Configuring Layer 2 External Connectivity

Configuring Layer 2 External Connectivity

Layer 2 External Connectivity represents the switching network between the ACI leaf switches (aka border leaf) and an External Router. The VLAN representing the external L2 network is mapped to one of the bridge-domains within the fabric, which provides the Layer 2 extension for the bridge-domain and lets the EPGs using the bridge-domain talk to the outside network. The outside network is mapped to an EPG, which helps in realizing contracts between different internal applications and different L2 outside VLANs across nodes.

Caution Do not mix the GUI and the CLI, when doing per-interface configuration on APIC. Configurations performed in the GUI, may only partially work in the NX-OS CLI.

For example, if you configure a switch port in the GUI at **Tenants** > ***tenant-name*** > **Application Profiles** > ***application-profile-name*** > **Application EPGs** > ***EPG-name*** > **Static Ports** > **Deploy Static EPG on PC, VPC, or Interface**

Then you use the show running-config command in the NX-OS style CLI, you receive output such as:

```
leaf 102
interface ethernet 1/15
switchport trunk allowed vlan 201 tenant t1 application ap1 epg ep1
 exit
 exit
```

If you use these commands to configure a static port in the NX-OS style CLI, the following error occurs:

```
apic1(config)# leaf 102
apic1(config-leaf)# interface ethernet 1/15
apic1(config-leaf-if)# switchport trunk allowed vlan 201 tenant t1 application ap1 epg ep1

No vlan-domain associated to node 102 interface ethernet1/15 encap vlan-201
```

This occurs because the CLI has validations that are not performed by the APIC GUI. For the commands from the show running-config command to function in the NX-OS CLI, a vlan-domain must have been previously configured. The order of configuration is not enforced in the GUI.

The configuration for Layer2 external connectivity is similar to a static application EPG, where you map a VLAN on a node port to an EPG and map the EPG to a bridge-domain to provide/consume contracts.

Procedure

	Command or Action	Purpose
Step 1	Access configuration mode. **Example:** `apic1# configure`	
Step 2	Enter tenant configuration mode. **Example:** `apic1(config)# tenant exampleCorp`	
Step 3	[**no**] **external-l2 epg** *epg-name* **Example:** `apic1(config-tenant)# external-l2 epg extendBD1`	Create (or delete) an external layer 2 EPG.
Step 4	Assign a bridge domain to the EPG. **Example:** `apic1(config-tenant-extl2epg)# bridge-domain member bd1`	
Step 5	Return to tenant configuration mode.	

	Command or Action	Purpose
	Example: `apic1(config-tenant-extl2epg)# exit`	
Step 6	Return to global configuration mode. **Example:** `apic1(config-tenant)# exit`	
Step 7	Specify the leaf to be configured. **Example:** `apic1(config)# leaf 101`	
Step 8	Specify a port for the external EPG. **Example:** `apic1(config-leaf)# interface eth 1/2`	
Step 9	By default, a port is in Layer 2 trunk mode. If the port is in Layer 3 mode, convert it to Layer 2 trunk mode using this command. **Example:** `apic1(config-leaf-if)# switchport`	
Step 10	Associate the interface with a VLAN domain. **Example:** `apic1(config-leaf-if)# vlan-domain member dom1`	
Step 11	Assigns a VLAN on the leaf port and maps the VLAN to a layer 2 external EPG, with the **switchport trunk allowed vlan** *vlan-id* **tenant** *tenant-name* **external-l2 epg** *epg-name* command. **Example:** `apic1(config-leaf-if)# switchport trunk allowed vlan 10 tenant exampleCorp external-l2 epg extendBD1`	**Note** The interface must be associated with a VLAN domain or this command is rejected.
Step 12	Assign a VLAN on the leaf port and map the VLAN to an external SVI with the **switchport** {**trunk allowed** | **trunk native** | **access**} **vlan** *vlan-id* **tenant** *tenant-name* **external-svi** command. **Example:** `apic1(config-leaf-if)# switchport trunk allowed vlan 10 tenant exampleCorp external-svi`	**Note** The interface must be associated with a VLAN domain or this command is rejected.

Examples

This example shows how to deploy a layer 2 port for external connectivity.

```
apic1# configure
apic1(config)# tenant exampleCorp
apic1(config-tenant)# external-l2 epg extendBD1
apic1(config-tenant-extl2epg)# bridge-domain member bd1
apic1(config-tenant-extl2epg)# exit
apic1(config-tenant)# exit

apic1(config)# leaf 101
apic1(config-leaf)# interface eth 1/2
apic1(config-leaf-if)# switchport
apic1(config-leaf-if)# switchport mode trunk
apic1(config-leaf-if)# switchport trunk allowed vlan 10 tenant exampleCorp external-l2 epg
 extendBD1
```

This example shows how to deploy a layer 2 port channel or vPC for external connectivity.

```
...

apic1(config)# leaf 101
apic1(config-leaf)# interface port-channel po1
apic1(config-leaf-if)# switchport trunk allowed vlan 10 tenant exampleCorp external-l2 epg
 extendBD1
```

These examples show how to configure SVI on a layer 2 interface for external connectivity.

```
apic1(config)# leaf 101

pic1(config-leaf)# interface ethernet 1/5
apic1(config-leaf-if)# vlan-domain member dom1
apic1(config-leaf-if)# switchport trunk allowed vlan 10 tenant exampleCorp external-svi
apic1(config-leaf-if)# no switchport trunk allowed vlan 10 tenant exampleCorp external-svi

apic1(config-leaf)# interface ethernet 1/37
apic1(config-leaf-if)# vlan-domain member dom1
apic1(config-leaf-if)# switchport access vlan 11 tenant exampleCorp external-svi
apic1(config-leaf-if)# no switchport access vlan 11 tenant exampleCorp external-svi

apic1(config-leaf)# interface port-channel po34
apic1(config-leaf-if)# vlan-domain member dom1
apic1(config-leaf-if)# switchport trunk native vlan 12 tenant exampleCorp external-svi
apic1(config-leaf-if)# no switchport trunk native vlan 12 tenant exampleCorp external-svi
```

Configuring VLAN Domains

About VLAN Domains

ACI fabric can be partitioned into groups of 4K VLANs to allow a large number of layer 2 domains across the fabric, which can be used by multiple tenants. A VLAN domain represents a set of VLANs that can be configured on group of nodes and ports. VLAN domains let multiple tenants share and independently manage common fabric resources such as nodes, ports, and VLANs. A tenant can be provided access to one or more VLAN domains. For more information about VLAN pools, see *Endpoint Groups* in the *ACI Policy Model* chapter in *Cisco Application Centric Infrastructure Fundamentals*.

VLAN domains can be static or dynamic. Static VLAN domains support static VLAN pools, while dynamic VLAN domains can support both static and dynamic VLAN pools. VLANs in static pools are managed by the user and are used for applications such as connectivity to bare metal hosts. VLANs in the dynamic pool are allocated and managed by the APIC without user intervention and are used for applications such as VMM. The default type for VLAN domains and VLAN pools within the domain is static.

The fabric administrator performs the following steps before tenants can start using the fabric resources for their L2/L3 configurations:

1. Create VLAN domains and assign VLANs in each VLAN domain.
2. Assign the external facing ports on the leaf switches to one or more VLAN domains.
3. Convert a port to L2/L3 by using the **[no] switchport** command. The default state of a port is L2(switchport) in trunk mode.
4. For an L2 port, set the scope of a VLAN on a port to be global or local. The default is global.

The fabric administrator can update any configuration in these steps even after VLAN domains are assigned to tenants and are in use by tenant applications.

A Note About Spanning Tree and VLAN Domains

Although the ACI fabric does not participate in spanning tree, it can partition a spanning tree domain based on access policy configuration. ACI does not rely on a bridge domain or its settings to determine spanning tree domains. Instead, leaf switches flood BPDUs within the same VLAN encapsulation, if a VLAN Pool is assigned to EPG domains. The VLAN pool assigned to EPG domains ultimately serves as the spanning tree domain.

Using multiple EPG domains tied to different VLAN Pools does not allow BPDUs to flood across endpoints properly, even if they are all using the same VLAN ID. The type of EPG domain, (physical or Layer 2 external), does not change this behavior.

Because the ACI Fabric floods all BPDUs from all devices within a spanning-tree domain, this may trigger behaviors on external devices that are verifying BPDU info, such as the MAC address per interface. An example of a feature that activates is "spanning-tree EtherChannel misconfig guard" found on IOS devices. These features should be taken into account when utilizing ACI as a Layer 2 Tunnel.

Note Multiple Spanning Tree (MST) is not supported on interfaces configured with the Per Port VLAN feature (configuring multiple EPGs on a leaf switch using the same VLAN ID with localPort scope).

Basic VLAN Domain Configuration

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `apic1# configure`	Enters global configuration mode.
Step 2	[**no**] **vlan-domain** *domain-name* [**dynamic**] **Example:** `apic1(config)# vlan-domain dom2 dynamic`	Creates a VLAN domain or edits an existing domain. Include the **dynamic** keyword to create a dynamic VLAN pool. The default is static.
Step 3	[**no**] **vlan** *range* [**dynamic**] **Example:** `apic1(config-vlan)# vlan 1000-1999,4001`	Assigns a range or a comma-separated list of VLANs to the VLAN domain. A VLAN can be either static or dynamic. A static VLAN is configured by the user, such as for providing connectivity from a host to an external switched network, while VLANs in the dynamic range are configured internally by an APIC application, such as a VMM or L4-L7 services. The default type is static. **Note** A static domain cannot contain dynamic VLANs. A VLAN on a given port can map to only one vlan-domain. This is enforced during configuration.

Examples

This example shows how to configure basic VLAN domains.

```
apic1# configure
apic1(config)# vlan-domain dom1
apic1(config-vlan)# vlan 1000-1999,4001
apic1(config-vlan)# exit
apic1(config)# vlan-domain dom2 dynamic
apic1(config-vlan)# vlan 101-200
apic1(config-vlan)# vlan 301-400 dynamic
```

Advanced VLAN Domain Configuration

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `apic1# configure`	Enters global configuration mode.
Step 2	[**no**] **vlan-domain** *domain-name* [**dynamic**] [**type** {**phys** | **l2ext** | **l3ext**}] **Example:** `apic1(config)# vlan-domain dom1 type phys`	Creates a VLAN domain or edits an existing domain. Include the **dynamic** keyword to create a dynamic VLAN pool. The default is static. The **type** option is visible and mandatory if one or more of the following conditions exist: • If all three vlan-domain types are not present for this domain name • If the three vlan-domain types have different VLAN pools • If the three vlan-domain types share the same VLAN pool but if the pool name differs from the vlan-domain name
Step 3	[**no**] **vlan-pool** *vlan-pool-name* **Example:** `apic1(config-leaf)# vlan-pool myVlanPool3`	Creates a VLAN pool. This command is available only when the **type** option is present in the **vlan-domain** command. You must declare the VLAN pool before adding VLANs with the **vlan** command.
Step 4	[**no**] **vlan** *range* [**dynamic**] **Example:** `apic1(config-vlan-domain)# vlan 1000-1999,4001`	Assigns a range or a comma-separated list of VLANs to the VLAN domain. A VLAN can be either static or dynamic. A static VLAN is configured by the user, such as for providing connectivity from a host to an external switched network, while VLANs in the dynamic range are configured internally by an APIC application, such as a VMM or L4-L7 services. The default type is static. **Note** A static domain cannot contain dynamic VLANs. A VLAN on a given port can map to only one vlan-domain. This is enforced during configuration.

	Command or Action	Purpose
Step 5	**show vlan-domain** [**name** *domain-name*] [**vlan** *vlan-id*] [**leaf** *leaf-id*] **Example:** `apic1(config-vlan-domain)# show vlan-domain name dom1 vlan 1002 leaf 102`	Displays vlan-domain usage for applications such as App-EPG, sub-interface, external SVI, and external-L2.

Examples

This example shows how to configure a VLAN domain with a VLAN pool.

```
apic1# configure
(config)# vlan-domain dom1 type phys
(config-vlan-domain)# vlan-pool myVlanPool3
(config-vlan-domain)# vlan 1000-1999, 4001
```

Associating a VLAN Domain to a Port

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `apic1# configure`	Enters global configuration mode.
Step 2	**leaf** *node-id1-node-id2* **Example:** `apic1(config)# leaf 101-102`	Specifies the pair of leafs to be configured.
Step 3	**interface** *type* **Example:** `apic1(config-leaf)# int eth 1/1-24`	Specifies a port or range of ports to be associated with the VLAN domain.
Step 4	[**no**] **vlan-domain member** *domain-name* **Example:** `apic1(config-leaf-if)# vlan-domain member dom1`	Assigns the specified ports to the VLAN domain.
Step 5	[**no**] **switchport** **Example:** `apic1(config-leaf-if)# switchport`	By default, a port is in Layer 2 trunk mode. If the port is in Layer 3 mode, it must be converted to Layer 2 trunk mode using this command.

	Command or Action	Purpose
Step 6	(Optional) [**no**] **switchport vlan scope local** **Example:** `apic1(config-leaf-if)# switchport vlan scope local`	By default, the scope of a VLAN is global to the node. One VLAN can be mapped to only one EPG in the node. When the VLAN scope is local to the port, the mapping from VLAN to EPG can be different for different ports on the same node. To return the scope to global, use the **no** command prefix.
Step 7	**show vlan-domain** [**name** *domain-name*] [**vlan** *vlan-id*] [**leaf** *leaf-id*] **Example:** `apic1(config-leaf-if)# show vlan-domain name dom1 vlan 1002 leaf 102`	Displays vlan-domain usage for applications such as App-EPG, external SVI, and external-L2.

Examples

This example shows how to associate a VLAN domain to ports.

```
apic1# configure
(config) # leaf 101-102
(config-leaf) # int eth 1/1-24
(config-leaf-if) # vlan-domain member dom1

(config-leaf) # int eth 1/1-12
(config-leaf-if) # no switchport
(config-leaf) # int eth 1/13-24
(config-leaf-if) # switchport

(config) # leaf 101-102
(config-leaf) # int eth 1/1-12
(config-leaf-if) # switchport vlan scope local

(config-leaf) # int eth 1/13
(config-leaf-if) # no switchport vlan scope local
```

Associating a VLAN Domain to a Port-Channel

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `apic1# configure`	Enters global configuration mode.

	Command or Action	Purpose
Step 2	**leaf** *node-id1-node-id2* **Example:** `apic1(config)# leaf 101-102`	Specifies the pair of leafs to be configured.
Step 3	**interface port-channel** *port-channel-name* **Example:** `apic1(config-leaf)# int port-channel pc1`	Specifies a port-channel to be associated with the VLAN domain.
Step 4	[**no**] **vlan-domain member** *domain-name* **Example:** `apic1(config-leaf-if)# vlan-domain member dom1`	Assigns the specified port-channel to the VLAN domain.

Examples

```
apic1# configure
apic1(config)# leaf 101-102
apic1(config-leaf)# int port-channel pc1
apic1(config-leaf-if)# vlan-domain member dom1
```

Associating a VLAN Domain to a Template Policy-Group

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `apic1# configure`	Enters global configuration mode.
Step 2	**template policy-group** *policy-group-name* **Example:** `apic1(config)# template policy-group myPolGp5`	Specifies the template policy-group to be configured.
Step 3	[**no**] **vlan-domain member** *domain-name* **Example:** `apic1(config-pol-grp-if)# vlan-domain member dom1`	Assigns the specified template policy-group to the VLAN domain.

Examples

```
apic1# configure
apic1(config)# template policy-group myPolGp5
apic1(config-pol-grp-if)# vlan-domain member dom1
```

Associating a VLAN Domain to a Template Port-Channel

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `apic1# configure`	Enters global configuration mode.
Step 2	**template port-channel** *policy-group-name* **Example:** `apic1(config)# template port-channel myPC7`	Specifies the template port-channel to be configured.
Step 3	[**no**] **vlan-domain member** *domain-name* **Example:** `apic1(config-if)# vlan-domain member dom1`	Assigns the specified template port-channel to the VLAN domain.

Examples

```
apic1# configure
apic1(config)# template port-channel myPC7
apic1(config-po-ch-if)# vlan-domain member dom1
```

Associating a VLAN Domain to a Virtual Port-Channel

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `apic1# configure`	Enters global configuration mode.

	Command or Action	Purpose
Step 2	**vpc context leaf** *node-id1 node-id2* [**fex** *fex-id1 fex-id2*] **Example:** `apic1(config)# vpc context leaf 101 102`	Specifies the VPC and leafs to be configured.
Step 3	**interface vpc** *vpc-name* [**fex** *fex-id1 fex-id2*] **Example:** `apic1(config-vpc)# int vpc vpc1`	Specifies a port-channel to be associated with the VLAN domain.
Step 4	[**no**] **vlan-domain member** *domain-name* **Example:** `apic1(config-vpc-if)# vlan-domain member dom1`	Assigns the specified VPC to the VLAN domain.

Examples

```
apic1# configure
apic1(config)# vpc context leaf 101 102
apic1(config-vpc)# int vpc vpc1
apic1(config-vpc-if)# vlan-domain member dom1
```

Configuring Q-in-Q Encapsulation Mapping for EPGs

Q-in-Q Encapsulation Mapping for EPGs

Using Cisco APIC, you can map double-tagged VLAN traffic ingressing on a regular interface, PC, or vPC to an EPG. When this feature is enabled, when double-tagged traffic enters the network for an EPG, both tags are processed individually in the fabric and restored to double-tags when egressing the ACI switch. Ingressing single-tagged and untagged traffic is dropped.

This feature is only supported on Nexus 9300-FX platform switches.

Both the outer and inner tag must be of EtherType 0x8100.

MAC learning and routing are based on the EPG port, sclass, and VRF, not on the access encapsulations.

QoS priority settings are supported, derived from the outer tag on ingress, and rewritten to both tags on egress.

EPGs can simultaneously be associated with other interfaces on a leaf switch, that are configured for single-tagged VLANs.

Service graphs are supported for provider and consumer EPGs that are mapped to Q-in-Q encapsulated interfaces. You can insert service graphs, as long as the ingress and egress traffic on the service nodes is in single-tagged encapsulated frames.

The following features and options are not supported with this feature:

- Per-Port VLAN feature
- FEX connections
- Mixed Mode is not supported. For example, an interface in Q-in-Q encapsulation mode can have a static path binding to an EPG with double-tagged encapsulation only, not with regular VLAN encapsulation.
- STP and the “Flood in Encapsulation” option
- Untagged and 802.1p mode
- Multi-pod and Multi-Site
- Legacy bridge domain
- L2Out and L3Out connections
- VMM integration
- Changing a port mode from routed to Q-in-Q encapsulation mode is not supported
- Per-vlan MCP is not supported between ports in Q-in-Q encapsulation mode and ports in regular trunk mode.
- When vPC ports are enabled for Q-in-Q encapsulation mode, VLAN consistency checks are not performed.

Mapping EPGs to Q-in-Q Encapsulated Leaf Interfaces Using the NX-OS Style CLI

Enable an interface for Q-in-Q encapsulation and associate the interface with an EPG.

Before you begin

Create the tenant, application profile, and application EPG that will be mapped with an interface configured for Q-in-Q mode.

Procedure

	Command or Action	Purpose
Step 1	**Configure** **Example:** `apic1# configure`	Enters global configuration mode.
Step 2	**leaf** *number* **Example:** apic1(config)# leaf 101	Specifies the leaf to be configured.
Step 3	**interface ethernet** *slot/port* **Example:** `apic1 (config-leaf)# interface ethernet 1/25`	Specifies the interface to be configured.

	Command or Action	Purpose
Step 4	**switchport mode dot1q-tunnel** doubleQtagPort **Example:** `apic1(config-leaf-if)# switchport mode dot1q-tunnel doubleQtagPort`	Enables an interface for Q-in-Q encapsulation.
Step 5	**switchport trunk qinq outer-vlan** *vlan-number* **inner-vlan** *vlan-number* **tenant** *tenant-name* **application** *application-name* **epg** *epg-name* **Example:** `apic1(config-leaf-if)# switchport trunk qinq outer-vlan 202 inner-vlan 203 tenant tenant64 application AP64 epg EPG64`	Associates the interface with an EPG.

Example

The following example enables Q-in-Q encapsulation (with outer-VLAN ID 202 and inner-VLAN ID 203) on the leaf interface 101/1/25, and associates the interface with EPG64.

```
apic1(config)# leaf 101
apic1(config-leaf)# interface ethernet 1/25
apic1(config-leaf-if)#switchport mode dot1q-tunnel doubleQtagPort
apic1(config-leaf-if)# switchport trunk qinq outer-vlan 202 inner-vlan 203 tenant tenant64
 application AP64 epg EPG64
```

Support Fibre Channel over Ethernet Traffic on the ACI Fabric

Supporting Fibre Channel over Ethernet Traffic on the ACI Fabric

Cisco ACI enables you to configure and manage support for Fibre Channel over Ethernet (FCoE) traffic on the ACI fabric.

