Programming and Automating Cisco Networks

A Guide to Network Programmability and Automation in the Data Center, Campus, and WAN

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Dedications

Ryan Tischer:

This book is dedicated to my wife Jennifer and my children Madeline, Alexander, and Elaina. When the road gets rough, you are the reason I do not give up. When scary arrives, you are the source for my courage. When good enough is reached, you make me push for better. When things don't go my way, you make me substitute my cuss words.

ILMF4EVER

Special thank you to my parents—Stop saying I turned out all right; there's still time.

To my friends—I know the best place for chili.

A message to my children—

Whatever your life has in store for you, be …

curious

passionate

thoughtful

Break ground and glass

Be anything but boring.

—*Ryan*

Jason Gooley:

I would like to dedicate this book to my family. To my wife Jamie for being so endlessly supportive of me with my various "projects." Without you, I would not have been able to make it this far. To my daughter Kaleigh, who at the time of this writing is just 15 months old: It is extremely difficult to leave your side when all I want to do is spend time with you. I feel like I have already missed so much just writing this paragraph! To my father and brother for always having my back and believing in me. To my late mother, you have been the guiding light that has kept me on the right path.

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Jason Gooley:

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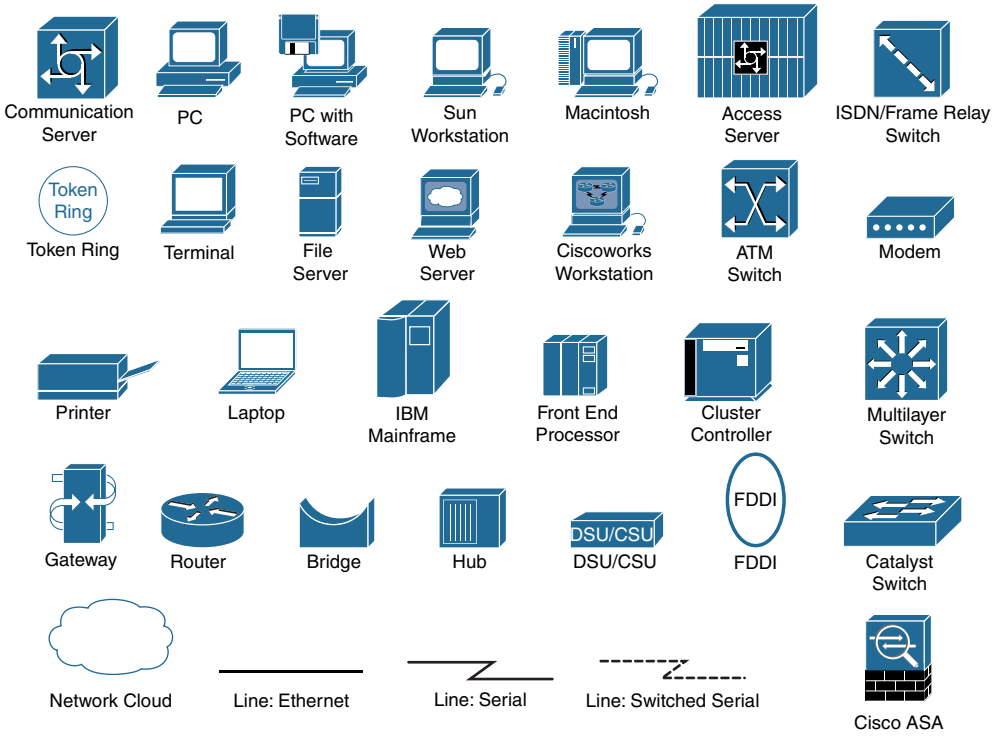

Command Syntax Conventions

The conventions used to present command syntax in this book are the same conventions used in the IOS Command Reference. The Command Reference describes these conventions as follows:

- **Boldface** indicates commands and keywords that are entered literally as shown. In actual configuration examples and output (not general command syntax), boldface indicates commands that are manually input by the user (such as a show command).
- *Italic* indicates arguments for which you supply actual values.
- Vertical bars (|) separate alternative, mutually exclusive elements.
- Square brackets ([ ]) indicate an optional element.
- Braces ({ }) indicate a required choice.
- Braces within brackets ([{ }]) indicate a required choice within an optional element.

Introduction

This book was designed with the focus on utilizing Cisco ACI Cisco Nexus 9000, Cisco UCS Director, Cisco (JSON), Python, Linux, Cisco APIC-EM, ConfD, and Data Models in a production environment as effectively as possible. Industry leaders were consulted for technical accuracy throughout this book.

Who Should Read This Book?

This book is designed for those network engineers and operators who want to implement, manage, and maintain Cisco networking solutions in modern environments. This book discusses automation and programming tools and techniques across the Cisco data center, campus, and LAN and WAN technologies.

