Cisco APIC Layer 4 to Layer 7 Device Package Development Guide

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CONTENTS

Preface

This preface includes the following sections:

Audience

This guide is intended primarily for data center administrators with responsibilities and expertise in one or more of the following:

- Virtual machine installation and administration
- Server administration
- Switch and network administration

Document Conventions

Command descriptions use the following conventions:

Convention	Description
bold	Bold text indicates the commands and keywords that you enter literally as shown.
Italic	Italic text indicates arguments for which the user supplies the values.
[x]	Square brackets enclose an optional element (keyword or argument).

Convention	Description
[x | y]	Square brackets enclosing keywords or arguments separated by a vertical bar indicate an optional choice.
{x | y}	Braces enclosing keywords or arguments separated by a vertical bar indicate a required choice.
[x {y | z}]	Nested set of square brackets or braces indicate optional or required choices within optional or required elements. Braces and a vertical bar within square brackets indicate a required choice within an optional element.
`variable`	Indicates a variable for which you supply values, in context where italics cannot be used.
string	A nonquoted set of characters. Do not use quotation marks around the string or the string will include the quotation marks.

Examples use the following conventions:

Convention	Description
`screen font`	Terminal sessions and information the switch displays are in screen font.
`boldface screen font`	Information you must enter is in boldface screen font.
italic screen font	Arguments for which you supply values are in italic screen font.
< >	Nonprinting characters, such as passwords, are in angle brackets.
[ ]	Default responses to system prompts are in square brackets.
!, #	An exclamation point (!) or a pound sign (#) at the beginning of a line of code indicates a comment line.

This document uses the following conventions:

Note Means *reader take note*. Notes contain helpful suggestions or references to material not covered in the manual.

Caution Means *reader be careful*. In this situation, you might do something that could result in equipment damage or loss of data.

Warning IMPORTANT SAFETY INSTRUCTIONS

This warning symbol means danger. You are in a situation that could cause bodily injury. Before you work on any equipment, be aware of the hazards involved with electrical circuitry and be familiar with standard practices for preventing accidents. Use the statement number provided at the end of each warning to locate its translation in the translated safety warnings that accompanied this device.

SAVE THESE INSTRUCTIONS

Related Documentation

The Application Centric Infrastructure documentation set includes the following documents:

Web-Based Documentation

- *Cisco APIC Management Information Model Reference*
- *Cisco APIC Online Help Reference*
- *Cisco ACI MIB Support List*

Downloadable Documentation

- *Cisco Application Centric Infrastructure Release Notes*
- *Cisco Application Centric Infrastructure Fundamentals Guide*
- *Cisco APIC Getting Started Guide*
- *Cisco APIC REST API User Guide*
- *Cisco APIC Command Line Interface User Guide*
- *Cisco APIC Faults, Events, and System Message Guide*
- *Cisco APIC Layer 4 to Layer 7 Device Package Development Guide*
- *Cisco APIC Layer 4 to Layer 7 Services Deployment Guide*
- *Cisco ACI Firmware Management Guide*
- *Cisco ACI Troubleshooting Guide*
- *Cisco ACI NX-OS Syslog Reference Guide*
- *Cisco ACI Switch Command Reference, NX-OS Release 11.0*
- *Cisco ACI MIB Quick Reference*
- *Cisco Nexus CLI to Cisco APIC Mapping Guide*
- *Installing the Cisco Application Virtual Switch with the Cisco APIC*
- *Configuring the Cisco Application Virtual Switch using the Cisco APIC*
- *Application Centric Infrastructure Fabric Hardware Installation Guide*

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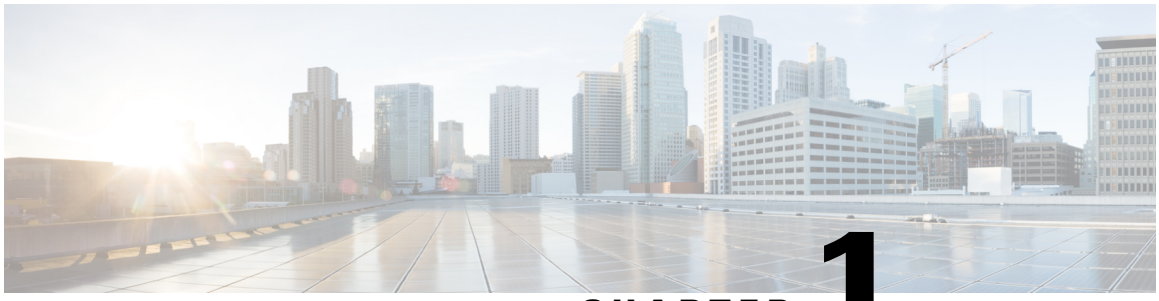


CHAPTER 1

Overview

About Service Integration with the Application Policy Infrastructure Controller

The Application Policy Infrastructure Controller (APIC) automates the insertion and provisioning of network services, such as Secure Sockets Layer (SSL) offload, server load balancing (SLB), Web Application Firewalls (WAFs), and traditional firewalls. The network services are rendered by service appliances, such as Application Delivery Controllers (ADCs) and firewalls. A service appliance can perform one or more service function.

The APIC enables you to define a service graph. Each node in the service graph represents a network function. A graph defines set of service functions that are based on user-defined policies. A service appliance (device) performs a service function within the graph. One or more service appliances can render the services that are required by a graph. One or more service functions can be performed by a single service device.

The APIC requires a device package that you can use to insert and configure network service functions on a network service appliance (device). A device package is a zip file that contains the following:

- `DeviceModel.xml`—The device package must contain a single XML file called `DeviceModel.xml` that is the device specification. The device specification is an XML file that provides a hierarchical description of the device, including the configuration of each function, and is mapped to a set of managed objects on the APIC. The device specification defines the following:
  - Device functions
  - Parameters that are required by the APIC to configure each function
  - Interfaces and network connectivity information for each function
- `DeviceScript.py`—The device package must contain a single Python file called `DeviceScript.py`. You should define the APIs for interfacing between the APIC and the device in this Python file. The device specification XML file associates the device script to this Python file.

The device script manages communication between the APIC and the device. It defines the mapping between APIC events and the function calls representing device interactions, converting calls from a generic API to device-specific calls.

When you upload a device package to the APIC, the APIC creates a hierarchy of managed objects representing the device and validates the device script.

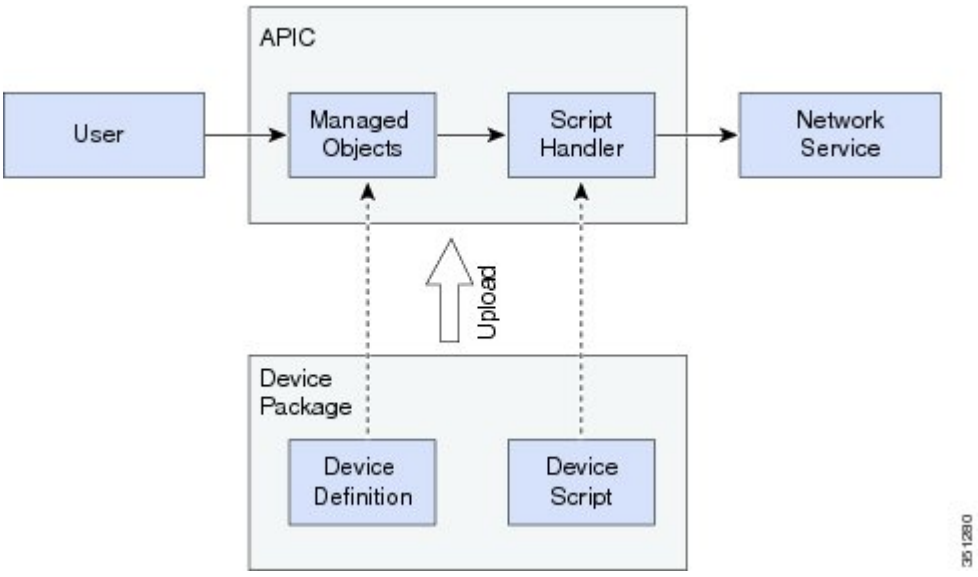
- Additional files and directories that contain Python or text files. The device package can include any supporting Python libraries for interfacing and configuring the device. The supporting Python files can be split across multiple directories. The package can also include any supporting text files. A device package can contain supporting Python egg files.
- `images` directory—The device package must contain the `images` directory, and the directory must contain a single file named *`vendor_name`*`.gif`. The image size must be 28 pixels x 28 pixels.

The following example shows a listing of a package zip file from the vendor named Insieme:

```
bash-4.1$ unzip -l insiemeDevicePackage.zip
Archive:  insiemeDevicePackage.zip
  Length      Date    Time    Name
---------  ---------- -----   ----
   309597  03-17-2014 17:39   DeviceModel.xml
     1597  03-17-2014 17:39   DeviceScript.py
        0  01-30-2014 15:36   common/
     1919  02-06-2014 11:35   common/deviceInterface.py
        0  01-30-2014 15:36   feature/
    21919  02-06-2014 11:35   feature/functionCommon.py
     6485  10-31-2013 06:32   feature/function2.py
     7747  10-31-2013 06:32   feature/function1.py
        0  10-31-2013 06:32   feature/__init__.py
        0  01-30-2014 15:36   lib/
     1919  02-06-2014 11:35   lib/
        0  01-30-2014 15:36   util/
    21919  02-06-2014 11:35   util/logging.py
        0  10-31-2013 06:32   parser/configParser.py
        0  02-12-2014 10:07   images/
     1380  02-12-2014 10:07   images/insieme.gif
```

The following figure describes the relationship between a device package and the APIC.

Figure 1: APIC Package Upload



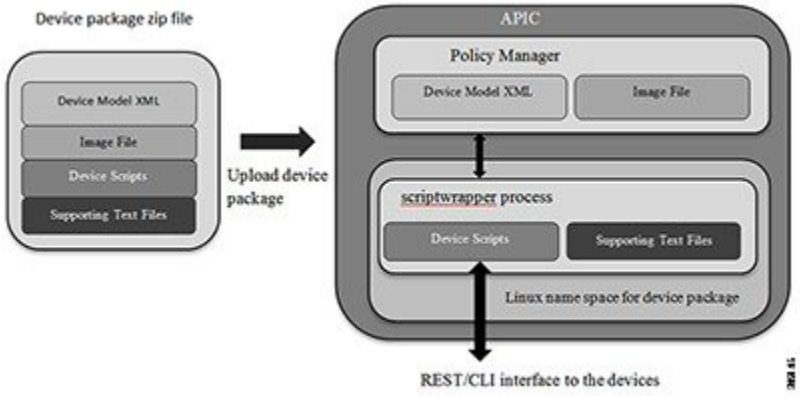
After you develop the device package, you can manage the following:

- Health Monitoring
- Faults
- Counters

About the Device Package Architecture

The following figure shows the Application Policy Infrastructure Controller (APIC) service automation and insertion architecture through the device package.

Figure 2: Device Package Architecture



When you upload a device package through the GUI or northbound APIC interface, the APIC creates a namespace for each unique device package. The content of the device package is unzipped and copied to the namespace. The file structure created for a device package namespace is as follows:

```
root@apic1:/# ls
bin  dbin  dev  etc  fwk  install images lib  lib64  logs  pipe  sbin  tmp  usr util

root@apic1:/install# ls
DeviceScript.py DeviceSpecification.xml feature common images  lib  util.py
```

The contents of the device package are copied under the `install` directory.

The APIC parses the device model. The managed objects that are defined in the XML file are added to the APIC's managed object tree that is maintained by the Policy Manager.

The Python scripts that are defined in the device package are launched within a script wrapper process in the name space. The access to the file system is restricted. Python scripts can create temporary files under `/tmp` and can access any text files that were bundled as part of the device package. However, you should not create Python scripts that create or store any persistent data in a file.

The logs are written to two files: the debug.log and the periodic.log. Any configuration API event logs are written to the debug.log and any periodic poll API logs are written to the periodic.log. The logging framework is similar to the python logging framework.

The log files are accessible by logging in to the APIC as the fabric administrator. The log files are located in `/data/devicescript/<vendorname-model-pkgversion>/logs`.

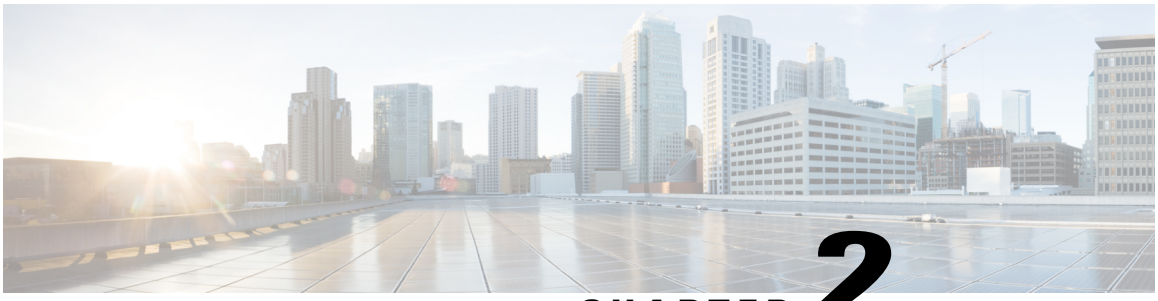
Multiple versions of a device package can coexist on the APIC, because each device package version runs in its own namespace. You can select a specific version for managing a set of devices.

About the Debug Logs

The Application Policy Infrastructure Controller (APIC) maintains log files that you can use to debug a device script. The log files are saved in the following directories:

Directory	Log Files
`/data/devicescript`	`debug.log` and `periodic.log`
`/var/log/dme`	• DME logs—requires administrator privileges to view. • Core files—requires root privileges to use backtrace to check the process stack of a core file. • `svc_ifc_*.log`—requires administrator privileges to view. You need to view these log files only in the event of an issue with the APIC. For more information about exporting log files, see the *Cisco ACI Troubleshooting Guide*.

You must have administrator privileges to access these directories.



CHAPTER 2

Developing Device Specifications

About Device Types

The Application Policy Infrastructure Controller (APIC) classifies network service devices into two types:

- GoTo—Represents any device that is Layer 3 (L3) attached. The packet is delivered to a GoTo device because either the destination MAC or destination IP within the packet identifies the device. Typically, Application Delivery Controllers (ADCs) or L3 firewalls represent a GoTo device.
- GoThrough—Represents any transparent device. The destination MAC or destination IP address is not addressed to the device, but the packet is steered through the device due to VLAN stitching. Typically, Layer 2 (L2) firewall or Intrusion Detection System (IDS) devices represent a GoThrough device. The end stations that exchange packets are not aware of the presence of a GoThrough (transparent device) within the path.

The APIC further classifies device instances registered with an APIC into two categories:

- Concrete device—Represented by vnsCDev, which identifies an instance of a service device. A concrete device can be physical or virtual. A concrete device has its own management IP address to configure and monitor through the APIC.
- Logical device—Represented by vnsLDevVip. vnsLDevVip identifies a cluster of one or more concrete devices. A logical device is addressed and managed through a management IP address that is assigned to the cluster. The service functions offered by the service device are always rendered on a logical device. Typically, a logical device represents a cluster of devices deployed in active-active mode or active-standby high availability mode. If you deploy a device in standalone mode, the logical device contains only one

concrete device. The management IP address for logical devices and concrete devices will be the same. All service operations are always done on a logical device instance.

For information about registering a device with an APIC, see the *Cisco APIC Layer 4 to Layer 7 Services Deployment Guide*.

A service device can be single-context or multi-context. A multi-context device supports multiple routing domains, which means that the device supports overlapping IP addresses to be configured across different routing contexts.

A single-context device must be registered to a specific tenant. A single-context device cannot be shared by multiple tenants. A multi-context device can be registered under a common tenant and can be shared by multiple tenants.

About Device Specifications

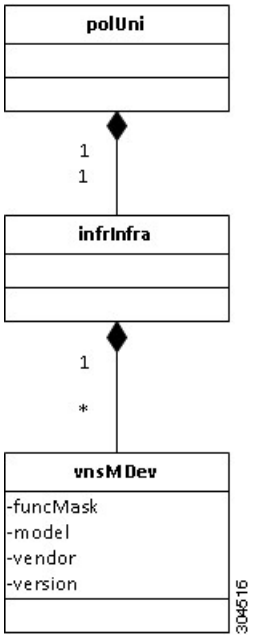
The configuration of the Application Policy Infrastructure Controller (APIC) is represented as an object model that consists of a large number of managed objects (MOs). A device type is defined by a tree of managed objects that have Meta Device (MDev) at the root. The device specification XML file extends the APIC's managed object model by defining a new MDev object.

A device specification file must define a Meta Device (`vnsMDev`) object. The `vnsMDev` object contains metadata that describes vendor-specific information, such as the vendor name, device package version, device version supported, device script binding, and device model describing that functions and parameters that are required to realize these functions on the device.

Each unique version of a device package results in the creation of one instance of a `vnsMDev` object instance with the APIC Policy Manager. The APIC can support many instances of the `vnsMDev` object. The `vnsMDev` object is contained within an infra-policy (represented by infraInfra) under the APIC global policy. The global

policy is the universe of policies, which is represented as polUni. The following figure describes the relations of `vnsMDev` to the APIC's managed object hierarchy.

Figure 3: Relations of vnsMDev to the APIC's Managed Object Hierarchy



The device model is contained by a `vnsMDev` object. The device specification file must have the following structure:

```
<poliUni>
   <infraInfra>
      <vnsMDev>
         <!-- device Sepcification-->
      </vnsMdev>
   </infraInfra>
</poliUni>
```

`vnsMDev` must have the following attributes:

- vendor—Identifies the device package vendor.
- model—Identifies the device models that are managed by the device specification.
- version—Identifies the device package version. You can upload and use one or more versions of a device package on the APIC. The APIC allows you to select a device package to be used for managing a device instance that is registered with the APIC.

  The device package version can be incremented when additional functionality is added to the device package or when the device package is updated to manage later revisions of the device. You should increment the major version of a device package when new functionality is added. You should also increment a minor version for any bug fixes or minor enhancements that are made to the device package.
- funcMask—Indicates whether a device package can support service functions deployed in GoTo or GoThrough mode. A device package can support both the GoTo and the GoThrough mode of service insertion. If both modes are supported, define funcMask as a comma-separated list in the following format:

  `GoTo,GoThrough`

A service function on a device can be deployed as GoTo or GoThrough only when a device package supports such a configuration. Typically, funcMask for firewall device packages supports both the GoTo mode and the GoThrough mode to allow firewalls to be deployed in routed or transparent bridge mode.