FCoE is a protocol that encapsulates Fibre Channel (FC) packets within Ethernet packets, thus enabling storage traffic to move seamlessly between a Fibre Channel SAN and an Ethernet network.

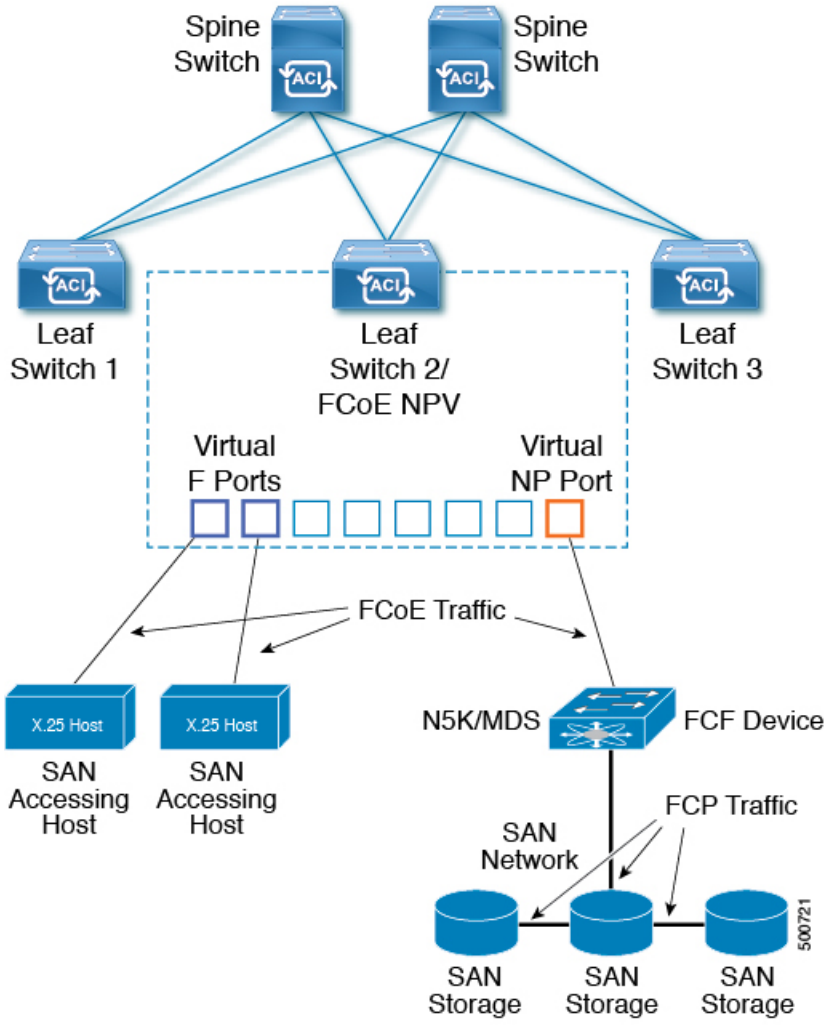
A typical implementation of FCoE protocol support on the ACI fabric enables hosts located on the Ethernet-based ACI fabric to communicate with SAN storage devices located on an FC network. The hosts are connecting through virtual F ports deployed on an ACI leaf switch. The SAN storage devices and FC network are connected through a Fibre Channel Forwarding (FCF) bridge to the ACI fabric through a virtual NP port, deployed on the same ACI leaf switch as is the virtual F port. Virtual NP ports and virtual F ports are also referred to generically as virtual Fibre Channel (vFC) ports.

Note In the FCoE topology, the role of the ACI leaf switch is to provide a path for FCoE traffic between the locally connected SAN hosts and a locally connected FCF device. The leaf switch does not perform local switching between SAN hosts, and the FCoE traffic is not forwarded to a spine switch.

Topology Supporting FCoE Traffic Through ACI

The topology of a typical configuration supporting FCoE traffic over the ACI fabric consists of the following components:

Figure 1: ACI Topology Supporting FCoE Traffic



- One or more ACI leaf switches configured through FC SAN policies to function as an NPV backbone.
- Selected interfaces on the NPV-configured leaf switches configured to function as virtual F ports, which accommodate FCoE traffic to and from hosts running SAN management or SAN-consuming applications.
- Selected interfaces on the NPV-configured leaf switches configured to function as virtual NP ports, which accommodate FCoE traffic to and from a Fibre Channel Forwarding (FCF) bridge.

The FCF bridge receives FC traffic from fibre channel links typically connecting SAN storage devices and encapsulates the FC packets into FCoE frames for transmission over the ACI fabric to the SAN management or SAN Data-consuming hosts. It receives FCoE traffic and repackages it back to FC for transmission over the fibre channel network.

Note In the above ACI topology, FCoE traffic support requires direct connections between the hosts and virtual F ports and direct connections between the FCF device and the virtual NP port.

APIC servers enable an operator to configure and monitor the FCoE traffic through the APIC GUI, the APIC NX-OS style CLI, or through application calls to the APIC REST API.

Topology Supporting FCoE Initialization

In order for FCoE traffic flow to take place as described, you must also set up separate VLAN connectivity over which SAN Hosts broadcast FCoE Initialization protocol (FIP) packets to discover the interfaces enabled as F ports.

vFC Interface Configuration Rules

Whether you set up the vFC network and EPG deployment through the APIC GUI, NX-OS style CLI, or the REST API, the following general rules apply across platforms:

- F port mode is the default mode for vFC ports. NP port mode must be specifically configured in the Interface policies.
- The load balancing default mode is for leaf-switch or interface level vFC configuration is src-dst-ox-id.
- One VSAN assignment per bridge domain is supported.
- The allocation mode for VSAN pools and VLAN pools must always be static.
- vFC ports require association with a VSAN domain (also called Fibre Channel domain) that contains VSANs mapped to VLANs.

FCoE Guidelines and Limitations

FCoE is supported on the following switches:

- N9K-C93180LC-EX (When 40 Gigabit Ethernet (GE) ports are enabled as FCoE F or NP ports, they cannot be enabled for 40GE port breakout. FCoE is not supported on breakout ports.)
- N9K-C93108TC-EX
- N9K-C93180YC-EX
- N9K-C93180LC-EX (FCoE support on FEX ports)
- N9K-C93180YC-FX (FCoE support on FEX ports, 40G ports (1/49-54), and 4x10G breakout ports)

FCoE is supported on the following Nexus FEX devices:

- N2K-C2348UPQ-10GE
- N2K-C2348TQ-10GE
- N2K-C2232PP-10GE
- N2K-B22DELL-P
- N2K-B22HP-P

- N2K-B22IBM-P
- N2K-B22DELL-P-FI

The vlan used for FCoE should have vlanScope set to Global. vlanScope set to portLocal is not supported for FCoE. The value is set via the L2 Interface Policy l2IfPol.

FCoE NX-OS Style CLI Configuration

Configuring FCoE Connectivity Without Policies or Profiles Using the NX-OS Style CLI

The following sample NX-OS style CLI sequences configure FCoE connectivity for EPG **e1** under tenant **t1** without configuring or applying switch-level and interface-level policies and profiles.

Procedure

	Command or Action	Purpose

Step 1	Under the target tenant configure a bridge domain to support FCoE traffic.
	Example:
	`apic1(config)# tenant t1`
	`apic1(config-tenant)# vrf context v1`
	`apic1(config-tenant-vrf)# exit`
	`apic1(config-tenant)# bridge-domain b1`
	`apic1(config-tenant-bd)# fc`
	`apic1(config-tenant-bd)# vrf member v1`
	`apic1(config-tenant-bd)# exit`
	`apic1(config-tenant)# exit`
		The sample command sequence creates bridge domain **b1** under tenant **t1** configured to support FCoE connectivity.

Step 2	Under the same tenant, associate the target EPG with the FCoE-configured bridge domain.
	Example:
	`apic1(config)# tenant t1`
	`apic1(config-tenant)# application a1`
	`apic1(config-tenant-app)# epg e1`
	`apic1(config-tenant-app-epg)#`
	`bridge-domain member b1`
	`apic1(config-tenant-app-epg)# exit`
	`apic1(config-tenant-app)# exit`
	`apic1(config-tenant)# exit`
		The sample command sequence creates EPG **e1** and associates that EPG with the FCoE-configured bridge domain **b1**.

Step 3	Create a VSAN domain, VSAN pools, VLAN pools and VSAN to VLAN mapping.
	Example:
	A
	`apic1(config)# vsan-domain dom1`
	`apic1(config-vsan)# vsan 1-10`
	`apic1(config-vsan)# vlan 1-10`
		In **Example A**, the sample command sequence creates VSAN domain, **dom1** with VSAN pools and VLAN pools, maps VSAN 1 to VLAN 1 and maps VSAN 2 to VLAN 2
		In **Example B**, an alternate sample command sequence creates a reusable VSAN attribute template **pol1** and then creates VSAN domain

	Command or Action	Purpose
	apic1(config-vsan)# fcoe vsan 1 vlan 1 loadbalancing src-dst-ox-id apic1(config-vsan)# fcoe vsan 2 vlan 2 **Example:** **B** apic1(config)# template vsan-attribute pol1 apic1(config-vsan-attr)# fcoe vsan 2 vlan 12 loadbalancing src-dst-ox-id apic1(config-vsan-attr)# fcoe vsan 3 vlan 13 loadbalancing src-dst-ox-id apic1(config-vsan-attr)# exit apic1(config)# vsan-domain dom1 apic1(config-vsan)# vsan 1-10 apic1(config-vsan)# vlan 1-10 apic1(config-vsan)# inherit vsan-attribute pol1 apic1(config-vsan)# exit	**dom1**, which inherits the attributes and mappings from that template.
Step 4	Create the physical domain to support the FCoE Initialization (FIP) process. **Example:** apic1(config)# vlan-domain fipVlanDom apic1(config-vlan)# vlan 120 apic1(config-vlan)# exit	In the example, the command sequence creates a regular VLAN domain, **fipVlanDom**, which includes VLAN **120** to support the FIP process.
Step 5	Under the target tenant configure a regular bridge domain. **Example:** apic1(config)# tenant t1 apic1(config-tenant)# vrf context v2 apic1(config-tenant-vrf)# exit apic1(config-tenant)# bridge-domain fip-bd apic1(config-tenant-bd)# vrf member v2 apic1(config-tenant-bd)# exit apic1(config-tenant)# exit	In the example, the command sequence creates bridge domain **fip-bd**.
Step 6	Under the same tenant, associate this EPG with the configured regular bridge domain. **Example:** apic1(config)# tenant t1 apic1(config-tenant)# application a1 apic1(config-tenant-app)# epg epg-fip apic1(config-tenant-app-epg)# bridge-domain member fip-bd apic1(config-tenant-app-epg)# exit apic1(config-tenant-app)# exit apic1(config-tenant)# exit	In the example, the command sequence associates EPG **epg-fip** with bridge domain **fip-bd**.
Step 7	Configure a VFC interface with F mode. **Example:**	In example **A** the command sequence enables interface **1/2** on leaf switch **101** to function as

	Command or Action	Purpose

	A
	`apic1(config)# leaf 101`
	`apic1(config-leaf)# interface ethernet 1/2`
	`apic1(config-leaf-if)# vlan-domain member fipVlanDom`
	`apic1(config-leaf-if)# switchport trunk native vlan 120 tenant t1 application a1 epg epg-fip`
	`apic1(config-leaf-if)# exit`
	
	`apic1(config-leaf)# exit`
	`apic1(config-leaf)# interface vfc 1/2`
	`apic1(config-leaf-if)# switchport mode f`
	`apic1(config-leaf-if)# vsan-domain member dom1`
	`apic1(config-leaf-if)# switchport vsan 2 tenant t1 application a1 epg e1`
	`apic1(config-leaf-if)# switchport trunk allowed vsan 3 tenant t1 application a1 epg e2`
	`apic1(config-leaf-if)# exit`
	Example:
	B
	`apic1(config)# vpc context leaf 101 102`
	`apic1(config-vpc)# interface vpc vpc1`
	`apic1(config-vpc-if)# vlan-domain member vfdom100`
	`apic1(config-vpc-if)# vsan-domain member dom1`
	`apic1(config-vpc-if)# #For FIP discovery`
	`apic1(config-vpc-if)# switchport trunk native vlan 120 tenant t1 application a1 epg epg-fip`
	`apic1(config-vpc-if)# switchport vsan 2 tenant t1 application a1 epg e1`
	`apic1(config-vpc-if)# exit`
	`apic1(config-vpc)# exit`
	`apic1(config)# leaf 101-102`
	`apic1(config-leaf)# interface ethernet 1/3`
	`apic1(config-leaf-if)# channel-group vpc1 vpc`
	`apic1(config-leaf-if)# exit`
	`apic1(config-leaf)# exit`
	Example:
	C
	`apic1(config)# leaf 101`
	`apic1(config-leaf)# interface vfc-po pc1`
	`apic1(config-leaf-if)# vsan-domain member dom1`
	`apic1(config-leaf-if)# switchport vsan 2 tenant t1 application a1 epg e1`
	`apic1(config-leaf-if)# exit`
	`apic1(config-leaf)# interface ethernet 1/2`
		an **F** port and associates that interface with VSAN domain **dom1**.
		Each of the targeted interfaces must be assigned one (and only one) VSAN in native mode. Each interface may be assigned one or more additional VSANs in regular mode.
		The sample command sequence associates the target interface **1/2** with:
		• VLAN **120** for FIP discovery and associates it with EPG **epg-fip** and application **a1** under tenant **t1**.
		• VSAN **2** as a native VSAN and associates it with EPG **e1** and application **a1** under tenant **t1**.
		• VSAN **3** as a regular VSAN.
		In example **B**, the command sequence configures a vFC over a vPC with the same VSAN on both the legs. From the CLI you cannot specify different VSANs on each log. The alternate configuration can be carried out in the APIC advanced GUI.

	Command or Action	Purpose

	`apic1(config-leaf-if)# channel-group pc1`
	`apic1(config-leaf-if)# exit`
	`apic1(config-leaf)# exit`	

Step 8	Configure a VFC interface with NP mode.
	Example:
	`apic1(config)# leaf 101`
	`apic1(config-leaf)# interface vfc 1/4`
	`apic1(config-leaf-if)# switchport mode np`
	`apic1(config-leaf-if)# vsan-domain member dom1`
		The sample command sequence enables interface **1/4** on leaf switch **101** to function as an **NP** port and associates that interface with VSAN domain **dom1**.

Step 9	Assign the targeted FCoE-enabled interfaces a VSAN.
	Example:
	`apic1(config-leaf-if)# switchport trunk allowed vsan 1 tenant t1 application a1 epg e1`
	`apic1(config-leaf-if)# switchport vsan 2 tenant t4 application a4 epg e4`
		Each of the targeted interfaces must be assigned one (and only one) VSAN in native mode. Each interface may be assigned one or more additional VSANs in regular mode.
		The sample command sequence assigns the target interface to VSAN **1** and associates it with EPG **e1** and application **a1** under tenant **t1**. "trunk allowed" assigns vsan 1 regular mode status. The command sequence also assigns the interface a required **native mode** VSAN **2**. As this example shows, it is permissible for different VSANs to provide different EPGs running under different tenants access to the same interfaces.

Configuring FCoE Connectivity With Policies and Profiles Using the NX-OS Style CLI

The following sample NX-OS style CLI sequences create and use policies to configure FCoE connectivity for EPG **e1** under tenant **t1**.

Procedure

	Command or Action	Purpose

Step 1	Under the target tenant configure a bridge domain to support FCoE traffic.
	Example:
	`apic1# configure`
	`apic1(config)# tenant t1`
	`apic1(config-tenant)# vrf context v1`
	`apic1(config-tenant-vrf)# exit`
	`apic1(config-tenant)# bridge-domain b1`
	
	`apic1(config-tenant-bd)# fc`
	`apic1(config-tenant-bd)# vrf member v1`
	`apic1(config-tenant-bd)# exit`
		The sample command sequence creates bridge domain **b1** under tenant **t1** configured to support FCoE connectivity.

	Command or Action	Purpose
	`apic1(config-tenant)# exit` `apic1(config)#`	

Step 2	Under the same tenant, associate your target EPG with the FCoE configured bridge domain.
	Example:
	`apic1(config)# tenant t1`
	`apic1(config-tenant)# application a1`
	`apic1(config-tenant-app)# epg e1`
	`apic1(config-tenant-app-epg)#`
	`bridge-domain member b1`
	`apic1(config-tenant-app-epg)# exit`
	`apic1(config-tenant-app)# exit`
	`apic1(config-tenant)# exit`
	`apic1(config)#`
		The sample command sequence creates EPG **e1** associates that EPG with FCoE-configured bridge domain **b1**.

Step 3	Create a VSAN domain, VSAN pools, VLAN pools and VSAN to VLAN mapping.
	Example:
	A
	`apic1(config)# vsan-domain dom1`
	`apic1(config-vsan)# vsan 1-10`
	`apic1(config-vsan)# vlan 1-10`
	`apic1(config-vsan)# fcoe vsan 1 vlan 1`
	`loadbalancing`
	`src-dst-ox-id`
	`apic1(config-vsan)# fcoe vsan 2 vlan 2`
	Example:
	B
	`apic1(config)# template vsan-attribute`
	`pol1`
	`apic1(config-vsan-attr)# fcoe vsan 2`
	`vlan 12`
	`loadbalancing`
	`src-dst-ox-id`
	`apic1(config-vsan-attr)# fcoe vsan 3`
	`vlan 13`
	`loadbalancing`
	`src-dst-ox-id`
	`apic1(config-vsan-attr)# exit`
	`apic1(config)# vsan-domain dom1`
	`apic1(config-vsan)# inherit`
	`vsan-attribute pol1`
	`apic1(config-vsan)# exit`
		In **Example A**, the sample command sequence creates VSAN domain, **dom1** with VSAN pools and VLAN pools, maps VSAN 1 VLAN 1 and maps VSAN 2 to VLAN 2
		In **Example B**, an alternate sample command sequence creates a reusable vsan attribute template **pol1** and then creates VSAN domain **dom1**, which inherits the attributes and mappings from that template.

Step 4	Create the physical domain to support the FCoE Initialization (FIP) process.
	Example:
	`apic1(config)# vlan-domain fipVlanDom`
	`apic1(config)# vlan-pool fipVlanPool`	

	Command or Action	Purpose

Step 5	Configure a Fibre Channel SAN policy.
	Example:
	`apic1#`
	`apic1# configure`
	`apic1(config)# template fc-fabric-policy ffp1`
	`apic1(config-fc-fabric-policy)# fctimer e-d-tov 1111`
	`apic1(config-fc-fabric-policy)# fctimer r-a-tov 2222`
	`apic1(config-fc-fabric-policy)# fcoe fcmap 0E:FC:01`
	`apic1(config-fc-fabric-policy)# exit`
		The sample command sequence creates Fibre Channel SAN policy **ffp1** to specify a combination of error-detect timeout values (EDTOV), resource allocation timeout values (RATOV), and the default FC map values for FCoE-enabled interfaces on a target leaf switch.

Step 6	Create a Fibre Channel node policy.
	Example:
	`apic1(config)# template fc-leaf-policy flp1`
	`apic1(config-fc-leaf-policy)# fcoe fka-adv-period 44`
	`apic1(config-fc-leaf-policy)# exit`
		The sample command sequence creates Fibre Channel node policy **flp1** to specify a combination of disruptive load-balancing enablement and FIP keep-alive values. These values also apply to all the FCoE-enabled interfaces on a target leaf switch.

Step 7	Create Node Policy Group.
	Example:
	`apic1(config)# template leaf-policy-group lpg1`
	`apic1(config-leaf-policy-group)# inherit fc-fabric-policy ffp1`
	`apic1(config-leaf-policy-group)# inherit fc-leaf-policy flp1`
	`apic1(config-leaf-policy-group)# exit`
	`apic1(config)# exit`
	`apic1#`
		The sample command sequence creates a Node Policy group, **lpg1**, which combines the values of the Fibre Channel SAN policy **ffp1** and Fibre Channel node policy, **flp1**. The combined values of this node policy group can be applied to Node profiles configured later.

Step 8	Create a Node Profile.
	Example:
	`apic1(config)# leaf-profile lp1`
	`apic1(config-leaf-profile)# leaf-group lg1`
	`apic1(config-leaf-group)# leaf 101`
	`apic1(config-leaf-group)# leaf-policy-group lpg1`
		The sample command sequence creates node profile **lp1** associates it with node policy group **lpg1**, node group **lg1**, and leaf switch **101**.

