Configuring Layer 3 Virtualization

This chapter describes how to configure Layer 3 virtualization.

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About Layer 3 Virtualization

Overview of Layer 3 Virtualization

Cisco NX-OS supports virtual routing and forwarding instances (VRFs). Each VRF contains a separate address space with unicast and multicast route tables for IPv4 and makes routing decisions independent of any other VRF.

Each router has a default VRF and a management VRF. All Layer 3 interfaces and routing protocols exist in the default VRF until you assign them to another VRF. The mgmt0 interface exists in the management VRF. With the VRF-lite feature, the switch supports multiple VRFs in customer edge (CE) switches. VRF-lite allows a service provider to support two or more virtual private networks (VPNs) with overlapping IP addresses using one interface.

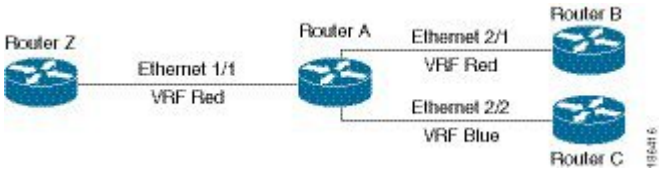
Note The switch does not use Multiprotocol Label Switching (MPLS) to support VPNs.

VRF and Routing

All unicast and multicast routing protocols support VRFs. When you configure a routing protocol in a VRF, you set routing parameters for the VRF that are independent of routing parameters in another VRF for the same routing protocol instance.

You can assign interfaces and route protocols to a VRF to create virtual Layer 3 networks. An interface exists in only one VRF. The following figure shows one physical network split into two virtual networks with two VRFs. Routers Z, A, and B exist in VRF Red and form one address domain. These routers share route updates that do not include router C because router C is configured in a different VRF.

Figure 1: VRFs in a Network



By default, Cisco NX-OS uses the VRF of the incoming interface to select which routing table to use for a route lookup. You can configure a route policy to modify this behavior and set the VRF that Cisco NX-OS uses for incoming packets.

VRF supports route leaking (import or export) between VRFs. Certain limitations apply to route leaking in VRF-Lite. For more information, see Guidelines and Limitations for VRF Route Leaking.

VRF-Lite

VRF-lite is a feature that enables a service provider to support two or more VPNs, where IP addresses can be overlapped among the VPNs. VRF-lite uses input interfaces to distinguish routes for different VPNs and forms virtual packet-forwarding tables by associating one or more Layer 3 interfaces with each VRF. Interfaces in a VRF can be either physical, such as Ethernet ports, or logical, such as VLAN SVIs, but a Layer 3 interface cannot belong to more than one VRF at any time.

Note Multiprotocol Label Switching (MPLS) and MPLS control plane are not supported in the VRF-lite implementation.

Note VRF-lite interfaces must be Layer 3 interfaces.

VRF-Aware Services

A fundamental feature of the Cisco NX-OS architecture is that every IP-based feature is VRF aware.

The following VRF-aware services can select a particular VRF to reach a remote server or to filter information based on the selected VRF:

- AAA

- Call Home
- HSRP
- HTTP
- Licensing
- NTP
- RADIUS
- Ping and Traceroute
- SSH
- SNMP
- Syslog
- TACACS+
- TFTP
- VRRP

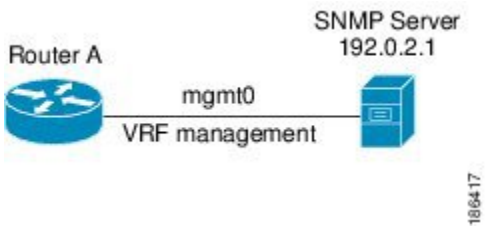
See the appropriate configuration guide for each service for more information on configuring VRF support in that service.

Reachability

Reachability indicates which VRF contains the routing information necessary to get to the server providing the service. For example, you can configure an SNMP server that is reachable on the management VRF. When you configure that server address on the router, you also configure which VRF that Cisco NX-OS must use to reach the server.

The following shows an SNMP server that is reachable over the management VRF. You configure router A to use the management VRF for SNMP server host 192.0.2.1.

