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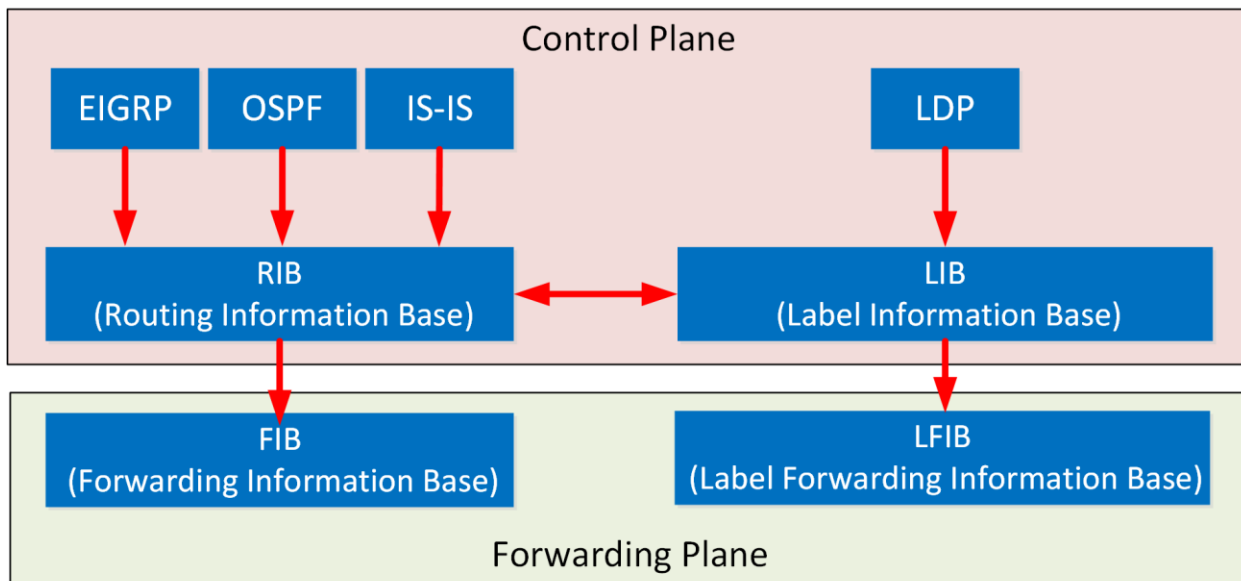
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## What is Multi-Protocol Label Switching (MPLS)?

- **MPLS is a method of forwarding IP packets by using labels instead of IP addresses** or layer 3 packet headers.
- It combines the best characteristics of the Overlay and Peer-to-peer model. **Because it uses labels, it speeds up packet forwarding and IP routing.**
- **It removes the processing load of IP inspection when using a normal routing operation.**
- **MPLS is considered as 2.5 Layer protocol** due to its special feature of LDP protocol.
- MPLS is a forwarding mechanism in which packet are forwarded based on **labels**.



## MPLS Operation

- On a normal routing operation, the router receives the packet, checks the **layer 3 headers**, and gets **the destination IP address to decide which path the packet should go.**
- The router always checks the routing table in forwarding the packet.
- On an MPLS network, the router only checks on the label, which **reduces the overhead processing** and boosts the **speed of the network.**
- The **MPLS label is a 4-byte header** that is inserted between the Layer 2 header and the IP header of a packet. The label contains information about the next hop for the packet, and it allows routers to forward packets more quickly and efficiently than if they had to examine the entire IP header.

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- **The IP header is a 20-byte header that contains information about the source and destination addresses of the packet, as well as other routing information.** When a router receives an IP packet, it must examine the IP header to determine the next hop for the packet. This process can take some time, especially if the router is handling a large number of packets.
- The MPLS label eliminates the need for routers to examine the entire IP header. Instead, routers only need to examine the 4-byte label to determine the next hop for the packet. This can significantly reduce the amount of time that routers need to spend processing packets, which can improve network performance.
- In addition to reducing the processing time, MPLS labels can also help to improve network scalability. By eliminating the need to examine the entire IP header, MPLS allows routers to forward packets more quickly and efficiently, even when the network is congested.
- Here is a table that summarizes the differences between IP headers and MPLS labels:

Feature	IP header	MPLS label
Length	20 bytes	4 bytes
Information	Source and destination addresses, routing information	Next hop
Processing time	More time-consuming	Less time-consuming
Scalability	Less scalable	More scalable

The below diagram shows how labels are transferred on each router.



### What does multi-protocol label switching mean?

**Multi-protocol:** besides IP you can tunnel pretty much anything...IP, IPv6, Ethernet, PPP, frame-relay, etc.

**Label switching:** forwarding is done based on labels, not by looking up the destination in the routing table.

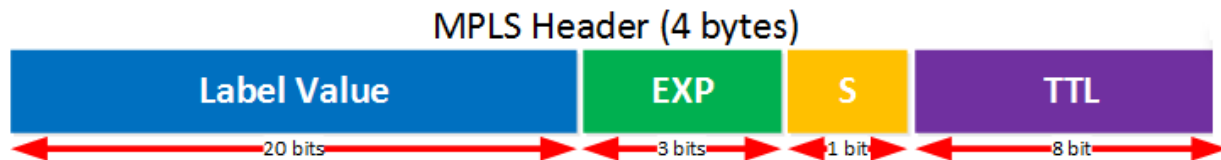
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## MPLS Label Format:



Here's what the different fields are used for:

**Label value:** the name says it all; this is where you will find the value of the label.

**EXP:** these are the three experimental bits. These are used for QoS; normally the IP precedence value of the IP packet will be copied here.

**S:** this is the "bottom of stack" bit. With MPLS it's possible to add more than one label. When this bit is set to one, it's the last MPLS header. When it's set to zero then there is one or more MPLS headers left.

**TTL:** just like in the IP header, this is the time to live field. We can use this for traces in the MPLS network. Each hop decrements the TTL by one.



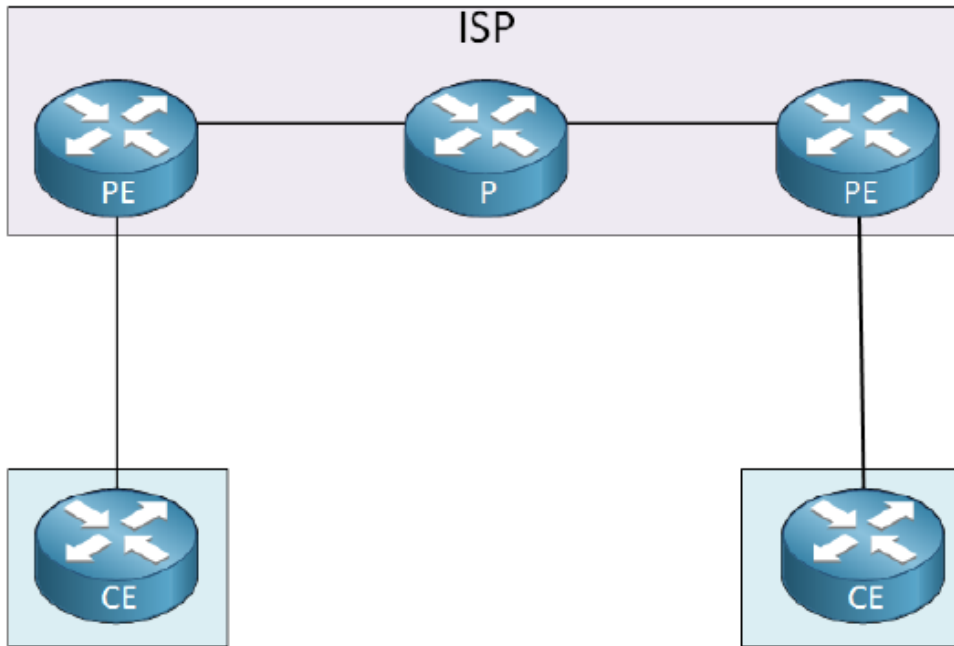
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## MPLS Devices and Operations:



