Cisco Live!
July 10-14, 2016 • Las Vegas, NV
Your Time Is Now
The CCIE Candidate’s Introduction to MPLS L3VPN Networks

Keith Barker, Scott Morris
BRKCCIE-3345
Agenda

- MPLS IP Unicast Forwarding
- VRFs
- MPLS L3 VPNs
Tour Guide

- Keith Barker, CCIE #6783, CISSP
  - CCIE Route/Switch and Security
  - VMware, HP, Juniper, Palo Alto, Check Point
  - Twitter: @KeithBarkerCCIE
  - YouTube & Facebook: Keith Barker Networking
Tour Guide

• Scott Morris, CCIEx4 #4713, CCDE #2009::13, JNCIEx2
  • CCIE Route & Switch, ISP/Dial, Security, Service Provider
  • Cisco Certified Design Expert
  • Juniper Networks JNCIE-SP #153 and JNCIE-ENT #102
  • CISSP, CCNP-V, CCNP-DC and several other random things!
  • Twitting: @ScottMorrisCCIE
Journey

- MPLS IP Unicast Forwarding
- VRFs
- MPLS L3 VPNs
End Goal: Routes and Transit for each customer.
Ingredients in the MPLS L3VPN Recipe

- IGPs
- MPLS
- VRFs
- iBGP
- MP-BGP
- Routers and Administrators that know how the game is played
MPLS Building Blocks
MPLS Vocabulary

- **P** Provider router (not-customer facing)
- **PE** Provider-Edge router (customer facing)
- **CE** Customer-Edge router (customers router, connect to provider)
- **MPLS** Multi Protocol Label Switching (forwarding method, based on labels)
- **LSR** Label Switching Router (router that can forward based on labels)
- **Label** 32 bit header (with a 20 bit label #) added at layer 2.5
- **LDP** Label Distribution Protocol (like an IGP for label advertisements)
- **LFIB** Label Forwarding Information Base (like CEF for labels)
Let's apply the vocabulary to our topology
Let's apply the vocabulary to our topology.
Labels

Labels in MPLS are OK!
MPLS Header

- MPLS (Layer 2.5) Header Fields:
  - Label, 20 bits
  - Experimental (CoS), 3 bits
  - Stacking bit, 1 bit. This is the bottom-of-stack bit. 1=on=last label.
  - Time to live, 8 bits
Where Does the Label Go?

- **MPLS Header**
  - Inserted between L2 and L3
  - L2 protocol identifier (PID) indicates an MPLS label is present
    - Unlabeled IP unicast PID = 0x 0800
    - Labeled IP unicast PID = 0x 8847

---

```
Frame 2: 118 bytes on wire (944 bits), 118 bytes captured (944 bits)
  Type: MPLS label switched packet (0x8847)
MultiProtocol Label Switching Header, Label: 302, Exp: 0, S: 1, TTL: 254
  MPLS Label: 302
  MPLS Experimental Bits: 0
  MPLS Bottom Of Label Stack: 1
  MPLS TTL: 254
Internet Protocol Version 4, Src: 1.1.1.1 (1.1.1.1), Dst: 4.4.4.4 (4.4.4.4)
Internet Control Message Protocol
```
Stacks of MPLS Labels

Frame 4: 122 bytes on wire (976 bits), 122 bytes captured (976 bits)


MultiProtocol Label Switching Header, Label: 202, Exp: 0, S: 0, TTL: 254

MPLS Label: 202
MPLS Experimental Bits: 0
MPLS Bottom Of Label Stack: 0
MPLS TTL: 254

MultiProtocol Label Switching Header, Label: 406, Exp: 0, S: 1, TTL: 254

MPLS Label: 406
MPLS Experimental Bits: 0
MPLS Bottom Of Label Stack: 1
MPLS TTL: 254

Internet Protocol Version 4, Src: 172.16.0.2 (172.16.0.2), Dst: 172.16.129.2

Internet Control Message Protocol
Commonly asked questions regarding MPLS labels

• Where do the labels come from?
  • As routes appear in the routing table, each router assigns a locally significant label for each IP route.

