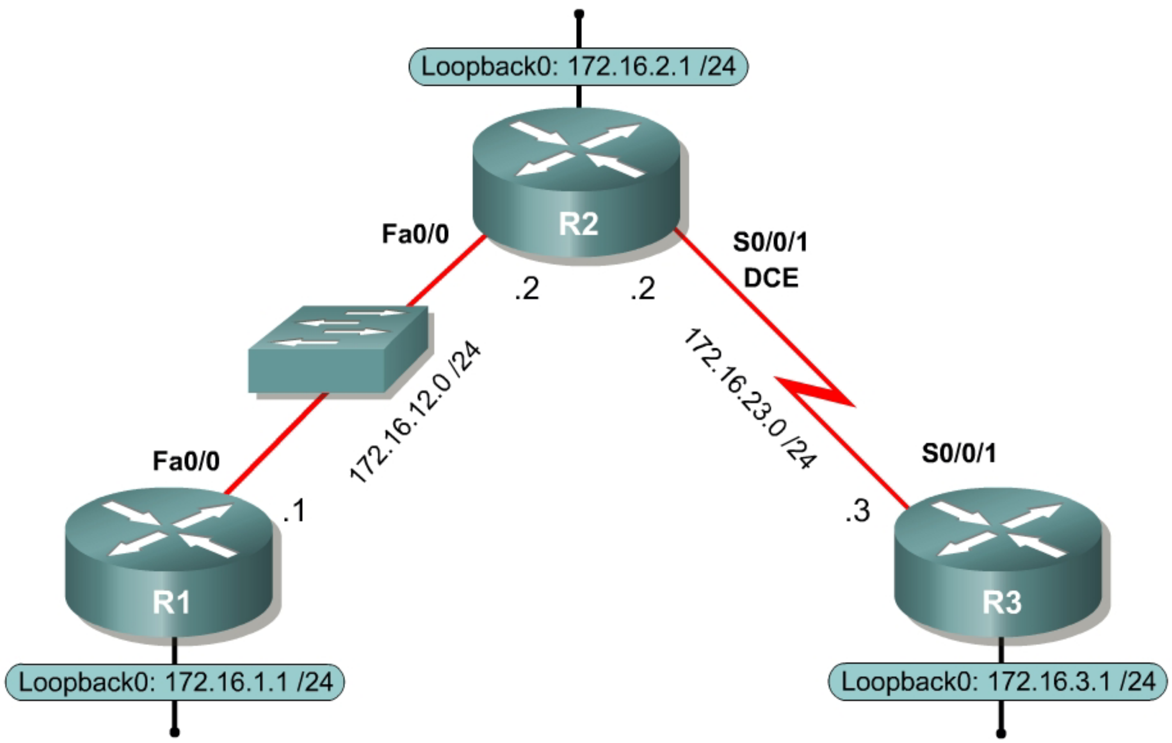
Lab 4.1 Configuring Frame Mode MPLS

Learning Objectives

- Configure EIGRP on a router
- Configure Label Distribution Protocol on a router
- Change the size of the Maximum Transmission Unit (MTU)
- Verify MPLS behavior

Topology Diagram



Scenario

In this lab, you will configure a simple Enhanced Interior Gateway Routing Protocol (EIGRP) network to route IP packets. You will run Multiprotocol Label Switching (MPLS) over the IP internetwork to fast-switch Layer 2 frames.

Step 1: Configure Addressing

Configure the loopback interfaces with the addresses shown in the topology diagram. Also configure the serial interfaces shown in the diagram. Set the clock rate on the appropriate interface and issue the **no shutdown** command on all serial connections. Verify that you have connectivity across the local subnet using the **ping** command.


```
R1(config)# interface loopback 0
R1(config-if)# ip address 172.16.1.1 255.255.255.0
R1(config-if)# interface fastethernet 0/0
R1(config-if)# ip address 172.16.12.1 255.255.255.0
R1(config-if)# no shutdown

R2(config)# interface loopback 0
R2(config-if)# ip address 172.16.2.1 255.255.255.0
R2(config-if)# interface fastethernet 0/0
R2(config-if)# ip address 172.16.12.2 255.255.255.0
R2(config-if)# no shutdown
R2(config-if)# interface serial 0/0/1
R2(config-if)# ip address 172.16.23.2 255.255.255.0
R2(config-if)# clockrate 64000
R2(config-if)# no shutdown

R3(config)# interface loopback 0
R3(config-if)# ip address 172.16.3.1 255.255.255.0
R3(config-if)# interface serial 0/0/1
R3(config-if)# ip address 172.16.23.3 255.255.255.0
R3(config-if)# no shutdown
```