**CE (Customer Edge):** This device is the last device in the customer's network, it could be a L2 or L3 device. This device does not use MPLS.

**PE (Provider Edge):** This device is owned by the ISP and sits at the edge of the ISP's network. It has an important role. It receives packets or frames from the customer and will then add a MPLS label to it and forwards towards the core. Another common name for this device is **LER (Label Edge Router)**. **A sequence of labels to reach a destination is called an LSP (Label switch path).**

**P (Provider):** This device connects to PE routers and other P routers. It has a simple job; it switches packets based on their labels or removes the labels. Another common name for this device is the **LSR (Label Switch Router)** or transit router.

### There are three actions we can perform with labels:

**Label push:** when we add a label to a packet, we call it a label push.

**Label swap:** replacing a label with another value is called a label swap.

**Label pop:** removing the label is called a label pop.

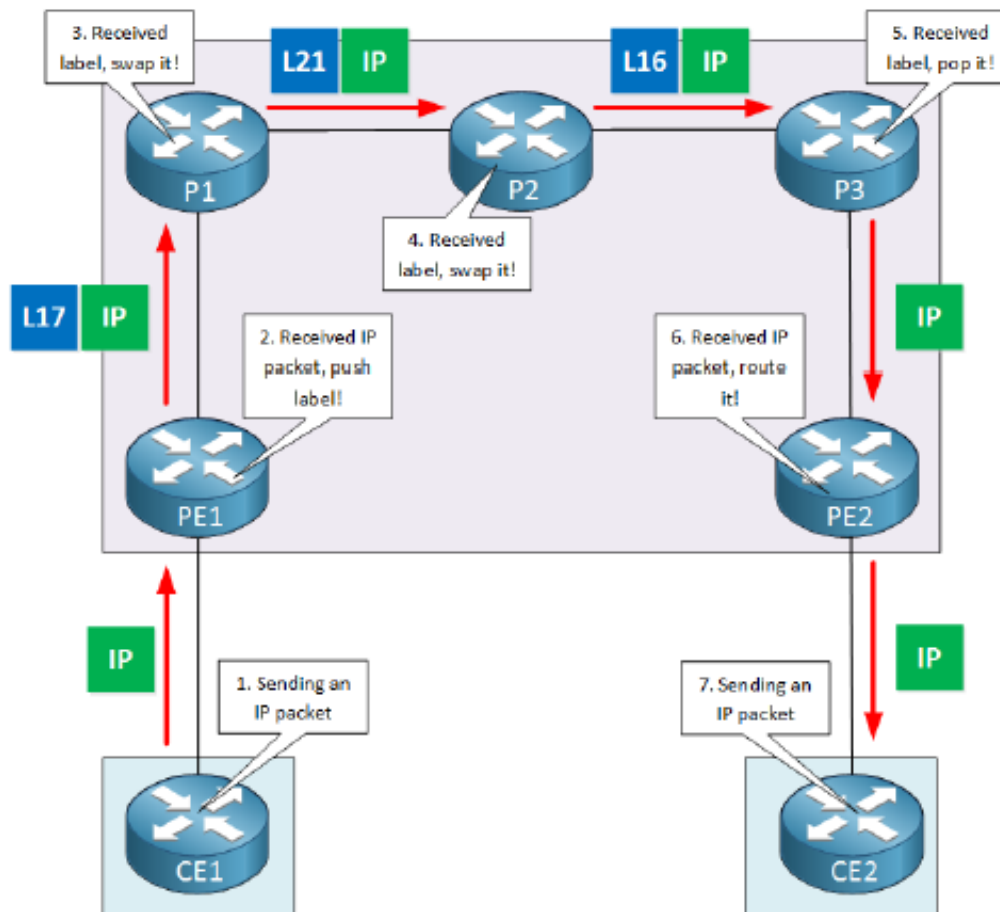
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Let's look at an example of how labels are pushed, swapped and popped in a MPLS network:



1. The CE1 router is owned by the customer and connected to the ISP's PE1 router. This device doesn't have a clue what MPLS is and sends an IP packet that should end up at CE2 (another site of the customer).
2. The PE1 router receives the IP packet from the CE1 router, it will push a label on it and forwards it further into the core of the ISP network.
3. P1 receives the labeled packet from PE1, swaps the label and forwards it to P2. Labels are only locally significant.
4. P2 receives the labeled packet from P1, swaps the label and forwards it to P3.

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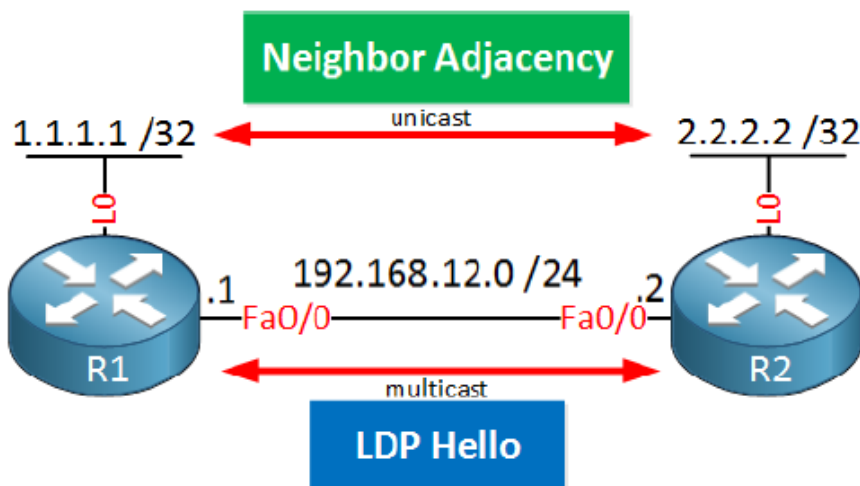
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5. P3 receives the labeled packet and will pop the label, forwarding the IP packet to PE2. This is called penultimate hop popping (PHP) and is performed to save PE2 the trouble of looking at the MPLS label.
6. PE2 receives the IP packet and forwards it to the CE2 router.
7. The CE2 router receives the IP packets.