The following example shows the `vnsMDev` attributes:

```
<vnsMDev vendor="Insieme"
  model="SampleDevice"
  version="1.0"
  funcMask="GoTo,GoThrough">
```

The `vnsMDev` object instance is identified by the <vendor-model-version> string. The APIC creates a `vnsMDev` instance for each unique <vendor-model-version> string.

The device model is divided into following parts:

- Generic Part—Defines generic information about the device. It consists of the following objects:
  - Device Credentials
  - Interface Labels
- Cluster and Device Configuration Part—Defines any cluster or device specific configuration. It consists of the following objects:
  - Cluster Configuration
  - Device Configuration
- Functional Part—Describes the service functions and its configuration. The configuration is divided under the following objects:
  - Global Functional Device Configuration
  - Group Configuration
  - Function Configuration

Device Script

The device script information is defined through the <vnsDevScript> object. The device Script object associates the python file defining APIC APIs. APIC calls these python APIs to instantiate any service functions defined by the device package.

The device script object contains following attributes:

Attribute	Type	Description
ctrlrVersion	String	Identifies controller API version compatibility. It is a string. It should match with APIC API version - Current accepted value is "1.0"

Attribute	Type	Description
minorversion	String (512 characters)	Identifies the script version. The device package developers should use this version string to track any revisions that are made only to the device script without changing the device model.
versionExpr	String (512 character)	APIC passes this versionExpr string to the script during a deviceValidate call. The device package developer defines any string (it can be regular expression) to indicate device versions that this device package can support.

The minorversion string provides a non-disruptive upgrade of a device package. If only the device scripts have changed and no changes are made to the model, the device package developer should update only the minor version string. When APIC identifies only that the minorversion has changed and that the device package version has not been incremented, it restarts the scripts associated with the package with the new set of files bundled in the device package. The Managed Object Model is not refreshed with the device model specified in the device package. This allows efficient upgrade of the script without triggering re-rendering of the graphs that used the device package.

Devices Credentials

The devices credentials object allows vendors to specify the type of credentials that the Application Policy Infrastructure Controller (APIC) passes to the device script for authentication while communicating with the device. Currently, only the username and password-based authentication is supported. The device specification file must define the following object:

```
<vnsMCred name="username" key="username"/>
<vnsMCredSecret name="password" key="password"/>
```

The device specification file must define only one instance of `vnsMCred` and `vnsMCredSecret`. During the device registration, you provide a value for the username and password object. For more information, see the *Cisco APIC Layer 4 to Layer 7 Services Deployment Guide*.

Interface Labels

Interfaces on the device must be labeled in an abstract way. A function associates with these interfaces to represent a logical flow of packets through the service function. For example, a firewall device could label the interfaces as trusted, untrusted, cluster, and management interfaces. Packets that are received from an untrusted interface could be directed through the firewall function and emitted out of a trusted interface. As another example, a device could label its interface as an external, internal, HA, and management interface. A load balancing function could receive packet from an external interface and load balance to a pool through an internal interface. A single physical interface (or vNIC in case of virtual service) can be assigned one or more labels. The labels are assigned to the interfaces on a device at the time of registering logical and concrete

devices. You can assign multiple labels to a single interface for single arm deployment. The device models must specify labels for its interfaces. The labels are defined using the `vnsMIfLbl` object type.

The following example defines the labels:

```
<vnsMIfLbl name="external" shortName="ext"/>
<vnsMIfLbl name="internal" shortName="int"/>
<vnsMIfLbl name="management" shortName="mgmt" />
```

The `vnsMIfLbl` object must contain the name attribute and shortName attribute. The short name must be four characters or less. The device specification can define one or more types of the `vnsMIfLbl` object.

About Cluster and Device Configurations

The Application Policy Infrastructure Controller (APIC) allows devices to be deployed in standalone, High-Available Active-Standby mode or as a Cluster in Active-Active mode. The cluster and device configuration section allows vendors to specify any configuration that applies to the cluster or a specific node within a cluster irrespective of the HA mode. Cluster and device specification is not mandatory.

Cluster Configurations

The device specification file can define just one cluster configuration object referred to as `vnsClusterCfg`. The cluster configuration contains the configuration for an entire cluster. The configuration that applies to a cluster is represented by one or more objects of type `vnsMParam` that can be further grouped logically under one or more `vnsMFolder` objects.

You can instantiate parameters and folders defined under the cluster configuration for a logical device registered with an Application Policy Infrastructure Controller (APIC). The configuration defined under a cluster configuration is passed to the device script only during a `clusterModify`() or `clusterAudit`() call. The configuration defined under a cluster cannot be referenced by a service function. The cluster configuration is not passed to the scripts during a `serviceModify`(), `serviceAudit`(), `serviceHealth`(), or `serviceCounters`() API call.

`vnsClusterCfg` can contain one or more `vnsMFeature` objects. The `vnsMFeature` object allows logical grouping of cluster configurations. Folders are grouped based on the `dispFeature` attribute defined under folder. The Application Policy Infrastructure Controller (APIC) GUI uses the `vnsMFeature` object to order and group the folders for user input.

A device package developer should define any cluster level configuration within a `vnsClusterCfg` object. For example, a cluster configuration can include a Network Time Protocol (NTP) server configuration and the syslog server IP address.

The following example shows a cluster configuration:

```
<vnsClusterCfg name="ClusterConfig">
  <vnsMFolder key="SyslogConfig">
    <vnsMParam key="ipaddress"
      description="Syslog Server IP address"
      dType="str"
      validation="isIPAddress"/>
  </vnsMFolder>

  <vnsMFolder key="NTPConfig">
    <vnsMParam key="ipaddress"
      description="NTP Server IP address"
      dType="str"
      validation="isIPAddress"/>
  </vnsMFolder>
</vnsClusterCfg>
```

Device Configurations

The device specification file can contain one instance of `vnsDevCfg` that contains a device-specific configuration. The `vnsDevCfg` is contained within a `vnsClusterCfg`. The device-specific configuration is represented by one or more `vnsMParam`, which can be further grouped under one or more `vnsMFolder`.

The configuration that is defined under a device configuration is instantiated by the user during concrete device registration within a logical device. The device configuration is passed to the device scripts only during the `deviceAudit`(), `deviceModify`(), `deviceHealth`(), and `deviceCounters`() calls. The device configuration cannot be referenced from a service function, during the `clusterModify`() call, or during the `clusterAudit`() call.

A device configuration can contain a configuration such as the HA mode on the device, the peer IP address for cluster, or the port-channel (LACP) configuration that must be pushed to a specific device within a cluster.

The following example shows a device configuration:

```
<vnsClusterCfg name="ClusterConfig">
  <vnsDevCfg name="DevCfg">
    <vnsMFolder key="HighAvailabilityCfg" cardinality="n">
      <vnsMParam key="peerIP"
        description="HA Pair peer IP address"
        dType="str"
        validation="isIPAddress"/>
    </vnsMFolder>
  </vnsDevCfg>
</vnsClusterCfg>
```

About Functional Configurations

A device package and a device can support many service functions. Typically, any function that transforms and influences packet forwarding on the device can be represented as a service function. For example, SSL offload, VPN, server load balancing, and web application filtering can be modeled as functions that are supported by the device. One or more such functions can be modeled in the device specification file.

The functions are represented by a `vnsMFunc` object. The `vnsMFunc` object has a name attribute. Each function that is defined within the device package must have a unique name. The name is used to look up a function that is defined under an instance of an MDev.

The `vnsMFunc` object must contain the following objects:

- vnsMConn
- vnsImage

The parameters that are required to render a specific service function can be defined under the following categories:

- Function
- Group
- Device global

The following example shows the structure of a function configuration:

```
<poliUni>
   <infraInfra>
```

```
      <vnsMDev>
        <!-- Generic Part -->

        <!-- Device Credentials -->
        <vnsMCred name=”username” key=”username”/>
        <vnsMCredSecret name=”password” key=”password”/>

        <!-- Interface Labels -->
        <vnsMIfLbl name="external" shortName="ext"/>

        <!-- Cluster Configuration -->
        <vnsClusterCfg name="ClusterCfg">

          <!-- Device Configuration -->
          <vnsDevCfg name="DeviceConfig">

          </vnsDevCfg>
        </vnsClusterCfg>

        <!-- Functional Configuration -->

        <!-- Global Functional Device Configuration -->
        <vnsMDevCfg>
        </vnsMDevCfg>

        <!-- Group Configuration -->
        <vnsGrpCfg>
        </vnsGrpCfg>

        <!—Function configuration: Could be one or more such configuration -->
        <vnsMFunc>
        </vnsMFunc>
      </vnsMdev>
   </infraInfra>
</poliUni>
```

Connector Objects

A function must have at least one connector object: `vnsMConn`. The connector object is used to link one or more functions to form a service graph. If a function is a transit function, it must have at least two connectors. If a function is a stub function, such as a collector, it can have just one connector. Typically, only IDS devices that are in passive mode and are capturing packets that are copied to the device have just one connector defined for the capture function. All other functions, such as a firewall, load balancers, and SSL offload, have two or more connectors. Currently, the Application Policy Infrastructure Controller (APIC) supports a maximum of two connectors per function, which means that you can define an input and output connector for any transit function.

The connector has the following attributes:

Attribute	Mandatory	Description
name	Yes	Specifies the name of the connector. Every connector within a function must have a unique name.

Attribute	Mandatory	Description
encType	Yes	Specifies the connector encapsulation type. This attribute is the encapsulation that is used for traffic on the connector and is specified as a value of `vlan` or `vxlan`. The value specifies whether the packet is sent encapsulated from the network to the device VLAN or VXLAN encapsulated. On a virtual device, the encapsulation might be removed by the virtual switch and the VLAN or VXLAN encapsulation header might not be seen by the virtual service device. Currently, the APIC supports only VLAN encapsulation.
dir	No	Specifies the connector direction. This direction can be specified as either `input` or `output`.
cardinality	No	If a function supports multiple instances of a given connector type, the device model can specify this explicitly by setting the cardinality to `n`. By default, the cardinality is `1`.

Attribute	Mandatory	Description
notification	No	Allows endpoint or network attach/detach notifications to be generated for the function. This attribute is used to determine whether the APIC calls the device script when an endpoint or subnet association changes for an endpoint group (EPG) that is attached directly or indirectly to this connector. The notification can take the following values: • `none` • `subnet` • `endpoint` If the notification attribute is not specified, it defaults to `none`, which means that the APIC will not attach nor detach the network or endpoint APIs.

A connector must contain just one `vnsRsInterface` object. This object associates a connector to a specific interface type that is identified by the labels that are defined by using `vnsMIfLbl`. The APIC uses this relation to pass the specific interface information while rendering the service function. For more information, see Fabric Connectivity, on page 65.

Images

A function must be linked to a `gif` image file that is bundled in the device package. The Application Policy Infrastructure Controller (APIC) displays this image in the GUI for a function within a graph. The image provides a graphical identity of a particular function in the graph that is rendered on a specific vendor device.

The link to the image is done through instantiating one `vnsMImage` object, as shown in the following example:

```
<vnsMImage
name="insieme.gif"/>
```

Function Configurations

A device package developer can define parameters that are required to configure a service function under a function object. Any parameter that is defined under `vnsMFunc` is scoped under a specific function. The parameters that are defined under a function can be further grouped logically under one or more folders.

The parameter and folders defined under a function persist if the instance of the function persists. The Application Policy Infrastructure Controller (APIC) deletes the parameters and folders that are defined under a function when the function instance is deleted.

The parameter and folders under a function cannot be shared or referenced by any other function within the same graph or a different graph that is rendered on the same device. The parameter and folders defined under the function must have a unique instance on the device for each function instance. The scope of the parameter and folders the are being limited within a functions context is similar to a local variable in the C language.

The following example defines the parameters of a service function:

```
<vnsMFunc name="SLB">
     <vnsMImage name="insieme.png"/>

      <vnsMConn name="external"
                dir="input"
                encType="vlan"
                 notifications="endpoint">
               <vnsRsInterface tDn="uni/infra/mDev-Insieme-SampleDevice-1.0/mIfLbl-external"
 />
       </vnsMConn>

       <vnsMConn name="internal"
                 dir="output"
                 encType="vlan"
                 notifications="endpoint">
                <vnsRsInterface tDn="uni/infra/mDev-Insieme-SampleDevice-1.0/mIfLbl-internal"
 />
        </vnsMConn>

        <vnsMFolder key="VServer"
                    scopedBy="epg">
                 <vnsMParam key="vservername"
                            description="Name of VServer"
                            mandatory="true"
                            dType="str"
                            validation="isAlpha"/>
                 <vnsMParam key="port"
                            description="Port for Virtual server"
                            validation="isL4Port"/>
                 <vnsMParam key="persistencetype"
                            description="persistencetype"/>

                 <vnsMParam key="servicename"
                                  description="Service bound to this vServer"/>
                 <vnsMParam key="servicetype"
                                  description="Service bound to this vServer"
                            dType="str"
                                  validation="isProtocol"/>
                 <vnsMParam key="clttimeout"
                            description="Client timeout"/>

          </vnsMFolder>
  </vnsMFunc>
```

Group Configurations

Any parameter and folders that are defined under a group configuration can be shared across multiple functions in a graph. A device package developer can define parameters and folders that can be shared across multiple functions that are rendered on a single device within a single graph under a group configuration.

The parameters and folders within a group configuration are scoped under a graph instance. Any function within a graph instance can share and reference the configuration.

Objects defined under a group configuration persists as long as the graph instance persists. The Application Policy Infrastructure Controller (APIC) deletes the parameter and folder defined under a group configuration when the graph instance is deleted. Any parameter that is defined under a group configuration must have a unique instance per graph on a device; a parameter must not be shared or referenced by any other graph instance that is rendered on the same device.

The group configuration is represented by the `vnsGrpCfg` object. Only one definition of `vnsGrpCfg` can be under `vnsMDev`. All group parameters and folders that are scoped under a group must be contained within a `vnsGrpCfg` object.

Parameters and folders that are defined under a group configuration are similar to static variables in the C language. The variables persist beyond a function.

Global Function Configurations

Any parameter and folders defined under an `vnsMDev` configuration can be shared across multiple functions across multiple graphs. A device package developer can define parameters and folders that can be shared across multiple functions across multiple graphs that are rendered on a single device under `vnsMDevCfg`.

Objects defined under a `vnsMDev` configuration persist if there is at least one graph instance refers to the parameter or the folder. The Application Policy Infrastructure Controller (APIC) deletes the parameter and folder that is defined under a `vnsMDev` configuration when all functions across all graph instances are deleted from a specific device.

On a multi-context device, the global configuration must have a unique instance per context. The parameters and folders that are defined under `vnsMDev` must not be shared across multiple contexts.

The parameter and folders that are defined under a `vnsMDev` configuration are similar to global variables in the C language.

Typically, network attributes, such as an IP address configured on an interface, routes, and subnets, have a global scope. The encapsulation tags that are allocated by the APIC are globally scoped, which allows multiple parallel functions to be deployed on the same network across multiple graphs.

Relations

A service function can reference a particular parameter or a folder that is defined under a group or `vnsMDevCfg`, which allows the function to use an instance of a parameter or a folder that is defined under a group or a device scope. The relation to a folder is defined using the `vnsMRel` object. A `vnsMRel` object can exist only within a `vnsMFolder` object. A folder can have one or more relations objects defined.

The `vnsMRel` object has the following attributes:

Attribute	Mandatory	Description
key	Yes	Identifies the object. Each object key must have a unique value within the containing object. The key can contain only alphanumeric characters, '_', or '-'. A key cannot contain any other characters. The Application Policy Infrastructure Controller (APIC) uses the key to look up a specific object within a containing object. The key size is limited to a maximum of 512 characters.

Attribute	Mandatory	Description
Description	Yes	Holds the description of this configuration item. The description field is used by the APIC GUI to provide help to the user. A device package developer should provide an accurate description and intent of the relation. The description field size is limited to a maximum of 512 characters.
mandatory	No	Indicates whether this relation is mandatory. This property is a Boolean value (yes or no). By default, a relation is not mandatory unless explicitly specified, meaning that the user is not required to specify a relations object. The given relation is not necessary to render a function on the device.
cardinality	No	Specifies the number of occurrences of this relation. By default, only one instance of a relation is permitted under the contained object. If a user is allowed to instantiate more than one instance of the relation object, the device specification file should define the relation with `cardinality="n"`.

The `vnsMRel` object contains a `vnsRsTarget` object that identifies the object to which a relation is referring. The target is a fully qualified key of the object that is defined in the device specification file. The `vnsMRel` object can contain only one instance of a `vnsRsTarget` object.

The following example defines a relations object:

```
<vnsMRel key="ServerConfig">
   <vnsRsTarget tDn="uni/infra/mDev-Insieme-SampleDevice-1.0/mDevCfg/mFolder-Server"/>
 </vnsMRel>
```

The above example indicates that the `ServerConfig` that is defined within a function has a relation to an instance of a server folder that is defined under `vnsMDevCfg`. You can instantiate a relation by specifying the target folder instance name qualified by a full path under a device configuration. When a service function is rendered on a device, the APIC looks for a specific instance of the folder that is referred to by the relations. If the APIC finds a matching instance, it includes the folder in the configuration dictionary that is passed in the service API call. The APIC also passes an instance of relations as part of the function configuration dictionary. For an example of a configuration dictionary that is passed in the API, see Developing Device Scripts, on page 37.

Parameter Scope and API Configuration Dictionary

Any parameter and folders that are defined under vnsMDevCfg, vnsGrpCfg, or vnsMFunc are passed to the device script only during the serviceAudit(), serviceModify(), serviceHealth(), and serviceCounters() function calls. The parameters and folders that are defined in a vnsMDevCfg object are passed in a service API call only if there is a service function with a relations object that refers to that parameter and folder.

About Parameter Objects and Folders

The cluster, device, and functional configuration is defined by one or more `vnsMParam` objects. These objects can be grouped logically under one or more folders that are represented as the `vnsMFolder` object.

Parameter Objects

The configuration parameters are represented by the `vnsMParam` object type. A device package can have one or more `vnsMParam` objects. A parameter object contains the following attributes:

Attribute	Mandatory	Description
key	Yes	Specifies the key for the meta parameter. This property uniquely identifies the parameter. Each parameter key must have a unique value within the containing object. The key can contain only alphanumeric characters, "_", or "-". The key cannot contain any other characters. The Application Policy Infrastructure Controller (APIC) uses the key to look up a specific object within a containing object, which is typically the `vnsMFolder` object. The key size is limited to a maximum of 512 characters.
Description	Yes	Holds the description of this configuration item. The description field is used by the APIC GUI to provide help to the user. The device package developer should provide an accurate description and intent of the parameter. The description field size is limited to a maximum of 512 characters.