Step 2: Configure EIGRP AS 1

Configure EIGRP for AS1 on all three routers. Add the whole major network 172.16.0.0 and disable automatic summarization.

```
R1(config)# router eigrp 1
R1(config-router)# no auto-summary
R1(config-router)# network 172.16.0.0

R2(config)# router eigrp 1
R2(config-router)# no auto-summary
R2(config-router)# network 172.16.0.0

R3(config)# router eigrp 1
R3(config-router)# no auto-summary
R3(config-router)# network 172.16.0.0
```

EIGRP neighbor adjacencies should form between R1 and R2 and between R2 and R3. If the adjacencies do not form, troubleshoot by checking your interface configuration, EIGRP configuration, and physical connectivity.

What impact does IP connectivity have on MPLS?

Step 3: Observe CEF Operation

Since all the routers have EIGRP adjacencies and are advertising the entire major 172.16.0.0 network, all routers should have full routing tables.


```
R1# show ip route
Codes: 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

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 5 subnets
D       172.16.23.0 [90/2172416] via 172.16.12.2, 00:01:56, FastEthernet0/0
C       172.16.12.0 is directly connected, FastEthernet0/0
C       172.16.1.0 is directly connected, Loopback0
D       172.16.2.0 [90/156160] via 172.16.12.2, 00:01:56, FastEthernet0/0
D       172.16.3.0 [90/2300416] via 172.16.12.2, 00:01:51, FastEthernet0/0
```

On R1, if you perform a **traceroute** to the R3s loopback, you see the path the packet follows. This output changes slightly once we configure MPLS.

```
R1# traceroute 172.16.3.1

Type escape sequence to abort.
Tracing the route to 172.16.3.1

  1 172.16.12.2 0 msec 0 msec 0 msec
  2 172.16.23.3 16 msec 12 msec *
```

Cisco Express Forwarding (CEF) is Cisco's proprietary Layer 3 switching algorithm for Cisco IOS routers. CEF allows forwarding to be distributed throughout the line cards on Cisco models like the Catalyst 6500. CEF also provides quicker switching than switching based on the routing table (process switching) or switching based on a standards-compliant forwarding information base (fast switching).

What is the function of CEF?

Which information does CEF view as significant in making a forwarding determination for an IP packet?

You can also see that CEF is enabled by default by using the **show ip cef command**.


```
R1# show ip cef
Prefix              Next Hop             Interface
0.0.0.0/0           drop                 Null0 (default route handler entry)
0.0.0.0/32          receive
172.16.1.0/24       attached             Loopback0
172.16.1.0/32       receive
172.16.1.1/32       receive
172.16.1.255/32     receive
172.16.2.0/24       172.16.12.2          FastEthernet0/0
172.16.3.0/24       172.16.12.2          FastEthernet0/0
172.16.12.0/24      attached             FastEthernet0/0
172.16.12.0/32      receive
172.16.12.1/32      receive
172.16.12.2/32      172.16.12.2          FastEthernet0/0
172.16.12.255/32    receive
172.16.23.0/24      172.16.12.2          FastEthernet0/0
224.0.0.0/4         drop
224.0.0.0/24        receive
255.255.255.255/32  receive
```

Another important CEF command is the **show ip cef non-recursive** command which allows the user to display CEF forwarding information for prefixes installed in the routing table.

```
R1# show ip cef non-recursive
Prefix              Next Hop             Interface
172.16.1.0/24       attached             Loopback0
172.16.2.0/24       172.16.12.2          FastEthernet0/0
172.16.3.0/24       172.16.12.2          FastEthernet0/0
172.16.12.0/24      attached             FastEthernet0/0
172.16.12.2/32      172.16.12.2          FastEthernet0/0
172.16.23.0/24      172.16.12.2          FastEthernet0/0
```

CEF records both the Layer 3 next-hop information and the Layer 2 frame next-hop information. CEF currently supports the following Layer 2 protocols: ATM, Frame Relay, Ethernet, Fiber Distributed Data Interface (FDDI), PPP, High-Level Datalink Control (HDLC), and tunnels.