• How are they advertised?
  • Routers advertise their local label to neighbors, using Label Distribution Protocol (LDP). It’s like an IGP for labels.
Generating local labels

- IPv4 Network 4.4.4.4 /32 (connected to R4) will be the subject for these labels
Discover the local bindings for 4.4.4.4

R4-PE#show mpls ldp bindings 4.4.4.4 32
lib entry: 4.4.4.4/32, rev 4
    local binding: label: imp-null
    remote binding: lsr: 3.3.3.3:0, label: 302

R3#show mpls ldp bindings 4.4.4.4 32
lib entry: 4.4.4.4/32, rev 12
    local binding: label: 302
    remote binding: lsr: 2.2.2.2:0, label: 202
    remote binding: lsr: 4.4.4.4:0, label: imp-null

R2#show mpls ldp bindings 4.4.4.4 32
lib entry: 4.4.4.4/32, rev 12
    local binding: label: 202
    remote binding: lsr: 1.1.1.1:0, label: 100
    remote binding: lsr: 3.3.3.3:0, label: 302

R1-PE#show mpls ldp bindings 4.4.4.4 32
lib entry: 4.4.4.4/32, rev 6
    local binding: label: 100
    remote binding: lsr: 2.2.2.2:0, label: 202
Advertising our labels

- Each router advertises its local label (for net 4.4.4.4) to its LDP neighbors
Implicit Null Advertisement

- Label Mapping Message
  0... .... = U bit: Unknown bit not set
  Message Type: Label Mapping Message (0x400)
  Message Length: 24
  Message ID: 0x000000eb

- Forwarding Equivalence Classes TLV
  00... .... = TLV Unknown bits: Known TLV, do not Forward (0x00)
  TLV Type: Forwarding Equivalence Classes TLV (0x100)
  TLV Length: 8

- FEC Elements
  - FEC Element 1
    FEC Element Type: Prefix FEC (2)
    FEC Element Address Type: IPv4 (1)
    FEC Element Length: 32
    Prefix: 4.4.4.4

- Generic Label TLV
  00... .... = TLV Unknown bits: Known TLV, do not Forward (0x00)
  TLV Type: Generic Label TLV (0x200)
  TLV Length: 4
  Generic Label: 3

R4 advertising "Implicit Null" (label 3) regarding network 4.4.4.4
R3 advertises its label of 302 to R2 and R4

- Each router advertises its local label (for net 4.4.4.4) to its LDP neighbors
R2 advertises its label of 202 to R1 and R3

- Each router advertises its local label (for net 4.4.4.4) to its LDP neighbors
How R2 chooses between label 100 (from R1) and 302 (from R3) for forwarding

- (in reference to network 4.4.4.4/32)

```
R2#show mpls ldp bindings 4.4.4.4 32
lib entry: 4.4.4.4/32, rev 12
  local binding: label: 202
    remote binding: lsr: 1.1.1.1:0, label: 100
    remote binding: lsr: 3.3.3.3:0, label: 302

R2#
R2#show mpls forwarding-table 4.4.4.4
Local Label or VC Label or VC
Outgoing Prefix or Tunnel Id
202 302 Winner 4.4.4.4/32
```

```
  Bytes Label
  Switched 3425
  Outgoing interface
  Gi1/0
  Next Hop
  10.23.0.3
```
Why R2 chooses to use the label from R3

• (regarding network 4.4.4.4/32)

R2#show ip route | inc 4.4.4.4
O 4.4.4.4 [110/3] via 10.23.0.3, 00:45:13, GigabitEthernet1/0
R2#
R2#show mpls ldp neighbor 3.3.3.3
Peer LDP Ident: 3.3.3.3:0; Local LDP Ident 2.2.2.2:0
TCP connection: 3.3.3.3.37456 - 2.2.2.2.646
State: Oper; Msgs sent/rcvd: 276/274; Downstream
Up time: 03:53:37
LDP discovery sources:
  GigabitEthernet1/0, Src IP addr: 10.23.0.3
Addresses bound to peer LDP Ident:
  10.23.0.3   3.3.3.3   10.34.0.3
Control and Data Planes