Attribute	Mandatory	Description
mandatory	No	Indicates whether this parameter is mandatory. This property is a Boolean value (yes or no). By default, a parameter is not mandatory unless explicitly specified.
dType	No	Specifies the data type for this parameter. It can take following values: • `int` • `real` • `str` If the dType is not specified, the parameter defaults to `str`.
validation	No	Specifies the validation expression to be used by the APIC for validating a value for this parameter. The validation string cannot exceed 255 characters. The dType need not be `str` if validation is specified. The validation string refers to a composite or a comparison object name. For more information, see #unique_41.
cardinality	No	Specifies the number of occurrences of this parameter. By default, only one instance of a parameter is permitted under the contained object. If a user is allowed to instantiate more than one instance of the parameter object, the device specification file should define the parameter with `cardinality="n"`. For example, if you can instantiate multiple static routes on a device that has a parameter object called route, set the cardinality of the route parameter to `cardinality="n"`.

The following example defines a parameter object:

```
 <vnsMParam key="vservername"
  description="Name of VServer"
  mandatory="true"
  dType="str"
  validation="isAlpha"/>

<vnsMParam key="subnetipaddress"
  description="Subnet IPAddress of the Device"
  dType="str"
  cardinality=”n”
  validation="isIPAddress"/>
```

Folders

The configuration parameters can be logically grouped under folders. A folder can contain one or more folders and parameters. A folder is represented by the vnsMFolder object and has the following attributes:

Attribute	Mandatory	Description
key	Yes	Specifies the key for the meta folder. This property uniquely identifies the folder. Each folder key must have a unique value within the containing object. The key can contain only alphanumeric characters, '_', or '-'. The key cannot contain any other characters. The Application Policy Infrastructure Controller (APIC) uses the key to look up a specific object within a containing object. The key size is limited to a maximum of 512 characters. The key for the top most folder defined under <vnsMDevCfg>, <vnsGrpCfg> or <vnsMfunc> must be unique within the device package.
Description	Yes	Holds the description of this configuration item. The description field is used by the APIC GUI to provide help to the user. The device package developer should provide an accurate description and intent of the folder. The description field size is limited to a maximum of 512 characters.

Attribute	Mandatory	Description
scopedBy	No	Specifies the scope for this configuration folder. This attribute specifies where in the Management Information Tree (MIT) to look for the value of this folder when instantiating a function. The APIC resolves the value by looking up an instance that is defined under different objects to which a graph is associated. The scopedBy attribute can contain the following values: • tenant—The folder can be instantiated only under a tenant. • ap—The folder can be instantiated only under an application profile or tenant. • bd—The folder can be instantiated only under a bd or tenant. • epg—The folder can be instantiated only under an endpoint group (EPG), bridge domain, application profile, or tenant. • none A device package developer can limit the resolution to a higher level. By default, scopedBy is defined as "none", which means that the device package does not impose any restriction on where a particular folder can be instantiated. The APIC user can define an instance of the folder under a tenant, application profile, bridge domain, or EPG.

Attribute	Mandatory	Description
cardinality	No	Specifies the number of occurrences of this folder. By default, only one instance of a folder is permitted under the contained object. If the user is allowed to instantiate more than one instance of the folder object, the device specification file should define the folder with `cardinality="n"`.

The following example defines a folder object:

```
<vnsMFolder key="Server"
  scopedBy="epg">
  <vnsMParam key="servername"
    description="Server Name"
    dType="str"
    validation="isAlpha"/>
  <vnsMParam key="domain"
    description="Domain name of the server"/>
  <vnsMParam key="ipaddress"
    description="Server IP address"
    dType="str"
    validation="isIPAddress"/>
</vnsMFolder>
```

Parameter Validation

The Application Policy Infrastructure Controller (APIC) can do parameter validation by using the `vnsComparison` and `vnsComposite` objects. A device package developer can define and associate validation to any string type parameter by using either basic or composite comparisons.

The basic comparisons (`vnsComparison`) can perform the following operations:

- Equal—`eq` (the default)
- Not equal—`ne`
- Less than—`lt`
- Greater than—`gt`
- Greater than or equal to—`ge`
- Less than or equal to—`le`
- Match—`match` (requires a regular expression)

The comparison object `vnsComparison` is defined under the `vnsMDev`, `vnsMFunc`, `vnsMFolder`, `vnsMParam`, or `vnsComposite` objects. The `vnsComparison` object has the following attributes:

Attribute	Mandatory	Description
name	Yes	Holds the name of the comparison assertion.
cmp	Yes	Defines the comparison operator: • `eq`—Equal, which is the default. • `ne`—Not equal. • `lt`—Less than. • `gt`—Greater than. • `ge`—Greater than or equal to. • `le`—Less than or equal to. • `match`—Match. The `match` comparison requires a regular expression.

In the following example, the parameter validates IP addresses using a regular expression match:

```
<vnsMParam key="vipaddress"
           description="VIP IPAddress"
           dType="str"
           validation="isIPAddress"
/>

<vnsComparison name="isIPAddress"
               cmp="match"

value="([01]?\d\d?|2[0-4]\d|25[0-5])\.([01]?\d\d?|2[0-4]\d|25[0-5])\.([01]?\d\d?|2[0-4]\d|25[0-5])\.([01]?\d\d?|2[0-4]\d|25[0-5])"
/>
```

The composite comparison (`vnsComposite`) provides the following types of comparisons to be performed:

- All match (the default)—Validation passes when the parameter value matches all of the comparison objects that are defined by the composite object.
- Any match—Validation passes when a parameter value matches one of the comparison objects that is defined within the composite object.
- Exactly one match—Validation passes when a parameter value matches one of the comparison objects.

The composite object can contain one or more `vnsComparison` objects. A composite object can be defined under `vnsMDev`, `vnsMFunc`, `vnsMFolder` or `vnsMParam`. A `vnsComposite` has the following attributes:

Attribute	Mandatory	Description
name	Yes	Holds the name of the composite.

Attribute	Mandatory	Description
cmp	Yes	Defines the type of comparison to be performed. It takes the following values: • `and`—All comparison strings that are contained within the composite must match for the validation to return as a success. The `and` type is the default comparison. • `or`—Any comparison string that is contained within the composite can match for the validation to return as a success. • `one`—Only one comparison string contained within the composite can match for the validation to return as a success. This operator enables the package developer to define a mutual exclusion.

In the following example, the element defines a match with any of the contained values:

```
<vnsComposite name="isProtocol" comp="or">
    <vnsComparison name="ip" cmp="eq" value="IP" />
    <vnsComparison name="tcp" cmp="eq" value="TCP" />
    <vnsComparison name="udp" cmp="eq" value="UDP" />
    <vnsComparison name="http" cmp="eq" value="HTTP" />
 </vnsComposite>

 <vnsComposite name="yesNo" comp="one">
     <vnsComparison name="yes" cmp="eq" value="YES" />
     <vnsComparison name="No" cmp="eq" value="NO" />
 </vnsComposite>
```

Faults Codes

The device specification file can define fault codes with help strings that describe the nature of a fault and possible corrective action. When a device script encounters an issue with rendering a function due to a parameter or folder, the script can return a specific fault code with a path of the object that had an issue. The Application Policy Infrastructure Controller (APIC) refers to the fault code that is defined in the device specification file and picks the description and corrective action that is described while displaying the fault. Defining a fault code provides a description of the reason for the fault and the corrective action that the user can take to resolve the fault.

The fault codes are defined under a vnsMDfcts object. A device specification can have one instance of vnsMDfcts under vnsMDev. A vnsMDfcts object can contain one or more fault codes that are described by the vnsMDfct object.

The vnsMDfct object contains the following attributes:

Attribute	Mandatory	Description
code	Yes	Specifies aA unit16 value that identifies a unique defect.
Description	Yes	Describes the defect. The description field is used by the APIC GUI to provide help to the user. The device package developer should provide an accurate description. The field size is limited to a maximum of 512 characters.
htmlFile	No	Specifies the URL link to online help that can help a user understand and correct the issue. The field size is limited to a maximum of 512 characters.
recAct	Yes	Specifies the recommended action. This field is used by the APIC GUI to provide the recommended action for the user to take. The device package developer should provide an accurate recommended action to resolve the defect. The field size is limited to a maximum of 512 characters.

The following example defines a fault object:

```
<vnsMDfcts>
     <vnsMDfct code="100"
               recAct="Configure a Netmask for the vipaddress"
               descr="VIP requires vipaddress and NetMask"/>
     <vnsMDfct code="200"
               recAct="Configure a relation to VIP Folder"
               descr="A function should have a valid relations to a VIP folder that is
specifying the VIP Address and Netmask"/>
</vnsMDfcts>
```

Function Profile

APIC allows a device package developer to define a function profile within a device model. A function profile is a template for one or more functions suitable for a specific application. A function profile is the equivalent

of defining an abstract graph within a device package with meaningful defaults for a function that defines the graph. The user can leverage the built-in function profile by referencing the built-in function profile in the device package at the time of defining a service graph. Using the function profile reduces the number of parameters that a user has to provide to instantiate a service function for a specific application. A device package developer can include as many function profiles as applicable.

Following is an example of defining function profile in a device package:

```
<vnsAbsFuncProfContr name = "FunctionProfiles">

          <vnsAbsFuncProfGrp name = "Function Profiles for Service graph
                                     for an Application 1 ">
              <vnsAbsFuncProf name = "Function 1 Name">
                  <vnsRsProfToMFunc
                         tDn="uni/infra/mDev-<vendor-model-version>/mFunc-function1"/>

                  <vnsAbsDevCfg>
                      <vnsAbsFolder key="Folder_Key"
                                    name="Folder Instance name" scopedBy="epg">
                          <vnsAbsParam name="Param Instance name"
                                       "key="Param Name" value="Value"/>
                          ...
                      </vnsAbsFolder>
                       ...

                  </vnsAbsDevCfg>

                  <vnsAbsFuncCfg>

                       <vnsAbsFolder key="Folder_Key"
                                     name="Folder Instance name" scopedBy="epg">
                        <vnsAbsCfgRel key="relation_key"
                                      name="rel name" targetName="targetValue"/>
                      </vnsAbsFolder>
                   ...
                  <vnsAbsFuncCfg>

              </vnsAbsFuncProf>

              <vnsAbsFuncProf name = "Function 2 Name">
                  <vnsRsProfToMFunc
                         tDn="uni/infra/mDev-<vendor-model-version>/mFunc-function2"/>
                  ....
                  <vnsAbsFuncProf>

          </vnsAbsFuncProfGrp>

          <vnsAbsFuncProfGrp name = "Function Profiles for
                                     Service graph for an Application 2 ">
              ...
          </vnsAbsFuncProfGrp>

      </vnsAbsFuncProfContr>
```

The function profile definition is contained within <vnsAbsFuncProfContr>. The profile for each unique application is identified by <vnsAbsFuncProfGrp>. The <vnsAbsFuncProfGrp> name should be intuitive to relate to an application for which the template is being defined. For example, if the function profile is for a load balancing function for a web application, the vnsAbsFuncProfGrp should be named "Web Application Virtual Server".

A function profile identified by <vnsAbsFuncProfGrp> can contain one or more functions as applicable. If the graph requires the chaining of multiple functions on the same device, the profile could define defaults for these functions within the <vnsAbsFuncProfGrp>. Each function configuration within the profile is contained within <vnsAbsFuncProf>.

Each vnsAbsFuncProf has one relation to a function defined by the device model. The relation identifies type of function being instantiated by the function profile. The relation to the function is defined by object

vnsRsProfToMFunc contained within vnsAbsFuncProf. The vnsRsProfToMFunc has a tDn attribute identifying a function with a fully qualified name of the function object. The example shows a sample tDn for identifying a function within a device model.

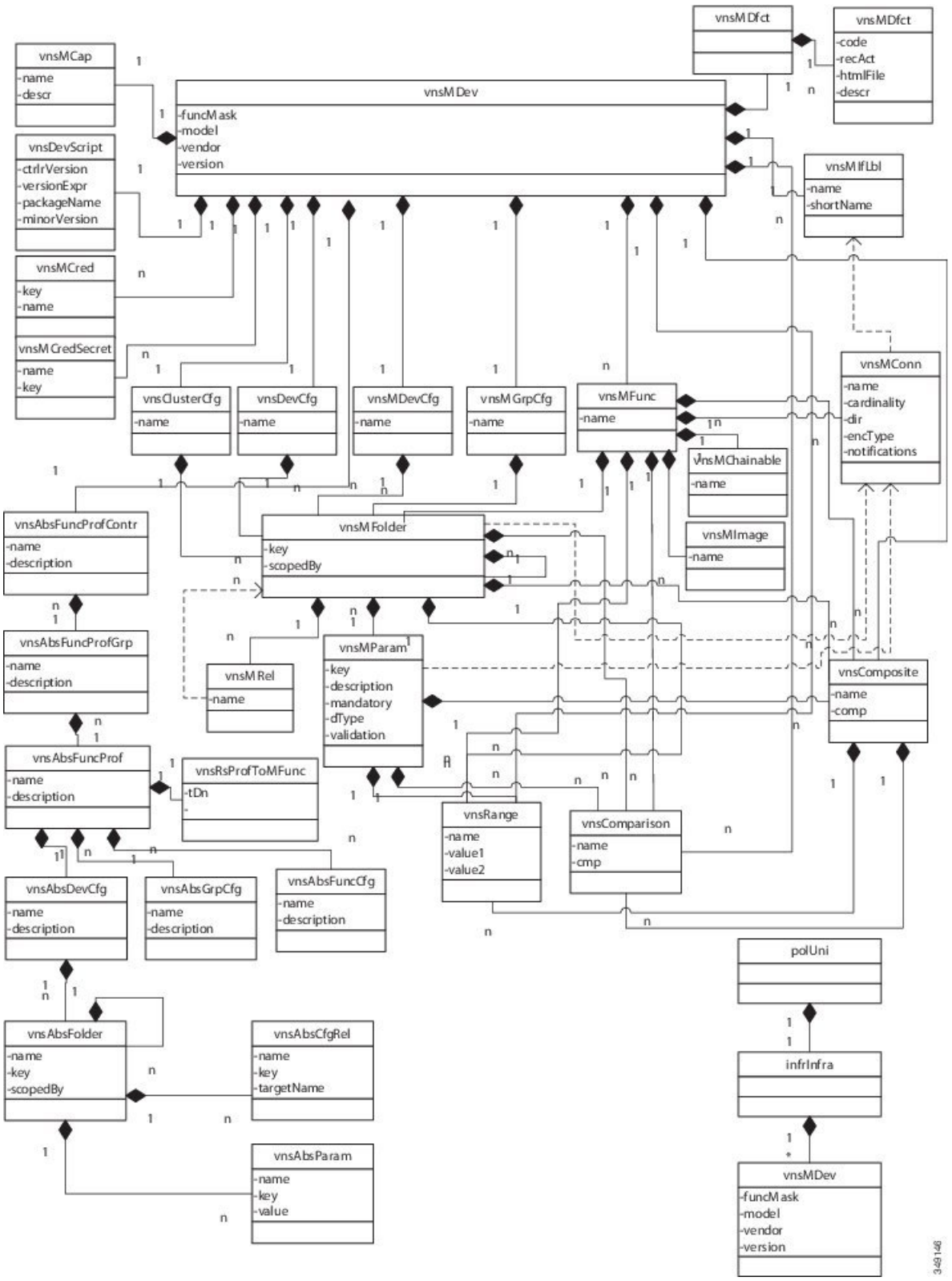
The mechanism to configure parameters for these functions are identical to creating a service graph on APIC. The parameter, relations, and folders in a function profile can be an instance of the parameters, relations and folders defined under vnsMDevCfg, vnsGrpCfg, and vnsFuncCfg.

For information about creating a service graph through the northbound API, see the *Cisco APIC Layer 4 to Layer 7 Services Deployment Guide*.

Managed Object Model

The following figure shows the object model for representing a device.

Figure 4: Managed Object Model


vnsMDfct
vnsMDfct
-code
-recAct
-htmlFile
-descr
vnsMCap
-name
-descr
vnsMDev
-funcMask
-model
-vendor
-version
vnsDevScript
-ctrlrVersion
-versionExpr
-packageName
-minorVersion
vnsMIfLbl
-name
-shortName
vnsMCred
-key
-name
vnsMCredSecret
-name
-key
vnsMConn
-name
-cardinality
-dir
-encType
-notifications
vnsClusterCfg
-name
vnsDevCfg
-name
vnsMDevCfg
-name
vnsMGrpCfg
-name
vnsMFunc
-name
vnsMChainable
-name
vnsMImage
-name
vnsAbsFuncProfContr
-name
-description
vnsMFolder
-key
-scopedBy
vnsAbsFuncProfGrp
-name
-description
vnsMRel
-name
vnsMParam
-key
-description
-mandatory
-dfType
-validation
vnsComposite
-name
-comp
vnsAbsFuncProf
-name
-description
vnsRsProfToMFunc
-tDn
vnsRange
-name
-value1
-value2
vnsComparison
-name
-cmp
vnsAbsDevCfg
-name
-description
vnsAbsGrpCfg
-name
-description
vnsAbsFuncCfg
-name
-description
polUni
vnsAbsFolder
-name
-key
-scopedBy
vnsAbsCfgRel
-name
-key
-targetName
infrInfra
vnsAbsParam
-name
-key
-value
vnsMDev
-funcMask
-model
-vendor
-version
349148

The following table describes the objects in the object model.

Component	Description
`vnsMDev`	Contains definitions of the metadata for a service device type. The metadata contains vendor-specific data, including the vendor name, device model, and device version. The service devices are categorized as GoTo and GoThrough devices. A device is a GoTo device if the packet is addressed to the device's MAC address or IP address. A device is considered as a GoThrough device if a packet transits through the device by in-path insertion and the packet is not addressed to the device's MAC address or IP address. A firewall in transparent mode is an example of a GoThrough device. A device package and device specification model could support devices in both GoTo and GoThrough mode. By default, the device specification is assumed to represent devices in GoTo mode. The device specification file can be changed to support both modes or the GoThrough mode only by using the following attribute: `funcMask: "GoTo,GoThrough"`
`vnsMCred`	Represents the credentials necessary to authenticate a user into the device. For example, `key` is used for key-based authentication schemes. This model details the meta-information for such key-based authentication of credentials.
`vnsDevScript`	Represents a device script handler. This managed object contains meta-information about the script handler's related attributes, including its name, package name, and version.
`vnsClusterCfg`	Contains the cluster configuration folders and parameters. The cluster configuration affects the functionality of the device cluster independent of graphs rendered on the device cluster.
`vnsDevCfg`	Contains device-specific configuration folders and parameters. The device configuration affects the functionality of a specific device within a cluster independent of the graphs rendered on the device cluster.
`vnsMCredSecret`	Contains the password for logging into a service device.
`vnsMDevCfg`	Represents the base level device configuration. This object serves as an anchor to differentiate between different device configurations and the shared configuration (`MGrpCfg`). The configuration under `MDevCfg` can be shared across multiple instances of a function across multiple graphs.
`vnMGrpCfg`	Represents the meta-group configuration. It contains the part of the configuration that can be shared across multiple functions in a graph. A configuration under a group configuration is scoped within a graph instance and cannot be referred to by another graph.
`vnsMFolder`	Represents meta-folder information. The model uses a generic configuration that consists of `MFolders` and `MParams`. This object allows the configuration to be specified as a hierarchy.

