C H A P T E R 12

Configuring Layer 3 Virtualization

This chapter describes how to configure Layer 3 virtualization.

This chapter includes the following sections:

Layer 3 Virtualization

This section includes the following topics:

Overview of Layer 3 Virtualization

Cisco NX-OS supports a hierarchy of virtualization that can divide the physical system resources into multiple virtual device contexts (VDCs). Each VDC acts as a standalone device with both Layer 2 and Layer 3 services available. You can configure up to 4 VDCs, including the default VDC. See the *Cisco NX-OS Virtualization Configuration Guide* for more information on VDCs.

Cisco NX-OS further virtualizes each VDC to supports virtual routing and forwarding instances (VRFs). You can configure multiple VRFs in a VDC. Each VRF contains a separate address space with unicast and multicast route tables for IPv4 and IPv6 and makes routing decisions independent of any other VRF.

Figure 12-1 shows multiple independent VRFs in two different VDCs.

Figure 12-1   Multiple VRFs in VDCs

A VRF name is local to a VDC, so you can configure two VRFs with the same name if the VRFs exist in different VDCs. In Figure 12-1, VRF A in VDC 2 is independent of VRF B and VRF A in VDC n.

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 and is accessible from any VDC. Each VDC has a unique IP address for the mgmt0 interface (see the *Cisco Nexus 7000 Series NX-OS Fundamentals Configuration Guide, Release 5.x*).

 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. Figure 12-2 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 12-2   VRFs in a Network
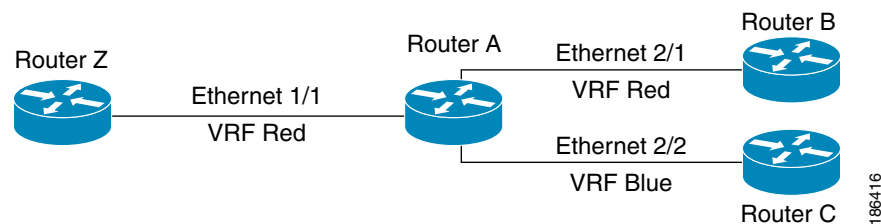
By default, Cisco NX-OS uses the VRF of the incoming interface to select which routing table to use for a route lookup. You can configure a route policy to modify this behavior and set the VRF that Cisco NX-OS uses for incoming packets. See Chapter 17, "Configuring Policy-Based Routing" for more information.

Cisco NX-OS prevents route leakage (import or export) between VRFs.

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—See the *Cisco Nexus 7000 Series NX-OS Security Configuration Guide, Release 5.x*, for more information.

- Call Home—See the *Cisco Nexus 7000 Series NX-OS System Management Configuration Guide, Release 5.x*, for more information.

- HSRP—See Chapter 16, "Configuring HSRP" for more information.

- HTTP—See the *Cisco Nexus 7000 Series NX-OS Fundamentals Configuration Guide, Release 5.x*, for more information.

- Licensing—See the *Cisco NX-OS Licensing Guide* for more information.

- NetFlow—See the *Cisco Nexus 7000 Series NX-OS System Management Configuration Guide, Release 5.x* for more information.

- NTP—See the *Cisco Nexus 7000 Series NX-OS System Management Configuration Guide, Release 5.x*, for more information.

- RADIUS—See the *Cisco Nexus 7000 Series NX-OS Security Configuration Guide, Release 5.x*, for more information.

- Ping and Traceroute —See the *Cisco Nexus 7000 Series NX-OS Fundamentals Configuration Guide, Release 5.x*, for more information.

- SSH—See the *Cisco Nexus 7000 Series NX-OS Fundamentals Configuration Guide, Release 5.x*, for more information.

- SNMP—See the *Cisco Nexus 7000 Series NX-OS System Management Configuration Guide, Release 5.x*, for more information.

- Syslog—See the *Cisco Nexus 7000 Series NX-OS System Management Configuration Guide, Release 5.x*, for more information.

- TACACS+—See the *Cisco Nexus 7000 Series NX-OS Security Configuration Guide, Release 5.x*, for more information.