Step 9	Create an interface policy group for F port interfaces.
	Example:
	`apic1(config)# template policy-group ipg1`
	`apic1(config-pol-grp-if)# priority-flow-control mode auto`
	`apic1(config-pol-grp-if)# switchport mode f`
	`apic1(config-pol-grp-if)# slow-drain pause timeout 111`
		The sample command sequence creates interface policy group **ipg1** and assigns a combination of values that determine priority flow control enablement, F port enablement, and slow-drain policy values for any interface that this policy group is applied to.

	Command or Action	Purpose
	`apic1(config-pol-grp-if)# slow-drain congestion-timeout count 55` `apic1(config-pol-grp-if)# slow-drain congestion-timeout action log`	

Step 10	Create an interface policy group for NP port interfaces.
	Example:
	`apic1(config)# template policy-group ipg2`
	`apic1(config-pol-grp-if)# priority-flow-control mode auto`
	`apic1(config-pol-grp-if)# switchport mode np`
	`apic1(config-pol-grp-if)# slow-drain pause timeout 111`
	`apic1(config-pol-grp-if)# slow-drain congestion-timeout count 55`
	`apic1(config-pol-grp-if)# slow-drain congestion-timeout action log`
		The sample command sequence creates interface policy group **ipg2** and assigns a combination of values that determine priority flow control enablement, NP port enablement, and slow-drain policy values for any interface that this policy group is applied to.

Step 11	Create an interface profile for F port interfaces.
	Example:
	`apic1# configure`
	`apic1(config)# leaf-interface-profile lip1`
	`apic1(config-leaf-if-profile)# description 'test description lip1'`
	`apic1(config-leaf-if-profile)# leaf-interface-group lig1`
	`apic1(config-leaf-if-group)# description 'test description lig1'`
	`apic1(config-leaf-if-group)# policy-group ipg1`
	`apic1(config-leaf-if-group)# interface ethernet 1/2-6, 1/9-13`
		The sample command sequence creates an interface profile **lip1** for F port interfaces, associates the profile with F port specific interface policy group **ipg1**, and specifies the interfaces to which this profile and its associated policies applies.

Step 12	Create an interface profile for NP port interfaces.
	Example:
	`apic1# configure`
	`apic1(config)# leaf-interface-profile lip2`
	`apic1(config-leaf-if-profile)# description 'test description lip2'`
	`apic1(config-leaf-if-profile)# leaf-interface-group lig2`
	`apic1(config-leaf-if-group)# description 'test description lig2'`
	`apic1(config-leaf-if-group)# policy-group ipg2`
	`apic1(config-leaf-if-group)# interface ethernet 1/14`
		The sample command sequence creates an interface profile **lip2** for NP port interfaces, associates the profile with NP port specific interface policy group **ipg2**, and specifies the interface to which this profile and its associated policies applies.

	Command or Action	Purpose

Step 13	Configure QoS Class Policy for Level 1.
	Example:
	`apic1(config)# qos parameters level1`
	`apic1(config-qos)# pause no-drop cos 3`
		The sample command sequence specifies the QoS level of FCoE traffic to which priority flow control policy might be applied and pauses no-drop packet handling for Class of Service level 3.

Configuring FCoE Over FEX Using NX-OS Style CLI

FEX ports are configured as port VSANs.

Procedure

Step 1 Configure Tenant and VSAN domain:

Example:

```
apic1# configure
apic1(config)#  tenant t1
apic1(config-tenant)#   vrf context v1
apic1(config-tenant-vrf)#     exit
apic1(config-tenant)#   bridge-domain b1
apic1(config-tenant-bd)#       fc
apic1(config-tenant-bd)#       vrf member v1
apic1(config-tenant-bd)#       exit
apic1(config-tenant)#   application a1
apic1(config-tenant-app)#      epg e1
apic1(config-tenant-app-epg)# bridge-domain member b1
apic1(config-tenant-app-epg)# exit
apic1(config-tenant-app)#      exit
apic1(config-tenant)# exit

apic1(config)#  vsan-domain dom1
apic1(config-vsan)# vlan 1-100
apic1(config-vsan)# vsan 1-100
apic1(config-vsan)# fcoe vsan 2 vlan 2 loadbalancing src-dst-ox-id
apic1(config-vsan)# fcoe vsan 3 vlan 3 loadbalancing src-dst-ox-id
apic1(config-vsan)# fcoe vsan 5 vlan 5
apic1(config-vsan)# exit
```

Step 2 Associate FEX to an interface:

Example:

```
apic1(config)#  leaf 101
apic1(config-leaf)#  interface ethernet 1/12
apic1(config-leaf-if)#  fex associate 111
apic1(config-leaf-if)#  exit
```

Step 3 Configure FCoE over FEX per port, port-channel, and VPC:

Example:

```
apic1(config-leaf)#  interface vfc 111/1/2
apic1(config-leaf-if)#  vsan-domain member dom1
apic1(config-leaf-if)#  switchport vsan 2 tenant t1 application a1 epg e1
```

```
apic1(config-leaf-if)# exit

apic1(config-leaf)#  interface vfc-po pc1 fex 111
apic1(config-leaf-if)# vsan-domain member dom1
apic1(config-leaf-if)# switchport vsan 2 tenant t1 application a1 epg e1
apic1(config-leaf-if)# exit
apic1(config-leaf)# interface ethernet 111/1/3
apic1(config-leaf-if)# channel-group pc1
apic1(config-leaf-if# exit
apic1(config-leaf)# exit

apic1(config)# vpc domain explicit 12 leaf 101 102
apic1(config-vpc)# exit
apic1(config)# vpc context leaf 101 102
apic1(config-vpc)#     interface vpc vpc1 fex 111 111
apic1(config-vpc-if)#       vsan-domain member dom1
apic1(config-vpc-if)#       switchport vsan 2 tenant t1 application a1 epg e1
apic1(config-vpc-if)#       exit
apic1(config-vpc)#     exit
apic1(config)# leaf 101-102
apic1(config-leaf)# interface ethernet 1/2
apic1(config-leaf-if)# fex associate 111
apic1(config-leaf-if)# exit
apic1(config-leaf)# interface ethernet 111/1/2
apic1(config-leaf-if)# channel-group vpc1 vpc
apic1(config-leaf-if)# exit
```

Step 4 Verify the configuration with the following command:

Example:

```
apic1(config-vpc)# show vsan-domain detail
vsan-domain : dom1

vsan : 1-100

vlan : 1-100

Leaf          Interface         Vsan  Vlan  Vsan-Mode    Port-Mode  Usage
Operational State
------------  ----------------  ----  ----  -----------  ---------
---------------------------------------
101           vfc111/1/2       2       2    Native                  Tenant: t1
Deployed
                                                                     App: a1
                                                                     Epg: e1

101           PC:pc1           5       5    Native                Tenant: t1
Deployed
                                                                     App: a1
                                                                     Epg: e1

101           vfc111/1/3       3       3    Native       F          Tenant: t1
Deployed
                                                                     App: a1
                                                                     Epg: e1
```

Verifying FCoE Configuration Using the NX-OS Style CLI

The following **show** command verifies the FCoE configuration on your leaf switch ports.

Procedure

Use the **show vsan-domain** command to verify FCoE is enabled on the target switch.

The command example confirms FCoE enabled on the listed leaf switches and its FCF connection details.

Example:

```
ifav-isim8-ifc1# show vsan-domain detail
vsan-domain : iPostfcoeDomP1

vsan : 1-20  51-52  100-102  104-110  200  1999  3100-3101  3133
       2000

vlan : 1-20  51-52  100-102  104-110  200  1999  3100-3101  3133
       2000

                                    Vsan    Port                    Operational
 Leaf  Interface       Vsan  Vlan   Mode    Mode  Usage             State
 ----  ---------       ----  ----   ------- ----  ----------------  ------------
 101   vfc1/11         1     1      Regular  F    Tenant: iPost101  Deployed

                                                 App: iPost1

                                                 Epg: iPost1


 101   vfc1/12         1     1      Regular  NP   Tenant: iPost101  Deployed

                                                 App: iPost1

                                                 Epg: iPost1


 101   PC:infraAccBndl 4     4      Regular  NP   Tenant: iPost101  Deployed

          Grp_pc01                               App: iPost4

                                                 Epg: iPost4


 101   vfc1/30         2000        Native        Tenant: t1        Not deployed
                                                 App: a1           (invalid-path)

                                                 Epg: e1
```

Undeploying FCoE Elements Using the NX-OS Style CLI

Any move to undeploy FCoE connectivity from the ACI fabric requires that you remove the FCoE components on several levels.

Procedure

Step 1 List the attributes of the leaf port interface, set its mode setting to default, and then remove its EPG deployment and domain association.

The example sets the port mode setting of interface vfc **1/2** to default and then removes the deployment of EPG **e1** and the association with VSAN Domain **dom1** from that interface.

Example:

```
apic1(config)# leaf 101
apic1(config-leaf)# interface vfc 1/2
apic1(config-leaf-if)# show run
# Command: show running-config leaf 101 interface vfc 1 / 2
# Time: Tue Jul 26 09:41:11 2016
  leaf 101
    interface vfc 1/2
      vsan-domain member dom1
      switchport vsan 2 tenant t1 application a1 epg e1
      exit
    exit
apic1(config-leaf-if)# no switchport mode
apic1(config-leaf-if)# no switchport vsan 2 tenant t1 application a1 epg e1
apic1(config-leaf-if)# no vsan-domain member dom1
apic1(config-leaf-if)# exit
apic1(config-leaf)# exit
```

Step 2 List and remove the VSAN/VLAN mapping and the VLAN and VSAN pools.

The example removes the VSAN/VLAN mapping for **vsan 2**, VLAN pool **1-10**, and VSAN pool **1-10** from VSAN domain **dom1**.

Example:

```
apic1(config)# vsan-domain dom1
apic1(config-vsan)# show run
# Command: show running-config vsan-domain dom1
# Time: Tue Jul 26 09:43:47 2016
  vsan-domain dom1
    vsan 1-10
    vlan 1-10
    fcoe vsan 2 vlan 2
    exit
apic1(config-vsan)# no fcoe vsan 2
apic1(config-vsan)# no vlan 1-10
apic1(config-vsan)# no vsan 1-10
apic1(config-vsan)# exit

################################################################################
NOTE: To remove a template-based VSAN to VLAN mapping use an alternate sequence:
################################################################################

apic1(config)# template vsan-attribute <template_name>
apic1(config-vsan-attr)# no fcoe vsan 2
```

Step 3 Delete the VSAN Domain.

The example deletes VSAN domain **dom1**.

Example:

```
apic1(config)# no vsan-domain dom1
```

Step 4 You can delete the associated tenant, EPG, and selectors if you do not need them.

Fibre Channel NPV

Fibre Channel Connectivity Overview

A switch is in NPV mode after enabling NPV. NPV mode applies to an entire switch. All end devices connected to a switch that are in NPV mode must log in as an N port to use this feature (loop-attached devices are not supported). All links from the edge switches (in NPV mode) to the NPV core switches are established as NP ports (not E ports), which are used for typical inter-switch links.

FC NPV Benefits

FC NPV provides the following:

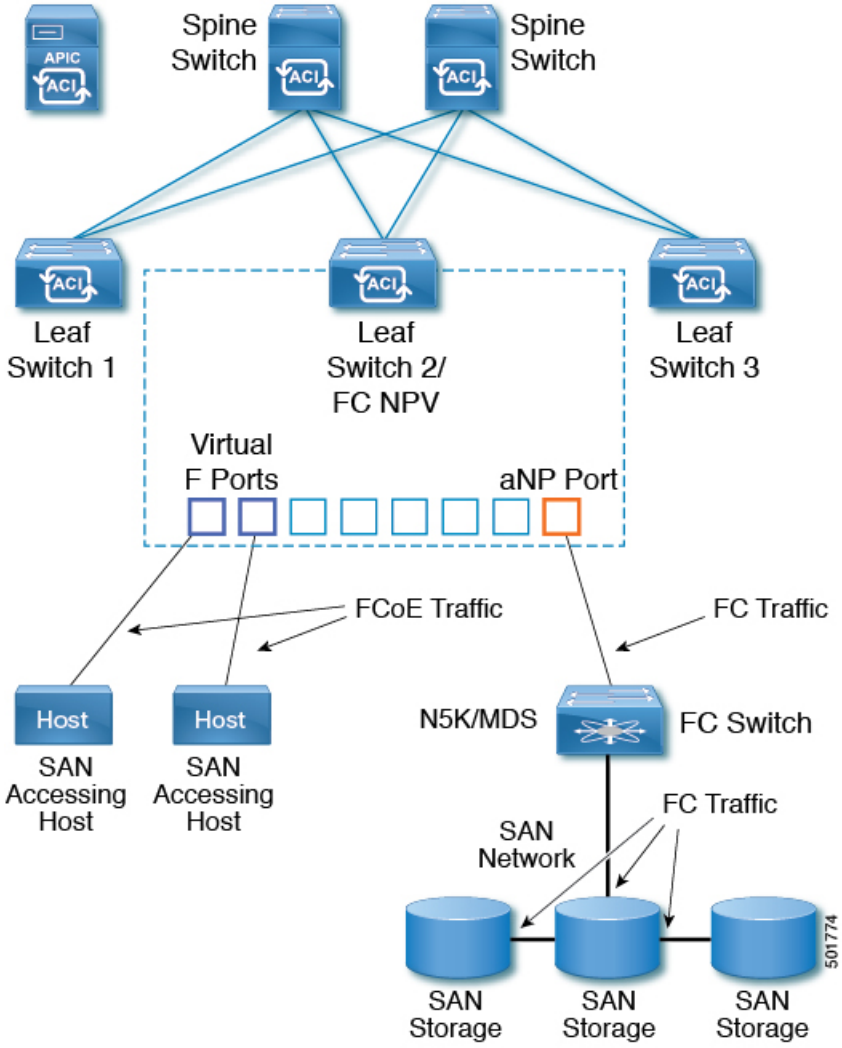
- Increased number of hosts that connect to the fabric without adding domain IDs in the fabric
- Connection of FC and FCoE hosts and targets to SAN fabrics using FC interfaces
- Automatic traffic mapping
- Static traffic mapping
- Disruptive automatic load balancing

FC NPV Mode

Feature-set fcoe-npv in ACI will be enabled automatically by default when first FCoE/FC configuration is pushed.

FC Topology

The topology of a typical configuration supporting FC traffic over the ACI fabric consists of the following components:



- A Leaf can be connected to a FC switch by using FCoE NP port or native FC NP port.
- An ACI Leaf can be directly connected with a server/Storage using FCoE links.
- FC/FCoE traffic is not sent to fabric/spine. A Leaf switch does not do local switching for FCoE traffic. The switching is done by a core switch which is connected with a leaf switch via FC/FCoE NPV link.
- Multiple FDISC followed by Flogi is supported with FCoE host and FC/FCoE NP links.

Fibre Channel N-Port Virtualization Guidelines and Limitations

When configuring Fibre Channel N-Port Virtualization (NPV), note the following guidelines and limitations:

- Fibre Channel NP ports support trunk mode, but Fibre Channel F ports do not.
- On a trunk Fibre Channel port, internal login happens on the highest VSAN.
- On the core switch, the following features must be enabled:

```
feature npiv
feature fport-channel-trunk
```

- To use an 8G uplink speed, you must configure the IDLE fill pattern on the core switch.

Note Following is an example of configuring IDLE fill pattern on a Cisco MDS switch:

```
Switch(config)# int fc2/3
Switch(config)# switchport fill-pattern IDLE speed 8000
Switch(config)# show run int fc2/3

interface fc2/3
switchport speed 8000
switchport mode NP
switchport fill-pattern IDLE speed 8000
no shutdown
```

- In the Cisco APIC 4.1(1) release and later, Fibre Channel NPV support is limited to the Cisco N9K-C93180YC-FX switch.
- You can use ports 1 through 48 for Fibre Channel configuration. Ports 49 through 54 cannot be Fibre Channel ports.
- If you convert a port from Ethernet to Fibre Channel or the other way around, you must reload the switch. Currently, you can convert only one contiguous range of ports to Fibre Channel ports, and this range must be a multiple of 4, ending with a port number that is a multiple of 4. For example, 1-4, 1-8, or 21-24.
- Fibre Channel Uplink (NP) connectivity to Brocade Port Blade Fibre Channel 16-32 is not supported when a Cisco N9K-93180YC-FX leaf switch port is configured in 8G speed.
- The selected port speed must be supported by the SFP. For example, because a 32G SFP supports 8/16/32G, a 4G port speed requires an 8G or 16G SFP. Because a 16G SFP supports 4/8/16G, a 32G port speed requires a 32G SFP.
- Speed autonegotiation is supported. The default speed is 'auto'.
- You cannot use Fibre Channel on 40G and breakout ports.
- FEX cannot be directly connected to FC ports.
- FEX HIF ports cannot be converted to FC.

Configuring FC Connectivity Without Policies or Profiles Using the NX-OS CLI

The sample command sequence below creates bridge domain b1 under tenant t1 configured to support FCoE connectivity.

Before you begin

- Under the target tenant configure a bridge domain to support FCoE traffic.

Procedure

Step 1 To create a bridge domain for FCoE connectivity:

Example:

```
apic1(config)# tenant t1
apic1(config-tenant)# vrf context v1
apic1(config-tenant-vrf)# exit
apic1(config-tenant)# bridge-domain b1
apic1(config-tenant-bd)# fc
apic1(config-tenant-bd)# vrf member v1
apic1(config-tenant-bd)# exit
apic1(config-tenant)# exit
```

Step 2 Under the same tenant, associate the target EPG with the FCoE-configured bridge domain. The sample command sequence below creates EPG e1 and associates that EPG with the FCoE-configured bridge domain b1:

Example:

```
apic1(config)# tenant t1
apic1(config-tenant)# application a1
apic1(config-tenant-app)# epg e1
apic1(config-tenant-app-epg)# bridge-domain member b1
apic1(config-tenant-app-epg)# exit
apic1(config-tenant-app)# exit
apic1(config-tenant)# exit
```

Step 3 The following example creates vsan domain dom1 with vsans 1-10:

Example:

```
apic1(config)# vsan-domain dom1
apic1(config-vsan)# vsan 1-10
```

Step 4 Convert range of ports from Ethernet to FC mode. The following example converts port 1/1-4 on switch 101 to FC:

Example:

```
apic1# config
apic1(config)# leaf 101
apic1(config-leaf)# slot 1
apic1(config-leaf-slot)# port 1 4 type fc
apic1(config-leaf-slot)# exit
apic1(config-leaf)# exit
```

Note Port conversion from Ethernet to FC and vice versa requires reload of switch.

Step 5 Configure FC interface in NP mode. The following example sets various interface properties on interface fc 1/10 and associates that interface with VSAN domain dom1. Each of the targeted interfaces must be assigned one (and only one) VSAN in native mode. The sample command sequence associates the target interface 1/10 with VSAN 10 as a native VSAN and associates it with EPG e1 and application a1 under tenant t1.

Example:

```
apic1(config-leaf)# interface fc 1/10
apic1(config-leaf-fc-if)# switchport mode [f | np]
apic1(config-leaf-fc-if)# switchport rxbbcredit <16-64>
apic1(config-leaf-fc-if)# switchport speed [16G | 32G | 4G | 8G | auto | unknown]
apic1(config-leaf-fc-if)# vsan-domain member dom1
apic1(config-leaf-fc-if)# switchport vsan 10 tenant t1 application a1 epg e1
```

Step 6 Create traffic map to pin server ports to uplink ports. The following example creates Traffic map for vFC 1/47 server interface pinned to FC 1/7 uplink interface:

Example:

```
apic1# config
apic1(config)# leaf 101
apic1(config-leaf)# npv traffic-map server-interface vfc 1/47 label label1 tenant tenant1
application app1 epg epg1
apic1(config-leaf)# npv traffic-map external-interface fc 1/7 tenant tenant1 label label1
```

Configuring FC Connectivity With Policies or Profiles Using the NX-OS CLI

The sample command sequence below creates bridge domain b1 under tenant t1 configured to support FCoE connectivity.

Before you begin

- Under the target tenant configure a bridge domain to support FCoE traffic.