### MPLS LDP (Label Distribution Protocol):

- **MPLS do not forward based on the label automatically.** We need to share the label information using LDP.
- **LDP is a protocol that automatically generates and exchanges labels between routers.** Each router will locally generate labels for its prefixes and will then advertise the label values to its neighbors.
- It's a standard, based on Cisco's proprietary **TDP (Tag Distribution Protocol)**. It's pretty much the same story as 802.1Q/ISL or PaGP/LACP. Cisco created a protocol and a standard was created later. Nowadays almost **everyone uses LDP instead of TDP.**
- **Like many other protocols, LDP first establishes a neighbor adjacency before it exchanges label information.** It works a bit different than most protocols though.
- **First, we send UDP multicast hello packets to discover other neighbors. Once two routers decide to become neighbors, they build the neighbor adjacency using a TCP connection. This connection is then used for the exchange of label information. Normally a loopback interface is used for the neighbor adjacency.**



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## Configuration MPLS:

### Pre requirements:

#### 1. CEF Enable #sh ip cef

By default CISCO new models routers it is enables.

To Enable CEF:

```
R1(Config)#ip cef
```

#### 2. IGP Routing

```
R1(Config)# mpls label protocol ldp! option by default this is enable.
```

```
R1(Config)# mpls ldp router-id loopback 0 ! This is also optional.
```

```
R1(Config)# int f0/0
```

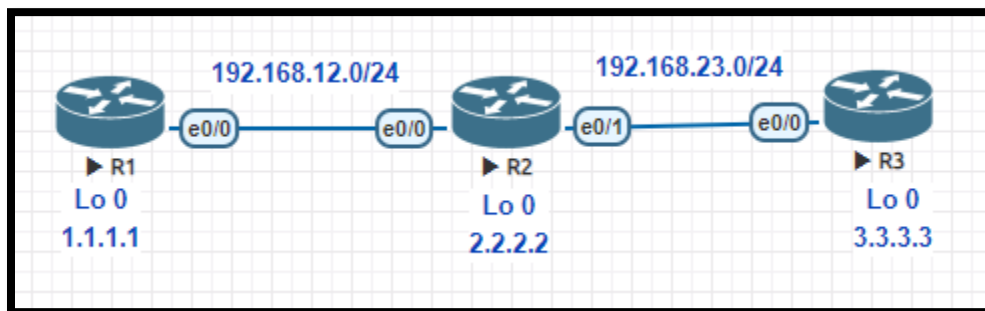
```
R1(Config-if)# mpls ip
```

```
R1(Config)# end
```

```
#sh mpls ldp neighbor
```

```
#sh mpls interfaces
```

Lab time:



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R1 Configuration:	R2 Configuration:
<pre>en config t hostname R1  int e0/0 mpls ip ip add 192.168.12.1 255.255.255.0 no sh  int lo 0 ip add 1.1.1.1 255.255.255.255  router ospf 1 router-id 1.1.1.1 int lo 0 ip ospf 1 area 0 int e0/0 ip ospf 1 area 0</pre>	<pre>en config t hostname R2  int e0/0 mpls ip ip add 192.168.12.2 255.255.255.0 no sh  int e0/1 mpls ip ip add 192.168.23.2 255.255.255.0 no sh  int lo 0 ip add 2.2.2.2 255.255.255.255  router ospf 1 router-id 2.2.2.2 int e0/1 ip ospf 1 area 0 int e0/0 ip ospf 1 area 0 int lo 0 ip ospf 1 area 0</pre>
R3 Configuration:	Sh Comments:
<pre>en config t hostname R3  int e0/0 mpls ip ip add 192.168.23.3 255.255.255.0 no sh  int lo 0 ip add 3.3.3.3 255.255.255.255</pre>	<pre>show mpls interfaces show mpls ldp neighbor show mpls ldp bindings show mpls forwarding-table show ip route</pre>

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```
router ospf 1
router-id 3.3.3.3
int lo 0
ip ospf 1 area 0
int e0/0
ip ospf 1 area 0
```

**First let's check if LDP is enabled on the interface:**

**For R1:**

```
R1#show mpls interfaces
Interface          IP          Tunnel  BGP  Static  Operational
Ethernet0/0        Yes (l dp)  No      No   No      Yes
```

**For R2:**

```
R2#sh mpls interfaces
Interface          IP          Tunnel  BGP  Static  Operational
Ethernet0/0        Yes (l dp)  No      No   No      Yes
Ethernet0/1        Yes (l dp)  No      No   No      Yes
```

**For R3:**

```
R3#sh mpls interfaces
Interface          IP          Tunnel  BGP  Static  Operational
Ethernet0/0        Yes (l dp)  No      No   No      Yes
```

The **show mpls interfaces** command is a quick way to see if LDP is enabled or not. It tells us what interfaces are enabled and if they are operational or not.

The next thing to check is if we have LDP neighbors or not:

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```
R2#show mpls ldp neighbor
Peer LDP Ident: 1.1.1.1:0; Local LDP Ident 2.2.2.2:0
TCP connection: 1.1.1.1.646 - 2.2.2.2.25405
State: Oper; Msgs sent/rcvd: 15/15; Downstream
Up time: 00:06:41
LDP discovery sources:
  Ethernet0/0, Src IP addr: 192.168.12.1
Addresses bound to peer LDP Ident:
  192.168.12.1 1.1.1.1
Peer LDP Ident: 3.3.3.3:0; Local LDP Ident 2.2.2.2:0
TCP connection: 3.3.3.3.42395 - 2.2.2.2.646
State: Oper; Msgs sent/rcvd: 15/15; Downstream
Up time: 00:06:24
LDP discovery sources:
  Ethernet0/1, Src IP addr: 192.168.23.3
Addresses bound to peer LDP Ident:
  192.168.23.3 3.3.3.3
```

**Above you see the output of R2. Here's what you see:**

R2 and R3 have become neighbors:

R2 uses 2.2.2.2 as its LSR ID, R3 uses 3.3.3.3 as the LSR ID.

R2 and R3 have formed a TCP connection using 2.2.2.2 and 3.3.3.3 as the transport addresses.

Discovery (hello packets) was done using the Ethernet0/0 interface.

R1 and R2 have become neighbors:

R2 uses 2.2.2.2 as its LSR ID, R1 uses 1.1.1.1 as the LSR ID.

R1 and R2 have formed a TCP connection using 2.2.2.2 and 1.1.1.1 as the transport addresses.

Discovery (hello packets) was done using the FastEthernet0/1 interface.

Now we have confirmed that we have LDP neighbors, let's look at the labels.

### LDP Control Plane:

- When we use LDP, all routers will start assigning labels with label value 16.
- This might be a bit annoying if you are new to MPLS as some routers will use the same label value.
- To make it easier to read the different tables we will configure each router to use different label values.