- TFTP—See the *Cisco Nexus 7000 Series NX-OS Fundamentals Configuration Guide, Release 5.x*, for more information.

- VRRP—See Chapter 17, "Configuring VRRP" for more information.

- XML—See the *Cisco NX-OS XML Management Interface User Guide, Release 5.x* for more information.

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

This section contains the following topics:

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.

Figure 12-3 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 12-3   Service VRF Reachability
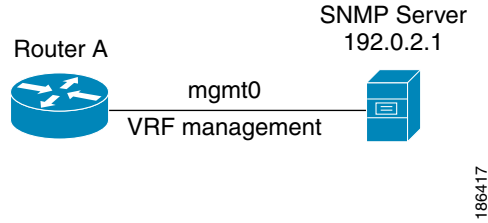
Filtering

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. Figure 12-4 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 12-4   Service VRF Filtering
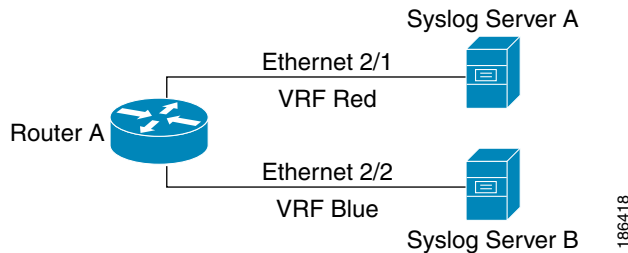
Combining Reachability and Filtering

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.

Figure 12-5 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 12-5   Service VRF Reachability Filtering
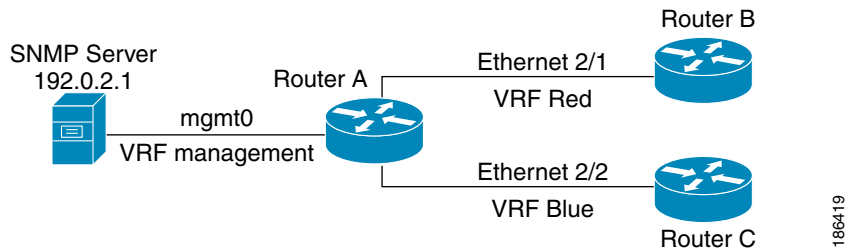
Licensing Requirements for VRFs

The following table shows the licensing requirements for this feature:

Product	License Requirement
Cisco NX-OS	The default inband and outband management VRFs require no license. Any feature not included in a license package is bundled with the Cisco NX-OS system images and is provided at no extra charge to you. For a complete explanation of the Cisco NX-OS licensing scheme, see the *Cisco NX-OS Licensing Guide*.
Cisco NX-OS	VRF-lite requires an Enterprise services license. For a complete explanation of the Cisco NX-OS licensing scheme, see the *Cisco NX-OS Licensing Guide*.

Prerequisites for VRF

VRFs have the following prerequisites:

- You must install the Advanced Services license to use VDCs besides the default VDC.

Guidelines and Limitations

VRFs have the following configuration guidelines and limitations:

- 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.

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, LDP adjacency, 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.

- The Layer 3 TCAM resource is shared between all VRFs. To ensure that any one VRF has sufficient CAM space, use the **maximum routes** command.

- The total number of routes supported by all the VRF's is limited by the size of the TCAM.

- VRF-lite supports BGP, RIP, and static routing.
- VRF-lite does not support EIGRP.
- VRF-lite does not affect the packet switching rate.
- Multicast cannot be configured on the same Layer 3 interface at the same time.

Default Settings

Table 12-1 lists the default settings for VRF parameters.

Table 12-1   Default VRF Parameters

Parameters	Default
Configured VRFs	default, management
routing context	default VRF

Configuring VRFs

This section contains the following topics:

Note If you are familiar with the Cisco IOS CLI, be aware that the Cisco NX-OS commands for this feature might differ from the Cisco IOS commands that you would use.

Creating a VRF

You can create a VRF in a switchvirtual device context (VDC).

BEFORE YOU BEGIN

Ensure that you are in the correct VDC (or use the **switchto vdc** command).