Component	Description
vnsMParam	Enables a configuration to be specified as a hierarchy. The metadata within this model consists of a key, a type (integer, string), and other attributes that are related to parameters.
vnsMRel	Represents a meta-relation to another object. It allows the referencing of another folder or parameter.
vnsMFunc	Contains the metadata for a single function on a device. A function contains a set of connectors and a function-specific configuration tree. This managed object contains the metadata for all such operations.
vnsMConn	Represents a connector between logical functions. The metadata includes the cardinality, direction, and encapsulation type (VXLAN or VLAN) for the given connection.
vnsMIfLbl	Represents an interface label. Interfaces can be labeled in an abstract way on devices. For example, a firewall device can implement trusted, untrusted, and management interfaces. The concrete models specify how many labels that a device supports.
vnsMChainable	Identifies the function names on a device that can immediately follow the parent function. This managed object contains the function names that can be chained together.
vnsAbsFuncProfContr	A Function profile group container. Defines a collection of function profile groups (graphs) for a specific application. Each function profile group can contain one or more functions initialized with certain default parameters for a specific application. A Function profile container can be defined within a device model by a device package developer or can be defined by the tenant to provide a catalog of graphs for a set of applications.
vnsAbsFuncProfGrp	Represents a function profile group. A collection of functions initialized with default parameters for a specific application. A function profile group can be defined within a device package by a device package developer or it can be defined by an APIC tenant as a catalog of graph for a specific applications.
vnsAbsFuncProf	Represents a function profile. It contains vnsAbsDevCfg (an instance of vnsMDevCfg), vnsAbsGrpCfg (an instance of vnsMGrpCfg) and vnsAbsFuncCfg (an instance of vnsMFunc). A function profile is linked to a specific function defined in the device model. A function profile can be defined within a device package or can be defined by a APIC tenant as a catalog of function within a vnsAbsFuncProfGrp.

Managed Object Example

The following XML file contains a sample managed object configuration. You can use a similar XML file to instantiate a network device on the APIC.

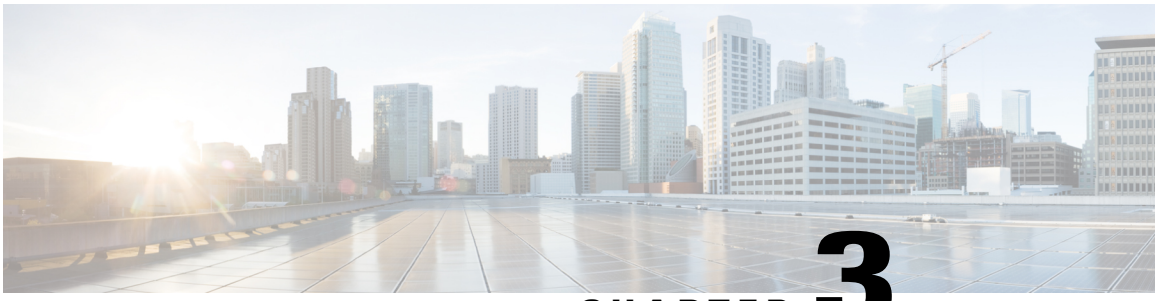
```
<polUni>
    <infraInfra>

        <vnsMDev vendor="Insieme"
                 model="SampleDevice"
                 version="1.0">

            <vnsMIfLbl name="external"/>
            <vnsMIfLbl name="internal" />
            <vnsMIfLbl name="management" />

            <vnsMCred name="username"
                      key="username"/>
            <vnsMCredSecret name="password"
                      key="password"/>

            <vnsDevScript name="Insieme"
                         packageName="DeviceScript.py"
                         versionExpr="1.0"
                         ctrlrVersion="1.0"/>

            <vnsComparison name="isAlpha" cmp="match" value="[a-zA-Z]+" />

            <vnsComposite name="isL4Port" comp="or">
                <vnsRange name="between1And64K" value1="0" value2="65535" />
            </vnsComposite>

            <vnsComposite name="isProtocol" comp="or">
                <vnsComparison name="ip" cmp="eq" value="IP" />
                <vnsComparison name="tcp" cmp="eq" value="TCP" />
                <vnsComparison name="udp" cmp="eq" value="UDP" />
                <vnsComparison name="http" cmp="eq" value="HTTP" />
            </vnsComposite>

            <vnsComposite name="yesNo" comp="or">
                <vnsComparison name="yes" cmp="eq" value="YES" />
                <vnsComparison name="No" cmp="eq" value="NO" />
            </vnsComposite>

            <vnsComposite name="enableDisable" comp="or">
                <vnsComparison name="enabled" cmp="match" value="ENABLED" />
                <vnsComparison name="disabled" cmp="match" value="DISABLED" />
            </vnsComposite>

            <vnsComposite name="onOff" comp="or">
                <vnsComparison name="on" cmp="match" value="ON" />
                <vnsComparison name="off" cmp="match" value="OFF" />
            </vnsComposite>

            <vnsComparison name="isIPAddress"
                           cmp="match"

value="([01]?\d\d?|2[0-4]\d|25[0-5])\.([01]?\d\d?|2[0-4]\d|25[0-5])\.([01]?\d\d?|2[0-4]\d|25[0-5])\.([01]?\d\d?|2[0-4]\d|25[0-5])"/>


            <vnsComparison name="isIPMask"
                           cmp="match"

value="([01]?\d\d?|2[0-4]\d|25[0-5])\.([01]?\d\d?|2[0-4]\d|25[0-5])\.([01]?\d\d?|2[0-4]\d|25[0-5])\.([01]?\d\d?|2[0-4]\d|25[0-5])"/>


            <vnsMDfcts>
                 <vnsMDfct code="100"
                           recAct="Configure a Netmask for the vipaddress"
```

```
                descr="VIP requires vipaddress and NetMask"/>
     <vnsMDfct code="200"
                recAct="Configure a relation to VIP Folder"
                descr="Description of defect 100"/>
</vnsMDfcts>

<vnsMDevCfg name="DeviceConfig">
    <vnsMFolder key="Network"
                scopedBy="epg">

        <vnsMFolder key="vip">
            <vnsMParam key="vipaddress"
                       description="VIP IPAddress"
                       dType="str"
                       validation="isIPAddress"/>
            <vnsMParam key="NetMask"
                       dType="str"
                       description="NetMask for the IP Address"
                       validation="isIPMask"/>
        </vnsMFolder>

        <vnsMFolder key="subnetip">
            <vnsMParam key="subnetipaddress"
                       description="Subnet IPAddress of the Device"
                       dType="str"
                       validation="isIPAddress"/>
            <vnsMParam key="NetMask"
                       description="NetMask for the IP Address"
                       dType="str"
                       validation="isIPMask"/>
        </vnsMFolder>

        <vnsMFolder key="mgmtip">
            <vnsMParam key="mgmtipaddress"
                       description="Mgmtm IPAddress of the Device"
                       dType="str"
                       validation="isIPAddress"/>
            <vnsMParam key="NetMask"
                       dType="str"
                       description="NetMask for the IP Address"
                       validation="isIPMask"/>
        </vnsMFolder>
    </vnsMFolder>

    <vnsMFolder key="Monitor"
              scopedBy="epg">
       <vnsMParam key="dup_state"
                  description="dup_state"/>
       <vnsMParam key="dup_weight"
                  description="dup_state"/>
       <vnsMParam key="state"
                  description="state"/>
       <vnsMParam key="weight"
                  description="state"/>
  </vnsMFolder>

    <vnsMFolder key="Server"
                scopedBy="epg">

        <vnsMParam key="name"
                   description="Server Name"
                   dType="str"
                   validation="isAlpha"/>
        <vnsMParam key="domain"
                   description="Domain name of the server"/>
        <vnsMParam key="ipaddress"
                   description="Server IP address"
                   dType="str"
                   validation="isIPAddress"/>
    </vnsMFolder>

    <vnsMFolder key="Service"
                scopedBy="epg" cardinality="n">
```

```
                    <vnsMParam key="servicename"
                               description="Service Name"
                               dType="str"
                               validation="isAlpha"/>
                    <vnsMParam key="servicetype"
                               description="Service Type"
                               dType="str"
                               validation="isProtocol"/>
                    <vnsMParam key="servername"
                               description="Server Name"
                               dType="str"
                               validation="isAlpha"/>
                    <vnsMParam key="serveripaddress"
                               description="Server IP Address"
                               dType="str"
                               validation="isIPAddress"/>
                    <vnsMParam key="serviceport"
                               description="IP port number for service"
                               validation="isL4Port"/>

                    <vnsMRel key="MonitorConfig"
                             cardinality="n">
                        <vnsRsTarget
tDn="uni/infra/mDev-Insieme-SampleDevice-1.0/mDevCfg/mFolder-Monitor"/>
                    </vnsMRel>

                </vnsMFolder>

                <vnsMGrpCfg name="SharedConfig">
                </vnsMGrpCfg>

                <vnsMFolder key="Monitor"
                            scopedBy="epg">
                    <vnsMParam key="dup_state"
                               description="dup_state"/>
                    <vnsMParam key="dup_weight"
                               description="dup_state"/>
                    <vnsMParam key="state"
                               description="state"/>
                    <vnsMParam key="weight"
                               description="state"/>
                </vnsMFolder>

            </vnsMDevCfg>

            <vnsMGrpCfg name="SharedConfig">
            </vnsMGrpCfg>

            <vnsMFunc name="SLB">


                <vnsMConn name="external"
                          dir="input"
                          encType="vlan"
                          notifications="Endpoint">
                    <vnsRsInterface
tDn="uni/infra/mDev-Insieme-SampleDevice-1.0/mIfLbl-external" />
                </vnsMConn>

                <vnsMConn name="internal"
                          dir="output"
                          encType="vlan"
                          notifications="Endpoint">
                    <vnsRsInterface
tDn="uni/infra/mDev-Insieme-SampleDevice-1.0/mIfLbl-internal" />
                </vnsMConn>

                <vnsMFolder key="VServer"
                            scopedBy="epg">

                    <vnsMParam key="vservername"
                               description="Name of VServer"
```

```
                                mandatory="true"
                                dType="str"
                                validation="isAlpha"/>
                        <vnsMParam key="port"
                                description="Port for Virtual server"
                                validation="isL4Port"/>
                        <vnsMParam key="persistencetype"
                                description="persistencetype"/>
                        <vnsMParam key="servicename"
                                description="Service bound to this vServer"/>
                        <vnsMParam key="servicetype"
                                description="Service bound to this vServer"
                                dType="str"
                                validation="isProtocol"/>
                        <vnsMParam key="clttimeout"
                                description="Client timeout"/>

                        <vnsMFolder key="VServerGlobalConfig"
                                description="This references VServer global Configuration">


                            <vnsMRel key="ServiceConfig">
                                <vnsRsTarget
tDn="uni/infra/mDev-Insieme-SampleDevice-1.0/mDevCfg/mFolder-Service"/>
                            </vnsMRel>

                            <vnsMRel key="ServerConfig">
                                <vnsRsTarget
tDn="uni/infra/mDev-Insieme-SampleDevice-1.0/mDevCfg/mFolder-Server"/>
                            </vnsMRel>

                            <vnsMRel key="VipConfig">
                                <vnsRsTarget
tDn="uni/infra/mDev-Insieme-SampleDevice-1.0/mDevCfg/mFolder-Network/mFolder-vip"/>
                                <vnsRsConnector
tDn="uni/infra/mDev-Insieme-SampleDevice-1.0/mFunc-SLB/mConn-external"/>
                            </vnsMRel>

                        </vnsMFolder>

                    </vnsMFolder>

                </vnsMFunc>

                <vnsMFunc name="SSL">
                    <vnsMChainable name="SLB"/>


                    <vnsMConn name="internal"
                              dir="input"
                              encType="vlan">
                        <vnsRsInterface
tDn="uni/infra/mDev-Insieme-SampleDevice-1.0/mIfLbl-external" />
                    </vnsMConn>

                    <vnsMConn name="external"
                              dir="output"
                              encType="vlan">
                        <vnsRsInterface
tDn="uni/infra/mDev-Insieme-SampleDevice-1.0/mIfLbl-internal" />
                    </vnsMConn>

                    <vnsMFolder key="Certificate"
                                scopedBy="epg">

                        <vnsMParam key="passplain"
                                description="passplain"/>
                        <vnsMParam key="servicename"
                                description="servicename"/>
                        <vnsMParam key="clientcertnotbefore"
                                description="clientcertnotbefore"/>
                        <vnsMParam key="serial"
                                description="serial"/>
```

```
                        <vnsMParam key="publickeysize"
                                   description="publickeysize"/>
                        <vnsMParam key="subject"
                                   description="subject"/>
                        <vnsMParam key="fipskey"
                                   description="fipskey"/>
                        <vnsMParam key="data"
                                   description="data"/>
                        <vnsMParam key="nodomaincheck"
                                   description="nodomaincheck"/>
                        <vnsMParam key="priority"
                                   description="priority"/>
                        <vnsMParam key="publickey"
                                   description="publickey"/>
                        <vnsMParam key="version"
                                   description="version"/>
                        <vnsMParam key="notificationperiod"
                                   description="notificationperiod"/>
                        <vnsMParam key="issuer"
                                   description="issuer"/>
                        <vnsMParam key="status"
                                   description="status"/>
                        <vnsMParam key="clientcertnotafter"
                                   description="clientcertnotafter"/>
                        <vnsMParam key="certkey"
                                   description="certkey"/>
                        <vnsMParam key="passcrypt"
                                   description="passcrypt"/>
                        <vnsMParam key="key"
                                   description="key"/>
                        <vnsMParam key="password"
                                   description="password"/>
                        <vnsMParam key="signaturealg"
                                   description="signaturealg"/>
                        <vnsMParam key="expirymonitor"
                                   description="expirymonitor"/>
                        <vnsMParam key="linkcertkeyname"
                                   description="linkcertkeyname"/>
                        <vnsMParam key="inform"
                                   description="inform"/>
                        <vnsMParam key="cert"
                                   description="cert"/>
                        <vnsMParam key="daystoexpiration"
                                   description="daystoexpiration"/>
                    </vnsMFolder>
                </vnsMFunc>
            </vnsMDev>
        </infraInfra>
    </polUni>
```



CHAPTER 3

Developing Device Scripts

About Device Scripts

The device script acts as an adapter between the Application Policy Infrastructure Controller (APIC) and the network service by converting calls to the APIC service API into device-specific calls.

Figure 5: Device Script Model

The device script runs in the context of a `ScriptWrapper`, which is an environment that handles calls for each device type. A `ScriptWrapper` runs within a namespace that limits CPU, file, and socket resource consumption.

Uploading a device package creates a `ScriptWrapper` that imports the module from the device script file. The module exposes the functions described in the API.

The device scripts must be stateless and idempotent (producing the same result if run more than once). No file I/O operations are permitted within a script, except for generating a temporary state in the `/tmp` directory. You should not use any file that is created within the `/tmp` directory for storing a persistent state. The APIC can be deployed in a cluster. The device script can get invoked from any one of the APIC instances. Any data stored in the `/tmp` directory is not guaranteed to be available across two API calls. A script must not store its own state in any file.

The APIC requires scripts to be developed for Python 2.7. Other than standard libraries that are available in Python 2.7, the script environment provides Python Requests library v1.2.3. If the device package requires any other libraries, the device package developer can bundle those libraries in the device script's `zip` file.

Note The script must be thread-safe, which means that for any instance, multiple threads can invoke the same function in the script in order to configure different devices. The script should execute in the invoking thread context and must not spawn any new threads as part of its execution.

Guidelines for Creating Device Scripts

You must implement all the scripting APIs to establish the adapters between the Application Policy Infrastructure Controller (APIC) and the network services. The APIs receive the Python dictionaries that correspond to the device specification hierarchy. You must convert the Python dictionaries to the internal format that is needed by the specific device. Similarly, when a device returns a value, the API must convert the return value to the format needed by the APIC. For examples, see the specification in Developing Device Specifications and the sample script at the end of this section.

Device Script APIs

The device script APIs are divided into four categories:

- Device
- Cluster
- Service
- Endpoint and Network Event

APIC requires users to register one or more device cluster within a tenant. All service functions are applied to a cluster. A cluster can contain one or more network service devices. A device can be deployed in standalone mode without any redundancy by defining a cluster with a single device. A device can be deployed in active-standby HA mode by registering two devices configured as active-standby peers within a cluster. Similarly devices can be deployed in active-active mode by registering multiple devices configured as active peers within a cluster. The devices registered within a cluster are assumed to have active-active or active-standby pairing. The HA configuration of devices within a cluster can be pushed via APIC or it could be done out-of-band directly on the device prior to registering the devices with the APIC.

The configuration on the device is split into three categories: service function specific configuration, device specific configuration, or cluster specific configuration. The service configuration is pushed via Service APIs; the device configuration is pushed via Device APIs; and the cluster configuration is pushed via Cluster APIs.

Device APIs

The following APIs are called for each device registered within a cluster with APIC:

```
def deviceValidate( device, version )
def deviceModify( device, interfaces, configuration)
def deviceAudit( device, interfaces, configuration )
def deviceHealth( device, interfaces, configuration )
def deviceCounters( device, interfaces, configuration )
```

The configuration dictionary passed in these APIs contains any device specific configuration done on the APIC.

Note APIC does not pass any cluster level or service function configuration information during device API callouts.

The device APIs are assumed to act on any device specific configuration and should not reference or affect cluster level configuration or affect service functions.

Typically configuration like link bundling (such as LACP, etc.), that is device specific, can be done in deviceModify(), deviceAudit() callouts.

The configuration passed in the dictionary will be an instance of any folder and parameter defined under vnsDevCfg in the device Model.

Cluster APIs

The following APIs are called for each device cluster that is registered with the APIC:

```
def clusterModify( device, interfaces, configuration )
def clusterAudit( device, interfaces, configuration )
```

The configuration dictionary contains any cluster configuration done on the APIC.

Note APIC does not pass any device configuration or service configuration information during cluster API callouts.

The cluster APIs are assumed to act on any cluster level configuration and should not reference or affect device specific of function specific configuration.

Typically NTP server, syslog server, etc. like configuration that is done at the HA cluster level is configured through cluster API.

The configuration passed in the dictionary is an instance of any folder and parameter defined directly under vnsClusterCfg in the device Model.