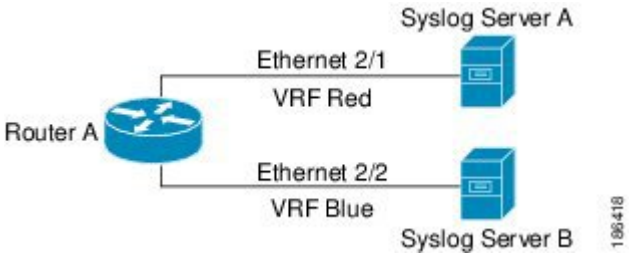
Figure 2: Service VRF Reachability



Filtering

Filtering allows you to limit the type of information that goes to a VRF-aware service based on the VRF. For example, you can configure a syslog server to support a particular VRF. The following figure shows two syslog servers with each server supporting one VRF. syslog server A is configured in VRF Red, so Cisco NX-OS sends only system messages generated in VRF Red to syslog server A.

Figure 3: Service VRF Filtering

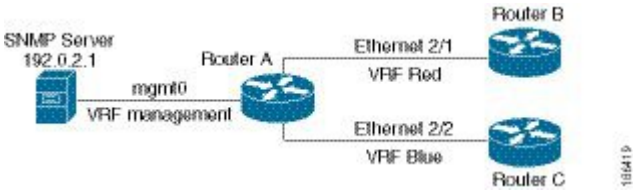


Combining Reachability and Filtering

You can combine reachability and filtering for VRF-aware services. You configure the VRF that Cisco NX-OS uses to connect to that service as well as the VRF that the service supports. If you configure a service in the default VRF, you can optionally configure the service to support all VRFs.

The following figure shows an SNMP server that is reachable on the management VRF. You can configure the SNMP server to support only the SNMP notifications from VRF Red, for example.

Figure 4: Service VRF Reachability Filtering



Guidelines and Limitations for VRF

VRFs have the following configuration guidelines and limitations in a VRF-lite scenario:

- When you make an interface a member of an existing VRF, Cisco NX-OS removes all Layer 3 configuration. You should configure all Layer 3 parameters after adding an interface to a VRF.
- You should add the mgmt0 interface to the management VRF and configure the mgmt0 IP address and other parameters after you add it to the management VRF.
- If you configure an interface for a VRF before the VRF exists, the interface is operationally down until you create the VRF.
- Cisco NX-OS creates the default and management VRFs by default. You should make the mgmt0 interface a member of the management VRF.
- The **write erase boot** command does not remove the management VRF configuration. You must use the **write erase** command and then the **write erase boot** command.

Guidelines and Limitations for VRF-Lite

VRF-lite has the following guidelines and limitations:

- A switch with VRF-lite has a separate IP routing table for each VRF, which is separate from the global routing table.
- Because VRF-lite uses different VRF tables, the same IP addresses can be reused. Overlapped IP addresses are allowed in different VPNs.
- VRF-lite does not support all MPLS-VRF functionality; it does not support label exchange or labeled packets.
- Multiple virtual Layer 3 interfaces can be connected to a VRF-lite switch.
- The switch supports configuring a VRF by using physical ports, VLAN SVIs, or a combination of both. The SVIs can be connected through an access port or a trunk port.
- VRF-lite supports BGP and static routing.
- VRF-lite does not support Enhanced Interior Gateway Routing Protocol (EIGRP).
- VRF-lite does not affect the packet switching rate.
- Multicast cannot be configured on the same Layer 3 interface at the same time.

Guidelines and Limitations for VRF Route Leaking

VRF route leaking has the following guidelines and limitations:

- Route leaking is supported between any two nondefault VRFs. It is also supported between the default VRF and any other VRF.
- Route leaking to the default VRF is not allowed because it is the global VRF.
- You can restrict route leaking to specific routes using route map filters to match designated IP addresses.
- By default, the maximum number of IP prefixes that can be leaked is set to 1000 routes. This number can be configured to any value from 0 to 1000.
- VRF route leaking requires an Enterprise license, and BGP must be enabled.

Default Settings

The following table lists the default settings for VRF parameters.