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Here's how to do this:

```
R1(config)#mpls label range 100 199
R2(config)#mpls label range 200 299
R3(config)#mpls label range 300 399
```

When you use this command, you will have to **reload the routers**, clearing the neighbor adjacency is not enough.

```
R1#show mpls ldp bindings
lib entry: 1.1.1.1/32, rev 2
  local binding: label: imp-null
  remote binding: lsr: 2.2.2.2:0, label: 200
lib entry: 2.2.2.2/32, rev 6
  local binding: label: 100
  remote binding: lsr: 2.2.2.2:0, label: imp-null
lib entry: 3.3.3.3/32, rev 10
  local binding: label: 102
  remote binding: lsr: 2.2.2.2:0, label: 201
lib entry: 192.168.12.0/24, rev 4
  local binding: label: imp-null
  remote binding: lsr: 2.2.2.2:0, label: imp-null
lib entry: 192.168.23.0/24, rev 8
  local binding: label: 101
  remote binding: lsr: 2.2.2.2:0, label: imp-null
```

Above you can see the LIB of R1. Let's see some of the things here:

- The first entry is for 1.1.1.1/32, the loopback interface of R1. This router doesn't generate a label value for this entry since it's directly connected.
- You can see however that R2 has advertised to R1 that it uses label value 200 for this prefix.
- The second entry is for 2.2.2.2/32. R1 has chosen label value 100 for this entry, we can also see that R2 doesn't use a label for this prefix. Since it's directly connected for R2.
- The third entry for 3.3.3.3/32 has a local label value of 102. R2 is using label value 201 for this entry.
- The fourth entry is 192.168.12.0/24. We don't use a label for this entry since it's directly connected. R2 also doesn't use a label value since it's directly connected there as well.
- The fifth entry is for 192.168.23.0/24, R1 uses label value 101 for this one.

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Now let's take a look at the LFIB, that's what we will actually use when we forward MPLS packets

```
R1#show mpls forwarding-table
Local   Outgoing   Prefix      Bytes Label  Outgoing   Next Hop
Label   Label      or Tunnel Id  Switched     interface
100     Pop Label  2.2.2.2/32   0            Et0/0      192.168.12.2
101     Pop Label  192.168.23.0/24 0            Et0/0      192.168.12.2
102     Pop Label  3.3.3.3/32   0            Et0/0      192.168.12.2
```

The LFIB is much smaller, this is similar to the CEF table that we use for IP forwarding. There is no entry for 1.1.1.1 /32 or 192.168.12.0/24 here since we don't have a label for these prefixes. When we want to reach 3.3.3.3 /32 then we will add label value 201 to the MPLS header before

we send it to R2.

When R1 receives something for 2.2.2.2/32 or 192.168.23.0/24 then we will "pop the label" before we forward it to R2. This is called penultimate hop popping. it's done to save R2 some time by already removing the MPLS header.

Let see the RIB, LIB and LFIB of R2 and R3:

```
R2#show ip route
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
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is not set

  1.0.0.0/32 is subnetted, 1 subnets
O       1.1.1.1 [110/11] via 192.168.12.1, 00:37:07, Ethernet0/0
  2.0.0.0/32 is subnetted, 1 subnets
C       2.2.2.2 is directly connected, Loopback0
  3.0.0.0/32 is subnetted, 1 subnets
O       3.3.3.3 [110/11] via 192.168.23.3, 00:36:57, Ethernet0/1
 192.168.12.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.12.0/24 is directly connected, Ethernet0/0
L       192.168.12.2/32 is directly connected, Ethernet0/0
 192.168.23.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.23.0/24 is directly connected, Ethernet0/1
L       192.168.23.2/32 is directly connected, Ethernet0/1
```

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```
R2#show mpls ldp bindings
lib entry: 1.1.1.1/32, rev 8
  local binding: label: 200
  remote binding: lsr: 1.1.1.1:0, label: imp-null
  remote binding: lsr: 3.3.3.3:0, label: 301
lib entry: 2.2.2.2/32, rev 2
  local binding: label: imp-null
  remote binding: lsr: 1.1.1.1:0, label: 100
  remote binding: lsr: 3.3.3.3:0, label: 300
lib entry: 3.3.3.3/32, rev 10
  local binding: label: 201
  remote binding: lsr: 1.1.1.1:0, label: 102
  remote binding: lsr: 3.3.3.3:0, label: imp-null
lib entry: 192.168.12.0/24, rev 4
  local binding: label: imp-null
  remote binding: lsr: 1.1.1.1:0, label: imp-null
  remote binding: lsr: 3.3.3.3:0, label: 302
lib entry: 192.168.23.0/24, rev 6
  local binding: label: imp-null
  remote binding: lsr: 1.1.1.1:0, label: 101
  remote binding: lsr: 3.3.3.3:0, label: imp-null
```

```
R2#show mpls forwarding-table
Local   Outgoing Prefix      Bytes Label  Outgoing  Next Hop
Label   Label    or Tunnel Id  Switched     interface
200     Pop Label 1.1.1.1/32    0            Et0/0     192.168.12.1
201     Pop Label 3.3.3.3/32    0            Et0/1     192.168.23.3
```

```
R3#show ip route
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
       a - application route
       + - replicated route, % - next hop override

Gateway of last resort is not set

1.0.0.0/32 is subnetted, 1 subnets
O       1.1.1.1 [110/21] via 192.168.23.2, 00:40:04, Ethernet0/0
2.0.0.0/32 is subnetted, 1 subnets
O       2.2.2.2 [110/11] via 192.168.23.2, 00:40:04, Ethernet0/0
3.0.0.0/32 is subnetted, 1 subnets
C       3.3.3.3 is directly connected, Loopback0
O       192.168.12.0/24 [110/20] via 192.168.23.2, 00:40:04, Ethernet0/0
C       192.168.23.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.23.0/24 is directly connected, Ethernet0/0
L       192.168.23.3/32 is directly connected, Ethernet0/0
```

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```
R3#show mpls ldp bindings
lib entry: 1.1.1.1/32, rev 8
  local binding: label: 301
  remote binding: lsr: 2.2.2.2:0, label: 200
lib entry: 2.2.2.2/32, rev 6
  local binding: label: 300
  remote binding: lsr: 2.2.2.2:0, label: imp-null
lib entry: 3.3.3.3/32, rev 2
  local binding: label: imp-null
  remote binding: lsr: 2.2.2.2:0, label: 201
lib entry: 192.168.12.0/24, rev 10
  local binding: label: 302
  remote binding: lsr: 2.2.2.2:0, label: imp-null
lib entry: 192.168.23.0/24, rev 4
  local binding: label: imp-null
  remote binding: lsr: 2.2.2.2:0, label: imp-null
R3#
```

```
R3#show mpls forwarding-table
Local   Outgoing   Prefix          Bytes Label   Outgoing   Next Hop
Label   Label      or Tunnel Id   Switched      interface
300     Pop Label  2.2.2.2/32     0             Et0/0       192.168.23.2
301     200        1.1.1.1/32     0             Et0/0       192.168.23.2
302     Pop Label  192.168.12.0/24 0             Et0/0       192.168.23.2
R3#
```

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## MPLS L3 VPNs:

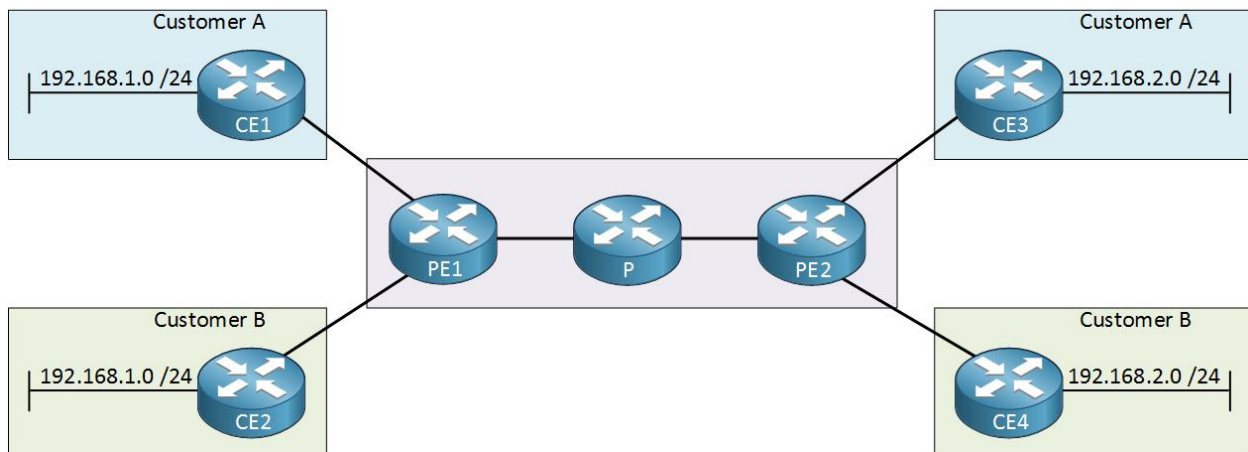
### Layer 3:

- The service provider will participate in routing with the customer.
- The customer will run OSPF, EIGRP, BGP or any other routing protocol with the service provider, these routes can be shared with other sites of the customer.

### VPN:

- Routing information from one customer is completely separated from other customers and tunneled over the service provider MPLS network.

Let discuss this.



- Above we have two customers connected to a service provider network.
- Customer A and B each have two sites and you can see that they are using the same IP ranges.
- Customer A might use OSPF between their sites and customer B could use EIGRP between their sites.
- Everything from these customers is completely separated by the service provider.

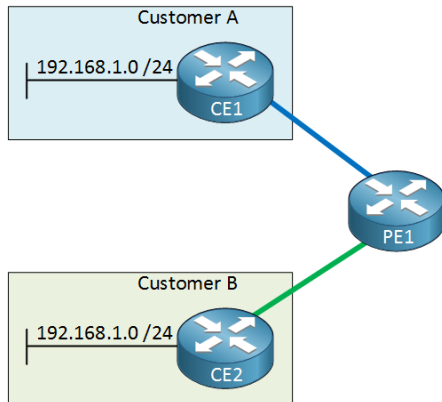
## VRF (Virtual Routing and Forwarding):

- Let's start with VRFs. This is the first step in separating traffic from different customers.
- Instead of using a single global routing table, we use multiple routing tables.
- Each customer of the service provider will use a different VRF.

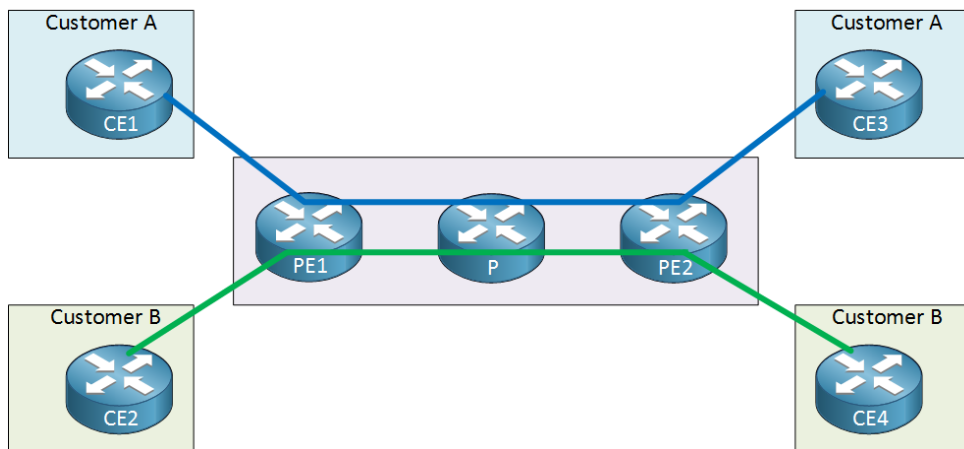
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- Above we have our PE1 router with the two customer sites.
- Each customer will use a different VRF so the overlapping address space is no problem.
- Now you might be wondering, why don't we use VRFs everywhere instead of MPLS? We could but there's one downside to using VRFs. Take a look at the below diagram:



- The problem with VRFs is that you have to create them everywhere.
- When our main aim is to have connectivity between CE1 and CE3 then we will have to add a VRF on the PE1, P and PE2 router.

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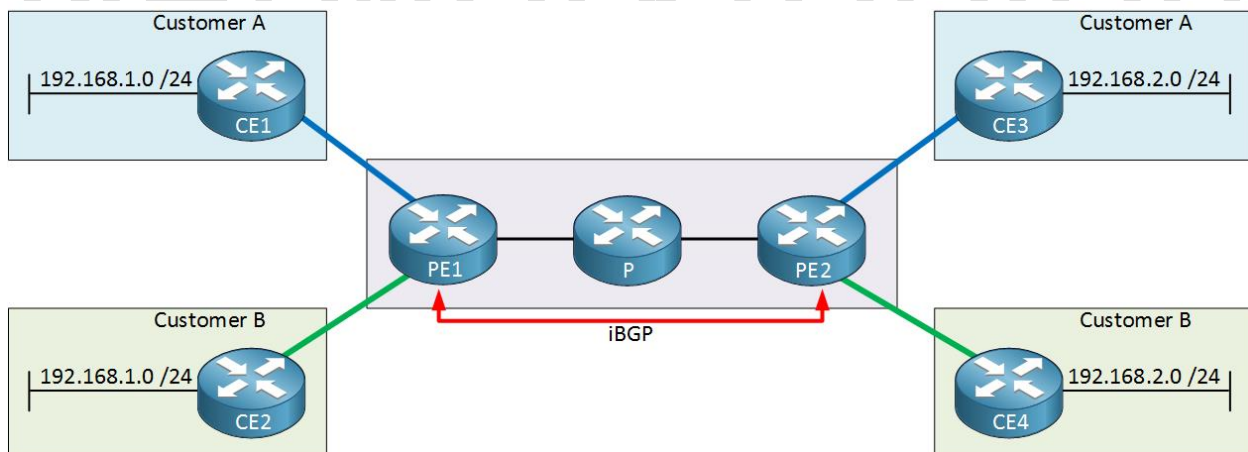
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- Also, all the service provider routes will have to participate with routing. For example, when customer A wants to run OSPF between their two sites then it means that we have to configure OSPF on the PE1, P and PE2 router of the service provider for their VRF.
- When customer B wants to run EIGRP between their sites, we have to participate. We'll have to configure EIGRP on all service provider routers for the VRF of customer B.
- This is not a scalable solution so it's not going to happen. Instead, we will configure the VRFs only on the PE routers.
- The core of the service provider network (P router) will only do switching based on labels. To share information about VRFs between PE routers, we will use BGP.