Service APIs

The following APIs are called for any service function that is rendered on the device:

```
def serviceModify( device, configuration )
def serviceAudit( device, configuration )
def serviceHealth( device, configuration )
def serviceCounters( device, configuration )
```

The configuration dictionary contains an instance of parameters and folders that are defined under `vnsMDevCfg`, `vnsGrpCfg`, or under `vnsMFunc`.

Note Instance of folders/parameters defined under vnsMDevCfg within a device model is passed in a service API callout if and only if an instance of a function in the service graph has a reference to these parameter. Not all parameter and folder instances defined under vnsMDevCfg are passed to the service function. APIC passes only those parameters and folders that are used by a specific function instance being referenced in the service API callout.

Endpoint and Network Event APIs

The following APIs are called when an endpoint or a network configuration changes for endpoint groups (EPGs) that are associated with the graph:

```
def attachEndpoint( device, configuration, endpoints )
def detachEndpoint( device, configuration, endpoints )
def attachNetwork( device, configuration, networks)
def detachNetwork( device, configuration, networks )
```

These APIs are called only if the device specification supports an endpoint or network attach notification and you have enabled a notification on the function connector. The AttachEndpoint and DetachEndpoint events are called when an endpoint within an EPG attaches or detaches. The network APIs are called when you modify the subnet configuration under the bridge domain or EPG. These APIs provide information to enable the automation of any service function configuration that should be modified on an endpoint or network configuration change. An example would be if you dynamically add and remove a server from a pool that is attached to a load balancer or dynamically update a subnet within an access list defined for a firewall. The device specification file can define an empty function that returns success in the return format that is required by the APIC. It is not mandatory to support endpoint or network event handling functionality.

If a device package does not support these functions, it should define a stub function that always returns a status of success with the return dictionary format as described in this document.

Script Framework

The two modules that must be imported by device script are as follows:

- Import Insieme.Logger
- Import Insieme.Config

Logging

Insieme.Logger defines a logging utility. A device script can use this utility to log debug information. The logging utility writes the configuration API logs to a file called `debug.log`. This file is included in any technical support data that is collected from the Application Policy Infrastructure Controller (APIC). A device script developer should log as much information as possible to help debug any script issues.

Logs for Periodic APIs like serviceHealth() serviceCounters() are redirected to the periodic.log. The debug.log and periodic.log files can be accessed as a fabric administrator on APIC under /data/devicescript/<vendor-model-version>/logs.

The logging function is similar to the Python logging function. The logs can be split into the following categories:

- CRIT = 0
- ERROR = 1
- WARN = 2
- INFO = 3
- DEBUG = 4
- DEBUG2 = 5
- DEBUG3 = 6
- DEBUG4 = 7

The script can invoke the API as follows:

```
Logger.log( level,  Log String)
```

The following example invokes the API:

```
Logger.log( Logger.DEBUG, 'Connection to device failed')
```

Constants

Insieme.Config defines constants that can be used for parsing the dictionary:

```
Type = Insieme.Fwk.Enum(
    DEV=0,
    GRP=1,
    CONN=2,
    FUNC=3,
    FOLDER=4,
    PARAM=5,
    RELATION=6,
    ENCAP=7,
    ENCAPASS=8,
    ENCAPREL=9,
    VIF=10,
    CIF=11,
    LIF=12,
)

State = Insieme.Fwk.Enum(
    UNCHANGED=0,
    NEW=1,
    CHANGED=2,
    DELETED=3,
)

Result = Insieme.Fwk.Enum(
    SUCCESS=0,
    TRANSIENT=1,
    PERMANENT=2,
    AUDIT=3,
)
```

Configuration Dictionary Format

The configuration dictionary that is passed in the cluster API, device API, and service API follows the same structure as defined in the device specification file. The configuration is passed as a hierarchy of dictionaries, with each level identifying a folder. The dictionary format is as follows:

```
(type,  key, name) : { 'state': ...
                       'transaction': ...
                       'connector': ...
                       'value': ...
                       'target': ...
                       'device': ...
                      }
```

The fields are as follows:

Field	Description

type	Identifies the type of the object represented by the dictionary. The field can have one of the following values:
	`DEV=0,`
	`GRP=1,`
	`CONN=2,`
	`FUNC=3,`
	`FOLDER=4,`
	`PARAM=5,`
	`RELATION=6,`
	`ENCAP=7,`
	`ENCAPASS=8,`
	`ENCAPREL=9,`
	`VIF=10,`
	`CIF=11,`
	`LIF=12`

Key	Specifies the key or name attribute that is defined in the device specification file for the object.
Name	Specifies the parameter or folder instance name that is provided by the user.

State	Identifies the object's state. This field can have one of the following values:
	`UNCHANGED=0,`
	`NEW=1,`
	`CHANGED=2,`
	`DELETED=3,`

Connector	Specifies the name of the connect instance that is resolved according to the relations that are defined the specification file. This field is populated for a folder or a relation dictionary only if the corresponding `vnsMFolder` object or `vnsMRel` object has `vnsRsConnector` relations defined in the device specification file.
Value	Defines the value for the object. In the case of a folder, this field can contain another dictionary. A relations object does not contain a value element, and instead has a target element. A value for a parameter object cannot exceed 512 characters.
Target	Defines the target folder to which a relations object is resolved. This element is populated only for a relations object.
Transaction	Contains the Application Policy Infrastructure Controller (APIC) transaction ID that resulted in a specific API callout. The transaction ID is used for correlating request/response between APIC and the device script. It is used primarily for debugging convenience. A script can ignore this value.

Field	Description
Device	Any configuration passed in a cluster API or service API is typically applied to the cluster and it is in effect on all devices within the cluster. However it is possible that there may be cases where the configuration has to be applied to a specific device within the cluster, such as when configuring the interface IP for devices within the cluster. Each device may be assigned a unique IP. As a result, the interface IP configuration should be applied to one specific device within the cluster. This is accomplished using device context labels on the APIC. When a user configures the parameter on APIC, a user can (optionally) associate a device context label identifying a device within the cluster on which the configuration should be applied. If a parameter is tied to a specific device context within a cluster, APIC instantiates a 'device' key in the dictionary with device name as its value. The script can lookup the device name in the device dictionary passed in the callout. A script can apply the parameter configuration to a specific device identified by device field.

For more information about the configuration dictionary format, see Sample Script, on page 51. For an example dictionary for connector, encapsulation, and interface information, see Fabric Connectivity, on page 65

API Return Value

The APIs return a dictionary with the following format:

```
{ 'state':
  'health': []
  'fault': []
}
```

The state returns one of the following values:

```
SUCCESS=0
TRANSIENT=1
PERMANENT=2
AUDIT=3
```

For information about the health, see Health Monitoring, on page 73. For information about faults, see #unique_54.

You should configure the device script to set a timeout of at least 30 seconds to establish a connection with the device. If the device script fails to establish network connectivity within the time interval, it returns a TRANSIENT (1) state in the return dictionary. The APIC retries the transaction until the Transient state is cleared.

Transient faults indicate failures that don't require immediate user attention to resolve the issue. It could be a temporary event that prevents a script from pushing the configuration. APIC will retry pushing the configuration

aggressively till the fault is cleared. If a transient fault fails to clear after multiple (5) retries, APIC marks the failure as permanent.

A device script can request for an audit call by returning AUDIT state in the return dictionary. APIC will trigger a clusterAudit(), deviceAudit(), or serviceAudit() depending on whether the cluster API, device API or service API returned an AUDIT state. The script can request for an audit in the event it detects a configuration mismatch between APIC and a device which cannot be resolved within the current API call

A device script returns a PERMANENT fault if the parameter values or configuration that was passed by you has an issue and requires a user intervention to resolve the problem.

A persistent transient fault may translate to a permanent fault. APIC will continue to periodically push the configuration till the fault is resolved. The retry is spaced at larger interval. Some faults may require a user intervention to clear (such as an invalid parameter value, etc.).

The **scriptwrapper** process that invokes the device script API expects the API to return within 120 seconds. If the script takes longer than 120 seconds, the **scriptwrapper** process terminates and restarts. Any outstanding transactions are replayed after the restart.

Service Configuration

The Application Policy Infrastructure Controller (APIC) creates an instance of a metadevice (`MDev`) for each tenant context. An `MDev` instance is referred to as a virtual device, or `vDev`. All service configuration instances for a tenant are rooted under a `vDev`. The APIC generates a unique id for identifying each `vDev`. The APIC also generates a unique ID for each graph instance, which is represented as `vGrp`. The group configuration and function configuration are rooted under this `vGrp` instance that identifies a specific graph instance.

The configuration dictionary that is passed in `serviceAudit`(), `serviceModify`(), `serviceHealth`(), and `serviceCounter`() always contains a `vDev` object and a `vGrp` object. A multi-context device script should use the `vDev` object to identify a tenant context uniquely, which could map to a specific routing domain or context.

Parameter Instance Name on Device

Any folders and parameters that are defined under `vnsMDevCfg` are instantiated under `vDev`. Either a multi-context device must create a configuration folder for each `vDev` ID, or the device or device script must concatenate the `vDev` ID that is passed in the configuration dictionary to generate a unique name across multiple contexts.

The following example shows a dictionary with a global folder and parameter for a function:

```
{
  (0,'',4304): {
     'state': 1,
     'transaction': 10000,
     'value': {
          (4,'Server','webserver1'): {
             'state': 1,
              'transaction': 10000,
              'value': {
              (5,'ipaddress','ipaddress'): {
                 'state': 1,
                 'transaction': 10000,
                 'value': '192.168.100.2'
               },
               (5,'servername','servername'): {
                 'state': 1,
                 'transaction': 10000,
                 'value': 'webserver1'
               }
          }
```

```
      }
}
```

A device script must make sure that the servername instance is uniquely identified across different contexts. Because the names can overlap across different contexts that are configured on the same device, a device script can append the `vDev` ID to the servername value to make the parameter and folder name unique across different contexts. The following examples are unique servername values:

```
4304_webserver1
webserver1_4304
webserver1.4304
```

Another method for creating unique servername values is by creating a folder called `4304`, and then creating the `webserver1` instance under the `4304` folder.

A single context device can ignore the `vDev` argument that is passed in the configuration dictionary. Similarly, a single context or multi-context device must append the group ID to keep the parameter and folder name that are configured for a graph instance unique from another graph instance that is rendered on the same device, as shown in the following example:

```
(0,'',4304): {
 'state': 1,
 'transaction': 10000,
 'value': {
    (1,'',4368): {
       'state': 1,
       'transaction': 10000,
       'value': {
          (3,'SLB','SLB'): {
             'state': 1,
              'transaction': 10000,
              'value': {
                  (5,'servicename','servicename'): {
                     'state': 1,
                     'transaction': 10000,
                     'value': 'webservice'
                  },
              }
          }
       }
    }
  }
}
```

The device script must ensure that the servicename instance that is created for this graph instance does not overlap with another graph instance that is rendered on the same device. The reason is because the parameter and folder that are defined under a Group or Function configuration in the device specification is unique for a graph instance or function instance within a graph. Such parameter or folder names might not be unique across different instances of the graph or instances of a function within a graph, respectively. The device script can append the group ID or the group ID and function name that is passed in the device dictionary to make the folder parameter name unique across graphs or functions within a graph, as shown in the following example:

```
4368.SLB.webservice
```

If the device supports creating folders, the script can create a folder for the graph identified by vgrp id passed in the configuration dictionary and group specific parameters can be instantiated under the vgrp folder. Similarly function configuration can created under a function specific folder within the group folder, thus maintaining uniqueness of each parameter/folder across multiple graph instances.

API Callouts

Cluster Configuration

Registering the first concrete device within a cluster with Application Policy Infrastructure Controller (APIC) triggers the following sequence of API callouts:

1. `deviceValidate`— This API validates whether a device version registered with the APIC can be supported by the device package.
2. `deviceAudit`— This APIC call clears any device global configuration that is not pushed from the APIC. The device script does not clear the management IP address, login credentials, and any configuration that the device needs to be operational that is not supported through the APIC. The `deviceAudit` call needs to be selective in clearing the configuration. Only the configuration that can be pushed from the APIC is cleared.
   deviceAudit() should not modify any service function parameter/configuration or cluster level configuration. The service functions should not be affected on a deviceAudit() call. The purpose of the deviceAudit() call is to bring the device level configuration in sync with the APIC. The script should bring the device in sync with minimal disruption to data path. It should identify the configuration found on the device which was not pushed by APIC, such a configuration should be removed.

Note This should be done only for a configuration that can be managed through the device package.

   The script should push any missing configuration or configuration that is not in sync to the device.

3. `clusterAudit`—The APIC calls this API when the first device is added to the logical device (device cluster). This API clears any configuration from the cluster that is not pushed by the APIC. Similar to the `deviceAudit`() call, this API clears only the configuration that can be supported through the APIC.
   clusterAudit() should not modify any service function parameter/configuration or device specific parameters. The service functions should not be affected on a clusterAudit() call. The purpose of the clusterAudit() call is to bring the cluster level configuration in sync with the APIC. The script should bring the device in sync with minimal disruption to the data path. It should identify the configuration found on the device which was not pushed by APIC, such a configuration should be removed.

Note This should be done only for configuration that can be managed through a device package.

   A script should push any missing configuration or configuration that is not in sync to the device.

4. `clusterModify`—This API is called for any device that is registered and added to a logical device (device cluster). The call results in configuring the cluster configuration.
5. `serviceAudit`—This API is called with function configuration applied by the user on APIC. The script should push any service functions passed in the configuration. If the device has any service function that is not configured on APIC but could be managed through the API, the script should remove such a configuration. The purpose of the serviceAudit() call is to make sure service specific functionality on the device is in sync with the APIC.

Note A device cluster state maintained within the APIC is changed to be operationally up when clusterAudit() returns success. All service level APIs are invoked only after cluster is operational.

The cluster can be marked operational once a single device within the cluster is operational.

Registering additional devices within a cluster triggers the following calls:

- deviceValidate()
- deviceAudit()
- clusterAudit()

Note clusterAudit() should not disrupt devices that are operational within the cluster. Besides service functions that are deployed on the cluster others should not be impacted by adding more devices (such as deviceAudit() or clusterAudit()) should not impact the service functions that are in operational state on the cluster.

After the device is registered, APIC periodically calls the following APIs:

- `deviceHealth`
- `deviceCounter`

Removing a device within a cluster results in calling clusterAudit(). If the last device is removed from the cluster and the cluster state changes to operationally down, APIC calls serviceModify() to remove any service specific configuration.

Service Graph Configuration

When you instantiate a graph by associating an abstract graph to a contract that is bound to an endpoint group (EPG), the APIC calls the following API:

- `serviceModify`—This API instantiates service functions on the device.

After a service has been rendered, the APIC periodically calls the following APIs:

- serviceHealth
- serviceCounter

Audit Calls

APIC will trigger a serviceAudit() when the APIC cluster changes while there is an outstanding transaction with the device. Since the cluster change can cause a different APIC to resume communication with the device, a previous configuration transaction may not have completed causing the device and the APIC cluster to go out of sync. The serviceAudit() call issued by a new master ensures the device state is kept in sync with the APIC.

APIC passes the entire service configuration that is associated with a given device in a single serviceAudit() call. A script is required to process serviceAudit() with a minimum disruption to services configured on the

device. The serviceAudit() call should not result in clearing any device specific global configuration or cluster configuration.

Similar to serviceAudit(), APIC triggers a deviceAudit() and clusterAudit() depending on whether there were any outstanding device configurations or cluster configuration transactions in progress.

The device script can trigger an audit call when it detects that the configuration on the device and the APIC has changed and the script cannot resolve the difference from within the API call.

The `clusterAudit`() call can be triggered by returning "3" (AUDIT) as the return state for the `clusterModify`() call. The APIC passes the entire cluster configuration that is defined by the folders and parameters under `vnsClusterCfg` in `clusterAudit`(). The service function configuration is not passed in `clusterAudit`(). The script must apply the configuration that is passed in the dictionary and remove any configuration that is not defined by the APIC. The script removes only unwanted configurations that are found on the device that can be managed by the APIC and is defined in a device specification file under `vnsClusterCfg`.

The `deviceAudit`() call can be triggered by returning "3" (AUDIT) as the return state for the `deviceModify`(), `deviceHealth`(), or `deviceCounter`() call. The APIC passes the entire device configuration that is defined by the folders and parameters under `vnsDevCfg` in the `deviceAudit`() call. The service function configuration is not passed in `deviceAudit`(). The script must apply the configuration that is passed in the dictionary and remove any device configuration that is not defined by the APIC. The script removes only a configuration that is defined on the APIC and can be managed through the APIC.

The `serviceAudit`() can be triggered by returning '3' as the return state for the `serviceModify`(), `serviceHealth`(), or `serviceCounter`() call. The APIC passes all service function configurations across all `vDev` (tenant) and graph instances that are rendered on the device cluster. The device removes any configuration that is not configured by the APIC and can be managed through the APIC.

Passing Parameters

The following example shows a configuration dictionary that is passed for service APIs:

```
Configuration = {
   (0, mDev-key, mDev-Instance-Name) : {
       'state': state
       'value': {
            (1, '', functionGroup-Instance) : {
               'state': state
               'value': {
                   (3, mDevFunction-Key, mDev-Function-Instance-Name): {
                       'state': state,
                       'value': {
                            (2, mDevFunction-Connector-Key, InstanceName): {
                               'state': state
                               'value': {
                                  'CDev-Instance-Name': 'EncapAssociation-Instance',
                                   ...
                               }
                            }
                            (4, mFolder-Key, mFolder-Instance): {
                                  'state': state
                                  'value': {
                                       (5, mParam-Key, mParam-Instance): {
                                            'state': state
                                             'device': cluster-node-instance
                                              'value': {
                                              }
                                       }
                                  }
                            }
                       }
```

```
                    }
                }
             }
             (4, mFolder-Key, mFolder-Instance): {
                'state': state
                'value': {
                     (5, mParam-Key, mParam-Instance): {
                          'state': state
                           'value': {
                           }
                     }
                }
             },
             (7, '', <encap-instance>): {'state': 1, 'tag': TagValue, 'type': TagType },
             (8, '', <encap-association-Instance>): {
                  'state': 1,
                  'encap': <encapInstance>,
                  'vif': <LogicalInterfaceInstanceID>
             },
             (10, '', <LogicalInterfaceInstance>): {
                  'state': 0,
                  'cifs': {'
                     'state': 0,
                     'value': <Interface Value>
                   }
             }
        }
  },
}         '

Device = {
   'devs': {
      cluster-node-Instance: {
            'host': cluster-node-ipaddress
            'port': cluster-node-port-number,
            'creds': {
               'username': username,
               'password': password
            }
      }
    },
    'name': cluster-name,
    'host': cluster-ipaddress
    'port': cluster-port-number,
    'creds': {
        'username': username,
        'password': password
    }
}
```

Note All parameters are strings.