Table 1: Default VRF Parameters

Parameters	Default
Configured VRFs	Default, management
Routing context	Default VRF

Configuring VRFs

Creating a VRF

You can create a VRF in a switch.

SUMMARY STEPS

1. **configure terminal**
2. **vrf context name**
3. **ip route** { *ip-prefix* | *ip-addr ip-mask* } {[*next-hop* | *nh-prefix*] | [*interface next-hop* | *nh-prefix*]} [**tag** *tag-value* [*pref*]
4. (Optional) **show vrf** [*vrf-name*]
5. (Optional) **copy running-config startup-config**

DETAILED STEPS

Procedure

	Command or Action	Purpose

Step 1	**configure terminal**
	Example:
	`switch# configure terminal`
	`switch(config)#`
		Enters global configuration mode.

Step 2	**vrf context name**
	Example:
	`switch(config)# vrf context Enterprise`
	`switch(config-vrf)#`
		Creates a new VRF and enters VRF configuration mode. The **name** can be any case-sensitive, alphanumeric string up to 32 characters.

Step 3	**ip route** { *ip-prefix* | *ip-addr ip-mask* } {[*next-hop* | *nh-prefix*] | [*interface next-hop* | *nh-prefix*]} [**tag** *tag-value* [*pref*] **Example:** `switch(config-vrf)# ip route 192.0.2.0/8 ethernet 1/2 192.0.2.4`	Configures a static route and the interface for this static route. You can optionally configure the next-hop address. The *preference* value sets the administrative distance. The range is from 1 to 255. The default is 1.
Step 4	(Optional) **show vrf** [*vrf-name*] **Example:** `switch(config-vrf)# show vrf Enterprise`	Displays VRF information.
Step 5	(Optional) **copy running-config startup-config** **Example:** `switch(config-vrf)# copy running-config startup-config`	Saves this configuration change.

Example

Use the **no vrf context** command to delete the VRF and the associated configuration:

Command	Purpose
no vrf context *name* **Example:** `switch(config)# no vrf context Enterprise`	Deletes the VRF and all associated configuration.

Any commands available in global configuration mode are also available in VRF configuration mode.

This example shows how to create a VRF and add a static route to the VRF:

```
switch# configure terminal
switch(config)# vrf context Enterprise
switch(config-vrf)# ip route 192.0.2.0/8 ethernet 1/2
switch(config-vrf)# exit
switch(config)# copy running-config startup-config
```

Assigning VRF Membership to an Interface

You can make an interface a member of a VRF.

Before you begin

Assign the IP address for an interface after you have configured the interface for a VRF.

SUMMARY STEPS

1. **configure terminal**
2. **interface** *interface-type* **slot/port**
3. **vrf member** *vrf-name*
4. **ip address** *ip-prefix/length*
5. **show vrf** *vrf-name* **interface** *interface-type number*
6. **copy running-config startup-config**

DETAILED STEPS

Procedure

	Command or Action	Purpose

Step 1	**configure terminal**
	Example:
	`switch# configure terminal`
	`switch(config)#`
		Enters global configuration mode.

	Command or Action	Purpose

Step 2	**interface** *interface-type* **slot/port**
	Example:
	`switch(config)# interface ethernet 1/2`
	`switch(config-if)#`
		Enters interface configuration mode.

Step 3	**vrf member** *vrf-name* **Example:** `switch(config-if)# vrf member RemoteOfficeVRF`	Adds this interface to a VRF.
Step 4	**ip address** *ip-prefix/length* **Example:** `switch(config-if)# ip address 192.0.2.1/16`	Configures an IP address for this interface. You must do this step after you assign this interface to a VRF.
Step 5	**show vrf** *vrf-name* **interface** *interface-type number* **Example:** `switch(config-if)# show vrf Enterprise interface ethernet 1/2`	Displays VRF information.
Step 6	**copy running-config startup-config** **Example:** `switch(config-if)# copy running-config startup-config`	Saves this configuration change.