CEF is critical to the operation of MPLS on Cisco routers because MPLS packets must be forwarded based on label. Since the CEF architecture can support multiple protocols such as IPv4, IPv6, CEF switching could naturally be extended to support MPLS labels as well.

CEF should be enabled by default. If CEF is not enabled, issue the **ip cef** command in global configuration mode on each router.

Step 4: Enable MPLS on All Physical Interfaces

MPLS is a standardized protocol that allows routers to switch packets based on labels, rather than route switch packets based on standards in the protocol's routing formula. Under normal IP routing, every intermediate system looks up the destination prefix of an IP packet in the Routing Information Base (RIB) of a router or in the Forwarding Information Base (FIB) of a fast switch at every Layer 3 node. Instead of switching that is based on prefix, the first router running MPLS can encapsulate the IP packet in an MPLS frame and then further encapsulate the packet in the Layer 2 frame before sending it across one of many supported Layer 2 media. At the next MPLS-enabled Label Switch Router (LSR), the MPLS frame is read and the IP packet is switched as an MPLS frame from router to router with little rewrite at each node.

This allows routers to switch multiple protocols (hence the name) using the same switching mechanism, as well as perform some other functionality not available in traditional destination-based forwarding, including Layer 2 VPNs (AToM), Layer 3 VPNs, and traffic engineering. MPLS runs between Layers 2 and 3 of the OSI model and, because of this, is sometimes said to run at Layer 2½. The MPLS header is 4 bytes long and includes a 20-bit label.

Configuring the interface-level command **mpls ip** on an interface tells the router to switch MPLS packets inbound and outbound on that interface as well as attempt to bring up MPLS adjacencies with the Label Distribution Protocol (LDP) out that egress interface. LDP facilitates communication between MPLS peers by allowing them to inform each other of labels to assign packets to particular destinations based on Layer 2, Layer 3, or other significant information.

Configure MPLS on all physical interfaces in the topology.

NOTE: If you are running the 12.4 version of the IOS on your routers, then the **mpls ip** command is what you will use in this lab. However, when Cisco first developed packet-labeling technology, it was called tag switching. Therefore, if you are running an older version of the IOS, then you may see one of two different variations. The first variation is that your router will accept the **mpls ip** command. However, the commands will be stored in IOS as **tag-switching** commands. The second variation is that your router will not accept the **mpls ip** command. In this event, the **mpls ip** command may be entered as the **tag-switching ip** command. Try the newer commands first, beginning with the **mpls** keyword.

```
R1(config)# interface fastethernet0/0
R1(config-if)# mpls ip

R2(config)# interface fastethernet0/0
R2(config-if)# mpls ip
*Jan 31 08:28:54.315: %LDP-5-NBRCHG: LDP Neighbor 172.16.1.1:0 (1) is UP
R2(config-if)# interface serial0/0/1
R2(config-if)# mpls ip

R3(config)# interface serial0/0/1
R3(config-if)# mpls ip
*Jan 31 08:32:11.571: %LDP-5-NBRCHG: LDP Neighbor 172.16.2.1:0 (1) is UP
```

Notice that as you configure MPLS on both ends of a connection, IOS logs a messages to the console on both routers indicating that an LDP neighbor adjacency has formed.

Although you are going to use LDP in this lab, there is another Cisco-proprietary label exchanging protocol called Tag Distribution Protocol (TDP) which was part of the Cisco Tag Switching architecture. To change the protocol being used, use the **mpls label protocol** *protocol* command either on a global level at the global configuration prompt or on a per-interface basis, using the interface-level version of this command. Cisco TDP and MPLS LDP are nearly identical in function, but use incompatible message formats and some different procedures. Cisco is changing from TDP to a fully compliant LDP.