- Control Plane (learned routes/labels) using routing protocols and LDP.
- Packets are forwarded on the Data Plane.
  - IP and MPLS, based on CEF and LFIB (Label Forwarding Information Base) respectively.
Labeled packet, leaving R1

Frame 4: 118 bytes on wire (944 bits), 118 bytes captured (944 bits)
MultiProtocol Label Switching Header, Label: 202, Exp: 0, S: 1, TTL: 255
  MPLS Label: 202
  MPLS Experimental Bits: 0
  MPLS Bottom Of Label Stack: 1
  MPLS TTL: 255
Internet Protocol Version 4, Src: 1.1.1.1 (1.1.1.1), Dst: 4.4.4.4 (4.4.4.4)
Internet Control Message Protocol

Captured between R1 and R2
How LSRs Use Labels

- **POP** – remove a label
- **PUSH** – add a label
- **SWAP** – which is a pop/push combo

Label Imposition (Push)  
L2/L3 Packet  
Label Swap  
Label Swap  
Label Disposition (PoP)
PHP

- PHP – Penultimate Hop Pop
  - Next to last LSR, removes top label, so that egress LSR (PE) doesn’t have to
Label Pushes, Pops and Swaps

R1-PE#traceroute 4.4.4.4

Type escape sequence to abort.
Tracing the route to 4.4.4.4

1 10.12.0.2 [MPLS: Label 202 Exp 0] 120 msec 84 msec 52 msec
2 10.23.0.3 [MPLS: Label 302 Exp 0] 68 msec 64 msec 60 msec
3 10.34.0.4 60 msec * 64 msec
Who do we Turn to for Lookups?

- IP Routing protocols populate the Routing Information Base (RIB) – control plane
- RIB populates CEF and its Forwarding Information Base (FIB) – data plane
  - **IP only packets: Use CEF**

- Label Distribution Protocol (LDP) populates the Label Information Base (LIB) – control plane
- LDP and RIB populate the Label Forwarding Information Base (LFIB) – data plane
  - **MPLS labeled packets: Use LFIB**
    - CEF also stores label information
LIB and LFIB

```
R2#show mpls ldp binding 4.4.4.4 32
  lib entry: 4.4.4.4/32, rev 12
    local binding: label: 202
    remote binding: lsr: 1.1.1.1:0, label: 100
    remote binding: lsr: 3.3.3.3:0, label: 302

R2#
R2#show mpls forwarding 4.4.4.4
Local  Outgoing  Prefix      Bytes Label  Outgoing  Next Hop
Label  Label or VC or Tunnel Id  Switched  interface   
202    302       4.4.4.4/32  6713          Gi1/0    10.23.0.3
```
MPLS Basic Configuration

- (config)# ip cef
- (config)# mpls ip
- (config)# interface G 3/0
- (config-if)# mpls ip

- MTU is automatically adjusted
- Can change with mpls mtu command
  - mpls mtu 1512 -- would support 3 labels (4 bytes per label)
MPLS LDP Configuration

(config)# mpls ldp router-id loopback0
(config)# interface fastethernet 0/0
(config-if)# mpls label protocol ldp

- Can use TDP, LDP or both on interface
- By default all prefixes have labels advertised for them, and all neighbors have labels advertised to them
- **LDP is the default protocol**
- Configure per interface
Conditional LDP Advertisements

(config)# no mpls ldp advertise-labels

(config)# mpls ldp advertise-labels
[for (ACL-of-networks)] [to (ACL-peers)]

(config-if)# mpls label range 200 120000
The Order of Things

- IP IGP routing protocols build the IP tables
- LSRs assign a *local* label for each route
- LSRs share their labels with other LSRs using LDP
- LSRs build their forwarding tables
Won’t You Be My Neighbor?