Example

This example shows how to add an interface to the VRF:

```
switch# configure terminal
switch(config)# interface ethernet 1/2
switch(config-if)# vrf member RemoteOfficeVRF
switch(config-if)# ip address 192.0.2.1/16
switch(config-if)# copy running-config startup-config
```

Configuring VRF Parameters for a Routing Protocol

You can associate a routing protocol with one or more VRFs. See the appropriate chapter for information on how to configure VRFs for the routing protocol. This section uses OSPFv2 as an example protocol for the detailed configuration steps.

SUMMARY STEPS

1. **configure terminal**
2. **router ospf** *instance-tag*
3. **vrf** *vrf-name*
4. (Optional) **maximum-paths** *paths*
5. **interface** *interface-type* **slot/port**

6. **vrf member** *vrf-name*
7. **ip address** *ip-prefix/length*
8. **ip router ospf** *instance-tag* **area** *area-id*
9. (Optional) **copy running-config startup-config**

DETAILED STEPS

Procedure

	Command or Action	Purpose

Step 1	**configure terminal**
	Example:
	`switch# configure terminal`
	`switch(config)#`
		Enters global configuration mode.

Step 2	**router ospf** *instance-tag*
	Example:
	`switch(config)# router ospf 201`
	`switch(config-router)#`
		Creates a new OSPFv2 instance with the configured instance tag.

Step 3	**vrf** *vrf-name*
	Example:
	`switch(config-router)# vrf RemoteOfficeVRF`
	`switch(config-router-vrf)#`
		Enters VRF configuration mode.

Step 4	(Optional) **maximum-paths** *paths* **Example:** `switch(config-router-vrf)# maximum-paths 4`	Configures the maximum number of equal OSPFv2 paths to a destination in the route table for this VRF. Used for load balancing.

Step 5	**interface** *interface-type* **slot/port**
	Example:
	`switch(config)# interface ethernet 1/2`
	`switch(config-if)#`
		Enters interface configuration mode.

Step 6	**vrf member** *vrf-name* **Example:** `switch(config-if)# vrf member RemoteOfficeVRF`	Adds this interface to a VRF.
Step 7	**ip address** *ip-prefix/length* **Example:** `switch(config-if)# ip address 192.0.2.1/16`	Configures an IP address for this interface. You must do this step after you assign this interface to a VRF.
Step 8	**ip router ospf** *instance-tag* **area** *area-id* **Example:** `switch(config-if)# ip router ospf 201 area 0`	Assigns this interface to the OSPFv2 instance and area configured.

	Command or Action	Purpose
Step 9	(Optional) **copy running-config startup-config** **Example:** `switch(config-if)# copy running-config startup-config`	Saves this configuration change.

Example

This example shows how to create a VRF and add an interface to the VRF:

```
switch# configure terminal
switch(config)# vrf context RemoteOfficeVRF
switch(config-vrf)# exit
switch(config)# router ospf 201
switch(config-router)# vrf RemoteOfficeVRF
switch(config-router-vrf)# maximum-paths 4
switch(config-router-vrf)# interface ethernet 1/2
switch(config-if)# vrf member RemoteOfficeVRF
switch(config-if)# ip address 192.0.2.1/16
switch(config-if)# ip router ospf 201 area 0
switch(config-if)# exit
switch(config)# copy running-config startup-config
```

Configuring a VRF-Aware Service

You can configure a VRF-aware service for reachability and filtering. See the VRF-Aware Services section for links to the appropriate chapter or configuration guide for information on how to configure the service for VRFs. This section uses SNMP and IP domain lists as example services for the detailed configuration steps.

SUMMARY STEPS

1. **configure terminal**
2. **snmp-server host** *ip-address* [**filter-vrf** *vrf-name*] [**use-vrf** *vrf-name*]
3. **vrf context** *vrf-name*
4. **ip domain-list** *domain-name* [**all-vrfs**][**use-vrf** *vrf-name*]
5. (Optional) **copy running-config startup-config**

DETAILED STEPS

Procedure

	Command or Action	Purpose

Step 1	**configure terminal**
	Example:
	`switch# configure terminal`
	`switch(config)#`
		Enters global configuration mode.