Procedure

Step 1 To create a bridge domain for FCoE connectivity:

Example:

```
apic1(config)# tenant t1
apic1(config-tenant)# vrf context v1
apic1(config-tenant-vrf)# exit
apic1(config-tenant)# bridge-domain b1
apic1(config-tenant-bd)# fc
apic1(config-tenant-bd)# vrf member v1
apic1(config-tenant-bd)# exit
apic1(config-tenant)# exit
```

Step 2 Under the same tenant, associate the target EPG with the FCoE-configured bridge domain. The sample command sequence below creates EPG e1 and associates that EPG with the FCoE-configured bridge domain b1:

Example:

```
apic1(config)# tenant t1
apic1(config-tenant)# application a1
apic1(config-tenant-app)# epg e1
apic1(config-tenant-app-epg)# bridge-domain member b1
apic1(config-tenant-app-epg)# exit
apic1(config-tenant-app)# exit
apic1(config-tenant)# exit
```

Step 3 Create a VSAN domain. The following example creates vsan domain dom1 with vsans 1-10:

Example:

```
apic1(config)# vsan-domain dom1
apic1(config-vsan)# vsan 1-10
```

Step 4 Create an interface policy group for NP port interfaces. The sample command sequence creates FC interface policy group ipg2 and assigns a combination of values that determine values for any interface that this policy group is applied to:

Example:

```
apic1(config)# template fc-policy-group ipg1
apic1(config-fc-pol-grp-if)# switchport ?
 fill-pattern  Configure fill pattern for fc interface
 mode         Configure port mode for fc interface
 rxbbcredit   Configure rxBBCredit for fc interface
 speed        Configure speed for fc interface
 trunk-mode    Configure trunk-mode for fc interface
apic1(config-fc-pol-grp-if)# switchport fill-pattern [ARBFF | IDLE]
apic1(config-fc-pol-grp-if)# switchport mode [f | np]
apic1(config-fc-pol-grp-if)# switchport rxbbcredit <16-64>
apic1(config-fc-pol-grp-if)# switchport speed [16G | 32G | 4G | 8G | auto | unknown]
apic1(config-fc-pol-grp-if)# vsan-domain member dom1
```

Step 5 Create an interface profile for FC port interfaces. The sample command sequence creates an interface profile lip1 for FC port interfaces, associates the profile with FC interface policy group ipg1, and specifies the interfaces to which this profile and its associated policies applies:

Example:

```
apic1# configure
apic1(config)# leaf-interface-profile lip1
apic1(config-leaf-if-profile)# description 'test description lip1'
apic1(config-leaf-if-profile)# leaf-interface-group lig1
apic1(config-leaf-if-group)# description 'test description lig1'
apic1(config-leaf-if-group)# fc-policy-group ipg1
apic1(config-leaf-if-group)# interface fc 1/1-4
```

Step 6 Create a leaf profile, assign the leaf interface profile to the leaf profile, and assign the leaf IDs on which the profile will be applied:

Example:

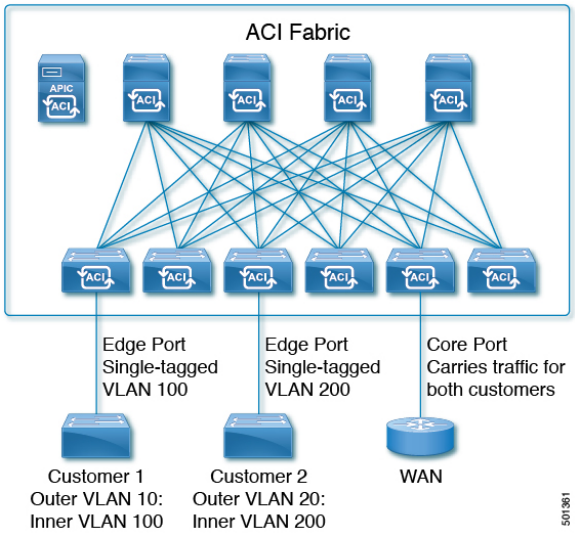
```
apic1(config)# leaf-profile lp103
apic1(config-leaf-profile)# leaf-interface-profile lip1
apic1(config-leaf-profile)# leaf-group range
apic1(config-leaf-group)# leaf 103
apic1(config-leaf-group)#
```

Note After associating leaf interface profile to leaf, reload of leaf is required to bring up these ports as FC ports.

Configuring 802.1Q Tunnels

About ACI 802.1Q Tunnels

Figure 2: ACI 802.1Q Tunnels



With Cisco ACI and Cisco APIC Release 2.2(1x) and higher, you can configure 802.1Q tunnels on edge (tunnel) ports to enable point-to-multi-point tunneling of Ethernet frames in the fabric, with Quality of Service (QoS) priority settings. A **Dot1q Tunnel** transports untagged, 802.1Q tagged, and 802.1ad double-tagged frames as-is across the fabric. Each tunnel carries the traffic from a single customer and is associated with a single bridge domain. ACI front panel ports can be part of a **Dot1q Tunnel**. Layer 2 switching is done based on Destination MAC (DMAC) and regular MAC learning is done in the tunnel. Edge-port **Dot1q Tunnels** are supported on second-generation (and later) Cisco Nexus 9000 series switches with "EX" on the end of the switch model name.

With Cisco ACI and Cisco APIC Release 2.3(x) and higher, you can also configure multiple 802.1Q tunnels on the same core port to carry double-tagged traffic from multiple customers, each distinguished with an access encapsulation configured for each 802.1Q tunnel. You can also disable MAC Address Learning on 802.1Q tunnels. Both edge ports and core ports can belong to an 802.1Q tunnel with access encapsulation and disabled MAC Address Learning. Both edge ports and core ports in **Dot1q Tunnels** are supported on third-generation Cisco Nexus 9000 series switches with "FX" on the end of the switch model name.

Terms used in this document may be different in the **Cisco Nexus 9000 Series** documents.

Table 1: 802.1Q Tunnel Terminology

ACI Documents	Cisco Nexus 9000 Series Documents
Edge Port	Tunnel Port
Core Port	Trunk Port

The following guidelines and restrictions apply:

- Layer 2 tunneling of VTP, CDP, LACP, LLDP, and STP protocols is supported with the following restrictions:
  - Link Aggregation Control Protocol (LACP) tunneling functions as expected only with point-to-point tunnels using individual leaf interfaces. It is not supported on port-channels (PCs) or virtual port-channels (vPCs).
  - CDP and LLDP tunneling with PCs or vPCs is not deterministic; it depends on the link it chooses as the traffic destination.
  - To use VTP for Layer 2 protocol tunneling, CDP must be enabled on the tunnel.
  - STP is not supported in an 802.1Q tunnel bridge domain when Layer 2 protocol tunneling is enabled and the bridge domain is deployed on Dot1q Tunnel core ports.
  - ACI leaf switches react to STP TCN packets by flushing the end points in the tunnel bridge domain and flooding them in the bridge domain.
  - CDP and LLDP tunneling with more than two interfaces flood packets on all interfaces.
  - With Cisco APIC Release 2.3(x) or higher, the destination MAC address of Layer 2 protocol packets tunneled from edge to core ports is rewritten as 01-00-0c-cd-cd-d0 and the destination MAC address of Layer 2 protocol packets tunneled from core to edge ports is rewritten with the standard default MAC address for the protocol.
- If a PC or vPC is the only interface in a **Dot1q Tunnel** and it is **deleted** and reconfigured, remove the association of the PC/VPC to the **Dot1q Tunnel** and reconfigure it.
- With Cisco APIC Release 2.2(x) the Ethertypes for double-tagged frames must be 0x9100 followed by 0x8100.

  However, with Cisco APIC Release 2.3(x) and higher, this limitation no longer applies for edge ports, on third-generation Cisco Nexus switches with "FX" on the end of the switch model name.
- For core ports, the Ethertypes for double-tagged frames must be 0x8100 followed by 0x8100.
- You can include multiple edge ports and core ports (even across leaf switches) in a **Dot1q Tunnel**.
- An edge port may only be part of one tunnel, but a core port can belong to multiple Dot1q tunnels.
- With Cisco APIC Release 2.3(x) and higher, regular EPGs can be deployed on core ports that are used in 802.1Q tunnels.
- L3Outs are not supported on interfaces enabled for **Dot1q Tunnels**.
- FEX interfaces are not supported as members of a **Dot1q Tunnel**.
- Interfaces configured as breakout ports do not support 802.1Q tunnels.
- Interface-level statistics are supported for interfaces in **Dot1q Tunnels**, but statistics at the tunnel level are not supported.

Configuring 802.1Q Tunnels Using the NX-OS Style CLI

Note You can use ports, port-channels, or virtual port channels for interfaces included in a **Dot1q Tunnel**. Detailed steps are included for configuring ports. See the examples below for the commands to configure edge and core port-channels and virtual port channels.

Create a **Dot1q Tunnel** and configure the interfaces for use in the tunnel using the NX-OS Style CLI, with the following steps:

Note **Dot1q Tunnels** must include 2 or more interfaces. Repeat the steps (or configure two interfaces together), to mark each interface for use in a **Dot1q Tunnel**. In this example, two interfaces are configured as edge-switch ports, used by a single customer.

Use the following steps to configure a **Dot1q Tunnel** using the NX-OS style CLI:

1. Configure at least two interfaces for use in the tunnel.
2. Create a **Dot1q Tunnel**.
3. Associate all the interfaces with the tunnel.

Before you begin

Configure the tenant that will use the **Dot1q Tunnel**.

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `apic1# configure`	Enters configuration mode.
Step 2	Configure two interfaces for use in an 802.1Q tunnel, with the following steps:	
Step 3	**leaf** *ID* **Example:** `apic1(config)# leaf 101`	Identifies the leaf where the interfaces of the **Dot1q Tunnel** will be located.
Step 4	**interface ethernet** *slot/port* **Example:** `apic1(config-leaf)# interface ethernet 1/13-14`	Identifies the interface or interfaces to be marked as ports in a tunnel.
Step 5	**switchport mode dot1q-tunnel** {**edgePort** | **corePort**}	Marks the interfaces for use in an 802.1Q tunnel, and then leaves the configuration mode.

	Command or Action	Purpose

	Example:
	`apic1(config-leaf-if)# switchport mode dot1q-tunnel edgePort`
	`apic1(config-leaf-if)# exit`
	`apic1(config-leaf)# exit`
	`apic1(config)# exit`
		The example shows configuring some interfaces for edge port use. Repeat steps 3 to 5 to configure more interfaces for the tunnel.

Step 6	Create an 802.1Q tunnel with the following steps:	
Step 7	**leaf** *ID* **Example:** `apic1(config)# leaf 101`	Returns to the leaf where the interfaces are located.
Step 8	**interface ethernet** *slot/port* **Example:** `apic1(config-leaf)# interface ethernet 1/13-14`	Returns to the interfaces included in the tunnel.

Step 9	**switchport tenant** *tenant-name* **dot1q-tunnel** *tunnel-name*
	Example:
	`apic1(config-leaf-if)# switchport tenant tenant64 dot1q-tunnel vrf64_edgetunnel`
	`apic1(config-leaf-if)# exit`
		Associates the interfaces to the tunnel and exits the configuration mode.

Step 10	Repeat steps 7 to 10 to associate other interfaces with the tunnel.	

Example: Configuring an 802.1Q Tunnel Using Ports with the NX-OS Style CLI

The example marks two ports as edge port interfaces to be used in a **Dot1q Tunnel**, marks two more ports to be used as core port interfaces, creates the tunnel, and associates the ports with the tunnel.

```
apic1# configure
apic1(config)# leaf 101
apic1(config-leaf)# interface ethernet 1/13-14
apic1(config-leaf-if)# switchport mode dot1q-tunnel edgePort
apic1(config-leaf-if)# exit
apic1(config-leaf)# exit
apic1(config)leaf 102
apic1(config-leaf)# interface ethernet 1/10, 1/21
apic1(config-leaf-if)# switchport mode dot1q-tunnel corePort
apic1(config-leaf-if)# exit
apic1(config-leaf)# exit

apic1(config)# tenant tenant64
apic1(config-tenant)# dot1q-tunnel vrf64_tunnel
apic1(config-tenant-tunnel)# l2protocol-tunnel cdp
apic1(config-tenant-tunnel)# l2protocol-tunnel lldp
```

```
apic1(config-tenant-tunnel)#  access-encap 200


apic1(config-tenant-tunnel)# mac-learning disable

apic1(config-tenant-tunnel)# exit
apic1(config-tenant)# exit
apic1(config)# leaf 101
apic1(config-leaf)# interface ethernet 1/13-14
apic1(config-leaf-if)# switchport tenant tenant64 dot1q-tunnel vrf64_tunnel
apic1(config-leaf-if)# exit
apic1(config-leaf)# exit
apic1(config)# leaf 102
apic1(config-leaf)# interface ethernet 1/10, 1/21
apic1(config-leaf-if)# switchport tenant tenant64 dot1q-tunnel vrf64_tunnel
apic1(config-leaf-if)# exit
apic1(config-leaf)# exit
```

Example: Configuring an 802.1Q Tunnel Using Port-Channels with the NX-OS Style CLI

The example marks two port-channels as edge-port 802.1Q interfaces, marks two more port-channels as core-port 802.1Q interfaces, creates a **Dot1q Tunnel**, and associates the port-channels with the tunnel.

```
apic1# configure
apic1(config)# tenant tenant64
apic1(config-tenant)# dot1q-tunnel vrf64_tunnel
apic1(config-tenant-tunnel)# l2protocol-tunnel cdp
apic1(config-tenant-tunnel)# l2protocol-tunnel lldp

apic1(config-tenant-tunnel)#  access-encap 200


apic1(config-tenant-tunnel)# mac-learning disable

apic1(config-tenant-tunnel)# exit
apic1(config-tenant)# exit
apic1(config)# leaf 101
apic1(config-leaf)# interface port-channel pc1
apic1(config-leaf-if)# exit
apic1(config-leaf)# interface ethernet 1/2-3
apic1(config-leaf-if)# channel-group pc1
apic1(config-leaf-if)# exit
apic1(config-leaf)# interface port-channel pc1
apic1(config-leaf-if)# switchport mode dot1q-tunnel edgePort
apic1(config-leaf-if)# switchport tenant tenant64 dot1q-tunnel vrf64_tunnel
apic1(config-tenant-tunnel)# exit
apic1(config-tenant)# exit

apic1(config)# leaf 102
apic1(config-leaf)# interface port-channel pc2
apic1(config-leaf-if)# exit
apic1(config-leaf)# interface ethernet 1/4-5
apic1(config-leaf-if)# channel-group pc2
apic1(config-leaf-if)# exit
apic1(config-leaf)# interface port-channel pc2
apic1(config-leaf-if)# switchport mode dot1q-tunnel corePort
apic1(config-leaf-if)# switchport tenant tenant64 dot1q-tunnel vrf64_tunnel
```

Example: Configuring an 802.1Q Tunnel Using Virtual Port-Channels with the NX-OS Style CLI

The example marks two virtual port-channels (vPCs) as edge-port 802.1Q interfaces for the**Dot1q Tunnel**, marks two more vPCs as core-port interfaces for the tunnel, creates the tunnel, and associates the virtual port-channels with the tunnel.

```
apic1# configure
apic1(config)# vpc domain explicit 1 leaf 101 102
apic1(config)# vpc context leaf 101 102
apic1(config-vpc)# interface vpc vpc1
apic1(config-vpc-if)# switchport mode dot1q-tunnel edgePort
apic1(config-vpc-if)# exit
apic1(config-vpc)# exit
apic1(config)# vpc domain explicit 1 leaf 103 104
apic1(config)# vpc context leaf 103 104
apic1(config-vpc)# interface vpc vpc2
apic1(config-vpc-if)# switchport mode dot1q-tunnel corePort
apic1(config-vpc-if)# exit
apic1(config-vpc)# exit
apic1(config)# tenant tenant64
apic1(config-tenant)# dot1q-tunnel vrf64_tunnel
apic1(config-tenant-tunnel)# l2protocol-tunnel cdp
apic1(config-tenant-tunnel)# l2protocol-tunnel lldp

apic1(config-tenant-tunnel)#  access-encap 200


apic1(config-tenant-tunnel)# mac-learning disable

apic1(config-tenant-tunnel)# exit
apic1(config-tenant)# exit
apic1(config)# leaf 103
apic1(config-leaf)# interface ethernet 1/6
apic1(config-leaf-if)# channel-group vpc1 vpc
apic1(config-leaf-if)# exit
apic1(config-leaf)# exit
apic1(config)# leaf 104
apic1(config-leaf)# interface ethernet 1/6
apic1(config-leaf-if)# channel-group vpc1 vpc
apic1(config-leaf-if)# exit
apic1(config-leaf)# exit
apic1(config-vpc)# interface vpc vpc1
apic1(config-vpc-if)# switchport tenant tenant64 dot1q-tunnel vrf64_tunnel
apic1(config-vpc-if)# exit
```

Configuring Dynamic Breakout Ports

Configuration of Dynamic Breakout Ports

Breakout cables are suitable for very short links and offer a cost effective way to connect within racks and across adjacent racks.

Breakout enables a 40 Gigabit (Gb) port to be split into four independent and logical 10Gb ports or a 100Gb port to be split into four independent and logical 25Gb ports.

Before you configure breakout ports, connect a 40Gb port to four 10Gb ports or a 100Gb port to four 25Gb ports with one of the following cables:

- Cisco QSFP-4SFP10G
- Cisco QSFP-4SFP25G

The 40Gb to 10Gb dynamic breakout feature is supported on the access facing ports of the following switches:

- N9K-C9332PQ
- N9K-C93180LC-EX
- N9K-C9336C-FX

The 100Gb to 25Gb breakout feature is supported on the access facing ports of the following switches:

- N9K-C93180LC-EX
- N9K-C9336C-FX2

Observe the following guidelines and restrictions:

- In general, breakouts and port profiles (ports changed from uplink to downlink) are not supported on the same port.
- Fast Link Failover policies are not supported on the same port with the dynamic breakout feature.
- Breakout subports can be used in the same way other port types in the policy model are used.
- When a port is enabled for dynamic breakout, other policies (expect monitoring policies) on the parent port are no longer valid.
- When a port is enabled for dynamic breakout, other EPG deployments on the parent port are no longer valid.
- A breakout sub-port can not be further broken out using a breakout policy group.

Configuring Dynamic Breakout Ports Using the NX-OS Style CLI

Use the following steps to configure a breakout port, verify the configuration, and configure an EPG on a sub port, using the NX-OS style CLI.

Before you begin

- The ACI fabric is installed, APIC controllers are online, and the APIC cluster is formed and healthy.
- An APIC fabric administrator account is available that will enable creating the necessary fabric infrastructure configurations.
- The target leaf switches are registered in the ACI fabric and available.
- The 40GE or 100GE leaf switch ports are connected with Cisco breakout cables to the downlink ports.

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `apic1# configure`	Enters configuration mode.
Step 2	**leaf** *ID* **Example:** `apic1(config)# leaf 101`	Selects the leaf switch where the breakout port will be located and enters leaf configuration mode.
Step 3	**interface ethernet** *slot/port* **Example:** `apic1(config-leaf)# interface ethernet 1/16`	Identifies the interface to be enabled as a 40 Gigabit Ethernet (GE) breakout port.
Step 4	**breakout 10g-4x | 25g-4x** **Example:** `apic1(config-leaf-if)# breakout 10g-4x`	Enables the selected interface for breakout. **Note** For switch support for the Dynamic Breakout Port feature, see Configuration of Dynamic Breakout Ports, on page 39.

Step 5	**show run**
	Example:
	`apic1(config-leaf-if)# show run`
	`# Command: show running-config leaf 101 interface ethernet 1 / 16`
	`# Time: Fri Dec 2 18:13:39 2016`
	`leaf 101`
	`interface ethernet 1/16`
	`breakout 10g-4x`
	`apic1(config-leaf-if)# exit`
	`apic1(config-leaf)# exit`
		Verifies the configuration by showing the running configuration of the interface and returns to global configuration mode.

Step 6	**tenant** *tenant-name* **Example:** `apic1(config)# tenant tenant64`	Selects or creates the tenant that will consume the breakout ports and enters tenant configuration mode.

Step 7	**vrf context** *vrf-name*
	Example:
	`apic1(config-tenant)# vrf context vrf64`
	`apic1(config-tenant-vrf)# exit`
		Creates or identifies the Virtual Routing and Forwarding (VRF) instance associated with the tenant and exits the configuration mode.

Step 8	**bridge-domain** *bridge-domain-name* **Example:** `apic1(config-tenant)# bridge-domain bd64`	Creates or identifies the bridge-domain associated with the tenant and enters BD configuration mode.

	Command or Action	Purpose

Step 9	**vrf member** *vrf-name*
	Example:
	`apic1(config-tenant-bd)# vrf member vrf64`
	`apic1(config-tenant-bd)# exit`
		Associates the VRF with the bridge-domain and exits the configuration mode.

Step 10	**application** *application-profile-name* **Example:** `apic1(config-tenant)# application app64`	Creates or identifies the application profile associated with the tenant and the EPG.
Step 11	**epg** *epg-name* **Example:** `apic1(config-tenant)# epg epg64`	Creates or identifies the EPG and enters into EPG configuration mode.

Step 12	**bridge-domain member** *bridge-domain-name*
	Example:
	`apic1(config-tenant-app-epg)# bridge-domain member bd64`
	`apic1(config-tenant-app-epg)# exit`
	`apic1(config-tenant-app)# exit`
	`apic1(config-tenant)# exit`
		Associates the EPG with the bridge domain and returns to global configuration mode.
		Configure the sub ports as desired, for example, use the speed command in leaf interface mode to configure a sub port.