- Two step process
  - Hello messages
    - LDP link hello uses destination UDP port 646 and is sent to 224.0.0.2
    - Hello may include the IP address desired for peering, different than the source IP in the header.
    - Indicates if the label space is system wide, or per interface.
  - Setup LDP session with neighbor who says hello.
    - Session is TCP based on destination port 646
    - Router with highest LDP router ID will initiate this TCP session (called the active LSR). Keepalives are sent every 60 seconds.
Why LDP Won’t Neighbor Up

• LDP router ID is highest IP on loopback, but we can force it.
  • (config)# mpls ldp router-id loopback0

• IGP Routing may disagree with LDP processes – RID must be reachable over connected interface, unless we use:
  • (config-if)# mpls ldp discovery transport-address interface
Other LDP Features

• Security – Computes MD5 Signatures
  • (config)# mpls ldp neighbor (ip#) password (pw)

• Label filters – inbound from neighbor
  • (config)# mpls ldp neighbor (ip#) labels accept (#)
    • (ip#) = IP address of LDP neighbor
    • (#) = number of access-list of network prefixes
MPLS & IP Header TTL

**MultiProtocol Label Switching Header, Label: 302, Exp: 0, S: 0, TTL: 253**
- MPLS Label: 302
- MPLS Experimental Bits: 0
- MPLS Bottom Of Label Stack: 0
- MPLS TTL: 253

**MultiProtocol Label Switching Header, Label: 406, Exp: 0, S: 1, TTL: 254**
- MPLS Label: 406
- MPLS Experimental Bits: 0
- MPLS Bottom Of Label Stack: 1
- MPLS TTL: 254

**Internet Protocol Version 4, Src: 172.16.0.2 (172.16.0.2), Dst: 172.16.129.2 (172.16.129.2)**
- 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: 0x000f (15)
- Flags: 0x00
- Fragment offset: 0
- Time to live: 254
- Protocol: ICMP (1)
- Header checksum: 0xe364 [correct]
  - Source: 172.16.0.2 (172.16.0.2)
  - Destination: 172.16.129.2 (172.16.129.2)

**IP Header**
Hide the MPLS Core from the Client

- Traceroute uses TTL manipulation to trigger feedback.
- Disabling the TTL propagation will not copy the initial IP TTL to the MPLS TTL, and MPLS will start at 255.
- Results: MPLS LSRs become the invisible network to the eyes of traceroute.
No mpls ip propagate-ttl (on All LSRs)

R1-PE#traceroute 4.4.4.4

Type escape sequence to abort.
Tracing the route to 4.4.4.4

Before

1 10.12.0.2 [MPLS: Label 202 Exp 0] 92 msec 60 msec 56 msec
2 10.23.0.3 [MPLS: Label 302 Exp 0] 56 msec 60 msec 64 msec
3 10.34.0.4 60 msec * 52 msec

R1-PE#traceroute 4.4.4.4

Type escape sequence to abort.
Tracing the route to 4.4.4.4

After

1 10.34.0.4 84 msec * 64 msec
Monitoring MPLS

• show mpls ldp parameters
• show mpls interface
• show mpls ldp discovery
• show mpls ldp neighbor [detail]
• show mpls ldp bindings (the LIB)
• show mpls forwarding table (the LFIB)
• show ip route a.b.c.d (the RIB)
• show ip cef a.b.c.d [detail] (the FIB)
• show cef interface
• debug mpls ldp
• debug mpls lfib
• debug mpls packets
Troubleshooting MPLS

• LDP neighborship failed
  • MPLS not enabled, LDP ports filtered, no L3 route to LDP neighbor LSR router-id, highest loopback address.