Device Identification

The device parameter is a simple dictionary that contains the device configuration and the credentials required to access the device. Most of the functions in the device script take a device parameter that identifies the device intended for modification, as shown in the following example:

```
{
  'creds': {
    'password': 'admin',
    'username': 'admin'
  },
  'host': '10.30.13.153',
  'port': 443
}
```

The APIC stores credentials in an encrypted partition.

The script must not store the credentials in temporary files. It should not print the credential in debug logs.

Handling Script Failures

The APIC services integration model is based on Promise Theory, in which individual agents join in a system of voluntary cooperation. The APIC pushes the intended state to the script and provides an API to raise faults on parts of the configuration.

Failures can occur when parameter values change or when a device error occurs. In the case of an APIC failure, the new APIC determines whether to reissue the `serviceModify` call or audit the function groups. The APIs can return a fault list that provides details about the cause for the fault and the potential corrective action for resolving the fault.

APIC does not maintain a transaction history. The state of an object within the configuration dictionary is determined based on the state of the managed object information tree. The object state is marked 'NEW (1)' when a new object is inserted in the managed object tree. Any subsequent API callouts from APIC sets that objects state to 'UNCHANGED (0)' till either the object value is changed by an explicit user configuration or an implicit APIC event that causes the object value to change.

On a change in objects value, the state of the object in the next modify() API call is set to 'CHANGED(2)". If the object is deleted, APIC indicates the deletion by setting the object state to 'DELETED (3)'.

Note if the API returns state 'PERMANENT(2)' indicating that the script encountered an error while processing the configuration, APIC retries the configuration until it receives 'SUCCESS(0)' from the script. If the user has not changed the value of any object between retries, APIC sets the object state to 'UNCHANGED(0)' during these retries. The state of the object is set to 'NEW(1)', 'CHANGED(2)' or 'DELETED(3)' only if a new object was created, an existing object was modified, or deleted between the retries.

The following example shows a case that can occur due to a lack of transaction history on APIC. The device package developer should be aware of such issues and address it in the device script.

Assume that a device package has three parameters: A, B, and C, where A depends on B and B depends on C.

- When A, B, C are created on APIC, this causes APIC to call device a script with state create (1) for all three parameters such that A =a(1) -> B=b (1) -> C=c (1).

  The script raises a fault for B, configures C, but does not configure A and returns state PERMANENT. The end of this callout device has only 'c'.

  APIC raises a fault on B as the configuration for object B was invalid.

- When the value of B is changed to b', this resolves the configuration issue. This change in configuration results in APIC calling the device script with the modification. The parameter state during the subsequent API callout is as follows

  A =a(0) -> B=b'(2) -> C=c(0)

  APIC does not maintain transaction history. APIC does not have any knowledge that A=a was not applied on the device during the previous transaction. APIC retries the configuration and updates the parameter state for B as it was the only parameter that changed between retries.

  The script tries to update parameter B to b'. The script should be able to identify that parameter B does not exist on the device and is being modified before create. Ideally the modify request to the device should return an error.

If the device is capable of identifying a modify before create as an error, the script should handle such an error from the device using one of the two following options:

- Option 1

  Create the parameter B with value b' on the device and resolve any dependent objects that could be missing from the device. The script must walk through the configuration passed in the dictionary and check if the objects that depend on the modified object were created on the device. If the objects were not created, the script should create the object. In this example, the script should create A=a that depends on B=b' as object A=a is not found on the device.

- Option 2

  Return AUDIT(3) state in the return response. APIC replays the entire configuration.

  Note Requesting an audit call can be an expensive operation as APIC passes the entire configuration.

  The device script needs to identify the missing configuration and apply any missing configuration. This option should be used only when a modified object in the dictionary has dependent objects in the configuration.

If the device is not capable of returning an error when a parameter is modified before create, the device script should read the object that is being modified before performing a modify operation on it. This approach of reading the configuration from the device before modifying can be expansive and impact performance. To keep the solution optimal, reading the configuration from the device should be done only if the object being modified could have other objects depending on it.

Sample Script

The following example shows a device script in Python:

```
import pprint
import sys
import Insieme.Logger as Logger

#
# Infra API
#def deviceValidate( device,version ):
    return {
        'state': 0,'version': '1.0'
        }

def deviceModify( device,interfaces,configuration):
    return {
        'state': 0,'faults': [],'health': []
        }

def deviceAudit( device,interfaces,configuration ):
    return {
        'state': 0,'faults': [],'health': []
        }

def deviceHealth( device,interfaces,configuration ):
    return {
        'state': 0,'faults': [],'health': [([], 100)]
        }
```

```
def deviceCounters( device,interfaces,configuration ):
    return {
        'state': 0,'counters': [
            ( [(11,'','eth0')],{
                'rxpackets':100,
                'rxerrors':101,
                'rxdrops':102,
                'txpackets':200,
                'txerrors':201,
                'txdrops':202
            }
          )
        ]
    }

def clusterModify( device,interfaces,configuration ):
    return {
        'state': 0,'faults': [],'health': []
        }

def clusterAudit( device,interfaces,configuration ):
    return {
        'state': 0,'faults': [],'health': []
        }

#
# FunctionGroup API
#

def serviceModify( device,configuration ):
    return {
        'state': 0,'faults': [],'health': []
       }

def serviceAudit( device,configuration ):
    return {
        'state': 0,'faults': [],'health': []
        }

def serviceHealth( device,configuration ):
    return {
        'state': 0,'faults': [],'health': []
        }

def serviceCounters( device,configuration ):
    externalIntferface, = [(0, 'Firewall', 4384), (1, '', 4432), (3, 'Firewall-Func',
'FW-1'),
        (2, 'external', 'external1') ]
    internalInterface = [(0, 'Firewall', 4384) (1, '', 4432) (3, 'Firewall-Func', 'FW-1'),
        (2, 'internal','internal1') ]
    Firewall-1-External-Counters = (externalInterface,
        { 'rxpackets': 100,
            'rxerrors': 0,
            'rxdrops': 0
            'txpackets': 100
            'txerrors': 4
            'txdrops': 2} )
    Firewall-1-Internal-Counters = (internalInterface,
        { 'rxpackets': 100,
            'rxerrors': 0,
            'rxdrops': 0
            'txpackets': 100
            'txerrors': 4
            'txdrops': 2} )
    Counters = [ Firewall-1-External-Counters, Firewall-1-Internal-Counters ]
        return {
            'state': 0,
            'counters': Counters
        }

#
# EndPoint/Network API
#
```

```
def attachEndpoint( device,
                    configuration,
                    endpoints ):
    return {
        'state': 0,
        'faults': [],
        'health': [],
        }

def detachEndpoint( device,
                    configuration,
                    endpoints ):
    return {
        'state': 0,
        'faults': [],
        'health': [],
        }

def attachNetwork( device,
                   configuration,
                   networks ):
    return {
        'state': 0,
        'faults': [],
        'health': [],
        }

def detachNetwork( device,
                   configuration,
                   networks ):
    return {
        'state': 0,
        'faults': [],
        'health': [],
        }
```

The following is an example invocation:

```
Function: deviceValidate

Arguments:

(
  {
    'creds':
      {
        'password': 'admin','username': 'admin'
      },
      'host': '10.30.13.153','port': 443
  }
  u'1.0'
)

Function: deviceAudit

Arguments:

(
  {
    'host': '10.30.13.153','port': 443,'creds':
      {
        'username': 'admin','password': 'admin'
      }
  },
  {
    (11,'','1_1'): {
      'state': 0,'label': 'int'
    },(11,'','1_2'): {
      'state': 0,'label': 'ext'
    },(11,'','1_3'): {
      'state': 0,'label': 'mgmt'
    }
```

```
  },
  {
    (4,'HighAvailabilityCfg','HA'): {
      'state': 2,'value': {
        (5,'peerIP','peerip'): {
          'state': 2,'value': '10.30.13.154'
        }
      }
    }
  }
)
```

Function: clusterAudit

Arguments:

```
(
  {
    'name': 'Cluster1',
    'virtual': False,
    'devs': {
      'SampleDevice1': {
        'host': '10.30.13.153',
        'port': 443,
        'creds': {
          'username': 'admin',
          'password': 'admin'
        }
      }
    },
    'host': '10.30.13.153',
    'port': 443,
    'creds': {
      'username': 'admin',
      'password': 'admin'
    }
  },
  {
    (12, '', 'internal'): {
      'state': 0,
      'label': 'int'
    },
    (12, '', 'external'): {
      'state': 0,
      'label': 'ext'
    }
  },
  {
    (4,'SyslogConfig','syslogconfig'): {
      'state': 2,
      'value': {
        (5,'ipaddress','syslogip'): {
          'state': 2,
          'value': '10.168.62.100'
        }
      }
    },
    (4,'NTPConfig','ntpconfig'): {
      'state': 2,
      'value': {
        (5,'ipaddress','syslogip'): {
          'state': 2,
          'value': '10.168.62.1'
        }
      }
    }
  }
)
```

Function: clusterModify

Arguments:

```
(
  {
    'name': 'Cluster1',
    'virtual': False,
    'devs': {
      'SampleDevice1': {
        'host': '10.30.13.153',
        'port': 443,
        'creds': {
          'username': 'admin',
          'password': 'admin'
        }
      }
    },
    'host': '10.30.13.153',
    'port': 443,
    'creds': {
      'username': 'admin',
      'password': 'admin'
    }
  },
  {
    (12, '', 'internal'): {
      'state': 0,
      'label': 'int'
    },
    (12, '', 'external'): {
      'state': 0,
      'label': 'ext'
    }
  },
  {
    (4,'SyslogConfig','syslogconfig'): {
      'state': 2,
      'value': {
        (5,'ipaddress','syslogip'): {
          'state': 2,
          'value': '10.168.62.100'
        }
      }
    },
    (4,'NTPConfig','ntpconfig'): {
      'state': 2,
      'value': {
        (5,'ipaddress','syslogip'): {
          'state': 2,
          'value': '10.168.62.1'
        }
      }
    }
  }
)
```

Function: serviceModify

Arguments:

```
{
  'creds': {
    'password': 'admin',
    'username': 'admin'
  },
  'devs': {
    'SampleDevice1': {
      'creds': {
        'password': 'admin',
        'username': 'admin'
      },
      'host': '10.30.13.153',
      'port': 443
    }
  },
  'host': '10.30.13.153',
```

```
  'name': 'Cluster1',
  'port': 443,
  'virtual': False
}
{
  (0,'',4304): {
    'state': 1,
    'transaction': 10000,
    'value': {
      (1,'',4368): {
        'state': 1,
        'transaction': 10000,
        'value': {
          (3,'SLB','SLB'): {
            'state': 1,
            'transaction': 10000,
            'value': {
              (2,'external','external'): {
                'state': 1,
                'transaction': 10000,
                'value': {
                  (9,'','Cluster1_external_40962'): {
                    'state': 2,
                    'target': 'Cluster1_external_40962',
                    'transaction': 10000
                  }
                }
              },
              (2,'internal','internal'): {
                'state': 1,
                'transaction': 10000,
                'value': {
                  (9,'','Cluster1_internal_57862'): {
                    'state': 2,
                    'target': 'Cluster1_internal_57862',
                    'transaction': 10000
                  }
                }
              },
              (4,'VServer','webVServer'): {
                'state': 1,
                'transaction': 10000,
                'value': {
                  (4,'VServerGlobalConfig','VServerGlobalConfig'): {
                    'state': 1,
                    'transaction': 10000,
                    'value': {
                      (6,'ServerConfig','serverConfig'): {
                        'state': 1,
                        'target': 'webserver1',
                        'transaction': 10000
                      },
                      (6,'ServiceConfig','serviceConfig'): {
                        'state': 1,
                        'target': 'webservice',
                        'transaction': 10000
                      },
                      (6,'VipConfig','vipConfig'): {
                        'state': 1,
                        'target': 'webnetwork/webvip',
                        'transaction': 10000
                      }
                    }
                  },
                  (5,'port','port'): {
                    'state': 1,
                    'transaction': 10000,
                    'value': '80'
                  },
                  (5,'servicename','servicename'): {
                    'state': 1,
                    'transaction': 10000,
                    'value': 'webservice'
```

```
            },
            (5,'servicetype','servicetype'): {
              'state': 1,
              'transaction': 10000,
              'value': 'tcp'
            },
            (5,'vservername','vservername'): {
              'state': 1,
              'transaction': 10000,
              'value': 'webvserver'
            }
          }
        }
      }
    }
  }
},
(4,'Network','webnetwork'): {
  'state': 1,
  'transaction': 10000,
  'value': {
    (4,'vip','webvip'): {
      'state': 1,
      'transaction': 10000,
      'value': {
        (5,'netmask','webnetmask'): {
          'state': 1,
          'transaction': 10000,
          'value': '255.255.255.255'
        },
        (5,'vipaddress','webvipaddress'): {
          'state': 1,
          'transaction': 10000,
          'value': '10.0.0.100'
        }
      }
    }
  }
},
(4,'Server','webserver1'): {
  'state': 1,
  'transaction': 10000,
  'value': {
    (5,'ipaddress','ipaddress'): {
      'state': 1,
      'transaction': 10000,
      'value': '192.168.100.2'
    },
    (5,'servername','servername'): {
      'state': 1,
      'transaction': 10000,
      'value': 'webserver1'
    }
  }
},
(4,'Service','webservice'): {
  'state': 1,
  'transaction': 10000,
  'value': {
    (5,'servicename','servicename'): {
      'state': 1,
      'transaction': 10000,
      'value': 'webservice'
    },
    (5,'serviceport','serviceport'): {
      'state': 1,
      'transaction': 10000,
      'value': '9080'},
    (5,'servicetype','servicetype'): {
      'state': 1,
      'transaction': 10000,
      'value': 'tcp'
    }
```

```
        }
      },
      (7,'','40962'): {
        'state': 1,
        'tag': 235,
        'transaction': 10000,
        'type': 1
      },
      (7,'','57862'): {
        'state': 1,
        'tag': 201,
        'transaction': 10000,
        'type': 1
      },
      (8,'','Cluster1_external_40962'): {
        'encap': '40962',
        'state': 1,
        'transaction': 10000,
        'vif': 'Cluster1_external'
      },
      (8,'','Cluster1_internal_57862'): {
        'encap': '57862',
        'state': 1,
        'transaction': 10000,
        'vif': 'Cluster1_internal'
      },
      (10,'','Cluster1_external'): {
        'cifs': {
          'SampleDevice1': '1_2'
        },
        'state': 1,
        'transaction': 10000
      },
      (10,'','Cluster1_internal'): {
        'cifs': {
          'SampleDevice1': '1_1'
        },
        'state': 1,'transaction': 10000
      }
    }
  }
}
```

Function: attachEndpoint

Arguments:

```
{
   'creds': {
     'password': 'admin',
     'username': 'admin'
   },
   'devs': {
      'SampleDevice1': {
         'creds': {
             'password': 'admin',
             'username': 'admin'
          },
         'host': '10.30.13.153',
         'port': 443
      }
   },
   'host': '10.30.13.153',
   'name': 'Cluster1',
   'port': 443,
   'virtual': False
}
{
(0,'',4304): {
  'state': 1,
  'transaction': 10000,
  'value': {
    (1,'',4368): {
```

```
'state': 1,
'transaction': 10000,
'value': {
(3,'SLB','SLB'): {
  'state': 1,
  'transaction': 10000,
  'value': {
     (2,'external','external'): {
       'state': 1,
       'transaction': 10000,
       'value': {
          (9,'','Cluster1_external_40962'): {
            'state': 2,
            'target': 'Cluster1_external_40962',
            'transaction': 10000
          }
       }
     },
     (2,'internal','internal'): {
       'state': 1,
       'transaction': 10000,
       'value': {
          (9,'','Cluster1_internal_57862'): {
            'state': 2,
            'target': 'Cluster1_internal_57862',
            'transaction': 10000
          }
       }
     },
     (4,'VServer','webVServer'): {
         'state': 1,
         'transaction': 10000,
         'value': {
             (4,'VServerGlobalConfig','VServerGlobalConfig'): {
                'state': 1,
                'transaction': 10000,
                'value': {
                    (6,'ServerConfig','serverConfig'): {
                       'state': 1,
                       'target': 'webserver1',
                       'transaction': 10000
                    },
                    (6,'ServiceConfig','serviceConfig'): {
                       'state': 1,
                       'target': 'webservice',
                       'transaction': 10000
                    },
                    (6,'VipConfig','vipConfig'): {
                       'state': 1,
                       'target': 'webnetwork/webvip',
                       'transaction': 10000
                    }
                }
             },
             (5,'port','port'): {
                'state': 1,
                'transaction': 10000,
                'value': '80'
             },
             (5,'servicename','servicename'): {
                'state': 1,
                'transaction': 10000,
                'value': 'webservice'
             },
             (5,'servicetype','servicetype'): {
                'state': 1,
                'transaction': 10000,
                'value': 'tcp'
             },
             (5,'vservername','vservername'): {
                'state': 1,
                'transaction': 10000,
                'value': 'webvserver'
```

```
                }
             }
          }
       }
    }
 },
 (4,'Network','webnetwork'): {
    'state': 1,
    'transaction': 10000,
    'value': {
       (4,'vip','webvip'): {
          'state': 1,
          'transaction': 10000,
          'value': {
              (5,'netmask','webnetmask'): {
                 'state': 1,
                 'transaction': 10000,
                 'value': '255.255.255.255'
              },
              (5,'vipaddress','webvipaddress'): {
                 'state': 1,
                 'transaction': 10000,
                 'value': '10.0.0.100'
              }
          }
       }
    }
 },
 (4,'Server','webserver1'): {
     'state': 1,
     'transaction': 10000,
     'value': {
         (5,'ipaddress','ipaddress'): {
            'state': 1,
            'transaction': 10000,
            'value': '192.168.100.2'
         },
         (5,'servername','servername'): {
            'state': 1,
            'transaction': 10000,
            'value': 'webserver1'
         }
     }
 },
 (4,'Service','webservice'): {
     'state': 1,
     'transaction': 10000,
     'value': {
        (5,'servicename','servicename'): {
           'state': 1,
           'transaction': 10000,
           'value': 'webservice'
        },
        (5,'serviceport','serviceport'): {
           'state': 1,
           'transaction': 10000,
           'value': '9080'},
        (5,'servicetype','servicetype'): {
           'state': 1,
           'transaction': 10000,
           'value': 'tcp'
        }
     }
 },
 (7,'','40962'): {
    'state': 1,
    'tag': 235,
    'transaction': 10000,
    'type': 1
 },
 (7,'','57862'): {
     'state': 1,
```

```
        'tag': 201,
        'transaction': 10000,
        'type': 1
    },
    (8,'','Cluster1_external_40962'): {
         'encap': '40962',
         'state': 1,
         'transaction': 10000,
         'vif': 'Cluster1_external'
    },
    (8,'','Cluster1_internal_57862'): {
         'encap': '57862',
         'state': 1,
         'transaction': 10000,
         'vif': 'Cluster1_internal'
    },
    (10,'','Cluster1_external'): {
        'cifs': {
            'SampleDevice1': '1_2'
         },
        'state': 1,
        'transaction': 10000
    },
    (10,'','Cluster1_internal'): {
        'cifs': {
            'SampleDevice1': '1_1'
         },
        'state': 1,
        'transaction': 10000
    }
  }
}
}
{
   'addr': '10.0.0.3',
   'conn': 'external'
}
```