Step 13	**leaf** *leaf-name*
	Example:
	`apic1(config)# leaf 1017`
	`apic1(config-leaf)# interface ethernet 1/13`
	`apic1(config-leaf-if)# vlan-domain member dom1`
	`apic1(config-leaf-if)# switchport trunk allowed vlan 20 tenant t1 application AP1 epg EPG1`
	Note The vlan-domain and vlan-domain member commands mentioned in the above example are a pre-requisite for deploying an EPG on a port.
		Associates the EPG with a break-out port.

Step 14	**speed** *interface-speed*
	Example:
	`apic1(config)# leaf 101`
	`apic1(config-leaf)# interface ethernet 1/16/1`
	`apic1(config-leaf-if)# speed 10G`
	`apic1(config-leaf-if)# exit`
		Enters leaf interface mode, sets the speed of an interface, and exits the configuration mode.

	Command or Action	Purpose
Step 15	**show run** **Example:** `apic1(config-leaf)# show run`	After you have configured the sub ports, entering this command in leaf configuration mode displays the sub port details.

The port on leaf 101 at interface 1/16 is confirmed enabled for breakout with sub ports 1/16/1, 1/16/2, 1/16/3, and 1/16/4.

Example

This example configures the port for breakout:

```
apic1# configure
apic1(config)# leaf 101
apic1(config-leaf)# interface ethernet 1/16
apic1(config-leaf-if)# breakout 10g-4x
```

This example configures the EPG for the sub ports.

```
apic1(config)# tenant tenant64
apic1(config-tenant)# vrf context vrf64
apic1(config-tenant-vrf)# exit
apic1(config-tenant)# bridge-domain bd64
apic1(config-tenant-bd)# vrf member vrf64
apic1(config-tenant-bd)# exit
apic1(config-tenant)# application app64
apic1(config-tenant-app)# epg epg64
apic1(config-tenant-app-epg)# bridge-domain member bd64
apic1(config-tenant-app-epg)# end
```

This example sets the speed for the breakout sub ports to 10G.

```
apic1(config)# leaf 101
apic1(config-leaf)# interface ethernet 1/16/1
apic1(config-leaf-if)# speed 10G
apic1(config-leaf-if)# exit

apic1(config-leaf)# interface ethernet 1/16/2
apic1(config-leaf-if)# speed 10G
apic1(config-leaf-if)# exit
apic1(config-leaf)# interface ethernet 1/16/3
apic1(config-leaf-if)# speed 10G
apic1(config-leaf-if)# exit
apic1(config-leaf)# interface ethernet 1/16/4
apic1(config-leaf-if)# speed 10G
apic1(config-leaf-if)# exit
```

This example shows the four sub ports connected to leaf 101, interface 1/16.

```
apic1#(config-leaf)# show run
# Command: show running-config leaf 101
# Time: Fri Dec  2 00:51:08 2016
  leaf 101
    interface ethernet 1/16/1
      speed 10G
      negotiate auto
      link debounce time 100
      exit
    interface ethernet 1/16/2
      speed 10G
      negotiate auto
```

```
  link debounce time 100
  exit
interface ethernet 1/16/3
  speed 10G
  negotiate auto
  link debounce time 100
  exit
interface ethernet 1/16/4
  speed 10G
  negotiate auto
  link debounce time 100
  exit
interface ethernet 1/16
  breakout 10g-4x
  exit
interface vfc 1/16
```

Configuring Port Profiles

Configuring Port Profiles

Prior to Cisco APIC, Release 3.1(1), conversion from uplink port to downlink port or downlink port to uplink port (in a port profile) was not supported on Cisco ACI leaf switches. Starting with Cisco APIC Release 3.1(1), uplink and downlink conversion is supported on Cisco Nexus 9000 series switches with names that end in EX or FX, and later (for example, N9K-C9348GC-FXP). A FEX connected to converted downlinks is also supported.

This functionality is supported on the following Cisco switches:

- N9K-C9348GC-FXP
- N9K-C93180LC-EX and N9K-C93180YC-FX
- N9K-93180YC-EX, N9K-C93180YC-EX, and N9K-C93180YC-EXU
- N9K-C93108TC-EX and N9K-C93108TC-FX
- N9K-C9336C-FX2 (only downlink to uplink conversion supported)

Restrictions

Fast Link Failover policies and port profiles are not supported on the same port. If port profile is enabled, Fast Link Failover cannot be enabled or vice versa.

The last 2 uplink ports of supported TOR switches cannot be converted to downlink ports (they are reserved for uplink connections.)

Up to Cisco APIC Release 3.2, port profiles and breakout ports are not supported on the same ports.

Guidelines

In converting uplinks to downlinks and downlinks to uplinks, consider the following guidelines.

Subject	Guideline
Decommissioning nodes with port profiles	If a decommissioned node has the Port Profile feature deployed on it, the port conversions are not removed even after decommissioning the node. It is necessary to manually delete the configurations after decommission, for the ports to return to the default state. To do this, log onto the switch, run the **setup-clean-config.sh** script, and wait for it to run. Then, enter the **reload** command.
FIPS	When you enable or disable Federal Information Processing Standards (FIPS) on a Cisco ACI fabric, you must reload each of the switches in the fabric for the change to take effect. The configured scale profile setting is lost when you issue the first reload after changing the FIPS configuration. The switch remains operational, but it uses the default scale profile. This issue does not happen on subsequent reloads if the FIPS configuration has not changed. FIPS is supported on Cisco NX-OS release 13.1(1) or later. If you must downgrade the firmware from a release that supports FIPS to a release that does not support FIPS, you must first disable FIPS on the Cisco ACI fabric and reload all the switches in the fabric for the FIPS configuration change.
Maximum uplink port limit	When the maximum uplink port limit is reached and ports 25 and 27 are converted from uplink to downlink and back to uplink on Cisco 93180LC-EX switches: On Cisco 93180LC-EX Switches, ports 25 and 27 are the native uplink ports. Using the port profile, if you convert port 25 and 27 to downlink ports, ports 29, 30, 31, and 32 are still available as four native uplink ports. Because of the threshold on the number of ports (which is maximum of 12 ports) that can be converted, you can convert 8 more downlink ports to uplink ports. For example, ports 1, 3, 5, 7, 9, 13, 15, 17 are converted to uplink ports and ports 29, 30, 31 and 32 are the 4 native uplink ports (the maximum uplink port limit on Cisco 93180LC-EX switches). When the switch is in this state and if the port profile configuration is deleted on ports 25 and 27, ports 25 and 27 are converted back to uplink ports, but there are already 12 uplink ports on the switch (as mentioned earlier). To accommodate ports 25 and 27 as uplink ports, 2 random ports from the port range 1, 3, 5, 7, 9, 13, 15, 17 are denied the uplink conversion and this situation cannot be controlled by the user. Therefore, it is mandatory to clear all the faults before reloading the leaf node to avoid any unexpected behavior regarding the port type. It should be noted that if a node is reloaded without clearing the port profile faults, especially when there is a fault related to limit-exceed, the port might not be in an expected operational state.

Breakout Limitations

Switch	Releases	Limitations
N9K-C9332PQ	Cisco APIC 2.2 (1n) and higher	• 40Gb dynamic breakouts into 4X10Gb ports are supported. • Ports 13 and 14 do not support breakouts. • Port profiles and breakouts are not supported on the same port.
N9K-C93180LC-EX	Cisco APIC 3.1(1i) and higher	• 40Gb and 100Gb dynamic breakouts are supported on ports 1 through 24 on odd numbered ports. • When the top ports (odd ports) are broken out, then the bottom ports (even ports) are error disabled. • Port profiles and breakouts are not supported on the same port.
N9K-C9336C-FX2	Cisco APIC 3.1(2m) and higher	• 40Gb and 100Gb dynamic breakouts are supported on ports 1 through 30. • Port profiles and breakouts are not supported on the same port.

Port Profile Configuration Summary

The following table summarizes supported uplinks and downlinks for the switches that support port profile conversions from Uplink to Downlink and Downlink to Uplink.

Switch Model	Default Links	Max Uplinks (Fabric Ports)	Max Downlinks (Server Ports)	Release Supported
N9K-C9348GC-FXP	48 x 100M/1G BASE-T downlinks 4 x 10/25-Gbps SFP28 downlinks 2 x 40/100-Gbps QSFP28 uplinks	48 x 100M/1G BASE-T downlinks 4 x 10/25-Gbps SFP28 uplinks 2 x 40/100-Gbps QSFP28 uplinks	Same as default port configuration	3.1(1i)

Switch Model	Default Links	Max Uplinks (Fabric Ports)	Max Downlinks (Server Ports)	Release Supported
N9K-C93180LC-EX	24 x 40-Gbps QSFP28 downlinks(1-24) 2 x 40/100-Gbps QSFP28 uplinks(25, 27) 4 x 40/100-Gbps QSFP28 uplinks(29-32) Or 12 x 100-Gbps QSFP28 downlinks(odd number from 1-24) 2 x 40/100-Gbps QSFP28 uplinks(25, 27) 4 x 40/100-Gbps QSFP28 uplinks(29-32)	18 x 40-Gbps QSFP28 downlinks (from 1-24) 6 x 40-Gbps QSFP28 uplinks(from 1-24) 2 x 40/100-Gbps QSFP28 uplinks(25, 27) 4 x 40/100-Gbps QSFP28 uplinks(29-32) Or 6 x 100-Gbps QSFP28 downlinks(odd number from 1-24) 6 x 100-Gbps QSFP28 uplinks(odd number from 1-24) 2 x 40/100-Gbps QSFP28 uplinks(25, 27) 4 x 40/100-Gbps QSFP28 uplinks(29-32)	24 x 40-Gbps QSFP28 downlinks(1-24) 2 x 40/100-Gbps QSFP28 downlinks(25, 27) 4 x 40/100-Gbps QSFP28 uplinks(29-32) Or 12 x 100-Gbps QSFP28 downlinks(odd number from 1-24) 2 x 40/100-Gbps QSFP28 downlinks (25, 27) 4 x 40/100-Gbps QSFP28 uplinks(29-32)	3.1(1i)
N9K-C93180YC-EX N9K-C93180YC-FX	48 x 10/25-Gbps fiber downlinks 6 x 40/100-Gbps QSFP28 uplinks	Same as default port configuration	48 x 10/25-Gbps fiber downlinks 4 x 40/100-Gbps QSFP28 downlinks 2 x 40/100-Gbps QSFP28 uplinks	3.1(1i)
		48 x 10/25-Gbps fiber uplinks 6 x 40/100-Gbps QSFP28 uplinks		4.0(1)
N9K-C93108TC-EX N9K-C93108TC-FX	48 x 10GBASE-T downlinks 6 x 40/100-Gbps QSFP28 uplinks	Same as default port configuration	48 x 10/25-Gbps fiber downlinks 4 x 40/100-Gbps QSFP28 downlinks 2 x 40/100-Gbps QSFP28 uplinks	3.1

Switch Model	Default Links	Max Uplinks (Fabric Ports)	Max Downlinks (Server Ports)	Release Supported
N9K-C9336C-FX2	30 x 40/100-Gbps QSFP28 downlinks 6 x 40/100-Gbps QSFP28 uplinks	18 x 40/100-Gbps QSFP28 downlinks 18 x 40/100-Gbps QSFP28 uplinks	Same as default port configuration	3.2(1i)
		18 x 40/100-Gbps QSFP28 downlinks 18 x 40/100-Gbps QSFP28 uplinks	34 x 40/100-Gbps QSFP28 downlinks 2 x 40/100-Gbps QSFP28 uplinks	3.2(3i)
		36 x 40/100-Gbps QSFP28 uplinks	34 x 40/100-Gbps QSFP28 downlinks 2 x 40/100-Gbps QSFP28 uplinks	4.1
N9K-93240YC-FX2	48 x 10/25-Gbps fiber downlinks 12 x 40/100-Gbps QSFP28 uplinks	Same as default port configuration	48 x 10/25-Gbps fiber downlinks	4.0(1)
		48 x 10/25-Gbps fiber uplinks 12 x 40/100-Gbps QSFP28 uplinks	10 x 40/100-Gbps QSFP28 downlinks 2 x 40/100-Gbps QSFP28 uplinks	4.1
N9K-C93216TC-FX2	96 x 10G BASE-T downlinks 12 x 40/100-Gbps QSFP28 uplinks	Same as default port configuration	96 x 10G BASE-T downlinks 10 x 40/100-Gbps QSFP28 downlinks 2 x 40/100-Gbps QSFP28 uplinks	4.1.2
N9K-C93360YC-FX2	96 x 10/25-Gbps SFP28 downlinks 12 x 40/100-Gbps QSFP28 uplinks	44 x 10/25Gbps SFP28 downlinks 52 x 10/25Gbps SFP28 uplinks 12 x 40/100Gbps QSFP28 uplinks	96 x 10/25-Gbps SFP28 downlinks 10 x 40/100-Gbps QSFP28 downlinks 2 x 40/100-Gbps QSFP28 uplinks	4.1.2

Configuring a Port Profile Using the NX-OS Style CLI

To configure a port profile using the NX-OS style CLI, perform the following steps:

Before you begin

- The ACI fabric is installed, APIC controllers are online, and the APIC cluster is formed and healthy.

- An APIC fabric administrator account is available that will enable creating or modifying the necessary fabric infrastructure configurations.
- The target leaf switches are registered in the ACI fabric and available.

Procedure

Step 1 **configure**

Enters global configuration mode.

Example:

```
apic1# configure
```

Step 2 **leaf** *node-id*

Specifies the leaf or leaf switches to be configured.

Example:

```
apic1(config)# leaf 102
```

Step 3 **interface** *type*

Specifies the interface that you are configuring. You can specify the interface type and identity. For an Ethernet port, use ethernet *slot* / *port*.

Example:

```
apic1(config-leaf)# interface ethernet 1/2
```

Step 4 **port-direction** {**uplink** | **downlink**}

Determines the port direction or changes it. This example configures the port to be a downlink.

Note On the N9K-C9336C-FX switch, changing a port from uplink to downlink is not supported.

Example:

```
apic1(config-leaf-if)# port-direction downlink
```

Step 5 Log on to the leaf switch where the port is located and enter the **setup-clean-config.sh -k** command, then the **reload** command.

Verifying Port Profile Configuration and Conversion Using the NX-OS Style CLI

You can verify the configuration and the conversion of the ports using the **show interface brief** CLI command.

Note Port profile can be deployed only on the top ports of a Cisco N9K-C93180LC-EX switch, for example, 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, and 23. When the top port is converted using the port profile, the bottom ports are hardware disabled. For example, if Eth 1/1 is converted using the port profile, Eth 1/2 is hardware disabled.

Procedure

Step 1 This example displays the output for converting an uplink port to downlink port. Before converting an uplink port to downlink port, the output is displayed in the example. The keyword **routed** denotes the port as uplink port.

Example:

```
switch# show interface brief
<snip>
Eth1/49          --      eth  routed  down   sfp-missing             100G(D)   --
Eth1/50          --      eth  routed  down   sfp-missing             100G(D)   --
<snip>
```

Step 2 After configuring the port profile and reloading the switch, the output is displayed in the example. The keyword **trunk** denotes the port as downlink port.

Example:

```
switch# show interface brief
<snip>
Eth1/49          0       eth  trunk   down   sfp-missing             100G(D)   --
Eth1/50          0       eth  trunk   down   sfp-missing             100G(D)   --
<snip>
```

Microsegmentation on Virtual Switches

Configuring Microsegmentation on Virtual Switches

Microsegmentation with the Cisco Application Centric Infrastructure (ACI) provides the ability to automatically assign endpoints to logical security zones called endpoint groups (EPGs) based on various network-based or virtual machine (VM)-based attributes. This section contains instructions for configuring microsegment (uSeg) EPGs on virtual switches.

Microsegmentation with Cisco ACI provides support for virtual endpoints attached to the following:

- VMware vSphere Distributed Switch (VDS)
- Cisco Application Virtual Switch (AVS)
- Microsoft vSwitch

See the *Cisco ACI Virtualization Guide* for information about how Microsegmentation with Cisco ACI works, prerequisites, guidelines, and scenarios.

Configuring Microsegmentation with Cisco ACI Using the NX-OS-Style CLI

This section describes how to configure Microsegmentation with Cisco ACI for Cisco ACI Virtual Edge, Cisco AVS, VMware VDS or Microsoft Hyper-V Virtual Switch using VM-based attributes within an application EPG.

Procedure

Step 1 In the CLI, enter configuration mode:

Example:

```
apic1# configure
apic1(config)#
```

Step 2 Create the uSeg EPG:

Example:

This example is for an application EPG.

Note The command to allow microsegmentation in the following example is required for VMware VDS only.

```
apic1(config)# tenant cli-ten1
apic1(config-tenant)# application cli-a1
apic1(config-tenant-app)# epg cli-baseEPG1
apic1(config-tenant-app-epg)# bridge-domain member cli-bd1
apic1(config-tenant-app-epg)# vmware-domain member cli-vmm1 allow-micro-segmentation
```

Example:

(Optional) This example sets match EPG precedence for the uSeg EPG:

```
apic1(config)# tenant Coke
apic1(config-tenant)# application cli-a1
apic1(config-tenant-app)# epg cli-uepg1 type micro-segmented
apic1(config-tenant-app-uepg)# bridge-domain member cli-bd1
apic1(config-tenant-app-uepg)# match-precedence 10
```

Example:

This example uses a filter based on the attribute VM Name.

```
apic1(config)# tenant cli-ten1
apic1(config-tenant)# application cli-a1
apic1(config-tenant-app)# epg cli-uepg1 type micro-segmented
apic1(config-tenant-app-uepg)# bridge-domain member cli-bd1
apic1(config-tenant-app-uepg)# attribute-logical-expression 'vm-name contains <cos1>'
```

Example:

This example uses a filter based on an IP address.

```
apic1(config)# tenant cli-ten1
apic1(config-tenant)# application cli-a1
apic1(config-tenant-app)# epg cli-uepg1 type micro-segmented
apic1(config-tenant-app-uepg)# bridge-domain member cli-bd1
apic1(config-tenant-app-uepg)# attribute-logical-expression 'ip equals <FF:FF:FF:FF:FF:FF>'
```

Example:

This example uses a filter based on a MAC address.

```
apic1(config)# tenant cli-ten1
apic1(config-tenant)# application cli-a1
apic1(config-tenant-app)# epg cli-uepg1 type micro-segmented
apic1(config-tenant-app-uepg)# bridge-domain member cli-bd1
apic1(config-tenant-app-uepg)# attribute-logical-expression ‘mac equals <FF-FF-FF-FF-FF-FF>’
```

Example:

This example uses the operator AND to match all attributes and the operator OR to match any attribute.

```
apic1(config)# tenant cli-ten1
apic1(config-tenant)# application cli-a1
apic1(config-tenant-app)# epg cli-uepg1 type micro-segmented
apic1(config-tenant-app-uepg)# attribute-logical-expression 'hv equals host-123 OR (guest-os
 equals "Ubuntu Linux (64-bit)" AND domain contains fex)'
```

Example:

This example uses a filter based on the attribute VM-Custom Attribute.

```
apic1(config)# tenant cli-ten1
apic1(config-tenant)# application cli-a1
apic1(config-tenant-app)# epg cli-uepg1 type micro-segmented
apic1(config-tenant-app-uepg)# bridge-domain member cli-bd1
apic1(config-tenant-app-uepg)# attribute-logical-expression 'custom <Custom Attribute Name>
 equals <Custom Attribute value>'
```

Step 3 (Cisco ACI Virtual Edge only): Attach the uSeg EPG to a Cisco ACI Virtual Edge VMM domain, specifying the switching and encapsulation modes:

Example:

```
vmware-domain member AVE-CISCO
    switching-mode AVE
    encap-mode vxlan
    exit
```

Step 4 Verify the uSeg EPG creation:

Example:

The following example is for a uSeg EPG with a VM name attribute filter

```
apic1(config-tenant-app-uepg)# show running-config
# Command: show running-config tenant cli-ten1 application cli-a1 epg cli-uepg1 type
micro-segmented # Time: Thu Oct 8 11:54:32 2015
  tenant cli-ten1
    application cli-a1
      epg cli-uepg1 type micro-segmented
        bridge-domain cli-bd1
        attribute-logical-expression ‘vm-name contains cos1 force’
        {vmware-domain | microsoft-domain} member cli-vmm1
        exit
     exit
exit
```

Configuring Microsegmentation on Bare-Metal

Using Microsegmentation with Network-based Attributes on Bare Metal

You can use Cisco APIC to configure Microsegmentation with Cisco ACI to create a new, attribute-based EPG using a network-based attribute, a MAC address or one or more IP addresses. You can configure Microsegmentation with Cisco ACI using network-based attributes to isolate VMs or physical endpoints within a single base EPG or VMs or physical endpoints in different EPGs.