• Labels not assigned
  • CEF not enabled

• Labels not shared
  • Compatible LDP between neighbors

• Slow convergence
  • Get rid of RIP 😁 IGP is biggest factor in convergence delay

• Large packets dropped
  • MTU not supported by switches. Multiple labels may be present pushing the MTU to a size not supported by the infrastructure.
Useful MPLS Troubleshooting Commands

- Verify routing protocol is running properly
  - Show ip route 10.10.10.0

- Verify CEF Switching
  - Show ip cef 10.10.10.0 detail

- Verify MPLS Operations
  - Show mpls interface

- Verify Label Distribution
  - Show mpls ldp discovery

- Verify Label Binding
  - Show mpls ip binding

- Ping/Traceroute
Stretch-  1, 2, 3 Go!
MPLS L3VPN Game Plan

• A customer router (CE) at site A peers with a provider router (PE).

• Customer shares their routes with provider, and provider puts learned routes in a local VRF on the provider router.

• Provider takes the routes from the VRF, and exports them from the VRF into Multiprotocol BGP (MP-BGP). The routes are now called VPNv4 routes.

• BGP is used to share these VPNv4 routes with other MP-BGP routers in the provider network with iBGP connections.

• A provider router (PE) peering with a customer router (CE) at site 2, takes the VPNv4 routes from MBGP and imports them into the local VRF for that same customer, and shares the routes from PE to CE at site B.
VRF: The Virtual Routing Table

- Cisco routers can have multiple VRFs
  - VRF: Virtual Routing and Forwarding instance

- Some details about VRFs:
  - Router can have multiple VRFs
  - Each VRF has its own RIB and CEF table
  - Interfaces are allocated to a specific VRF
    - Interfaces not assigned to a VRF are part of the global routing table on the router.
  - VRFs contains identity information such as Route Targets (RT), and Route Distinguishers (RD)
    - More on RT and RD coming up.
Creating a VRF and Allocating an Interface

```plaintext
ip vrf cust1
  rd 10:10
  route-target export 1.1.1.1:1
  route-target import 4.4.4.4:1
!
interface GigabitEthernet1/0
  ip vrf forwarding cust1
  ip address 172.16.0.1 255.255.255.252
```
Green VRF and Purple VRF, Allocated to Interfaces
How MPLS L3 VPNs May Appear to Some.
What if Cust1 and Cust2 Both Use the Same Private Network Address space of 10.0.0.0/8?
Uniquely Identifying Similar Routes

• What if customer 1 and customer 2 both have a 10.0.0.0/8 network, how do we differentiate these VPNv4 routes inside of MP-BGP?

  Wait for it....

• **Route Distinguisher (RD)** is added to each route to make it globally unique inside of MP-BGP

• The route, along with the RD, is the VPNv4 route

• VPNv4 routes are exchanged via iBGP between PE routers
  • BGP that supports other address families besides just IPv4 is called multi-protocol BGP
How the RD is Defined

```
ip vrf cust1
 rd 10:10
 route-target export 1.1.1.1:1
 route-target import 4.4.4.4:1

interface GigabitEthernet1/0
 ip vrf forwarding cust1
 ip address 172.16.0.1 255.255.255.252
```
Route Distinguisher

Network layer reachability information (15 bytes)

- Label Stack=108 (bottom) RD=10:10, IPv4=172.16.1.0/24
- MP Reach NLRI Prefix length: 112
- MP Reach NLRI Label Stack: 108 (bottom)
- MP Reach NLRI Route Distinguisher: 10:10
- MP Reach NLRI IPv4 prefix: 172.16.1.0 (172.16.1.0)

iBGP update from R1
# Viewing Routes in MP-BGP by RD

```plaintext
R1-PE#show bgp vpnv4 unicast rd 10:10
BGP table version is 11, local router ID is 1.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best,
r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

<table>
<thead>
<tr>
<th>Network</th>
<th>Next Hop</th>
<th>Metric</th>
<th>LocPrf</th>
<th>Weight</th>
<th>Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>172.16.0.0/30</td>
<td>0.0.0.0</td>
<td>0</td>
<td>32768</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>172.16.1.0/24</td>
<td>172.16.0.2</td>
<td>1</td>
<td>32768</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>172.16.128.0/30</td>
<td>4.4.4.4</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>172.16.129.0/24</td>
<td>4.4.4.4</td>
<td>130816</td>
<td>100</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
```