The `endpoints` dictionary in the API callout contains the following attributes:

- `'addr'`—The IP address of the endpoint that attached to an EPG.
- `'conn'`—The connector to which the EPG is attached directly or indirectly through other function nodes.

```
Function: attachEndpoint
Arguments:
{
   'creds': {
     'password': 'admin',
     'username': 'admin'
   },
   'devs': {
      'SampleDevice1': {
         'creds': {
             'password': 'admin',
             'username': 'admin'
          },
         'host': '10.30.13.153',
         'port': 443
      }
   },
   'host': '10.30.13.153',
   'name': 'Cluster1',
   'port': 443,
   'virtual': False
}
{
(0,'',4304): {
  'state': 1,
  'transaction': 10000,
  'value': {
    (1,'',4368): {
```

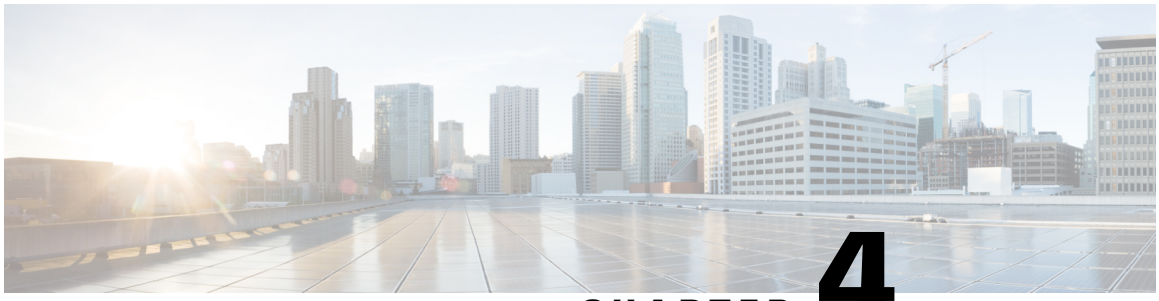
```
'state': 1,
'transaction': 10000,
'value': {
(3,'SLB','SLB'): {
  'state': 1,
  'transaction': 10000,
  'value': {
     (2,'external','external'): {
       'state': 1,
       'transaction': 10000,
       'value': {
          (9,'','Cluster1_external_40962'): {
            'state': 2,
            'target': 'Cluster1_external_40962',
            'transaction': 10000
          }
       }
     },
     (2,'internal','internal'): {
       'state': 1,
       'transaction': 10000,
       'value': {
          (9,'','Cluster1_internal_57862'): {
            'state': 2,
            'target': 'Cluster1_internal_57862',
            'transaction': 10000
          }
       }
     },
     (4,'VServer','webVServer'): {
         'state': 1,
         'transaction': 10000,
         'value': {
             (4,'VServerGlobalConfig','VServerGlobalConfig'): {
                'state': 1,
                'transaction': 10000,
                'value': {
                    (6,'ServerConfig','serverConfig'): {
                       'state': 1,
                       'target': 'webserver1',
                       'transaction': 10000
                    },
                    (6,'ServiceConfig','serviceConfig'): {
                       'state': 1,
                       'target': 'webservice',
                       'transaction': 10000
                    },
                    (6,'VipConfig','vipConfig'): {
                       'state': 1,
                       'target': 'webnetwork/webvip',
                       'transaction': 10000
                    }
                }
             },
             (5,'port','port'): {
                'state': 1,
                'transaction': 10000,
                'value': '80'
             },
             (5,'servicename','servicename'): {
                'state': 1,
                'transaction': 10000,
                'value': 'webservice'
             },
             (5,'servicetype','servicetype'): {
                'state': 1,
                'transaction': 10000,
                'value': 'tcp'
             },
             (5,'vservername','vservername'): {
                'state': 1,
                'transaction': 10000,
                'value': 'webvserver'
```

```
                }
            }
        }
    }
  }
},
(4,'Network','webnetwork'): {
   'state': 1,
   'transaction': 10000,
   'value': {
      (4,'vip','webvip'): {
         'state': 1,
         'transaction': 10000,
         'value': {
             (5,'netmask','webnetmask'): {
                'state': 1,
                'transaction': 10000,
                'value': '255.255.255.255'
             },
             (5,'vipaddress','webvipaddress'): {
                'state': 1,
                'transaction': 10000,
                'value': '10.0.0.100'
             }
         }
      }
   }
},
(4,'Server','webserver1'): {
    'state': 1,
    'transaction': 10000,
    'value': {
        (5,'ipaddress','ipaddress'): {
           'state': 1,
           'transaction': 10000,
           'value': '192.168.100.2'
        },
        (5,'servername','servername'): {
           'state': 1,
           'transaction': 10000,
           'value': 'webserver1'
        }
    }
},
(4,'Service','webservice'): {
    'state': 1,
    'transaction': 10000,
    'value': {
       (5,'servicename','servicename'): {
          'state': 1,
          'transaction': 10000,
          'value': 'webservice'
       },
       (5,'serviceport','serviceport'): {
          'state': 1,
          'transaction': 10000,
          'value': '9080'},
       (5,'servicetype','servicetype'): {
          'state': 1,
          'transaction': 10000,
          'value': 'tcp'
       }
    }
},
(7,'','40962'): {
   'state': 1,
   'tag': 235,
   'transaction': 10000,
   'type': 1
},
(7,'','57862'): {
    'state': 1,
```

```
        'tag': 201,
        'transaction': 10000,
        'type': 1
    },
    (8,'','Cluster1_external_40962'): {
         'encap': '40962',
         'state': 1,
         'transaction': 10000,
         'vif': 'Cluster1_external'
    },
    (8,'','Cluster1_internal_57862'): {
         'encap': '57862',
         'state': 1,
         'transaction': 10000,
         'vif': 'Cluster1_internal'
    },
    (10,'','Cluster1_external'): {
        'cifs': {
            'SampleDevice1': '1_2'
         },
        'state': 1,
        'transaction': 10000
    },
    (10,'','Cluster1_internal'): {
        'cifs': {
            'SampleDevice1': '1_1'
         },
        'state': 1,
        'transaction': 10000
    }
  }
}
}
{
   'addr': '10.0.0.0/24',
   'conn': 'external'
}
```

The `endpoints` dictionary in the API callout contains the following attributes:

- `'addr'`—The IP address of the endpoint that attached to an EPG.
- `'conn'`—The connector to which the EPG is attached directly or indirectly through other function nodes.



CHAPTER 4

Fabric Connectivity

About Fabric Connectivity

Registering Devices

To manage service nodes through the Application Policy Infrastructure Controller (APIC), the administrator must explicitly register the service devices. During the registration step, you must provide the following information:

- Topology information: How device interfaces are connected to the fabric leaf nodes.
- Label interfaces: Based on the device requirements. The labels are used by the APIC to bind an interface with a connector for specific functions that are provided by the service device.
- IP address and port information: Information that is needed to connect to the device.
- Username and password: Credentials used for configuring the device.

The sample firewall device specification below defines three labels for interfaces:

- `Inside`: Identifies network interfaces that are more trusted (secure).
- `Outside`: Identifies network interfaces that are less trusted.
- `Management`: Identifies the interface used for management connectivity.

The labels are defined in the device specification using the `vnsMIfLbl` tag. All interfaces on the firewall device are categorized into one of the types defined by the device specification.

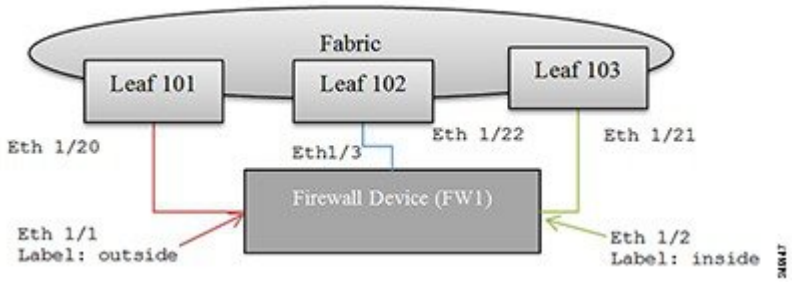
Note The APIC does not check if the interface actually exists on the device.

The following example shows a Northbound XML post for registering a device with the APIC. You can either post the request as shown or use the APIC GUI to register the device:

```
<polUni>
    <fvTenant
        dn="uni/tn-Tenant1"
        name="Tenant1">
        <vnsLDevVip name="Firewall-1">

            <vnsLIf name="external">
                <vnsRsMetaIf tDn="uni/infra/mDev-CISCO-ASA-1.0.1.16/mIfLbl-external"/>
                <vnsRsCIfAtt tDn="uni/tn-Tenant1/lDevVip-Firewall/cDev-ASA/cIf-Eth1_1"/>
            </vnsLIf>
            <vnsLIf name="internal">
                <vnsRsMetaIf tDn="uni/infra/mDev-CISCO-ASA-1.0.1.16/mIfLbl-internal"/>
                <vnsRsCIfAtt tDn="uni/tn-Tenant1/lDevVip-Firewall/cDev-ASA/cIf-Eth1_2"/>
            </vnsLIf>
            <vnsCDev name="FW1">

                <vnsCIf name="Eth1_1">
                       <vnsRsCIfPathAtt tDn="topology/pod-1/paths-101/pathep-[eth1/20]"/>
                </vnsCIf>
                <vnsCIf name="Eth1_2">
                       <vnsRsCIfPathAtt tDn="topology/pod-1/paths-102/pathep-[eth1/21]"/>
                </vnsCIf>
                <vnsCIf name="Eth1_3">
                       <vnsRsCIfPathAtt tDn="topology/pod-1/paths-103/pathep-[eth1/22]"/>
                </vnsCIf>

                <vnsCMgmt name="devMgmt"
                          host="192.168.78.62"
                          port="80"
                          />

               <vnsCCred name="username"
                          value="admin"
                          />
               <vnsCCredSecret name="password"
                          value="insieme"
                          />
            </vnsCDev>
        </vnsLDevVip>
    </fvTenant>
</polUni>
```

The following figure shows the topology of registering a device.

Figure 6: Topology of Registering a Device



The three steps the to register the device are as follows:

1 Register the interfaces:

- Eth 1/1: Labeled as `outside`. Connected to Leaf node 101, Eth 1/20.

- Eth 1/2: Labeled as `inside`. Connected to Leaf node 102, Eth 1/21.
- Ethernet 1/3: Labeled as `management`. Connected to Leaf node 103, Eth 1/22.

2 Provide the management IP address (192.168.78.62) and port (80) to reach to the device.

3 Provide the username and password credentials to use for communicating with the device.

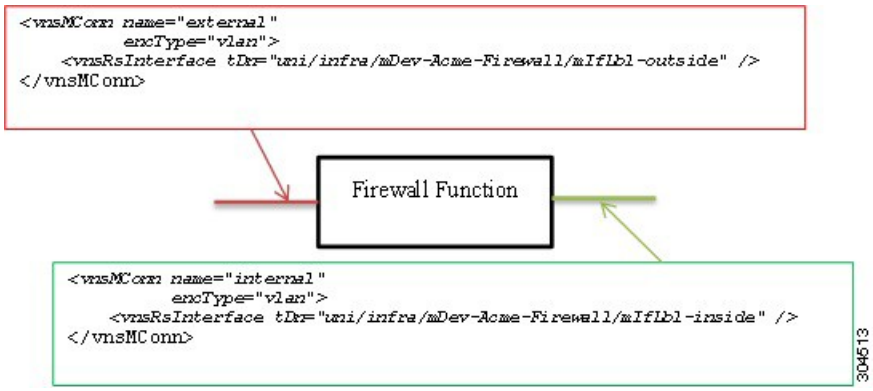
Connectors

The connectors for a `vnsMFunc` define connectivity between two or more function nodes or between a function node and the fabric within a graph. A connector has the following attributes:

- `name`: Identifies a specific connector.
- `encType`: Defines whether the packets are tagged with a VLAN header or are VXLAN encapsulated.
- `vnsRsInterface`: If the connector provides connectivity to the fabric, this interface associates the connector to an interface type on the device.

In the following figure, two connectors are associated to a firewall function. The first connector represents connectivity to an external or outside network, and the second connector represents connectivity to an internal or inside network on the firewall device. Both are tagged with a VLAN header.

Figure 7: Connectors Associated to a Firewall Function



Service Graphs

A service graph is an ordered set of functions between a set of terminals. You can manually create a service graph using the GUI or CLI, or create one programmatically using the Application Policy Infrastructure Controller (APIC) Northbound Service Integration API. A function within the graph might require one or more parameters and have one or more connectors.

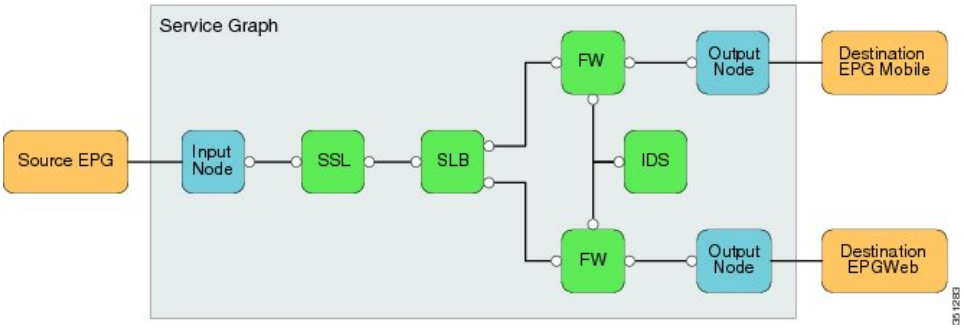
A service graph represents the network using the following elements:

- Function Nodes (green)—A function applied to traffic such as a transform (SSL termination, VPN gateway), filter (firewalls), or terminal (intrusion detection systems)
- Terminal Nodes (blue)—Input and outputs from the service graph

- Connector (white)—Input and output from a node
- Connections—How traffic is forwarded through the network

The following figure shows a service graph.

Figure 8: Service Graph



Note Although this generic service graph shows two output nodes, the fabric supports only a single input node and a single output node from a service graph at this time.

The `serviceModify` function is used to instantiate the network and function configurations.

Graph Rendering

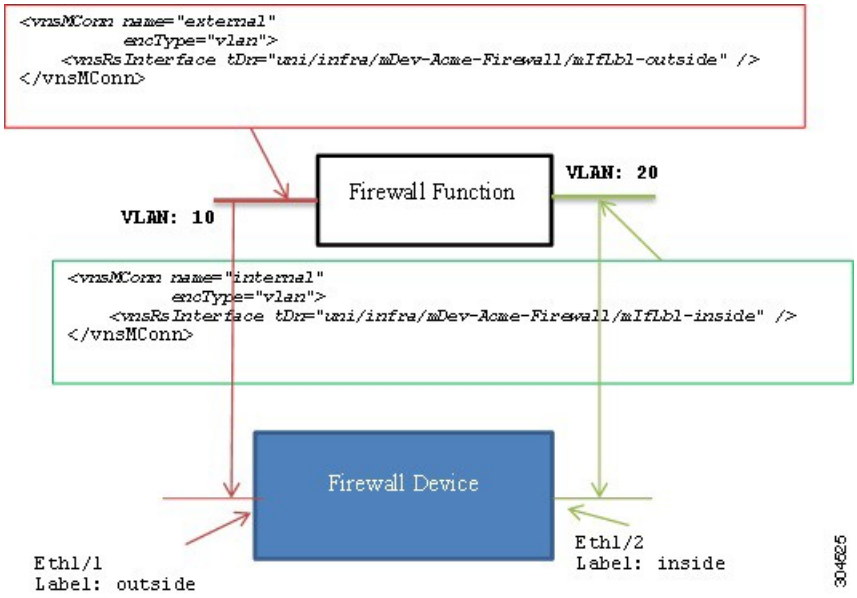
When instantiating a function on the device, the Application Policy Infrastructure Controller (APIC) does the following:

- Assigns a VLAN/VXLAN ID for the connector. The APIC checks whether the previous node has been allocated a VLAN/VXLAN ID. It either uses the previous node value or allocates a new tag for the connector. The `encType` indicates whether the VLAN/VXLAN ID is allocated.
- Uses interface relation and device interface label information to associate an interface to a connector. In the previous figure, rendering a firewall function on the firewall device will result in these bindings:
  - Connector labeled as `external`: Device Interface Eth1/1
  - Connector labeled as `internal`: Device Interface Eth1/2

You should enable or bind the VLAN or VXLAN tags that are assigned to the connector to the associated interfaces.

In the following figure, the APIC assigns VLAN 10 to the outside connector and VLAN 20 to the inside connector. The device script must configure VLAN 10 on interface Eth1/1 and bind it to the firewall function. Similarly, the device script must configure VLAN 20 on interface Eth1/2 and bind it to the firewall function.