Step 5: Verify MPLS Configuration

MPLS has many **show** commands that you can use to verify proper MPLS operation. Issue the **show mpls interfaces** command to see a quick summary of interfaces configured with MPLS. Keep in mind that you will see this output because you applied the **mpls ip** command to these interfaces.

```
R1# show mpls interfaces
Interface              IP            Tunnel   Operational
FastEthernet0/0        Yes (ldp)     No       Yes


R2# show mpls interfaces
Interface              IP            Tunnel   Operational
FastEthernet0/0        Yes (ldp)     No       Yes
Serial0/0/1            Yes (ldp)     No       Yes

R3# show mpls interfaces
Interface              IP            Tunnel   Operational
Serial0/0/1            Yes (ldp)     No       Yes
```

Issue the **show mpls ldp discovery** command to find out local sources for LDP exchanges and the **show mpls ldp neighbor** command to show LDP adjacencies. Notice that MPLS chooses its IDs based on loopback interfaces, similar to other protocols such asOpen Shortest Path First (OSPF), Border Gateway Protocol (BGP).

```
R1# show mpls ldp discovery
 Local LDP Identifier:
    172.16.1.1:0
    Discovery Sources:
    Interfaces:
        FastEthernet0/0 (ldp): xmit/recv
            LDP Id: 172.16.2.1:0; no host route

R1# show mpls ldp neighbor
    Peer LDP Ident: 172.16.2.1:0; Local LDP Ident 172.16.1.1:0
        TCP connection: 172.16.2.1.49525 - 172.16.1.1.646
        State: Oper; Msgs sent/rcvd: 29/26; Downstream
        Up time: 00:16:40
        LDP discovery sources:
          FastEthernet0/0, Src IP addr: 172.16.12.2
        Addresses bound to peer LDP Ident:
          172.16.12.2     172.16.23.2     172.16.2.1


R2# show mpls ldp discovery
```



```
 Local LDP Identifier:
    172.16.2.1:0
    Discovery Sources:
    Interfaces:
        FastEthernet0/0 (ldp): xmit/recv
            LDP Id: 172.16.1.1:0; no host route
        Serial0/0/1 (ldp): xmit/recv
            LDP Id: 172.16.3.1:0; no host route

R2# show mpls ldp neighbor
    Peer LDP Ident: 172.16.1.1:0; Local LDP Ident 172.16.2.1:0
        TCP connection: 172.16.1.1.646 - 172.16.2.1.49525
        State: Oper; Msgs sent/rcvd: 27/30; Downstream
        Up time: 00:17:06
        LDP discovery sources:
          FastEthernet0/0, Src IP addr: 172.16.12.1
        Addresses bound to peer LDP Ident:
          172.16.12.1     172.16.1.1
    Peer LDP Ident: 172.16.3.1:0; Local LDP Ident 172.16.2.1:0
        TCP connection: 172.16.3.1.34352 - 172.16.2.1.646
        State: Oper; Msgs sent/rcvd: 27/26; Downstream
        Up time: 00:16:23
        LDP discovery sources:
          Serial0/0/1, Src IP addr: 172.16.23.3
        Addresses bound to peer LDP Ident:
          172.16.23.3     172.16.3.1


R3# show mpls ldp discovery
 Local LDP Identifier:
    172.16.3.1:0
    Discovery Sources:
    Interfaces:
        Serial0/0/1 (ldp): xmit/recv
            LDP Id: 172.16.2.1:0; no host route
R3# show mpls ldp neighbor
    Peer LDP Ident: 172.16.2.1:0; Local LDP Ident 172.16.3.1:0
        TCP connection: 172.16.2.1.646 - 172.16.3.1.34352
        State: Oper; Msgs sent/rcvd: 27/28; Downstream
        Up time: 00:17:19
        LDP discovery sources:
          Serial0/0/1, Src IP addr: 172.16.23.2
        Addresses bound to peer LDP Ident:
          172.16.12.2     172.16.23.2     172.16.2.1
```

What interface does LDP use on R1 to identify itself to other LDP peers?

What transport protocol does LDP use to communicate with other LDP peers?

In the configuration you set up in Step 4, all routers are acting as Label Switch Routers (LSRs) and running LDP. On LSRs, each forwarding equivalence class (in this case, each routable IP prefix) is assigned an MPLS label. LDP automatically distributes labels to peers to be used when sending traffic to specific destinations through the LSR. Once labels have been distributed, switching for MPLS packets is done through the Label Information Base (LIB).