CiscosLive!
How do we Deliver the Correct Routes and Traffic for each customer between their sites?
Import/Export Route Targets

- Export Route Targets identifying VPN membership are added as extended community values with the customer route when the route is converted into a VPNv4 route (exported out of the VRF into MP-BGP)

- Each virtual routing table has a set of associated import Route Targets that select routes to be inserted into the virtual routing table (imported into the VRF from MP-BGP)

- VRF into BGP (export) – inject the export route target value(s)
- BGP into VRF (import) – only get the routes whose import route target(s) match the import route targets associated with that VRF
Route Target (Cont.)

- Route Targets are additional attributes attached to VPNv4 BGP routes to indicate VPN membership
- Extended BGP communities are used to encode these attributes
  - Extended communities carry the meaning of the attribute together with its value
- Multiple route targets can be attached to a single route
Secret to Remembering Import/Export

• Export policy means that routes will go from VRF into MP-BGP
• Import policy means that routes will come from the MP-BGP into VRF
• You can have multiple import/export route targets in a VRF
• Import or export policies can be filtered when desired
How the RT is Defined

• R1-PE
  
ip vrf cust1
  
  rd 10:10
  
  route-target export 1.1.1.1:1
  
  route-target import 4.4.4.4:1

  interface GigabitEthernet1/0
  
ip vrf forwarding cust1
  
ip address 172.16.0.1 255.255.255.252

• R4-PE
  
ip vrf cust1
  
  rd 10:10
  
  route-target export 4.4.4.4:1
  
  route-target import 1.1.1.1:1

  interface GigabitEthernet1/0
  
ip vrf forwarding cust1
  
ip address 172.16.1.1 255.255.255.252
Route Targets

- Used as extended community information inside MP-BGP for import/export to/from VRFs
Viewing the Route Target in MP-BGP

R1-PE# show bgp vpnv4 unicast vrf cust1 172.16.1.0/24
BGP routing table entry for 10:10:172.16.1.0/24, version 7
Paths: (1 available, best #1, table cust1)
    Advertised to update-groups:
        1
    Local
        172.16.0.2 from 0.0.0.0 (1.1.1.1)
        Origin incomplete, metric 1, localpref 100, weight 32768, valid
    Extended Community: RT:1.1.1.1:1
    mpls labels in/out 108/nolabel
Let’s Follow the Control Plane for 172.16.129.0/24
R4 VPN label for 172.16.129.0/24

```
R4-PE#show bgp vpnv4 unicast all labels
   Network                Next Hop       In label/Out label
Route Distinguisher: 10:10 (cust1)
  172.16.0.0/30          1.1.1.1        nolabel/107
  172.16.1.0/24          1.1.1.1        nolabel/108
  172.16.128.0/30        0.0.0.0         407/nolabel(cust1)
  172.16.129.0/24        172.16.128.2    408/nolabel
```

```
R4-PE#show mpls forwarding-table vrf cust1
  Local Label | Outgoing Label or VC | Outgoing Prefix | Outgoing Switched | Bytes Label | Next Hop | Outgoing Interface |
  407         | No Label             | 172.16.128.0/30 | 0                 | 0           | \        | aggregate/cust1    |
  408         | No Label             | 172.16.129.0/24 | 0                 | 0           | 172.16.128.2 | Gi1/0            |
```
MP-BGP Update from R4

```
Network layer reachability information (15 bytes)
- Label Stack=408 (bottom) RD=10:10, IPv4=172.16.129.0/24
  MP Reach NLRI Prefix length: 112
  MP Reach NLRI Label Stack: 408 (bottom)
  MP Reach NLRI Route Distinguisher: 10:10
  MP Reach NLRI IPv4 prefix: 172.16.129.0 (172.16.129.0)
```
R1 learned VPN label advertised from R4

```
R1-PE#show bgp vpnv4 unicast vrf cust1 labels
Route Distinguisher: 10:10 (cust1)
Network                Next Hop       In label/Out label
172.16.0.0/30          0.0.0.0        107/nolabel (cust1)
172.16.1.0/24          172.16.0.2     108/nolabel
172.16.128.0/30         4.4.4.4        nolabel/407
172.16.129.0/24         4.4.4.4        nolabel/408
```
VPN Label Assignments