### MP-BGP (Multi-Protocol BGP):

- We will use BGP between the PE routers so that they can share information from the VRFs.
- One of the CE routers advertises something to the PE router, this can be done through OSPF, EIGRP, BGP or any other routing protocol
- The PE router uses a VRF for the customer so it will store everything it learns in the routing table of the customer's VRF.
- The PE router will then redistribute everything in BGP.
- The PE router will advertise to the other PE router through iBGP.

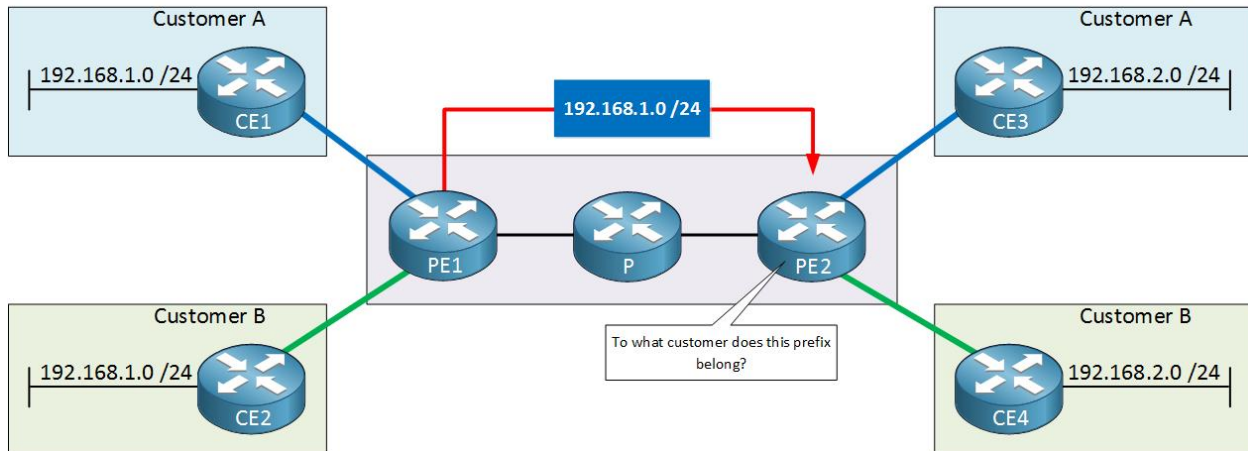


There's a couple of problems though. First of all, our two customers are using overlapping address space. Let's say that our PE1 router is advertising 192.168.1.0 /24 from customer A to the PE2 router on the other side. Here's what happens:

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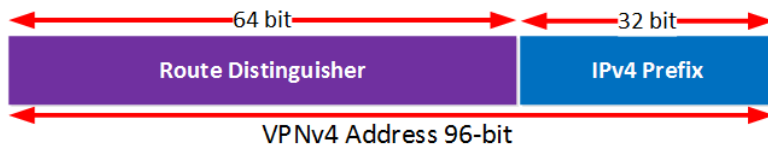
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- The PE2 router will learn 192.168.1.0 /24 from the PE1 router but it has no clue to what customer it will belong. There is no way to differentiate if something belongs to customer A or B.
- What we need is something to make all prefixes that we learn unique.

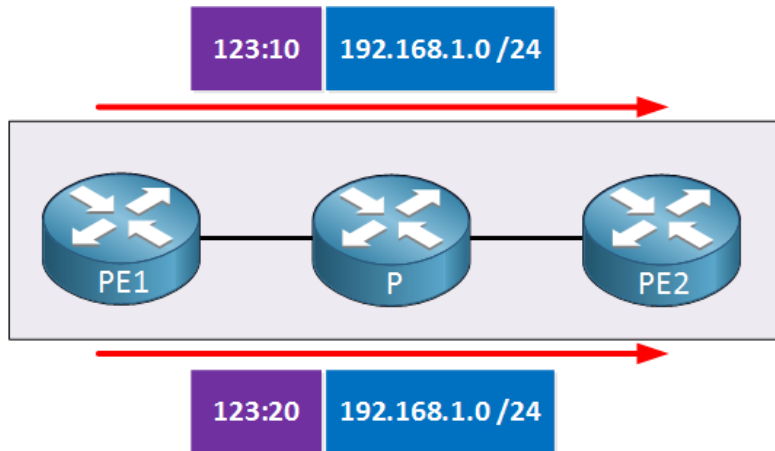
### RD (Route Distinguisher):

To fix this issue, we will use a RD (Route Distinguisher). We will add something to the prefix of the customer so that it will become unique:



- The RD is an 8-byte (64 bit) field. You can use any value you want but typically we use the ASN:NN format where ASN is the service provider's AS number and NN is a number we pick that identifies the site of the customer.
- The RD and the prefix combined is what we call a **VPNv4 route**. We now have a method to differentiate between the different prefixes of our customers.
- The below diagram show that as example.

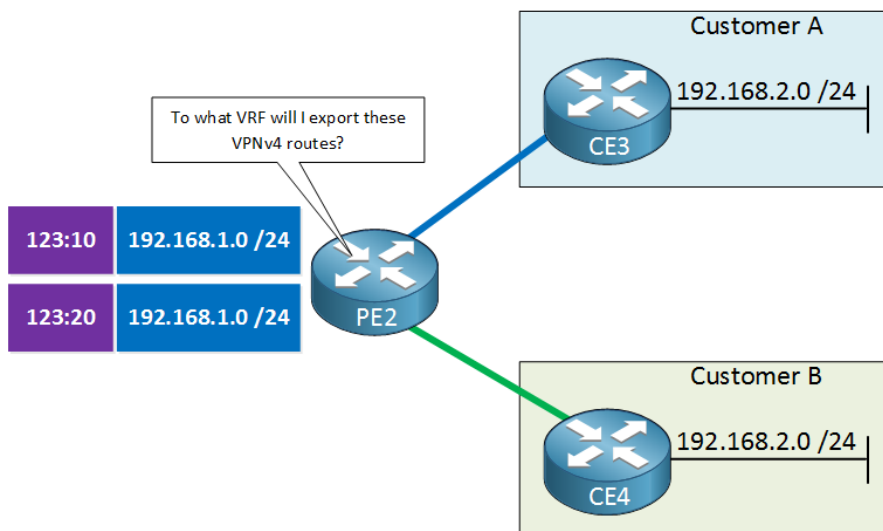
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- Let's say that we use RD 123:10 for customer A and RD 123:20 for customer B.
- By adding these values, we have unique VPNv4 routes.
- How do we advertise these VPNv4 routes? That's what we need MP-BGP for.
- MP-BGP supports IPv4 unicast/multicast, IPv6 unicast/multicast and it has support for VPNv4 routes.