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

	Command	Purpose
Step 1	**configure terminal** **Example:** switch# configure terminal switch(config)#	Enters configuration mode.
Step 2	**vrf context** *name* **Example:** switch(config)# vrf definition 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	**show vrf** [*vrf-name*] **Example:** switch(config-vrf)# show vrf Enterprise	(Optional) Displays VRF information.
Step 5	**copy running-config startup-config** **Example:** switch(config)# copy running-config startup-config	(Optional) Saves this configuration change.

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

Ensure that you are in the correct VDC (or use the **switchto vdc** command).

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. (Optional) **show vrf** *vrf-name* **interface** *interface-type number*
6. (Optional) **copy running-config startup-config**

DETAILED STEPS

	Command	Purpose
Step 1	**configure terminal** **Example:** switch# configure terminal switch(config)#	Enters configuration mode.
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-vrf)# show vrf Enterprise interface ethernet 1/2	(Optional) Displays VRF information.
Step 6	**copy running-config startup-config** **Example:** switch(config)# copy running-config startup-config	(Optional) Saves this configuration change.

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.

BEFORE YOU BEGIN

Ensure that you are in the correct VDC (or use the **switchto vdc** command).

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

	Command	Purpose
Step 1	**configure terminal** **Example:** switch# configure terminal switch(config)#	Enters configuration mode.
Step 2	**router ospf** *instance-tag* **Example:** switch(config-vrf)# 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.

	Command	Purpose
Step 4	**maximum-paths** *paths* Example: switch(config-router-vrf)# maximum-paths 4	(Optional) 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.
Step 9	**copy running-config startup-config** **Example:** switch(config)# copy running-config startup-config	(Optional) Saves this configuration change.

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 on page 12-3 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.

BEFORE YOU BEGIN

Ensure that you are in the correct VDC (or use the **switchto vdc** command).

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

	Command	Purpose
Step 1	**configure terminal** **Example:** switch# configure terminal switch(config)#	Enters configuration mode.
Step 2	**snmp-server host** *ip-address* [**filter-vrf** *vrf-name*] [**use-vrf** *vrf-name*] **Example:** switch(config)# snmp-server host 192.0.2.1 use-vrf Red switch(config-vrf)#	Configures a global SNMP server and configures the VRF that Cisco NX-OS uses to reach the service. Use the **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 switch(config-vrf)#	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	**copy running-config startup-config** **Example:** switch(config)# copy running-config startup-config	(Optional) Saves this configuration change.

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 red`
`switch%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%red# routing-context vrf default`
`switch#`
	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 VRF

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

```
configure terminal
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.:

```
configure terminal
!Create the VRFs
vrf context Red
vrf context Blue
!Create the OSPF instances and associate them with each VRF
feature ospf
router ospf Lab
 vrf Red
router ospf Production
 vrf Blue
!Configure one interface to use ospf Lab on VRF Red
interface ethernet 1/2
 vrf member Red
 ip address 192.0.2.1/16
 ip router ospf Lab area 0
 no shutdown
!Configure another interface to use ospf Production on VRF Blue
interface ethernet 10/2
 vrf member Blue
 ip address 192.0.2.1/16
 ip router ospf Production area 0
 no shutdown
!configure the SNMP server
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 this example.

Related Topics

The following topics can give more information on VRFs:

- *Cisco Nexus 7000 Series NX-OS Fundamentals Configuration Guide, Release 5.x*
- *Cisco Nexus 7000 Series NX-OS System Management Configuration Guide, Release 5.x*

Additional References

For additional information related to implementing virtualization, see the following sections:

- Related Documents, page 12-15
- Standards, page 12-15

Related Documents

Related Topic	Document Title
VRF CLI	*Cisco Nexus 3000 Series Command Reference,*
VDCs	*Cisco Nexus 7000 Series NX-OS Virtual Device Context Configuration Guide, Release 5.x*

Standards

Standards	Title
No new or modified standards are supported by this feature, and support for existing standards has not been modified by this feature.	—

Feature History for VRF

Table 12-2 lists the release history for this feature.

Table 12-2   Feature History for VRF

Feature Name	Releases	Feature Information
VRF	5.0(3)U1(1)	This feature was introduced.