Using an IP-based Attribute

You can use an IP-based filter to isolate a single IP address, a subnet, or multiple of noncontiguous IP addresses in a single microsegment. You might want to isolate physical endpoints based on IP addresses as a quick and simply way to create a security zone, similar to using a firewall.

Using a MAC-based Attribute

You can use a MAC-based filter to isolate a single MAC address or multiple MAC addresses. You might want to do this if you have a server sending bad traffic int he network. By creating a microsegment with a MAC-based filter, you can isolate the server.

Configuring a Network-Based Microsegmented EPG in a Bare-Metal Environment Using the NX-OS Style CLI

This section describes how to configure microsegmentation with Cisco ACI using network-based attributes (IP address or MAC address) within a base EPG in a bare-metal environment.

Procedure

	Command or Action	Purpose

Step 1	In the CLI, enter configuration mode:
	Example:
	`apic1# configure`
	`apic1(config)#`	

Step 2	Create the microsegment:
	Example:
	This example uses a filter based on an IP address.
	`apic1(config)# tenant cli-ten1`
	`apic1(config-tenant)# application cli-a1`
	`apic1(config-tenant-app)# epg cli-uepg1 type micro-segmented`
	`apic1(config-tenant-app-uepg)# bridge-domain member cli-bd1`
	`apic1(config-tenant-app-uepg)# attribute cli-upg-att match ip <X.X.X.X>`	

	Command or Action	Purpose

	#Schemes to express the ip
	A.B.C.D IP Address
	A.B.C.D/LEN IP Address and mask
	Example:
	This example uses a filter based on a MAC address.
	`apic1(config)# tenant cli-ten1`
	`apic1(config-tenant)# application cli-a1`
	`apic1(config-tenant-app)# epg cli-uepg1 type micro-segmented`
	`apic1(config-tenant-app-uepg)# bridge-domain member cli-bd1`
	`apic1(config-tenant-app-uepg)# attribute cli-upg-att match mac`
	<FF-FF-FF-FF-FF-FF>
	#Schemes to express the mac
	E.E.E MAC address (Option 1)
	EE-EE-EE-EE-EE-EE MAC address (Option 2)
	EE:EE:EE:EE:EE:EE MAC address (Option 3)
	EEEE.EEEE.EEEE MAC address (Option 4)
	Example:
	This example uses a filter based on a MAC address and enforces intra-EPG isolation between all members of this uSeg EPG:
	`apic1(config)# tenant cli-ten1`
	`apic1(config-tenant)# application cli-a1`
	`apic1(config-tenant-app)# epg cli-uepg1 type micro-segmented`
	`apic1(config-tenant-app-uepg)# isolation enforced`
	`apic1(config-tenant-app-uepg)# bridge-domain member cli-bd1`
	`apic1(config-tenant-app-uepg)# attribute cli-upg-att match mac`
	<FF-FF-FF-FF-FF-FF>
	#Schemes to express the mac
	E.E.E MAC address (Option 1)
	EE-EE-EE-EE-EE-EE MAC address (Option 2)
	EE:EE:EE:EE:EE:EE MAC address (Option 3)
	EEEE.EEEE.EEEE MAC address (Option 4)	

Step 3	Deploy the EPG.
	Example:
	This example deploys the EPG and bids to the leaf.
	`apic1(config)# leaf 101`
	`apic1(config-leaf)# deploy-epg tenant cli-ten1 application cli-a1 epg cli-uepg1 type micro-segmented`	

Step 4	Verify the microsegment creation: **Example:**	

	Command or Action	Purpose
	apic1(config-tenant-app-uepg)# show running-config # Command: show running-config tenant cli-ten1 application cli-app1 epg cli-uepg1 type micro-segmented # Time: Thu Oct 8 11:54:32 2015 tenant cli-ten1 application cli-app1 epg cli-esx1bu type micro-segmented bridge-domain cli-bd1 attribute cli-uepg-att match mac 00:11:22:33:44:55 exit exit exit	

Configuring Layer 2 IGMP Snoop Multicast

About Cisco APIC and IGMP Snooping

IGMP snooping is the process of listening to Internet Group Management Protocol (IGMP) network traffic. The feature allows a network switch to listen in on the IGMP conversation between hosts and routers and filter multicasts links that do not need them, thus controlling which ports receive specific multicast traffic.

Cisco APIC provides support for the full IGMP snooping feature included on a traditional switch such as the N9000 standalone.

- Policy-based IGMP snooping configuration per bridge domain

  APIC enables you to configure a policy in which you enable, disable, or customize the properties of IGMP Snooping on a per bridge-domain basis. You can then apply that policy to one or multiple bridge domains.

- Static port group implementation

  IGMP static port grouping enables you to pre-provision ports, already statically-assigned to an application EPG, as the switch ports to receive and process IGMP multicast traffic. This pre-provisioning prevents the join latency which normally occurs when the IGMP snooping stack learns ports dynamically.

  Static group membership can be pre-provisioned only on static ports (also called, *static-binding ports*) assigned to an application EPG.

- Access group configuration for application EPGs

  An “access-group” is used to control what streams can be joined behind a given port.

  An access-group configuration can be applied on interfaces that are statically assigned to an application EPG in order to ensure that the configuration can be applied on ports that will actually belong to the that EPG.

  Only Route-map-based access groups are allowed.

Note You can use **vzAny** to enable protocols such as IGMP Snooping for all the EPGs in a VRF. For more information about **vzAny**, see Use vzAny to Automatically Apply Communication Rules to all EPGs in a VRF.

To use **vzAny**, navigate to **Tenants** > ***tenant-name*** > **Networking** > **VRFs** > ***vrf-name*** > **EPG Collection for VRF**.

Enabling IGMP Snooping Static Port Groups

IGMP static port grouping enables you to pre-provision ports, that were previously statically-assigned to an application EPG, to enable the switch ports to receive and process IGMP multicast traffic. This pre-provisioning prevents the join latency which normally occurs when the IGMP snooping stack learns ports dynamically.

Static group membership can be pre-provisioned only on static ports assigned to an application EPG.

Static group membership can be configured through the APIC GUI, CLI, and REST API interfaces.

Configuring and Assigning an IGMP Snooping Policy to a Bridge Domain using the NX-OS Style CLI

Before you begin

- Create the tenant that will consume the IGMP Snooping policy.
- Create the bridge domain for the tenant, where you will attach he IGMP Snooping policy.

Procedure

	Command or Action	Purpose

Step 1	Create a snooping policy based on default values.
	Example:
	`apic1(config-tenant)# template ip igmp snooping policy cookieCut1`
	`apic1(config-tenant-template-ip-igmp-snooping)# show run all`
	`# Command: show running -config all`
	`tenant foo template ip igmp snooping policy cookieCut1`
	`# Time: Thu Oct 13 18:26:03 2016`
	`tenant t_10`
	`template ip igmp snooping policy cookieCut1`
	`ip igmp snooping`
	`no ip igmp snooping fast-leave`
	`ip igmp snooping last-member-query-interval 1`
	`no ip igmp snooping querier`
		The example NX-OS style CLI sequence:
		• Creates an IGMP Snooping policy named cookieCut1 with default values.
		• Displays the default IGMP Snooping values for the policy cookieCut1.

	Command or Action	Purpose

	`ip igmp snooping query-interval 125`
	`ip igmp snooping query-max-response-time 10`
	`ip igmp snooping stqrtup-query-count 2`
	`ip igmp snooping startup-query-interval 31`
	`no description`
	`exit`
	`exit`
	`apic1(config-tenant-template-ip-igmp-snooping)#`	

Step 2	Modify the snooping policy as necessary.
	Example:
	`apic1(config-tenant-template-ip-igmp-snooping)# ip igmp snooping query-interval 300`
	`apic1(config-tenant-template-ip-igmp-snooping)# show run all`
	`# Command: show running -config all`
	`tenant foo template ip igmp snooping policy cookieCut1`
	`#Time: Thu Oct 13 18:26:03 2016`
	`tenant foo`
	`template ip igmp snooping policy cookieCut1`
	`ip igmp snooping`
	`no ip igmp snooping fast-leave`
	`ip igmp snooping last-member-query-interval 1`
	`no ip igmp snooping querier`
	`ip igmp snooping query-interval 300`
	`ip igmp snooping query-max-response-time 10`
	`ip igmp snooping stqrtup-query-count 2`
	`ip igmp snooping startup-query-interval 31`
	`no description`
	`exit`
	`exit`
	`apic1(config-tenant-template-ip-igmp-snooping)#`
	`exit`
	`apic1(config--tenant)#`
		The example NX-OS style CLI sequence:
		• Specifies a custom value for the query-interval value in the IGMP Snooping policy named cookieCut1.
		• Confirms the modified IGMP Snooping value for the policy cookieCut1.

Step 3	Assign the policy to a bridge domain. **Example:** **`apic1(config-tenant)# int bridge-domain bd3`** **`apic1(config-tenant-interface)# ip igmp snooping policy cookieCut1`**	The example NX-OS style CLI sequence: • Navigates to bridge domain, BD3. for the query-interval value in the IGMP Snooping policy named cookieCut1. • Assigns the IGMP Snooping policy with a modified IGMP Snooping value for the policy cookieCut1.

What to do next

You can assign the IGMP Snooping policy to multiple bridge domains.

Enabling IGMP Snooping and Multicast on Static Ports in the NX-OS Style CLI

You can enable IGMP snooping and multicast on ports that have been statically assigned to an EPG. Then you can create and assign access groups of users that are permitted or denied access to the IGMP snooping and multicast traffic enabled on those ports.

The steps described in this task assume the pre-configuration of the following entities:

- Tenant: tenant_A
- Application: application_A
- EPG: epg_A
- Bridge Domain: bridge_domain_A
- vrf: vrf_A -- a member of bridge_domain_A
- VLAN Domain: vd_A (configured with a range of 300-310)
- Leaf switch: 101 and interface 1/10

  The target interface 1/10 on switch 101 is associated with VLAN 305 and statically linked with tenant_A, application_A, epg_A
- Leaf switch: 101 and interface 1/11

  The target interface 1/11 on switch 101 is associated with VLAN 309 and statically linked with tenant_A, application_A, epg_A

Before you begin

Before you begin to enable IGMP snooping and multicasting for an EPG, complete the following tasks.

- Identify the interfaces to enable this function and statically assign them to that EPG

  Note For details on static port assignment, see *Deploying an EPG on a Specific Port with APIC Using the NX-OS Style CLI* in the *Cisco APIC Layer 2 Networking Configuration Guide*.
- Identify the IP addresses that you want to be recipients of IGMP snooping multicast traffic.

Procedure

	Command or Action	Purpose
Step 1	On the target interfaces enable IGMP snooping and layer 2 multicasting	The example sequences enable:

	Command or Action	Purpose

	Example:
	`apic1# conf t`
	`apic1(config)# tenant tenant_A`
	`apic1(config-tenant)# application application_A`
	`apic1(config-tenant-app)# epg epg_A`
	`apic1(config-tenant-app-epg)# ip igmp snooping static-group 225.1.1.1 leaf 101 interface ethernet 1/10 vlan 305`
	`apic1(config-tenant-app-epg)# end`
	
	`apic1# conf t`
	`apic1(config)# tenant tenant_A;`
	`application application_A; epg epg_A`
	`apic1(config-tenant-app-epg)# ip igmp snooping static-group 227.1.1.1 leaf 101 interface ethernet 1/11 vlan 309`
	`apic1(config-tenant-app-epg)# exit`
	`apic1(config-tenant-app)# exit`
		• IGMP snooping on the statically-linked target interface 1/10 and associates it with a multicast IP address, 225.1.1.1
		• IGMP snooping on the statically-linked target interface 1/11 and associates it with a multicast IP address, 227.1.1.1

Enabling IGMP Snoop Access Groups

An “access-group” is used to control what streams can be joined behind a given port.

An access-group configuration can be applied on interfaces that are statically assigned to an application EPG in order to ensure that the configuration can be applied on ports that will actually belong to the that EPG.

Only Route-map-based access groups are allowed.

IGMP snoop access groups can be configured through the APIC GUI, CLI, and REST API interfaces.

Enabling Group Access to IGMP Snooping and Multicast using the NX-OS Style CLI

After you have enabled IGMP snooping and multicast on ports that have been statically assigned to an EPG, you can then create and assign access groups of users that are permitted or denied access to the IGMP snooping and multicast traffic enabled on those ports.

The steps described in this task assume the pre-configuration of the following entities:

- Tenant: tenant_A
- Application: application_A
- EPG: epg_A
- Bridge Domain: bridge_domain_A
- vrf: vrf_A -- a member of bridge_domain_A
- VLAN Domain: vd_A (configured with a range of 300-310)
- Leaf switch: 101 and interface 1/10

  The target interface 1/10 on switch 101 is associated with VLAN 305 and statically linked with tenant_A, application_A, epg_A

- Leaf switch: 101 and interface 1/11

  The target interface 1/11 on switch 101 is associated with VLAN 309 and statically linked with tenant_A, application_A, epg_A

Note For details on static port assignment, see *Deploying an EPG on a Specific Port with APIC Using the NX-OS Style CLI* in the *Cisco APIC Layer 2 Networking Configuration Guide*.

Procedure

	Command or Action	Purpose

Step 1	Define the route-map "access groups."
	Example:
	`apic1# conf t`
	`apic1(config)# tenant tenant_A; application application_A; epg epg_A`
	`apic1(config-tenant)# route-map fooBroker permit`
	`apic1(config-tenant-rtmap)# match ip multicast group 225.1.1.1/24`
	`apic1(config-tenant-rtmap)# exit`
	
	`apic1(config-tenant)# route-map fooBroker deny`
	`apic1(config-tenant-rtmap)# match ip multicast group 227.1.1.1/24`
	`apic1(config-tenant-rtmap)# exit`
		The example sequences configure:
		• Route-map-access group "foobroker" linked to multicast group 225.1.1.1/24, access permited
		• Route-map-access group "foobroker" linked to multicast group 227.1.1.1/24, access denied

Step 2	Verify route map configurations.
	Example:
	`apic1(config-tenant)# show running-config tenant test route-map fooBroker`
	`# Command: show running-config tenant test route-map fooBroker`
	`# Time: Mon Aug 29 14:34:30 2016`
	`tenant test`
	`route-map fooBroker permit 10`
	`match ip multicast group 225.1.1.1/24`
	`exit`
	`route-map fooBroker deny 20`
	`match ip multicast group 227.1.1.1/24`
	`exit`
	`exit`	

Step 3	Specify the access group connection path.
	Example:
	`apic1(config-tenant)# application application_A`
	`apic1(config-tenant-app)# epg epg_A`
		The example sequences configure:
		• Route-map-access group "foobroker" connected through leaf switch 101, interface 1/10, and VLAN 305.

	Command or Action	Purpose
	`apic1(config-tenant-app-epg)# ip igmp snooping access-group route-map fooBroker leaf 101 interface ethernet 1/10 vlan 305` `apic1(config-tenant-app-epg)# ip igmp snooping access-group route-map newBroker leaf 101 interface ethernet 1/10 vlan 305`	• Route-map-access group "newbroker" connected through leaf switch 101, interface 1/10, and VLAN 305.
Step 4	Verify the access group connections. **Example:** `apic1(config-tenant-app-epg)# show run # Command: show running-config tenant tenant_A application application_A epg epg_A # Time: Mon Aug 29 14:43:02 2016 tenant tenent_A application application_A epg epg_A bridge-domain member bridge_domain_A ip igmp snooping access-group route-map fooBroker leaf 101 interface ethernet 1/10 vlan 305 ip igmp snooping access-group route-map fooBroker leaf 101 interface ethernet 1/11 vlan 309 ip igmp snooping access-group route-map newBroker leaf 101 interface ethernet 1/10 vlan 305 ip igmp snooping static-group 225.1.1.1 leaf 101 interface ethernet 1/10 vlan 305 ip igmp snooping static-group 225.1.1.1 leaf 101 interface ethernet 1/11 vlan 309 exit exit exit`	

Deploying an EPG on a Specific Port with APIC Using the NX-OS Style CLI

Procedure

Step 1 Configure a VLAN domain:

Example:

```
apic1(config)# vlan-domain dom1
apic1(config-vlan)# vlan 10-100
```

Step 2 Create a tenant:

Example:

```
apic1# configure
apic1(config)# tenant t1
```

Step 3 Create a private network/VRF:

Example:

```
apic1(config-tenant)# vrf context ctx1
apic1(config-tenant-vrf)# exit
```

Step 4 Create a bridge domain:

Example:

```
apic1(config-tenant)# bridge-domain bd1
apic1(config-tenant-bd)# vrf member ctx1
apic1(config-tenant-bd)# exit
```

Step 5 Create an application profile and an application EPG:

Example:

```
apic1(config-tenant)# application AP1
apic1(config-tenant-app)# epg EPG1
apic1(config-tenant-app-epg)# bridge-domain member bd1
apic1(config-tenant-app-epg)# exit
apic1(config-tenant-app)# exit
apic1(config-tenant)# exit
```

Step 6 Associate the EPG with a specific port:

Example:

```
apic1(config)# leaf 1017
apic1(config-leaf)# interface ethernet 1/13
apic1(config-leaf-if)# vlan-domain member dom1
apic1(config-leaf-if)# switchport trunk allowed vlan 20 tenant t1 application AP1 epg EPG1
```

Note The vlan-domain and vlan-domain member commands mentioned in the above example are a pre-requisite for deploying an EPG on a port.

Configuring Port Security

About Port Security and ACI

The port security feature protects the ACI fabric from being flooded with unknown MAC addresses by limiting the number of MAC addresses learned per port. The port security feature support is available for physical ports, port channels, and virtual port channels.

Port Security Guidelines and Restrictions

The guidelines and restrictions are as follows:

- Port security is available per port.
- Port security is supported for physical ports, port channels, and virtual port channels (vPCs).
- Static and dynamic MAC addresses are supported.
- MAC address moves are supported from secured to unsecured ports and from unsecured ports to secured ports.
- The MAC address limit is enforced only on the MAC address and is not enforced on a MAC and IP address.
- Port security is not supported with the Fabric Extender (FEX).

Port Security at Port Level

In the APIC, the user can configure the port security on switch ports. Once the MAC limit has exceeded the maximum configured value on a port, all traffic from the exceeded MAC addresses is forwarded. The following attributes are supported:

- **Port Security Timeout**—The current supported range for the timeout value is from 60 to 3600 seconds.
- **Violation Action**—The violation action is available in protect mode. In the protect mode, MAC learning is disabled and MAC addresses are not added to the CAM table. Mac learning is re-enabled after the configured timeout value.
- **Maximum Endpoints**—The current supported range for the maximum endpoints configured value is from 0 to 12000. If the maximum endpoints value is 0, the port security policy is disabled on that port.

Configuring a Port Security Policy Group Template

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `apic1#` **`configure`**	Enters configuration mode.
Step 2	[**no**] **template policy-group** *policy-group-name* **Example:** `apic1(config)#` **`template policy-group PortSecGrp1`**	Creates (or deletes) a policy group template.

	Command or Action	Purpose
Step 3	[**no**] **switchport access vlan** *vlan-id* **tenant** *tenant-name* **application** *application-name* **epg** *epg-name* **Example:** `apic1(config-pol-grp-if)# switchport access vlan 4 tenant ExampleCorp application Web epg webEpg`	
Step 4	[**no**] **switchport port-security maximum** *number-of-addresses* **Example:** `apic1(config-pol-grp-if)# switchport port-security maximum 1`	Sets the maximum number of secure MAC addresses for the port. The range is 0 to 12000 addresses. The default is 1 address.
Step 5	[**no**] **switchport port-security violation protect** **Example:** `apic1(config-pol-grp-if)# switchport port-security violation protect`	Sets the action to be taken when a security violation is detected. The **protect** action drops packets with unknown source addresses until you remove a sufficient number of secure MAC addresses to drop below the maximum value.
Step 6	**exit** **Example:** `apic1(config-pol-grp-if)# exit`	Returns to global configuration mode.

Example

This example shows how to create a port security policy group template.

```
apic1# configure
apic1(config)# template policy-group PortSecGrp1
apic1(config-pol-grp-if)# switchport port-security maximum 20
apic1(config-pol-grp-if)# switchport port-security violation protect
apic1(config-pol-grp-if)# exit
```

What to do next

Apply the port security template to an interface.

Configuring Port Security on an Interface Using a Template

Before you begin

Create a port security policy group template.

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `apic1# configure`	Enters configuration mode.
Step 2	**leaf** *node-id* **Example:** `apic1(config)# leaf 101`	Specifies the leaf to be configured.
Step 3	**interface** *type-or-range* **Example:** `apic1(config-leaf)# interface eth 1/2-4`	Specifies a port or a range of ports to be configure.
Step 4	[**no**] **policy-group** *policy-group-name* **Example:** `apic1(config-leaf-if)# policy-group PortSecGrp1`	Applies the policy group template to the port or range of ports.