Display the contents of the LIB using the **show mpls ldp bindings** command. There is a binding for every routed prefix; however, the bindings may vary from router to router since they can get swapped at each hop. In a larger network, the way labels are swapped is easier to see. The LIB is also referred to on Cisco routers as the TIB, a legacy name from Tag Switching. Do not be alarmed to see the LIB entries listed instead as TIB entries: this does not signal that TDP is the protocol being used for distribution.

```
R1# show mpls ldp bindings
  tib entry: 172.16.1.0/24, rev 6
        local binding:  tag: imp-null
        remote binding: tsr: 172.16.2.1:0, tag: 16
  tib entry: 172.16.2.0/24, rev 8
        local binding:  tag: 17
        remote binding: tsr: 172.16.2.1:0, tag: imp-null
  tib entry: 172.16.3.0/24, rev 10
        local binding:  tag: 18
        remote binding: tsr: 172.16.2.1:0, tag: 17
  tib entry: 172.16.12.0/24, rev 4
        local binding:  tag: imp-null
        remote binding: tsr: 172.16.2.1:0, tag: imp-null
  tib entry: 172.16.23.0/24, rev 2
        local binding:  tag: 16
        remote binding: tsr: 172.16.2.1:0, tag: imp-null

R2# show mpls ldp bindings
  tib entry: 172.16.1.0/24, rev 6
        local binding:  tag: 16
        remote binding: tsr: 172.16.1.1:0, tag: imp-null
        remote binding: tsr: 172.16.3.1:0, tag: 17
  tib entry: 172.16.2.0/24, rev 8
        local binding:  tag: imp-null
        remote binding: tsr: 172.16.1.1:0, tag: 17
        remote binding: tsr: 172.16.3.1:0, tag: 18
  tib entry: 172.16.3.0/24, rev 10
        local binding:  tag: 17
        remote binding: tsr: 172.16.1.1:0, tag: 18
        remote binding: tsr: 172.16.3.1:0, tag: imp-null
  tib entry: 172.16.12.0/24, rev 4
        local binding:  tag: imp-null
        remote binding: tsr: 172.16.1.1:0, tag: imp-null
        remote binding: tsr: 172.16.3.1:0, tag: 16
  tib entry: 172.16.23.0/24, rev 2
        local binding:  tag: imp-null
        remote binding: tsr: 172.16.1.1:0, tag: 16
        remote binding: tsr: 172.16.3.1:0, tag: imp-null

R3# show mpls ldp bindings
  tib entry: 172.16.1.0/24, rev 6
        local binding:  tag: 17
        remote binding: tsr: 172.16.2.1:0, tag: 16
```



```
tib entry: 172.16.2.0/24, rev 8
      local binding:  tag: 18
      remote binding: tsr: 172.16.2.1:0, tag: imp-null
tib entry: 172.16.3.0/24, rev 10
      local binding:  tag: imp-null
      remote binding: tsr: 172.16.2.1:0, tag: 17
tib entry: 172.16.12.0/24, rev 4
      local binding:  tag: 16
      remote binding: tsr: 172.16.2.1:0, tag: imp-null
tib entry: 172.16.23.0/24, rev 2
      local binding:  tag: imp-null
      remote binding: tsr: 172.16.2.1:0, tag: imp-null
```

The local bindings are generated by LDP on a Label Switch Router when LDP is enabled. A label is generated for every prefix in the routing table. These labels are then sent to all of the router's LDP peers. A tag of implicit-NULL ("imp-null" in the output of the command **show mpls ldp bindings**) is advertised when the packet with not be forwarded locally based on label, but based on prefix. This situation regularly occurs with connected networks.

For instance, assume R2 and R3 have already peered with each other using LDP. Now R1 begins running MPLS and attempts to peer to R2:

1. R1 generates the locally bound label, namely 18, for the prefix 172.16.3.0/24 in its routing table.

2. R1 advertises the local binding to its LDP peer, R2.

3. R2 enters R1's binding for the 172.16.3.0/24 prefix, now classified as a remote binding, into its LIB, regardless of whether it uses it to reach the destination network. The remote binding for this IP prefix through R1 is label 18.

4. Based on the routing table, R2 will use R3 as the next hop for the 172.16.3.0/24. R2 will not forward IP packets inside an MPLS encapsulation, but rather simply as IP packets because R3 has advertised the label of implicit-NULL to R2.

What is the significance of the "local binding" entry?

What is the significance of a "remote binding" entry?

On R2, why is there more than one remote binding for each of the networks in the diagram?

Note that LDP assigns local labels to *all* Interior Gateway Protocol (IGP) prefixes and advertises the bindings to *all* LDP peers. The concept of split horizon does not exist; an LDP peer assigns its own local label to a prefix and advertises that back to the other LDP peer, even though that other LDP peer owns the prefix (it is a connected prefix) or that other LDP peer is the downstream LSR.