• R1 imposes two labels
  • Top label is transit label (to reach next hop of 4.4.4.4)
  • Bottom label VPN label (advertised by R4)
Regarding 172.16.129.0/24, R1 knows bottom VPN label (label 408) and top label for the BGP next hop of 4.4.4.4 (label 202)
Happy User at Cust1 Site A, Sends a Ping to Cust1 Site B address 172.16.129.2 What does R1 do with the inbound packet?
Top Label is swapped on each LSR in the path. R3 does PHP on top label. R4 receives vpn label, removes it, then forwards to cust.

Ping: 172.16.129.2

172.16.129.0/24
L3VPN related show commands

- `show ip route cef vrf (vrf name)`
- `show ip route vrf (vrf name) x.x.x.x`
- `show vrf (vrf name) {detail}`
- `show ip bgp vpnv4 all {summary}`
- `show ip bgp vpnv4 vrf {name}`
- `show bgp vpnv4 unicast vrf {name}`
- `show bgp vrf {name} ipv4 unicast summary`
Please join us for the Service Provider Innovation Talk featuring:

Yvette Kanouff | Senior Vice President and General Manager, SP Business
Joe Cozzolino | Senior Vice President, Cisco Services

Thursday, July 14th, 2016
11:30 am - 12:30 pm, In the Oceanside A room

What to expect from this innovation talk

• Insights on market trends and forecasts
• Preview of key technologies and capabilities
• Innovative demonstrations of the latest and greatest products
• Better understanding of how Cisco can help you succeed

Register to attend the session live now or watch the broadcast on cisco.com
Complete Your Online Session Evaluation

• Give us your feedback to be entered into a Daily Survey Drawing. A daily winner will receive a $750 Amazon gift card.

• Complete your session surveys though the Cisco Live mobile app or your computer on Cisco Live Connect.

Don’t forget: Cisco Live sessions will be available for viewing on-demand after the event at CiscoLive.com/Online
Continue Your Education

• Demos in the Cisco campus
• Walk-in Self-Paced Labs
• Lunch & Learn
• Meet the Engineer 1:1 meetings
• Related sessions
# R&S Related Cisco Education Offerings

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Cisco Certification</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCIE R&amp;S Advanced Workshops (CIERS-1 &amp; Ciers-2) plus Self Assessments, Workbooks &amp; Labs</td>
<td>Expert level trainings including: instructor led workshops, self assessments, practice labs and CCIE Lab Builder to prepare candidates for the CCIE R&amp;S practical exam.</td>
<td>CCIE® Routing &amp; Switching</td>
</tr>
</tbody>
</table>
| - Implementing Cisco IP Routing v2.0  
- Implementing Cisco IP Switched Networks V2.0  
- Troubleshooting and Maintaining Cisco IP Networks v2.0 | Professional level instructor led trainings to prepare candidates for the CCNP R&S exams (ROUTE, SWITCH and TSHOOT). Also available in self study eLearning formats with Cisco Learning Labs. | CCNP® Routing & Switching |
| Interconnecting Cisco Networking Devices: Part 2 (or combined) | Configure, implement and troubleshoot local and wide-area IPv4 and IPv6 networks. Also available in self study eLearning format with Cisco Learning Lab. | CCNA® Routing & Switching |
| Interconnecting Cisco Networking Devices: Part 1 | Installation, configuration, and basic support of a branch network. Also available in self study eLearning format with Cisco Learning Lab. | CCENT® Routing & Switching |