RT (Route Target)

When a PE router learns these VPNv4 routes, what will it do with it? Take a look at the diagram below:



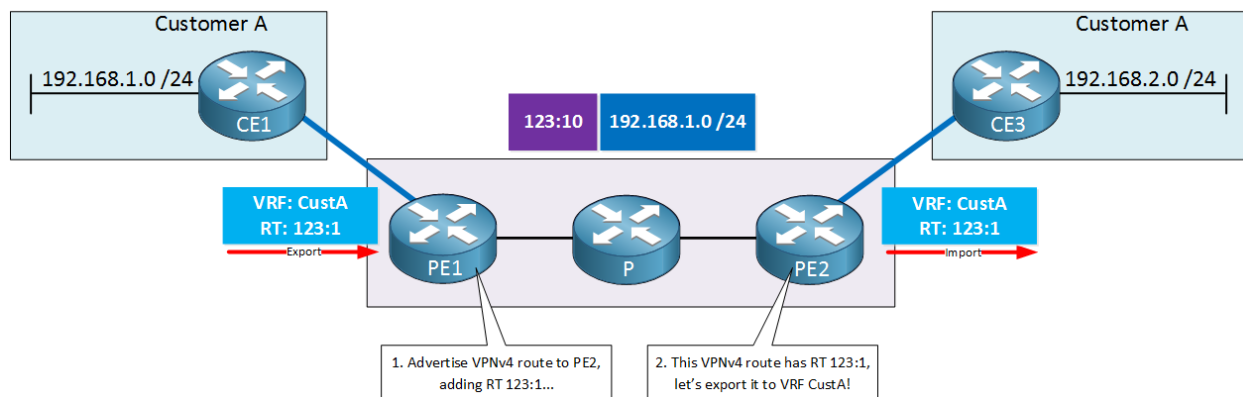
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- Our PE2 router has learned the two VPNv4 routes, one for each customer. You might think that the PE2 router will automatically export each VPNv4 route in the correct customer VRF but that's not going to happen.
- We use something called a RT (Route Target) to decide in which VRF we import and export VPNv4 routes.
- The RT is a 8 byte value that uses the same format as the RD (ASN:NN). It's advertised between PE routers by using a BGP extended community value.
- For each VRF that we configure, we tell it what RTs we want to import and export.



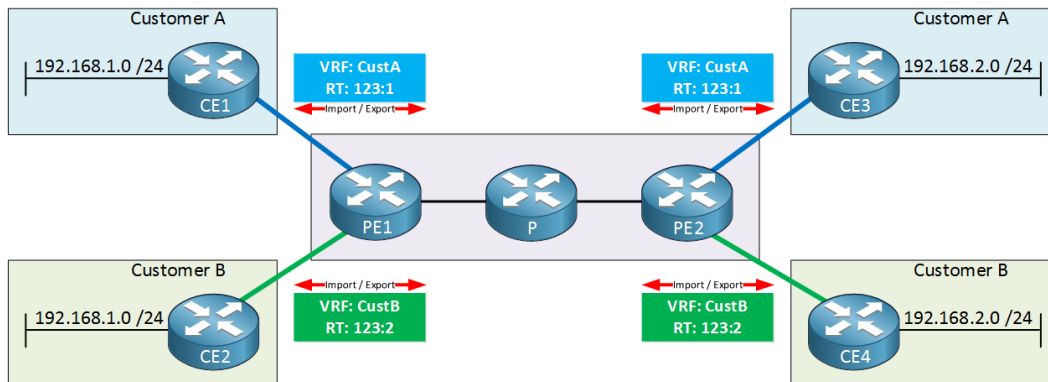
Let me explain the above diagram:

- Both PE routers are configured to use a VRF called "CustA" for customer A.
- When PE1 receives a prefix from CE1, it will add RD 123:10 to it to create a unique VPNv4 route.
- PE1 is configured to add RT 123:1 to all VPNv4 routes for VRF CustA.
- PE1 will advertise the VPNv4 route to PE2.
- PE2 is configured to export all VPNv4 routes that use RT 123:1 into VRF CustA.
- When PE2 receives the VPNv4 route, it will redistribute it into the VRF so that CE3 will learn the prefix.
- The end result will be that CE3 will learn prefix 192.168.1.0 /24 that was advertised by CE1.

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- In the picture above you can see that the PE routers are importing and exporting everything from customer A with RT value 123:1.
- This allows CE1 and CE3 to learn everything from each other. We do the same thing for customer B but we use RT 123:2 for VRF CustB. CE2 and CE4 will be able to learn everything from each other.

### Steps to configure MPLS L3 VPN:

1. Configure IGP inside SP Core.
2. Configure MPLS LDP inside the SP core.
3. Create VRF A, RD & Route Target.
4. Configure VPNV4 peering between both the PE Routers.
5. Configure Routing between PE and CE (Static/default, RIPV2, OSPF, EIGRP, BGP, ISIS).
6. Configure Redistribution on PE routers.