Step 2	**snmp-server host** *ip-address* [**filter-vrf** *vrf-name*] [**use-vrf** *vrf-name*]	Configures a global SNMP server and configures the VRF that Cisco NX-OS uses to reach the service. Use the

	Command or Action	Purpose
	Example: `switch(config)# snmp-server host 192.0.2.1 use-vrf Red`	**filter-vrf** keyword to filter information from the selected VRF to this server.

Step 3	**vrf context** *vrf-name*
	Example:
	`switch(config)# vrf context Blue`
	`switch(config-vrf)#`
		Creates a new VRF.

Step 4	**ip domain-list** *domain-name* [**all-vrfs**][**use-vrf** *vrf-name*] **Example:** `switch(config-vrf)# ip domain-list List all-vrfs use-vrf Blue`	Configures the domain list in the VRF and optionally configures the VRF that Cisco NX-OS uses to reach the domain name listed.
Step 5	(Optional) **copy running-config startup-config** **Example:** `switch(config-vrf)# copy running-config startup-config`	Saves this configuration change.

Example

This example shows how to send SNMP information for all VRFs to SNMP host 192.0.2.1, reachable on VRF Red:

```
switch# configure terminal
switch(config)# snmp-server host 192.0.2.1 for-all-vrfs use-vrf Red
switch(config)# copy running-config startup-config
```

This example shows how to Filter SNMP information for VRF Blue to SNMP host 192.0.2.12, reachable on VRF Red:

```
switch# configure terminal
switch(config)# vrf definition Blue
switch(config-vrf)# snmp-server host 192.0.2.12 use-vrf Red
switch(config)# copy running-config startup-config
```

Setting the VRF Scope

You can set the VRF scope for all EXEC commands (for example, **show** commands). This automatically restricts the scope of the output of EXEC commands to the configured VRF. You can override this scope by using the VRF keywords available for some EXEC commands.

To set the VRF scope, use the following command in EXEC mode:

Command	Purpose
routing-context vrf *vrf-name* **Example:** `switch# routing-context vrf redswitch%red#`	Sets the routing context for all EXEC commands. Default routing context is the default VRF.

To return to the default VRF scope, use the following command in EXEC mode:

Command	Purpose
routing-context vrf default **Example:** `switch# routing-context vrf default`	Sets the default routing context.

Verifying the VRF Configuration

To display the VRF configuration information, perform one of the following tasks:

Command	Purpose
show vrf [*vrf-name*]	Displays the information for all or one VRF.
show vrf [*vrf-name*] **detail**	Displays detailed information for all or one VRF.
show vrf [*vrf-name*] [**interface** *interface-type slot/port*]	Displays the VRF status for an interface.

Configuration Examples for VRFs

This example shows how to configure VRF Red, add an SNMP server to that VRF, and add an instance of OSPF to VRF Red:

```
vrf context Red
 snmp-server host 192.0.2.12 use-vrf Red
 router ospf 201
 interface ethernet 1/2

vrf member Red
 ip address 192.0.2.1/16
 ip router ospf 201 area 0
```

This example shows how to configure VRF Red and Blue, add an instance of OSPF to each VRF, and create an SNMP context for each OSPF instance in each VRF:

```
vrf context Red
vrf context Blue

feature ospf
 router ospf Lab
 vrf Red
 router ospf Production
 vrf Blue

interface ethernet 1/2
 vrf member Red
 ip address 192.0.2.1/16
 ip router ospf Lab area 0
 no shutdown

interface ethernet 10/2
 vrf member Blue
 ip address 192.0.2.1/16
```

```
 ip router ospf Production area 0
 no shutdown

snmp-server user admin network-admin auth md5 nbv-12345
 snmp-server community public ro
```

Create the SNMP contexts for each VRF

```
snmp-server context lab instance Lab vrf Red
 snmp-server context production instance Production vrf Blue
```

Use the SNMP context **lab** to access the OSPF-MIB values for the OSPF instance Lab in VRF Red in the previous example.