Example

This example shows how to apply a port security policy group template to a range of Ethernet ports.

```
apic1# configure
apic1(config)# leaf 101
apic1(config-leaf)# interface eth 1/2-4
apic1(config-leaf-if)# policy-group PortSecGrp1
```

This example shows how to configure port security on a port channel using a template.

```
apic1# configure
apic1(config)# template port-channel po1
apic1(config-if)# switchport port-security maximum 10
apic1(config-if)# switchport port-security violation protect
apic1(config-if)# exit
apic1(config)# leaf 101
apic1(config-leaf)# interface eth 1/3-4
apic1(config-leaf-if)# channel-group po1
apic1(config-leaf-if)# exit
apic1(config-leaf)# exit
```

Configuring Port Security on an Interface Using Overrides

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `apic1# configure`	Enters configuration mode.
Step 2	**leaf** *node-id* **Example:** `apic1(config)# leaf 101`	Specifies the leaf to be configured.
Step 3	**interface** *type-or-range* **Example:** `apic1(config-leaf)# interface eth 1/2-4`	Specifies an interface or a range of interfaces to be configured.
Step 4	[**no**] **switchport port-security maximum** *number-of-addresses* **Example:** `apic1(config-leaf-if)# switchport port-security maximum 1`	Sets the maximum number of secure MAC addresses for the interface. The range is 0 to 12000 addresses. The default is 1 address.
Step 5	[**no**] **switchport port-security violation protect** **Example:** `apic1(config-leaf-if)# switchport port-security violation protect`	Sets the action to be taken when a security violation is detected. The **protect** action drops packets with unknown source addresses until you remove a sufficient number of secure MAC addresses to drop below the maximum value.

Example

This example shows how to configure port security on an Ethernet interface.

```
apic1# configure
apic1(config)# leaf 101
apic1(config-leaf)# interface eth 1/2
apic1(config-leaf-if)# switchport port-security maximum 10
apic1(config-leaf-if)# switchport port-security violation protect
```

This example shows how to configure port security on a port channel.

```
apic1# configure
apic1(config)# leaf 101
apic1(config-leaf)# interface port-channel po2
apic1(config-leaf-if)# switchport port-security maximum 10
apic1(config-leaf-if)# switchport port-security violation protect
```

This example shows how to configure port security on a virtual port channel (VPC).

```
apic1# configure
apic1(config)# vpc domain explicit 1 leaf 101 102
apic1(config-vpc)# exit
apic1(config)# template port-channel po4
apic1(config-if)# exit
apic1(config)# leaf 101-102
apic1(config-leaf)# interface eth 1/11-12
apic1(config-leaf-if)# channel-group po4 vpc
apic1(config-leaf-if)# exit
apic1(config-leaf)# exit
apic1(config)# vpc context leaf 101 102
apic1(config-vpc)# interface vpc po4
apic1(config-vpc-if)# switchport port-security maximum 10
apic1(config-vpc-if)# switchport port-security violation protect
```

802.1x Port and Node Authentication

802.1x Port and Node Authentication

IEEE 802.1x is a port-based authentication mechanism to prevent unauthorized devices from gaining access to the network. You can configure 802.1x port and node authentication using the NX-OS style CLI.

Configuring a Port Authentication Policy

Procedure

Step 1 In the CLI, enter configuration mode:

Example:

```
apic1# configure
apic1(config)#
```

Step 2 Create a policy group:

Example:

```
apic1(config)# template policy-group mypol
```

Step 3 Configure port-level authentication policy in the policy group:

Example:

```
apic1(config-pol-grp-if)# switchport port-authentication mydot1x
```

Step 4 Configure host mode (two modes are supported: multi-host and single-host - single being the default setting):

Example:

```
apic1(config-port-authentication)# host-mode multi-host
```

Step 5 Enable this policy (policy is disabled by default):

Example:

```
apic1(config-port-authentication)# no shutdown
apic1(config-port-authentication)# exit
apic1(config-pol-grp-if)# exit
apic1(config)#
```

Step 6 Configure the leaf interface profile:

Example:

```
apic1(config)#leaf-interface-profile myprofile
```

Step 7 Configure a policy group for the leaf switch interface profile:

Example:

```
apic1(config-leaf-if-profile)#leaf-interface-group mygroup
```

Step 8 Specify ports and/or interfaces for your interface group:

Example:

```
apic1(config-leaf-if-group)# interface ethernet 1/10-12
```

Step 9 Apply the policy on your interface group:

Example:

```
apic1(config-leaf-if-group)# policy-group mypol
apic1(config-leaf-if-group)# exit
apic1(config-leaf-if-profile)# exit
```

Step 10 Configure the leaf profile :

Example:

```
apic1(config)#
apic1(config)# leaf-profile myleafprofile
```

Step 11 Configure the leaf policy group and specify leaf switch nodes for the group:

Example:

```
apic1(config-leaf-profile)# leaf-group myleafgrp
apic1(config-leaf-group)# leaf 101
apic1(config-leaf-group)# exit
```

Step 12 Apply an interface policy on the leaf switch profile:

Example:

```
apic1(config-leaf-profile)# leaf-interface-profile myprofile
apic1(config-leaf-group)# exit
apic1(config)#
```

Configuring a Node Authentication Policy

Procedure

Step 1 In the CLI, enter configuration mode:

Example:

```
apic1# configure
apic1(config)#
```

Step 2 Configure the radius authentication group:

Example:

```
apic1(config)# aaa group server radius myradiusgrp
 apic1(config-radius)#server 192.168.0.100 priority 1
apic1(config-radius)#exit
```

Step 3 Configure node level port authentication policy:

Example:

```
apic1(config)# policy-map type port-authentication mydot1x
apic1(config-pmap-port-authentication)#radius-provider-group myradiusgrp
```

Step 4 [Optional] Override the defaul VLAN ID if authentication fails. :

Example:

```
apic1(config-pmap-port-authentication)#fail-auth-vlan 2001
```

Step 5 [Optional] Override defaul EPG if authentication fails:

Example:

```
apic1(config-pmap-port-authentication)#fail-auth-epg tenant tn1 application ap1 epg epg256
apic1(config)# exit
```

Step 6 Configure policy group and specify port authentication policy in the group:

Example:

```
apic1(config)#template leaf-policy-group lpg2
apic1(config-leaf-policy-group)# port-authentication mydot1x
apic1(config-leaf-policy-group)#exit
```

Step 7 Configure the leaf switch profile:

Example:

```
apic1(config)# leaf-profile mylp2
```

Step 8 Configure a group for the leaf switch profile and specify the policy group:

Example:

```
apic1(config-leaf-profile)#leaf-group mylg2
apic1(config-leaf-group)#  leaf-policy-group lpg2
apic1(config-leaf-group)#exit
```

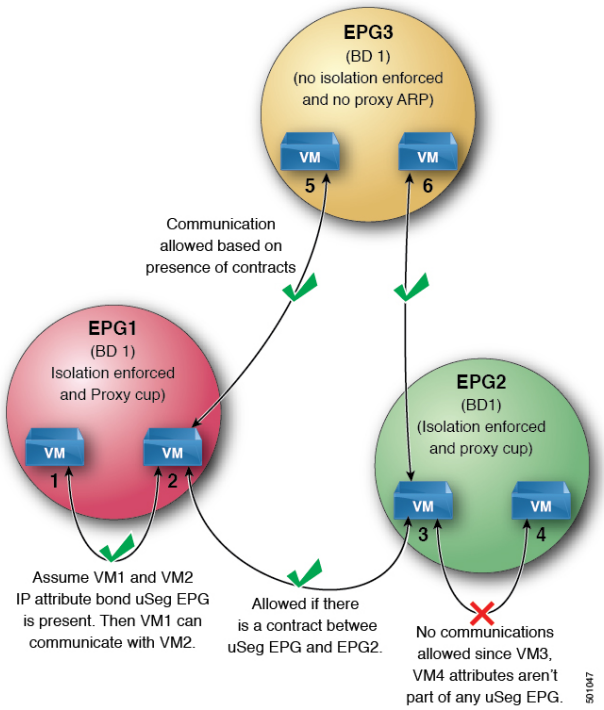
Configuring Proxy ARP

About Proxy ARP

Proxy ARP in Cisco ACI enables endpoints within a network or subnet to communicate with other endpoints without knowing the real MAC address of the endpoints. Proxy ARP is aware of the location of the traffic destination, and offers its own MAC address as the final destination instead.

To enable Proxy ARP, intra-EPG endpoint isolation must be enabled on the EPG see the following figure for details. For more information about intra-EPG isolation and Cisco ACI, see the *Cisco ACI Virtualization Guide*.

Figure 3: Proxy ARP and Cisco APIC



Proxy ARP within the Cisco ACI fabric is different from the traditional proxy ARP. As an example of the communication process, when proxy ARP is enabled on an EPG, if an endpoint A sends an ARP request for endpoint B and if endpoint B is learned within the fabric, then endpoint A will receive a proxy ARP response from the bridge domain (BD) MAC. If endpoint A sends an ARP request for endpoint B, and if endpoint B is not learned within the ACI fabric already, then the fabric will send a proxy ARP request within the BD. Endpoint B will respond to this proxy ARP request back to the fabric. At this point, the fabric does not send a proxy ARP response to endpoint A, but endpoint B is learned within the fabric. If endpoint A sends another ARP request to endpoint B, then the fabric will send a proxy ARP response from the BD MAC.

The following example describes the proxy ARP resolution steps for communication between clients VM1 and VM2:

1. VM1 to VM2 communication is desired.

Figure 4: VM1 to VM2 Communication is Desired.

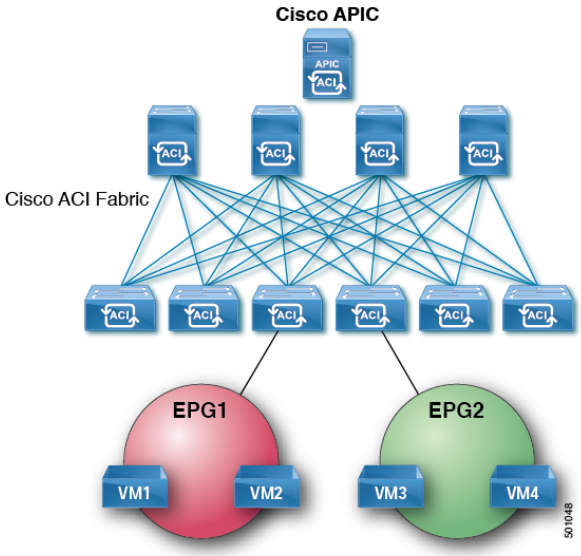


Table 2: ARP Table State

Device	State
VM1	IP = * MAC = *
ACI fabric	IP = * MAC = *
VM2	IP = * MAC = *

2. VM1 sends an ARP request with a broadcast MAC address to VM2.

Figure 5: VM1 sends an ARP Request with a Broadcast MAC address to VM2

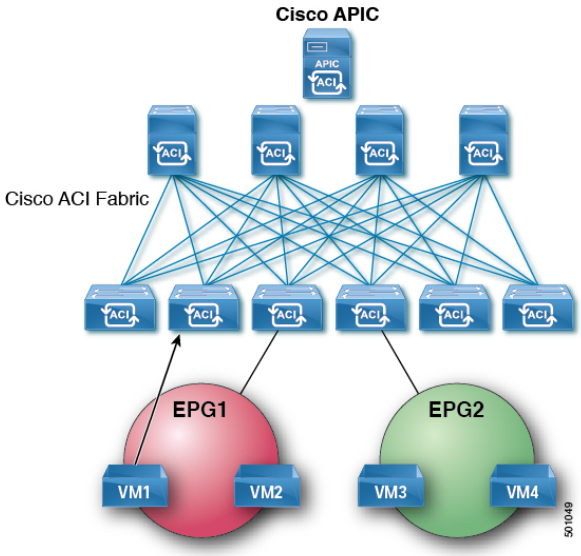


Table 3: ARP Table State

Device	State
VM1	IP = VM2 IP; MAC = ?
ACI fabric	IP = VM1 IP; MAC = VM1 MAC
VM2	IP = * MAC = *

3. The ACI fabric floods the proxy ARP request within the bridge domain (BD).

Figure 6: ACI Fabric Floods the Proxy ARP Request within the BD

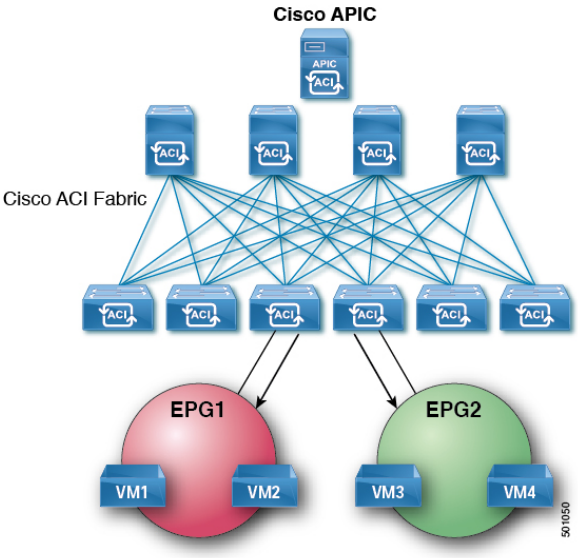


Table 4: ARP Table State

Device	State
VM1	IP = VM2 IP; MAC = ?
ACI fabric	IP = VM1 IP; MAC = VM1 MAC
VM2	IP = VM1 IP; MAC = BD MAC

4. VM2 sends an ARP response to the ACI fabric.

Figure 7: VM2 Sends an ARP Response to the ACI Fabric

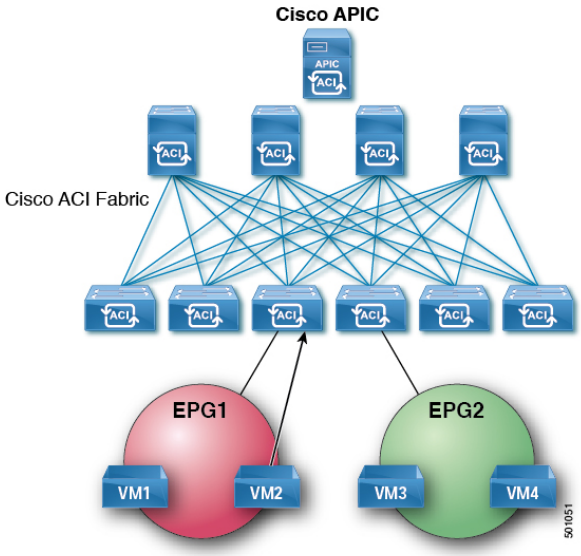


Table 5: ARP Table State

Device	State
VM1	IP = VM2 IP; MAC = ?
ACI fabric	IP = VM1 IP; MAC = VM1 MAC
VM2	IP = VM1 IP; MAC = BD MAC

5. VM2 is learned.

Figure 8: VM2 is Learned

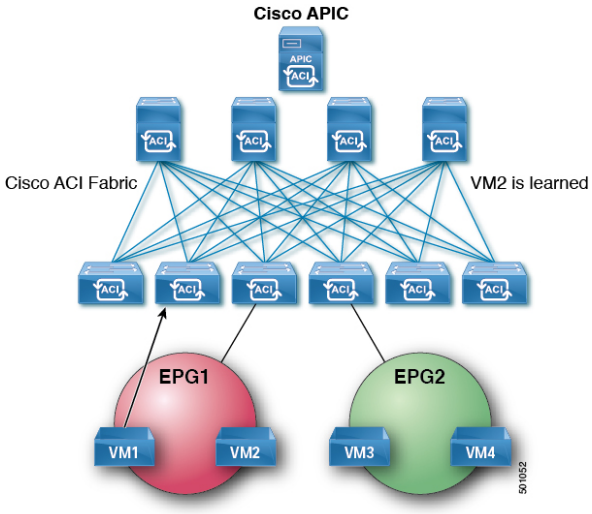


Table 6: ARP Table State

Device	State
VM1	IP = VM2 IP; MAC = ?
ACI fabric	IP = VM1 IP; MAC = VM1 MAC IP = VM2 IP; MAC = VM2 MAC
VM2	IP = VM1 IP; MAC = BD MAC

6. VM1 sends an ARP request with a broadcast MAC address to VM2.

Figure 9: VM1 Sends an ARP Request with a Broadcast MAC Address to VM2

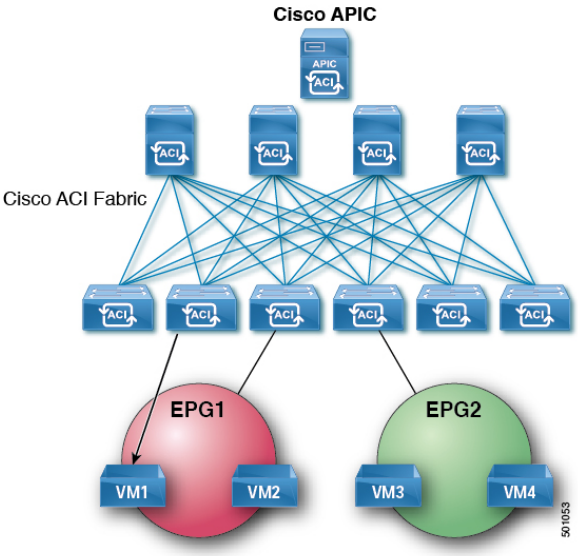


Table 7: ARP Table State

Device	State
VM1	IP = VM2 IP MAC = ?
ACI fabric	IP = VM1 IP; MAC = VM1 MAC IP = VM2 IP; MAC = VM2 MAC
VM2	IP = VM1 IP; MAC = BD MAC

7. The ACI fabric sends a proxy ARP response to VM1.

Figure 10: ACI Fabric Sends a Proxy ARP Response to VM1

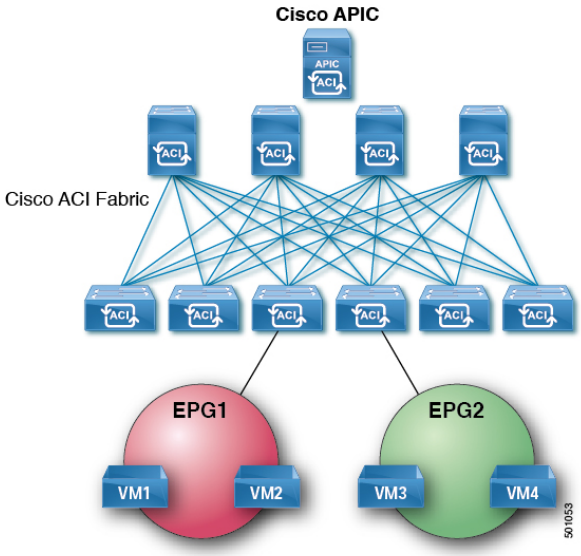


Table 8: ARP Table State

Device	State
VM1	IP = VM2 IP; MAC = BD MAC
ACI fabric	IP = VM1 IP; MAC = VM1 MAC IP = VM2 IP; MAC = VM2 MAC
VM2	IP = VM1 IP; MAC = BD MAC

Guidelines and Limitations

Consider these guidelines and limitations when using Proxy ARP:

- Proxy ARP is supported only on isolated EPGs. If an EPG is not isolated, a fault will be raised. For communication to happen within isolated EPGs with proxy ARP enabled, you must configure uSeg EPGs. For example, within the isolated EPG, there could be multiple VMs with different IP addresses, and you can configure a uSeg EPG with IP attributes matching the IP address range of these VMs.
- ARP requests from isolated endpoints to regular endpoints and from regular endpoints to isolated endpoints do not use proxy ARP. In such cases, endpoints communicate using the real MAC addresses of destination VMs.

Configuring Proxy ARP Using the Cisco NX-OS Style CLI

Before you begin

- The appropriate tenant, VRF, bridge domain, application profile and EPG must be created.

- Intra-EPG isolation must be enabled on the EPG where proxy ARP has to be enabled.

Procedure

	Command or Action	Purpose
Step 1	**configure** **Example:** `apic1# configure`	Enters configuration mode.
Step 2	**tenant** *tenant-name* **Example:** `apic1(config)# tenant Tenant1`	Enters the tenant configuration mode.
Step 3	**application** *application-profile-name* **Example:** `apic1(config-tenant)# application Tenant1-App`	Creates an application profile and enters the application mode.
Step 4	**epg** *application-profile-EPG-name* **Example:** `apic1(config-tenant-app)# epg Tenant1-epg1`	Creates an EPG and enter the EPG mode.
Step 5	**proxy-arp enable** **Example:** `apic1(config-tenant-app-epg)# proxy-arp enable`	Enables proxy ARP. **Note** You can disable proxy-arp with the **no proxy-arp** command.
Step 6	**exit** **Example:** `apic1(config-tenant-app-epg)# exit`	Returns to application profile mode.
Step 7	**exit** **Example:** `apic1(config-tenant-app)# exit`	Returns to tenant configuration mode.
Step 8	**exit** **Example:** `apic1(config-tenant)# exit`	Returns to global configuration mode.