For more details, please visit: [http://learningnetwork.cisco.com](http://learningnetwork.cisco.com)

Questions? Visit the Learning@Cisco Booth or contact ask-edu-pm-dcv@cisco.com
# Service Provider Cisco Education Offerings

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Cisco Certification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deploying Cisco Service Provider Network Routing (SPROUTE) &amp; Advanced</td>
<td>SPROUTE covers the implementation of routing protocols (OSPF, IS-IS, BGP), route manipulations, and HA routing features; SPADVROUTE covers advanced routing topics in BGP, multicast services including PIM-SM, and IPv6; SPCORE covers network services, including MPLS-LDP, MPLS traffic engineering, QoS mechanisms, and transport technologies; SPEDGE covers network services, including MPLS Layer 3 VPNs, Layer 2 VPNs, and Carrier Ethernet services; all within SP IP NGN environments.</td>
<td>CCNP Service Provider®</td>
</tr>
<tr>
<td>Implementing Cisco Service Provider Next-Generation Core Network Services (SPCORE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edge Network Services (SPEDGE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building Cisco Service Provider Next-Generation Networks, Part 1&amp;2</td>
<td>The two courses introduce networking technologies and solutions, including OSI and TCP/IP models, IPv4/6, switching, routing, transport types, security, network management, and Cisco OS (IOS and IOS XR).</td>
<td>CCNA Service Provider®</td>
</tr>
<tr>
<td>(SPNGN1), (SPNGN2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implementing Cisco Service Provider Mobility UMTS Networks (SPUMTS);</td>
<td>The three courses (SPUMTS, SPCDMA, SPLTE) cover knowledge and skills required to understand products, technologies, and architectures that are found in Universal Mobile Telecommunications Systems (UMTS) and Code Division Multiple Access (CDMA) packet core networks, plus their migration to Long-Term Evolution (LTE) Evolved Packet Systems (EPS), including Evolved Packet Core (EPC) and Radio Access Networks (RANs).</td>
<td>Cisco Service Provider Mobility CDMA to LTE Specialist; Cisco Service Provider Mobility UMTS to LTE Specialist</td>
</tr>
<tr>
<td>Implementing Cisco Service Provider Mobility CDMA Networks (SPCDMA);</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implementing Cisco Service Provider Mobility LTE Networks (SPLTE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implementing and Maintaining Cisco Technologies Using IOS XR (IMTXR)</td>
<td>Service Provider/Enterprise engineers to implement, verification-test, and optimize core/edge technologies in a Cisco IOS XR environment.</td>
<td>Cisco IOS XR Specialist</td>
</tr>
</tbody>
</table>

For more details, please visit: [http://learningnetwork.cisco.com](http://learningnetwork.cisco.com)

Questions? Visit the Learning@Cisco Booth or contact ask-edu-pm-dcv@cisco.com
# Internet of Things (IoT) Cisco Education Offerings

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Cisco Certification</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEW! IMINS2</td>
<td>An associate level instructor led training course designed to prepare you for the CCNA Industrial certification</td>
<td>CCNA® Industrial</td>
</tr>
<tr>
<td>Managing Industrial Networks with Cisco Networking Technologies (IMINS)</td>
<td>This curriculum addresses foundational skills needed to manage and administer networked industrial control systems. It provides plant administrators, control system engineers and traditional network engineers with an understanding of the networking technologies needed in today's connected plants and enterprises</td>
<td>Cisco Industrial Networking Specialist</td>
</tr>
<tr>
<td>Control Systems Fundamentals for Industrial Networking (ICINS)</td>
<td>For IT and Network Engineers, covers basic concepts in Industrial Control systems including an introduction to automation industry verticals, automation environment and an overview of industrial control networks</td>
<td></td>
</tr>
</tbody>
</table>

For more details, please visit: [http://learningnetwork.cisco.com](http://learningnetwork.cisco.com)

Questions? Visit the Learning@Cisco Booth or contact ask-edu-pm-dcv@cisco.com
Thank you