What is the meaning of the implicit NULL label?

As mentioned earlier, **traceroute** would differ slightly once MPLS was set up. The output now includes labels for each hop. Unfortunately, because of the size of this network, you only see one label. In a larger network, you would see more hops, and therefore more labels.

```
R1# traceroute 172.16.3.1

Type escape sequence to abort.
Tracing the route to 172.16.3.1

  1 172.16.12.2 [MPLS: Label 17 Exp 0] 44 msec 44 msec 48 msec
  2 172.16.23.3 12 msec 12 msec *
```

Step 6: Change MPLS MTU

Because you are adding in extra header information to packets, the MTU of packets can change. Remember that each MPLS header is 4 bytes. The default MTU size of MPLS packets is taken from the interface it is running on, which in the case of Ethernet is 1500 bytes. To verify this, use the **show mpls interfaces** *interface-type interface-number* **detail** command to the Ethernet connections of R1 and R2.

```
R1# show mpls interfaces fastethernet 0/0 detail
Interface FastEthernet0/0:
        IP labeling enabled (ldp):
          Interface config
        LSP Tunnel labeling not enabled
        BGP tagging not enabled
```



```
        Tagging operational
        Fast Switching Vectors:
          IP to MPLS Fast Switching Vector
          MPLS Turbo Vector
        MTU = 1500
```

```
R2# show mpls interfaces fastethernet 0/0 detail
Interface FastEthernet0/0:
        IP labeling enabled (ldp):
          Interface config
        LSP Tunnel labeling not enabled
        BGP tagging not enabled
        Tagging operational
        Fast Switching Vectors:
          IP to MPLS Fast Switching Vector
          MPLS Turbo Vector
        MTU = 1500
```

For this lab, we will change the Ethernet connection between R1 and R2 to support 2 MPLS headers, so we will change the MPLS MTU to 1508 on their Fast Ethernet interfaces. To change the MPLS MTU, use the **mpls mtu** *size* command in interface configuration mode. Verify the change using the **show mpls interfaces** *interface* **detail** command used earlier.

```
R1(config)# interface fastethernet 0/0
R1(config-if)# mpls mtu 1508

R2(config)# interface fastethernet0/0
R2(config-if)# mpls mtu 1508

R1# show mpls interface fastethernet 0/0 detail
Interface FastEthernet0/0:
        IP labeling enabled (ldp):
          Interface config
        LSP Tunnel labeling not enabled
        BGP tagging not enabled
        Tagging operational
        Fast Switching Vectors:
          IP to MPLS Fast Switching Vector
          MPLS Turbo Vector
        MTU = 1508

R2# show mpls interface fastethernet 0/0 detail
Interface FastEthernet0/0:
        IP labeling enabled (ldp):
          Interface config
        LSP Tunnel labeling not enabled
        BGP tagging not enabled
        Tagging operational
        Fast Switching Vectors:
          IP to MPLS Fast Switching Vector
          MPLS Turbo Vector
        MTU = 1508
```

Final Configurations

```
R1# show run
!
hostname R1
!
```



```
interface Loopback0
 ip address 172.16.1.1 255.255.255.0
!
interface FastEthernet0/0
 ip address 172.16.12.1 255.255.255.0
 mpls ip
 mpls mtu 1508
 no shutdown
!
router eigrp 1
 network 172.16.0.0
 no auto-summary
!
end

R2# show run
!
hostname R2
!
interface Loopback0
 ip address 172.16.2.1 255.255.255.0
!
interface FastEthernet0/0
 ip address 172.16.12.2 255.255.255.0
 mpls ip
 mpls mtu 1508
 no shutdown
!
interface Serial0/0/1
 ip address 172.16.23.2 255.255.255.0
 mpls ip
 clock rate 64000
 no shutdown
!
router eigrp 1
 network 172.16.0.0
 no auto-summary
!
end

R3# show run
!
hostname R3
!
interface Loopback0
 ip address 172.16.3.1 255.255.255.0
!
interface Serial0/0/1
 ip address 172.16.23.3 255.255.255.0
 mpls ip
 no shutdown
!
router eigrp 1
 network 172.16.0.0
 no auto-summary
!
end
```