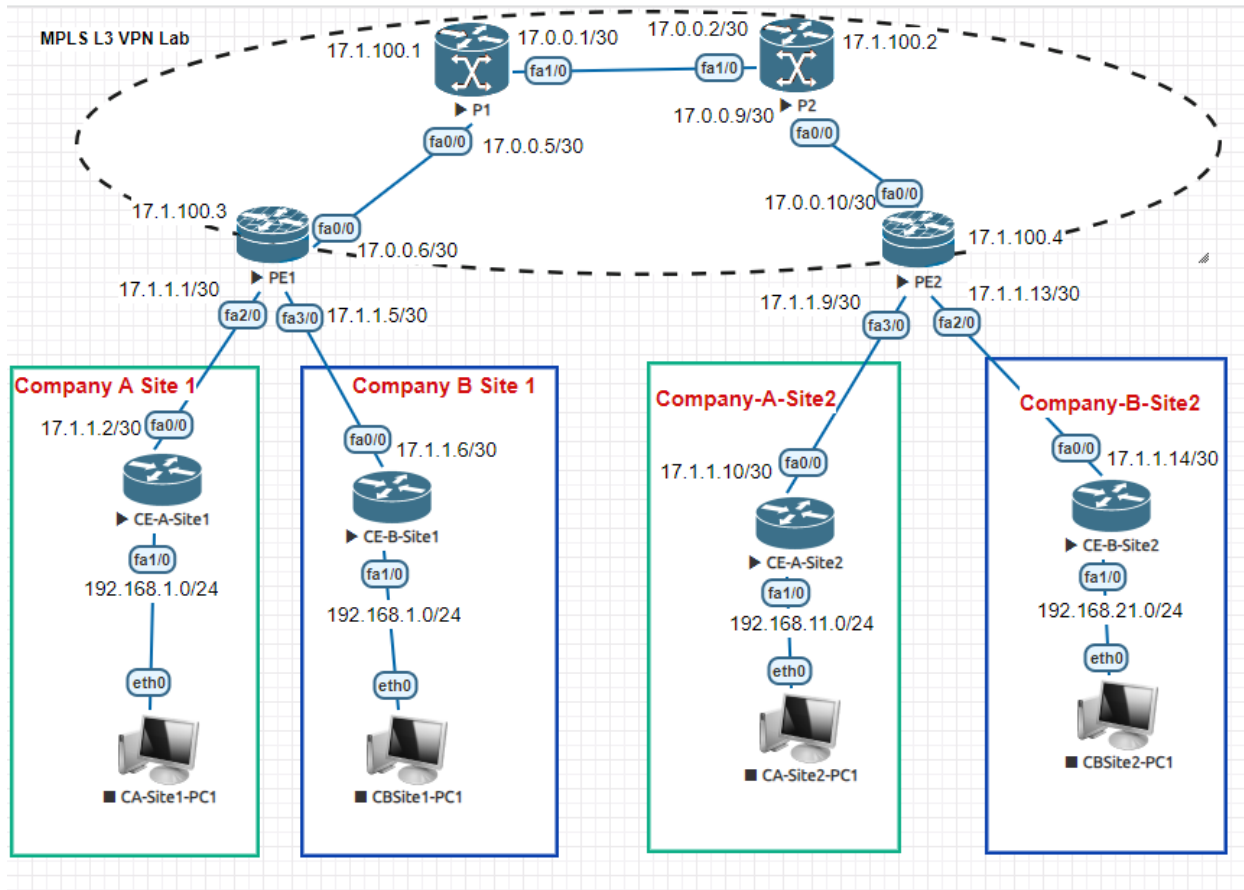
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Lab time:



### P1 Configuration:

```
en
config t
hostname P1
int f1/0
ip add 17.0.0.1 255.255.255.252
no sh
ip ospf 1 area 0
mpls ip

int f0/0
ip add 17.0.0.5 255.255.255.252
no sh
```

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```
ip ospf 1 area 0
mpls ip

int lo 0
ip add 17.1.100.1 255.255.255.255
ip ospf 1 area 0
router ospf 1

mpls ldp router-id lo 0
```

### PE2 Configuration:

```
en
config t
hostname P2
int f1/0
mpls ip
ip add 17.0.0.2 255.255.255.252
no sh
ip ospf 1 area 0
mpls ip

int f0/0
ip add 17.0.0.9 255.255.255.252
no sh
ip ospf 1 area 0
mpls ip

int lo 0
ip add 17.1.100.2 255.255.255.255
ip ospf 1 area 0
router ospf 1

mpls ldp router-id lo 0
```

### PE1 Configuration:

```
en
config t
hostname PE1
int f0/0
ip add 17.0.0.6 255.255.255.252
no sh
ip ospf 1 area 0
mpls ip
```

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```
int f2/0
ip add 17.1.1.1 255.255.255.252
no sh

int f3/0
ip add 17.1.1.5 255.255.255.252
no sh

int lo 0
ip add 17.1.100.3 255.255.255.255
ip ospf 1 area 0
router ospf 1
mpls ldp router-id lo 0

!Make VRF:

ip vrf customer_A
rd 65000:1
route-target both 65000:1
ip vrf customer_B
rd 65000:2
route-target both 65000:2

int f2/0
ip vrf forwarding customer_A
ip add 17.1.1.1 255.255.255.252
no sh

int f3/0
ip vrf forwarding customer_B
ip add 17.1.1.5 255.255.255.252
no sh

router bgp 65000
neighbor 17.1.100.4 remote-as 65000
neighbor 17.1.100.4 update-source loopback 0
address-family vpnv4
neighbor 17.1.100.4 activate

router ospf 2 vrf customer_A
```

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```
int f2/0
ip ospf 2 area 0

router ospf 3 vrf customer_B
int f3/0
ip ospf 3 area 0

router bgp 65000
address-family ipv4 vrf customer_A
redistribute ospf 2

address-family ipv4 vrf customer_B
redistribute ospf 3

router ospf 2
redistribute bgp 65000 subnet

router ospf 3
redistribute bgp 65000 subnet
```

### PE2 Configuration:

```
en
config t
hostname PE2
int f0/0
ip add 17.0.0.10 255.255.255.252
no sh
ip ospf 1 area 0
mpls ip
int f2/0
ip add 17.1.1.13 255.255.255.252
no sh

int f3/0
ip add 17.1.1.9 255.255.255.252
no sh

int lo 0
ip add 17.1.100.4 255.255.255.255
ip ospf 1 area 0
```

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```
router ospf 1
mpls ldp router-id lo 0

!Make VRF:

ip vrf customer_A
rd 65000:1
route-target both 65000:1

ip vrf customer_B
rd 65000:2
route-target both 65000:2
int f3/0
ip vrf forwarding customer_A
ip add 17.1.1.9 255.255.255.252
no sh

int f2/0
ip vrf forwarding customer_B
ip add 17.1.1.13 255.255.255.252

router bgp 65000
neighbor 17.1.100.3 remote-as 65000
neighbor 17.1.100.3 update-source loopback 0
address-family vpnv4
neighbor 17.1.100.3 activate

router ospf 2 vrf customer_A
int f3/0
ip ospf 2 area 0

router ospf 3 vrf customer_B
int f2/0
ip ospf 3 area 0

router bgp 65000
address-family ipv4 vrf customer_A
redistribute ospf 2

address-family ipv4 vrf customer_B
```

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```
redistribute ospf 3

router ospf 2
redistribute bgp 65000 subnet

router ospf 3
redistribute bgp 65000 subnet
```

#### CE-A-Site1 Configuration:

```
en
config t
hostname CE-A-Site1
int f0/0
ip add 17.1.1.2 255.255.255.252
no sh
ip ospf 2 area 0

int f1/0
ip add 192.168.1.1 255.255.255.0
no sh
ip ospf 2 area 0
router ospf 2
```

#### CE-A-Site2 Configuration:

```
en
config t
hostname CE-A-Site2
int f0/0
ip add 17.1.1.10 255.255.255.252
no sh
ip ospf 2 area 0

int f1/0
ip add 192.168.11.1 255.255.255.0
no sh
ip ospf 2 area 0
router ospf 2
```

#### CE-B-Site1 Configuration:

```
en
config t
hostname CE-B-Site1
```

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```
int f0/0
ip add 17.1.1.6 255.255.255.252
no sh
ip ospf 3 area 0
```

```
int f1/0
ip add 192.168.1.1 255.255.255.0
no sh
ip ospf 3 area 0
router ospf 3
```

### CE-B-Site2 Configuration:

```
en
config t
hostname CE-B-Site2
int f0/0
ip add 17.1.1.14 255.255.255.252
no sh
ip ospf 3 area 0

int f1/0
ip add 192.168.21.1 255.255.255.0
no sh
ip ospf 3 area 0
router ospf 3
```