This example shows how to configure route leaking between two non-default VRF's, and from the default VRF to a non-default VRF:

```
feature bgp
 vrf context Green
 ip route 33.33.33.33/32 35.35.1.254
 address-family ipv4 unicast
 route-target import 3:3
 route-target export 2:2
 export map test
 import map test
 import vrf default map test
 interface Ethernet1/7

vrf member Green
 ip address 35.35.1.2/24
 vrf context Shared
 ip route 44.44.44.44/32 45.45.1.254

address-family ipv4 unicast
 route-target import 1:1
 route-target import 2:2
 route-target export 3:3
 export map test
 import map test
 import vrf default map test
 interface Ethernet1/11
 vrf member Shared
 ip address 45.45.1.2/24
 router bgp 100

address-family ipv4 unicast
 redistribute static route-map test
 vrf Green
 address-family ipv4 unicast
 redistribute static route-map test
 vrf Shared
 address-family ipv4 unicast
 redistribute static route-map test
 ip prefix-list test seq 5 permit 0.0.0.0/0 le 32
 route-map test permit 10
 match ip address prefix-list test
 ip route 100.100.100.100/32 55.55.55.1

nexus# show ip route vrf all
 IP Route Table for VRF "default"
 '*' denotes best ucast next-hop
 '**' denotes best mcast next-hop
 '[x/y]' denotes [preference/metric]
 '%<string>' in via output denotes VRF <string
```

```
 55.55.55.0/24, ubest/mbest: 1/0, attached
 *via 55.55.55.5, Lo0, [0/0], 00:07:59, direct
 55.55.55.5/32, ubest/mbest: 1/0, attached
 *via 55.55.55.5, Lo0, [0/0], 00:07:59, local
 100.100.100.100/32, ubest/mbest: 1/0
 *via 55.55.55.1, [1/0], 00:07:42, static

IP Route Table for VRF "management"
 '*' denotes best ucast next-hop
 '**' denotes best mcast next-hop
 '[x/y]' denotes [preference/metric]
 '%<string>' in via output denotes VRF <string>
 0.0.0.0/0, ubest/mbest: 1/0
 *via 10.29.176.1, [1/0], 12:53:54, static
 10.29.176.0/24, ubest/mbest: 1/0, attached
 *via 10.29.176.233, mgmt0, [0/0], 13:11:57, direct
 10.29.176.233/32, ubest/mbest: 1/0, attached
 *via 10.29.176.233, mgmt0, [0/0], 13:11:57, local

IP Route Table for VRF "Green"
 '*' denotes best ucast next-hop
 '**' denotes best mcast next-hop
 '[x/y]' denotes [preference/metric]
 '%<string>' in via output denotes VRF <string>
 33.33.33.33/32, ubest/mbest: 1/0
 *via 35.35.1.254, [1/0], 00:23:44, static
 35.35.1.0/24, ubest/mbest: 1/0, attached
 *via 35.35.1.2, Eth1/7, [0/0], 00:26:46, direct
 35.35.1.2/32, ubest/mbest: 1/0, attached
 *via 35.35.1.2, Eth1/7, [0/0], 00:26:46, local
 44.44.44.44/32, ubest/mbest: 1/0
 *via 45.45.1.254%Shared, [20/0], 00:12:08, bgp-100, external, tag 100
 100.100.100.100/32, ubest/mbest: 1/0
 *via 55.55.55.1%default, [20/0], 00:07:41, bgp-100, external, tag 100

IP Route Table for VRF "Shared"
 '*' denotes best ucast next-hop
 '**' denotes best mcast next-hop
 '[x/y]' denotes [preference/metric]
 '%<string>' in via output denotes VRF <string>
 33.33.33.33/32, ubest/mbest: 1/0
 *via 35.35.1.254%Green, [20/0], 00:12:34, bgp-100, external, tag 100
 44.44.44.44/32, ubest/mbest: 1/0
 *via 45.45.1.254, [1/0], 00:23:16, static
 45.45.1.0/24, ubest/mbest: 1/0, attached
 *via 45.45.1.2, Eth1/11, [0/0], 00:25:53, direct
 45.45.1.2/32, ubest/mbest: 1/0, attached
 *via 45.45.1.2, Eth1/11, [0/0], 00:25:53, local
 100.100.100.100/32, ubest/mbest: 1/0
 *via 55.55.55.1%default, [20/0], 00:07:41, bgp-100, external, tag 100
nexus(config)#
```