Examples

This example shows how to configure proxy ARP.

```
apic1# conf t
apic1(config)# tenant Tenant1
apic1(config-tenant)# application Tenant1-App
apic1(config-tenant-app)# epg Tenant1-epg1
apic1(config-tenant-app-epg)# proxy-arp enable
apic1(config-tenant-app-epg)#
apic1(config-tenant)#
```

Configuring Flood in Encapsulation

The configuration for Layer 2 external connectivity is similar to a static application EPG, where you map a VLAN on a node port to an EPG and map the EPG to a bridge-domain to provide/consume contracts.

Procedure

	Command or Action	Purpose
Step 1	configure **Example:** `apic1# configure`	Enters configuration mode.
Step 2	tenant *tenant-name* **Example:** `apic1(config)# tenant Tenant1`	Enters the tenant configuration mode.
Step 3	application *application-profile-name* **Example:** `apic1(config)# application Tenant1-App`	Creates an application profile and enters the application mode.
Step 4	epg *application-profile-EPG-name* **Example:** `apic1(config)# epg Tenant1-epg1`	Creates an EPG and enter the EPG mode.
Step 5	flood-on-encapsulation enable **Example:** `apic1(config-tenant-app-epg)# flood-on-encapsulation enable`	Enables flood-on-encapsulation.
Step 6	exit **Example:** `apic1(config-tenant-app-epg)# exit`	Returns to application profile mode.

Configuring Traffic Storm Control

About Traffic Storm Control

A traffic storm occurs when packets flood the LAN, creating excessive traffic and degrading network performance. You can use traffic storm control policies to prevent disruptions on Layer 2 ports by broadcast, unknown multicast, or unknown unicast traffic storms on physical interfaces.

By default, storm control is not enabled in the ACI fabric. ACI bridge domain (BD) Layer 2 unknown unicast flooding is enabled by default within the BD but can be disabled by an administrator. In that case, a storm control policy only applies to broadcast and unknown multicast traffic. If Layer 2 unknown unicast flooding is enabled in a BD, then a storm control policy applies to Layer 2 unknown unicast flooding in addition to broadcast and unknown multicast traffic.

Traffic storm control (also called traffic suppression) allows you to monitor the levels of incoming broadcast, multicast, and unknown unicast traffic over a one second interval. During this interval, the traffic level, which is expressed either as percentage of the total available bandwidth of the port or as the maximum packets per second allowed on the given port, is compared with the traffic storm control level that you configured. When the ingress traffic reaches the traffic storm control level that is configured on the port, traffic storm control drops the traffic until the interval ends. An administrator can configure a monitoring policy to raise a fault when a storm control threshold is exceeded.

Storm Control Guidelines

Configure traffic storm control levels according to the following guidelines and limitations:

- Typically, a fabric administrator configures storm control in fabric access policies on the following interfaces:
  - A regular trunk interface.
  - A direct port channel on a single leaf switch.
  - A virtual port channel (a port channel on two leaf switches).
- Beginning with the APIC Release 4.2(1), support is now available for triggering SNMP traps from Cisco ACI when storm control thresholds are met, with the following restrictions:
  - There are two actions associated with storm control: drop and shutdown. With the shutdown action, interface traps will be raised, but the storm control traps to indicate that the storm is active or clear is not determined by the shutdown action. Storm control traps with the shutdown action on the policy should therefore be ignored.
  - If the ports flap with the storm control policy on, clear and active traps are seen together when the stats are collected. Clear and active traps are typically not seen together, but this is expected behavior in this case.
- For port channels and virtual port channels, the storm control values (packets per second or percentage) apply to all individual members of the port channel. Do not configure storm control on interfaces that are members of a port channel.

Note On switch hardware starting with the APIC 1.3(x) and switch 11.3(x) release, for port channel configurations, the traffic suppression on the aggregated port may be up to two times the configured value. The new hardware ports are internally subdivided into these two groups: slice-0 and slice-1. To check the slicing map, use the `vsh_lc` command `show platform internal hal l2 port gpd` and look for `slice 0` or `slice 1` under the `Sl` column. If port-channel members fall on both slice-0 and slice-1, allowed storm control traffic may become twice the configured value because the formula is calculated based on each slice.

- When configuring by percentage of available bandwidth, a value of 100 means no traffic storm control and a value of 0.01 suppresses all traffic.
- Due to hardware limitations and the method by which packets of different sizes are counted, the level percentage is an approximation. Depending on the sizes of the frames that make up the incoming traffic, the actual enforced level might differ from the configured level by several percentage points. Packets-per-second (PPS) values are converted to percentage based on 256 bytes.
- Maximum burst is the maximum accumulation of rate that is allowed when no traffic passes. When traffic starts, all the traffic up to the accumulated rate is allowed in the first interval. In subsequent intervals, traffic is allowed only up to the configured rate. The maximum supported is 65535 KB. If the configured rate exceeds this value, it is capped at this value for both PPS and percentage.
- The maximum burst that can be accumulated is 512 MB.
- On an egress leaf switch in optimized multicast flooding (OMF) mode, traffic storm control will not be applied.
- On an egress leaf switch in non-OMF mode, traffic storm control will be applied.
- On a leaf switch for FEX, traffic storm control is not available on host-facing interfaces.
- Traffic storm control unicast/multicast differentiation is not supported on Cisco Nexus C93128TX, C9396PX, C9396TX, C93120TX, C9332PQ, C9372PX, C9372TX, C9372PX-E, or C9372TX-E switches.
- SNMP traps for traffic storm control are not supported on Cisco Nexus C93128TX, C9396PX, C9396TX, C93120TX, C9332PQ, C9372PX, C9372TX, C9372PX-E, C9372TX-E switches.
- Traffic storm control traps is not supported on Cisco Nexus C93128TX, C9396PX, C9396TX, C93120TX, C9332PQ, C9372PX, C9372TX, C9372PX-E, or C9372TX-E switches.
- Storm Control Action is supported only on physical Ethernet interfaces and port-channel interfaces.

  Starting with release 4.1(1), Storm Control **Shutdown** option is supported. When the **shutdown** action is selected for an interface with the default Soak Instance Count, the packets exceeding the threshold are dropped for 3 seconds and the port is shutdown on the 3rd second. The default action is **Drop**. When **Shutdown** action is selected, the user has the option to specify the soaking interval. The default soaking interval is 3 seconds. The configurable range is from 3 to 10 seconds.
- Starting with release 4.1(1), Error Disable Recovery option for storm-control is supported for the ports which are in-error-disabled state due to storm **shutdown** action.

Configuring a Traffic Storm Control Policy Using the NX-OS Style CLI

Procedure

	Command or Action	Purpose

Step 1	Enter the following commands to create a PPS policy:
	Example:
	`(config)# template policy-group pg1`
	`(config-pol-grp-if)# storm-control pps 10000 burst-rate 10000`	

Step 2	Enter the following commands to create a percent policy:
	Example:
	`(config)# template policy-group pg2`
	`(config-pol-grp-if)# storm-control level 50 burst-rate 60`	

Step 3	Configure storm control on physical ports, port channels, or virtual port channels:
	Example:
	`[no] storm-control [unicast|multicast|broadcast] level <percentage> [burst-rate <percentage>]`
	`[no] storm-control [unicast|multicast|broadcast] pps <packet-per-second> [burst-rate <packet-per-second>]`
	
	`sd-tb2-ifc1# configure terminal`
	
	`sd-tb2-ifc1(config)# leaf 102`
	
	`sd-tb2-ifc1(config-leaf)# interface ethernet 1/19`
	`sd-tb2-ifc1(config-leaf-if)# storm-control unicast level 35 burst-rate 45`
	`sd-tb2-ifc1(config-leaf-if)# storm-control broadcast level 36 burst-rate 36`
	`sd-tb2-ifc1(config-leaf-if)# storm-control broadcast level 37 burst-rate 38`
	`sd-tb2-ifc1(config-leaf-if)#`
	
	`sd-tb2-ifc1# configure terminal`
	
	`sd-tb2-ifc1(config)# leaf 102`
	
	`sd-tb2-ifc1(config-leaf)# interface ethernet 1/19`
	`sd-tb2-ifc1(config-leaf-if)# storm-control broadcast pps 5000 burst-rate 6000`	

	Command or Action	Purpose
	sd-tb2-ifc1(config-leaf-if)# storm-control unicast pps 7000 burst-rate 7000 sd-tb2-ifc1(config-leaf-if)# storm-control unicast pps 8000 burst-rate 10000 sd-tb2-ifc1(config-leaf-if)#	

Configuring MACsec

About MACsec

MACsec is an IEEE 802.1AE standards based Layer 2 hop-by-hop encryption that provides data confidentiality and integrity for media access independent protocols.

MACsec, provides MAC-layer encryption over wired networks by using out-of-band methods for encryption keying. The MACsec Key Agreement (MKA) Protocol provides the required session keys and manages the required encryption keys.

The 802.1AE encryption with MKA is supported on all types of links, that is, host facing links (links between network access devices and endpoint devices such as a PC or IP phone), or links connected to other switches or routers.

MACsec encrypts the entire data except for the Source and Destination MAC addresses of an Ethernet packet. The user also has the option to skip encryption up to 50 bytes after the source and destination MAC address.

To provide MACsec services over the WAN or Metro Ethernet, service providers offer Layer 2 transparent services such as E-Line or E-LAN using various transport layer protocols such as Ethernet over Multiprotocol Label Switching (EoMPLS) and L2TPv3.

The packet body in an EAP-over-LAN (EAPOL) Protocol Data Unit (PDU) is referred to as a MACsec Key Agreement PDU (MKPDU). When no MKPDU is received from a participants after 3 hearbeats (each hearbeat is of 2 seconds), peers are deleted from the live peer list. For example, if a client disconnects, the participant on the switch continues to operate MKA until 3 heartbeats have elapsed after the last MKPDU is received from the client.

APIC Fabric MACsec

The APIC will be responsible for the MACsec keychain distribution to all the nodes in a Pod or to particular ports on a node. Below are the supported MACsec keychain and MACsec policy distribution supported by the APIC.

- A single user provided keychain and policy per Pod
- User provided keychain and user provided policy per fabric interface
- Auto generated keychain and user provided policy per Pod

A node can have multiple policies deployed for more than one fabric link. When this happens, the per fabric interface keychain and policy are given preference on the affected interface. The auto generated keychain and associated MACsec policy are then given the least preference.

APIC MACsec supports two security modes. The MACsec **must secure** only allows encrypted traffic on the link while the **should secure** allows both clear and encrypted traffic on the link. Before deploying MACsec in **must secure** mode, the keychain must be deployed on the affected links or the links will go down. For example, a port can turn on MACsec in **must secure** mode before its peer has received its keychain resulting in the link going down. To address this issue the recommendation is to deploy MACsec in **should secure** mode and once all the links are up then change the security mode to **must secure**.

Note Any MACsec interface configuration change will result in packet drops.

MACsec policy definition consists of configuration specific to keychain definition and configuration related to feature functionality. The keychain definition and feature functionality definitions are placed in separate policies. Enabling MACsec per Pod or per interface involves deploying a combination of a keychain policy and MACsec functionality policy.

Note Using internal generated keychains do not require the user to specify a keychain.

APIC Access MACsec

MACsec is used to secure links between leaf switch L3out interfaces and external devices. APIC provides GUI and CLI to allow users to program the MACsec keys and MacSec configuration for the L3Out interfaces on the fabric on a per physical/pc/vpc interface basis. It is the responsibility of the user to make sure that the external peer devices are programmed with the correct MacSec information.

Guidelines and Limitations for MACsec

Configure MACsec according to the following guidelines and limitations:

- Beginning with Cisco ACI Release 4.0, MACsec is supported on remote leaf switches.
- Fex ports are not supported for MACsec.
- Must-secure mode is not supported at Pod level.
- A MACsec policy with name ‘default’ is not supported.
- Auto key generation is only supported at the Pod level for fabric ports.
- Do not clean reboot a node if the fabric ports of that node is running MACsec in **must-secure** mode.
- Adding a new node to a Pod or stateless reboot of a node in a Pod which is running MACsec, **must-secure** mode requires changing the mode to should-secure in order for the node to join the Pod.
- Upgrade/Downgrade should only be initiated if the fabric links are in **should-secure** mode. Once upgrade/downgrade has completed, then the mode can be changed to **must-secure**.
  Upgrading/Downgrading in **must-secure** mode will result in nodes losing connectivity to the fabric. Recovering from connectivity loss requires that the fabric links of the nodes visible to the APIC be configured to **should-secure** mode. If the fabric was downgraded to a version which does not support MACsec, then nodes which are out of fabric will need to be clean rebooted.

- For PC/vPC interface, MACsec can be deployed via policy groups per PC/vPC interface. Port selectors are used to deploy the policies to a particular set of ports. Therefore, it is the user's responsibility to create the right port selector corresponding to the L3Out interfaces.
- It is recommended that MACsec polices be configured to **should-secure** mode before a configuration is exported.
- All the links on a spine are considered fabric links. However, if a spine link is used for IPN connectivity, then this link will be treated as an access link. This means that MACsec access policy needs to be used to deploy MACsec on these links.
- If a remote leaf fabric link is used for IPN connectivity, then this link will be treated as an access link. A MACsec access policy needs to be used to deploy MACsec on these links.
- Improper deployment of **must-secure** mode on remote leaf fabric links can result in loss of connectivity to the fabric. Follow the instructions provided in Deploying must-secure mode, on page 83 to prevent such issues.
- MACSEC Sessions may take up to a minute to form or tear down when a new key is added to an empty keychain or an active key is deleted from keychain.

Deploying must-secure mode

Incorrect deployment procedure of a policy that is configured for **must-secure** mode can result in a loss of connectivity. The procedure below should be followed in order to prevent such issues:

- It is necessary to ensure that each link pair has their keychains before enabling MACsec **must-secure** mode. To ensure this, the recommendation is to deploy the policy in **should-secure** mode, and once MACsec sessions are active on the expected links, change the mode to **must-secure**.
- Attempting to replace the keychain on a MACsec policy that is configured to **must-secure** can cause links to go down. The recommended procedure outlined below should be followed in this case:
  - Change MACsec policy that is using the new keychain to **should-secure** mode.
  - Verify that the affected interfaces are using should-secure mode.
  - Update MACsec policy to use new keychain.
  - Verify that relevant interfaces with active MACsec sessions are using the new keychain.
  - Change MACsec policy to **must-secure** mode.
- The following procedure should be followed to disable/remove a MACsec policy deployed in must-secure mode:
  - Change the MACsec policy to **should-secure**.
  - Verify that the affected interfaces are using **should-secure** mode.
  - Disable/remove the MACsec policy.

Keychain Definition

- There should be one key in the keychain with a start time of **now**. If **must-secure** is deployed with a keychain that doesn't have a key that is immediately active then traffic will be blocked on that link until

the key becomes current and a MACsec session is started. If **should-secure** mode is being used then traffic will be unencrypted until the key becomes current and a MACsec session has started.

- There should be one key in the keychain with an end time of **infinite**. When a keychain expires, then traffic is blocked on affected interfaces which are configured for **must-secure** mode. Interfaces configured for **should-secure** mode transmit unencrypted traffic.
- There should be overlaps in the end time and start time of keys that are used sequentially to ensure the MACsec session stays up when there is a transition between keys.

Configuring MACsec Using the NX-OS Style CLI

Procedure

Step 1 Configure MACsec Security Policy for access interfaces

Example:

```
apic1# configure
apic1(config)#   template macsec access security-policy accmacsecpol1
apic1(config-macsec-param)#     cipher-suite gcm-aes-128
apic1(config-macsec-param)#     conf-offset offset-30
apic1(config-macsec-param)#     description 'description for mac sec parameters'
apic1(config-macsec-param)#     key-server-priority 1
apic1(config-macsec-param)#     sak-expiry-time 110
apic1(config-macsec-param)#     security-mode must-secure
aapic1(config-macsec-param)#     window-size 1
apic1(config-macsec-param)#     exit
apic1(config)#
```

Step 2 Configure MACsec key chain for access interface:

PSK can be configured in 2 ways:

Note
- Inline with the **psk-string** command as illustrated in key 12ab below. The PSK is not secure because it is logged and exposed.
- Entered separately in a new command **Enter PSK string** after the **psk-string** command as illustrated in key ab12. The PSK is secured because it is only echoed locally and is not logged.

Example:

```
apic1# configure
apic1(config)#   template macsec access keychain acckeychainpol1
apic1(config-macsec-keychain)#     description 'macsec key chain kc1'
apic1(config-macsec-keychain)#     key 12ab
apic1(config-macsec-keychain-key)#       life-time start 2017-09-19T12:03:15 end
2017-12-19T12:03:15
apic1(config-macsec-keychain-key)#       psk-string 123456789a223456789a323456789abc
apic1(config-macsec-keychain-key)#       exit
apic1(config-macsec-keychain)#     key ab12
apic1(config-macsec-keychain-key)#       life-time start now end infinite
apic1(config-macsec-keychain-key)#       life-time start now end infinite
apic1(config-macsec-keychain-key)# psk-string
Enter PSK string: 123456789a223456789a323456789abc
apic1(config-macsec-keychain-key)# exit
apic1(config-macsec-keychain)# exit
apic1(config)#
```

Step 3 Configure MACsec interface policy for access interface:

Example:

```
apic1# configure
apic1(config)#   template macsec access interface-policy accmacsecifpol1
apic1(config-macsec-if-policy)#     inherit macsec security-policy accmacsecpol1 keychain
acckeychainpol1
apic1(config-macsec-if-policy)#     exit
apic1(config)#
```

Step 4 Associate MACsec interface policy to access interfaces on leaf (or spine):

Example:

```
apic1# configure
apic1(config)#   template macsec access interface-policy accmacsecifpol1
apic1(config-macsec-if-policy)#     inherit macsec security-policy accmacsecpol1 keychain
acckeychainpol1
apic1(config-macsec-if-policy)#     exit
apic1(config)
```

Step 5 Configure MACsec Security Policy for fabric interfaces:

Example:

```
apic1# configure
apic1(config)#   template macsec fabric security-policy fabmacsecpol1
apic1(config-macsec-param)#     cipher-suite gcm-aes-xpn-128
apic1(config-macsec-param)#     description 'description for mac sec parameters'
apic1(config-macsec-param)#     window-size 1
apic1(config-macsec-param)#     sak-expiry-time 100
apic1(config-macsec-param)#     security-mode must-secure
apic1(config-macsec-param)#     exit
apic1(config)#
```

Step 6 Configure MACsec key chain for fabric interface:

PSK can be configured in 2 ways:

Note

- Inline with the **psk-string** command as illustrated in key 12ab below. The PSK is not secure because it is logged and exposed.
- Entered separately in a new command **Enter PSK string** after the **psk-string** command as illustrated in key ab12. The PSK is secured because it is only echoed locally and is not logged.

Example:

```
apic1# configure
apic1(config)#   template macsec fabric security-policy fabmacsecpol1
apic1(config-macsec-param)#     cipher-suite gcm-aes-xpn-128
apic1(config-macsec-param)#     description 'description for mac sec parameters'
apic1(config-macsec-param)#     window-size 1
apic1(config-macsec-param)#     sak-expiry-time 100
apic1(config-macsec-param)#     security-mode must-secure
apic1(config-macsec-param)#     exit
apic1(config)#   template macsec fabric keychain fabkeychainpol1
apic1(config-macsec-keychain)#     description 'macsec key chain kc1'
apic1(config-macsec-keychain)#     key 12ab
apic1(config-macsec-keychain-key)#       psk-string 123456789a223456789a323456789abc
apic1(config-macsec-keychain-key)#       life-time start 2016-09-19T12:03:15 end
2017-09-19T12:03:15
apic1(config-macsec-keychain-key)#       exit
apic1(config-macsec-keychain)#     key cd78
apic1(config-macsec-keychain-key)# psk-string
```

```
Enter PSK string: 123456789a223456789a323456789abc
apic1(config-macsec-keychain-key)# life-time start now end infinite
apic1(config-macsec-keychain-key)# exit
apic1(config-macsec-keychain)# exit
apic1(config)#
```

Step 7 Associate MACsec interface policy to fabric interfaces on leaf (or spine):

Example:

```
apic1# configure
apic1(config)#   leaf 101
apic1(config-leaf)#     fabric-interface ethernet 1/52-53
apic1(config-leaf-if)#       inherit macsec interface-policy fabmacsecifpol2
apic1(config-leaf-if)#       exit
apic1(config-leaf)#
```