Figure 9: A Firewall With Bound VLANs



Device Script Interface

The VXLAN/VLAN encapsulation, interface, and association between the interface and VLAN/VXLAN are passed as device configuration parameters to the device script. In the previous figure, the Application Policy Infrastructure Controller (APIC) provides the following information in the device configuration:

- Encapsulation: VLAN 10, VLAN 20
- Interface: Eth1/1, Eth1/2
- Association of encapsulation to a logical interface:
  - 'Firewall-1_outside_1553': (VLAN -10, Eth1/1)
  - 'Firewall-1_inside_7697': (VLAN-20, Eth1/2)

The encapsulation tags, interfaces, and association are destroyed only when all functions across all graphs using the tag are deleted from the device. By providing encapsulation information in the device configuration, the APIC ensures the encapsulation tag is not deleted from the device until all functions that refer to the tag are deleted. The following example shows a sample dictionary:

```
Configuration =
{
 (0, '', <LdevInstance>): {
   ...
   (7, '', <encap-instance>): {'state': 1, 'tag': TagValue, 'type': TagType},
   (7, '', <encap-instance>): {'state': 1, 'tag': TagValue, 'type': 0},
   (8, '', <encap-association-Instance>): {
         'state': 1,
```

```
          'encap': <encapInstance>,
          'vif': <LogicalInterfaceInstanceID>}
   },
   (8, '', <encap-association-Instance>): {
          'state': 1,
          'encap': <encapInstance>,
          'vif': <LogicalInterfaceInstanceID>},
   },
   (10, '', <LogicalInterfaceInstance>): {
          'state': 0,
          'cifs': {
             'cDevInstance': <Interface Value>
          }
   },
   (10, '', <LogicalInterfaceInstance>): {
          'state': 0,
          'cifs': {
             'cDevInstance': <Interface Value>
          }
   },
 }
}
```

Legend:

```
The dictionary format is as follows:

(type, key, name): {
   'state': StateValue,
   'device': CDevName,
   'connector': connectorValue,
   'value': Parameter Value,
}


type:
7 – Encap Instance [Encap Type=0 (VLAN), Encap Type=1 (VXLAN))]
                    Encap Tag = VLAN ID or VNID (VXLAN case)
8 – VEncapAss (Device Interface and Encap (VXLAN/VLAN) association)
10 – VIF (logical interface) – Identifies interface on the device.

CDevName: Identifies a specific device within a cluster node. This attribute is not applicable
 to encap, VIF, or vEncapAss.

connectorValue: Identifies the connector to which this parameter should be bound. This
attribute is not applicable to encap, VIF, or vEncapAss.

value: Value of the parameter.

StateValue:
0 – No change
1 – Create
2 – Modify
3 - Destroy
```

The connectors within the function are related to the encapsulation association parameter specified in the device configuration. The encapsulation association parameter binds the connector to a specific VLAN/VXLAN tag and interface. In the above example, the dictionary for the function would contain the following connector information:

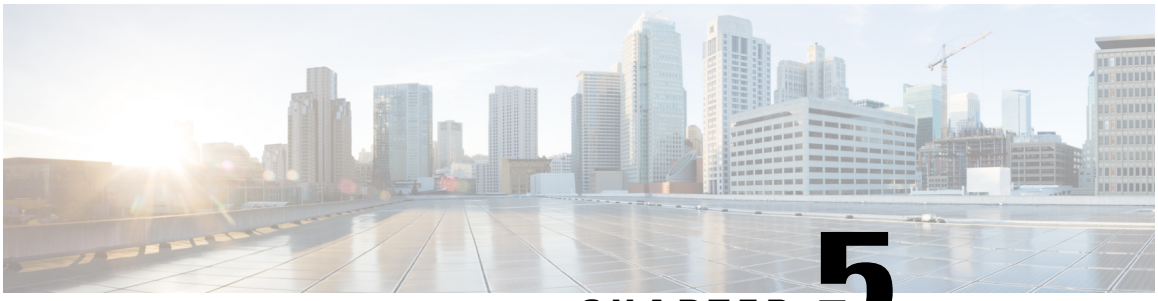
```
Configuration =
{
    (0, '', 'Firewall-1'): {
      'state': 2,
      'value': {
         (7, '', '1553'): {'state': 1, 'tag': 10, 'type': 0},
         (7, '', '7697'): {'state': 1, 'tag': 20, 'type': 0},
         (8, '', 'Firewall-1_outside_1553'): {'state': 1,
                                              'encap': '1553',
                                              'vif': 'Firewall-1_outside'},
         (8, '', 'Firewall-1_inside_7697'): {'state': 1,
                                             'encap': '1553',
```

```
                                          'vif': 'Firewall-1_inside'},

            (10, '', 'Firewall-1_outside'): {'state': 1,
                                             'cifs': {'FW2': 'Eth1/1' }
                                            },
            (10, '', 'Firewall-1_inside'):  {'state': 1,
                                             'cifs': {'FW': 'Eth1/2'}}
                                            }
            (1, '', '4552'): {
               'state': 1,
               'value': {
                 (3, 'Firewall', 'F1'): {
                     'state': 1,
                     'value': {
                         (2, 'external', 'conn1'): { 'state': 1,
                             'value': {
                                ('9', '', 'outside_1553'): {
                                     'state': 1,
                                     'value': 'Firewall-1-outside_1553'
                                },
                             }
                         },
                         (2, 'internal', 'conn2'): { 'state': 1
                             'value': {
                                ('9', '', 'inside_7697'): {
                                     'state': 1,
                                     'value': 'Firewall-1-inside_7697'
                                },
                             }
                         },
                         (4, 'Firewall-Config', 'FW-Config 1'): {
                              'state': 1,
                              'value' : {
                                  (5, 'Param-1', ''): { 'state': 1, 'value': value },
                              . . .
                              }
                         },
                     },
                 },
               },
            },
        },
}
```

Based on the above dictionary, you should configure the device script to do the following:

- Enable VLAN 10 on interface Eth1/1:
  - Create subinterface Eth1/1.10 with encap VLAN 10
  - Add Eth1/1 to VLAN 10
- Enable VLAN 20 on interface Eth1/2:
  - Create subinterfaceEth1/2.20 with encap VLAN 20
  - Add Eth1/2 to VLAN 20

Note The connector value is a dictionary that allows each device within the cluster to use different interfaces.



CHAPTER 5

Service Insertion Support

About Service Insertion Support

Health Monitoring

The Application Policy Infrastructure Controller (APIC) can query the health status of devices and services from 0 (not operational) to 100 (fully functional) by using the following functions:

- **deviceHealth—**Returns the health of a service device.
- **serviceHealth—**Returns the health of a service function, endpoint, or endpoint group.

The APIC periodically calls the `deviceHealth` API. The device script can return the health of the device. The health can be a normalized value that is computed by the script based on querying CPU utilization, memory utilization, and other critical resources, such as the state of the power supply or HA status. The value of the health can be a score between 0 to 100. 0 indicates that the device is not operational and 100 indicates that the device is fully functional.

The following example shows a return value from the `deviceHealth` API:

```
def deviceHealth (device,interfaces,configuration):
     ...
    return {
       'state': 0,'faults': [],'health': [([],80)]
    }
```

Note The health value is a normalized value based on memory utilization, CPU utilization, and the number of connections. The health element can be written as a part of the device modify or device audit API.

The device script can report the health of all the functions provided by the service node using the Service Health API. The APIC periodically invokes the Service Health API with the service node configuration.

The Service Health API is defined as follows:

```
serviceHealth (device, configuration)
```

The `serviceHealth` parameters are defined as follows:

- `device`: A dictionary providing the device IP and credentials. The APIC uses this information to connect to the service node.
- `configuration`: The service node configuration. The APIC pushes the entire device configuration across all graphs during the `serviceHealth` poll.

The Service Health API can query the device and accumulate information regarding the health of a service. For example, the script may collect CPU utilization, memory utilization, or the number of connections associated with the service. The script uses the data collected from the device to compute a normalized value between 0 – 100, representing the health of the service. 0 indicates bad health, and 100 indicates that the service is in a good state.

The APIC expects the script to return the service health as a list of `(path, Service Health)` tuples.

`path`: A list of tuples identifying a specific service function within the device:

```
Path = [ (type, key, name) (type, key, name) ...]
```

The `state` can take one of the following values:

- `OK`: Success
- `TRANSIENT`: Temporary failure. The Script Engine will retry the configuration by calling the device script API again.
- `PERMANENT`: Configuration failure. This may be due to an invalid configuration parameter or the use of an unsupported feature on the device. The Script Engine will not retry the configuration in this state.
- `AUDIT`: The script can request that an audit be triggered.
- `True`: Success
- `False`: Permanent failure. There is a configuration issue requiring user intervention.

Cisco recommends that you use `OK`, `TRANSIENT`, `PERMANENT`, or `AUDIT` as `state` values, rather than the boolean `True` and `False` values.

Faults are returned as a list of (object, fault) tuples, and are updated in the system as follows:

- If the script returns a `state` value of `OK`, `True`, or `PERMANENT`: Faults are replaced with the set of faults in the return value. Any previous fault that was not reported will be implicitly cleared. For example, if you had a fault on `obj1` but on the second attempt you return a fault only on `obj2`, the `obj1` fault is cleared and the APIC now reports a fault only on `obj2`. Faults are replaced only in this return state.
- If the script returns a `state` value of `TRANSIENT`, `False`, or `AUDIT`: Faults are augmented. For example, if the script had reported a fault on `obj1` but on the second attempt you return a fault only on `obj2`, the APIC reports a faults on both `obj1` and `obj2`.

The script should return a `TRANSIENT` state along with the fault on the device when the connection to the device breaks. Otherwise it can report transient fault on objects if the configuration could not be applied due to a temporary device resource issue.

The script should return a `PERMANENT` state along with faults on objects when the configuration could not be applied because of an invalid parameter or configuration issue. The user must change the configuration to clear the fault.

The script should return an `OK` or `True` state if the configuration could be successfully applied. Do not populate faults on success. The APIC will implicitly clear all faults that were reported prior to this call.

The script should return a `PERMANENT` state with the fault on the device if the configuration parsing fails.

The following example illustrates a return value in the case in which the device is configured with multiple instances of an SLB function:

```
device =
       {'creds': {'password': 'admin', 'username': 'admin'},
        'devs': {'cdev1': {'creds': {'password': 'admin',
                                     'username': 'admin'},
                           'host': '172.21.158.182',
                           'port': 80},
                 'cdev2': {'creds': {'password': 'admin',
                                     'username': 'admin'},
                                     'host': '172.21.158.224',
                                     'port': 80}},
        'host': '1.1.1.3',
        'name': 'cluster1',
        'port': 80}

configuration =
     {(0, '', 4447): {'state': 1, 'transaction': 10000,
                      'value': {(1, '', 4208): {'state': 1,
                                'transaction': 10000,
                                'value': {(3, 'SLB', 'Node1'): {'state': 1,
                                                                'transaction': 10000,
                                                                'value': { ... }
                                                               }
                                         }
                                }
                      }
     }
```

For each function:

- Query the physical devices.
- Determine a score for each device based on certain criteria relevant to the device, such as connections, CPU usage, or errors.
- Determine a score for the cluster. For an Active-Active cluster, determine a score using a minimum set of nodes and normalize the scores from each device. For an Active-Standby cluster, use active nodes for the score as well as the high availability state.

Note The health element can also be returned as part of the return dictionary for the service modify or service audit API.

- Return the health score the cluster and each device using this format:

```
func1 = [(0, '', 4447), (1, '', 4208), (3, 'SLB', 'Node1')]
   return { 'state': OK,
            'health': [ (func1, 100) ],
              'devs': {
                    'cdev1': {
                        'state': True,
                        'health': [ (func1, 100) ]
                    },
                    'cdev2': {
                        'state': True,
                        'health': [ (func1, 100) ]
                    },
                }
          }
```

Faults

The APIC has a comprehensive infrastructure for alarms, notifications and logging that you can use within the device script. The device package developer can define a set of faults using the `MDfct` object. The `MDfct` objects are contained within an `MDfcts` object. The APIC allows a device package developer to define one instance of `MDfcts` that is contained within `MDev`. The `MDfcts` object can contain one or more `MDfct` object. The hierarchy of the `MDfcts` object and the `MDfct` object is as follows:

```
<polUni>
   <infraInfra>
      <vnsMDev ...>
           <vnsMDfcts>
               <vnsMDfct ...>
                   <vnsRsDfctToCat.../>
               </vnsMDfct>
           </vnsMDfcts>
     ...
      </vnsMDev>
   </infraInfra>
</polUni>
```

Each `MDfct` object describes a class of fault that the device script can return, and provides additional information about the fault to the user. The `MDfct` object has following attributes:

Attribute	Mandatory	Description
`Code`	Yes	The `code` uniquely identifies a class of defect. The device script must return a `code` value along with a fault string.
`Description`	Yes	This field describes the fault. The `description` field is used by the APIC GUI to provide help to the user. A device package developer should provide an accurate description of the fault. The `description` field size is limited to maximum of 512 characters.
`recAct`	Yes	This field specifies the recommended corrective action for the user to resolve the fault. This field is limited to maximum of 512 characters.
`htmlFile`	No	The device package developer can add a link to additional help on the fault.

APIC classifies faults into four categories or severity levels:

- warning(1)
- minor(2)

- major(3)
- critical(4)

The device package developer should associate the fault that is described by the `MDfct` object to one of the severity levels. The relation to a severity level is specified using the `vnsRsDfctToCat` object, as shown in the following example:

```
<vnsRsDfctToCat tDn="dfctCats/dfctCat-warning"/>
<vnsRsDfctToCat tDn="dfctCats/dfctCat-minor"/>
<vnsRsDfctToCat tDn="dfctCats/dfctCat-major"/>
<vnsRsDfctToCat tDn="dfctCats/dfctCat-critical"/>
```

Following is an example of defining a fault code in the device package:

```
    <vnsMDfcts>
        <vnsMDfct code="10"
                  descr="This is a description of the fault 10"
                  recAct="Recommended action for resolving fault 10"
                  htmlFile="http://somewhere/file.html">
                 <vnsRsDfctToCat tDn="dfctCats/dfctCat-minor"/>
        </vnsMDfct>
        <vnsMDfct code="20"
                  descr="This is a description of the fault 20"
                  recAct="Recommended action for resolving fault 20"
                  htmlFile="http://somewhere/file.html">
                 <vnsRsDfctToCat tDn="dfctCats/dfctCat-major"/>
       </vnsMDfct>
   </vnsMDfcts>
```

The device script can return faults in the return dictionary for any API. The APIC allows scripts to return 'faults'. The return dictionary contains a python list of tuples. Each tuple in the fault list must contain the following elements:

```
(object-path, code, fault string)
```

- `object-path`—The object path uniquely identifies an object in the configuration dictionary that caused a fault. The script can raise a fault on one or more objects that are passed in the configuration that require user intervention to correct the issue.

  To raise a fault on the device in a specific tenant context, the script can return the object path as the `vDev` that is passed in the dictionary. For example:

  ```
  (0, '', 4133)
  ```

- `code`—The script must return a fault code that is defined in the `MDfct` object in the device package.
- `Fault string`—The device script can optionally add a fault string to provide more specific information about the fault. This fault string can be null or can be alphanumeric string with up to 512 characters.

The APIC updates the faults on the object that are specified by the path only whenthe device script returns the state as `OK`. The fault in the return dictionary is ignored by the APIC for all other states. The script must return all faults that were raised during API execution. The APIC clears any fault that previously existed on the device, graph, function, folder, relation, or parameter that was passed in the API, but was not reported again in the return dictionary. The APIC replaces the faults on objects that are passed in the API with the set of faults that are returned by the API, provided that the state is `OK` in the return dictionary. Any faults that are raised by the script will continue to exist as long as the API continues to return faults on those objects that are passed in the API. If the script stops returning a fault on the object that is passed in the API, the APIC will clear it, provided that the state was `OK`.

The faults that are returned by the device script can be queried through the APIC north bound API. The APIC GUI also reports faults that are returned by the device script. The APIC augments the severity to the fault code and string returned by the API.

The following example defines a fault code:

```
 <vnsMDfcts>
     <vnsMDfct code="10"
               descr="Invalid VIP address "
               recAct="Please enter valid unicast VIP address"
               htmlFile="http://insieme.net/SLBCfgExample.html">
              <vnsRsDfctToCat tDn="dfctCats/dfctCat-major"/>
     </vnsMDfct>
 </vnsMDfcts>
```

```
def serviceModify(device, configuration):
    path = [
        (0,'',1234), (1,'',2345), (3, 'Function', 'SLB'),
        (4, 'folder', 'network'), (5,'param','vip')
    ]
    code = 10
    message = '225.0.0.1'

    faults = [ (path,code,message) ]

    return {
      'state': Config.SUCCESS,
      'faults': faults,
      'health': []
    }
```

The APIC will display the fault and append the following text:

```
 (APIC defect category defined in MDfct object in device package,
  Defect-code defined in MDfct object in device package,
  Defect-Description defined in MDfct object in device package,
  Fault string passed in the return dictionary by the device script)
```

In the `serviceModify` fault example, the APIC will report following fault string on the VIP object:

```
Major Fault: 10, "Invalid VIP address ": '225.0.0.1'
```

Counters

The Application Policy Infrastructure Controller (APIC) can query packet counters using the `deviceCounter` and `serviceCounters` functions, which returns a dictionary with transmit and receive counters for packets, errors, and drops for interfaces and connectors that are associated with a service function, respectively.

The `deviceCounters` API returns interface statistics from a specific device and is defined as follows:

```
def deviceCounters( device,interfaces,configuration ):
```

The following example is a `deviceCounters` call:

```
def deviceCounters( device, interfaces, configuration ):
        return {
              'state': 0,
              'counters': [ ([cif], counters), ...]

counters: {
   'rxpackets': <rxpackets>,
   'rxerrors': <rxerrors>,
   'rxdrops': <rxdrops>,
   'txpackets': <txpackets>
   'txerrors': <txerrors>
   'txdrops': <txdrops>
}
```

`cif` is a (type, key, value) tuple that identifies an interface.

For example:

```
  eth0Count = {
```

```
   'rxpackets': 100,
   'rxerrors': 0,
   'rxdrops': 0
   'txpackets': 10
   'txerrors': 4
   'txdrops': 2
  }


  return {
        'state': 0,
        'counters': [ ([(11, '', 'eth0')], eth0Count) ]
  }
```

The `serviceCounters` API returns statistics for connectors associated with a service function and is defined as follows:

```
serviceCounters (device, configuration)
```

The `serviceCounters` parameters are defined as follows:

- `device`: A dictionary providing the device IP and credentials. APIC uses this information to connect to the service node.
- `configuration`: The service node configuration.

The following example illustrates how APIC can query packet counters for service functions:

```
def serviceCounters(device, configuration):
   externalIntferface, = [(0, 'Firewall', 4384), (1, '', 4432), (3, 'Firewall-Func', 'FW-1'),
 (2, 'external', 'external1') ]
   internalInterface = [(0, 'Firewall', 4384) (1, '', 4432) (3, 'Firewall-Func', 'FW-1'),
(2, 'internal','internal1') ]

   Firewall-1-External-Counters = (externalInterface,
                                   {  'rxpackets': 100,
                                      'rxerrors': 0,
                                      'rxdrops': 0
                                      'txpackets': 100
                                      'txerrors': 4
                                      'txdrops': 2} )

   Firewall-1-Internal-Counters =  (internalInterface,
                                    {  'rxpackets': 100,
                                       'rxerrors': 0,
                                       'rxdrops': 0
                                       'txpackets': 100
                                       'txerrors': 4
                                       'txdrops': 2} )


   Counters = [ Firewall-1-External-Counters,
                Firewall-1-Internal-Counters ]
   return {
     'state': 0,
     'counters': Counters
   }
```