How This Book Is Organized

Chapter 1, "Introduction: Why Network Programmability:" Network programmability can solve business problems, reduce operating expenses and increase business agility. Current network management is slow and prone to errors because it's a closed, box-by-box, CLI-driven system that requires constant and expensive attention. Network programmability serves as a tool kit to automate network configurations and troubleshooting, significantly reducing nonoperational states. Additionally network programmability allows the network to participate or add value to dynamic application environments, that is, DevOps, web, security, by facilitating a tight bond between applications and infrastructure.

Chapter 2, "Foundational Skills:" A basic introduction into software engineering and DEVOPS.

Chapter 3, "Next-Generation Cisco Data Center Networking:" This chapter discusses Cisco portfolio and where the reader could possibly implement network programmability and automation.

Chapter 4, "On-Box Programmability and Automation with Cisco Nexus NX-OS:" This chapter discusses writing software designed to run on the Nexus switch.

Chapter 5, "Off-Box Programmability and Automation with Cisco Nexus NX-OS:" This chapter discusses writing software to run on other systems and access Nexus switches remotely.

Chapter 6, "Network Programmability with Cisco ACI:" Chapter 6 discusses writing software to interact and enhance Cisco ACI.

Chapter 7, "On-Box Automation and Operations Tools:" This chapter discusses some of the automation and operations tools that are available on many Cisco platforms.

Chapter 8, "Network Automation Tools for Campus Environments:" Automation tools can be off-box as well as on-box. This chapter covers some of the tools available for Cisco campus networks including SDN, controllers, and more.

Chapter 9, "Piecing It All Together:" This chapter summarizes the contents of this book by giving our perspective on the many tools that are available to interact with Cisco networks.

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Chapter 7

On-Box Automation and Operations Tools

Automation for daily tasks is something that most network engineers rely on to handle their daily workload. However, there are many network engineers under the impression that new software or management tools with a steep learning curve must be purchased in order to accomplish such automation. This leads to automation tools often times getting overlooked or put aside. Other common drivers for not using automation tools are due to budget restraints, varying skill sets, and unfamiliarity with the different tools that are available. The good news is that there are many automation tools natively available on most Cisco IOS platforms. For instance, on most Cisco Catalyst switches, there are tools built into the operating system's command line interface (CLI) that allow the programmability of these devices automatically. This allows for the automation of large number of common tasks. For example, a network engineer could build a set of custom templates or macros that would apply various configuration parameters to particular ports on a switch, based on the types of devices that are connected to those specific ports. This chapter will cover the following on-box automation tools in greater detail:

- Auto SmartPorts
- AutoConf
- Auto Security
- AutoQoS
- Smart Call Home
- Tcl Shell
- Embedded Event Manager (EEM)

Note For brevity, all configuration examples and outputs in this chapter are displayed in IOS only. IOS XE and IOS XR outputs are not included in this chapter.

Automated Port Profiling

These types of automation tools are especially important when it comes to scale. Imagine a network team that handles an entire enterprise campus LAN. Commonly, there are only a select few network engineers who have access to the network switches and are authorized to make any configuration changes. These engineers are usually very busy and have a finite amount of time to work on daily moves, additions, and changes (MACs). From a business perspective, this greatly hinders the capability of being able to fluidly and dynamically move users around an office environment. For example, a user moves from one department to another and takes their IP phone with them. This would result in a network engineer having to get involved and reprogram the switch port that the user is going to be connecting to. Often, these users are moved by a help desk team without notifying the network engineering team of the move. If the new port wasn't properly provisioned prior to the user moving, then the user may not be able to connect to the network and perform their job.

There are many settings that need to be applied to a switch port in order for an IP phone to operate properly. Some of the more common switch port settings for an IP phone are:

- Power over Ethernet (PoE) settings
- Voice VLAN configuration
- Quality of Service (QoS) settings
- Data VLAN configuration
- Speed/Duplex settings

The following sections of this chapter will cover some of the simple, yet powerful tools that are included within most of the Cisco Catalyst switches. These are tools, available today, that can automate many configuration tasks, reduce downtime, and increase agility.

AutoSmart Ports

AutoSmart Ports (ASP) are an IOS tool that allows you to consolidate many of the necessary port settings for various device types into an automated process that can be applied to a single port or a series of ports. AutoSmart ports use a macro-based mechanism that commonly uses CDP and LLDP to discover the physical device type that is connected to a switch port. Once the device type is determined, the switch will then check to see if a corresponding macro is defined that matches the specific device type that was connected. If the device type is known and there is a macro definition for it, the switch will then automatically provision the port, based on the settings defined in the macro. This will significantly reduce the amount of time needed to establish connectivity to users who move around the environment or for new users who are being brought on board for the first time. Figure 7-1 outlines the process for what happens when a Cisco IP phone device is connected to a Catalyst switch while AutoSmart Ports are enabled.

Note AutoSmart Ports are available in IOS 12.2(55)SE or later.

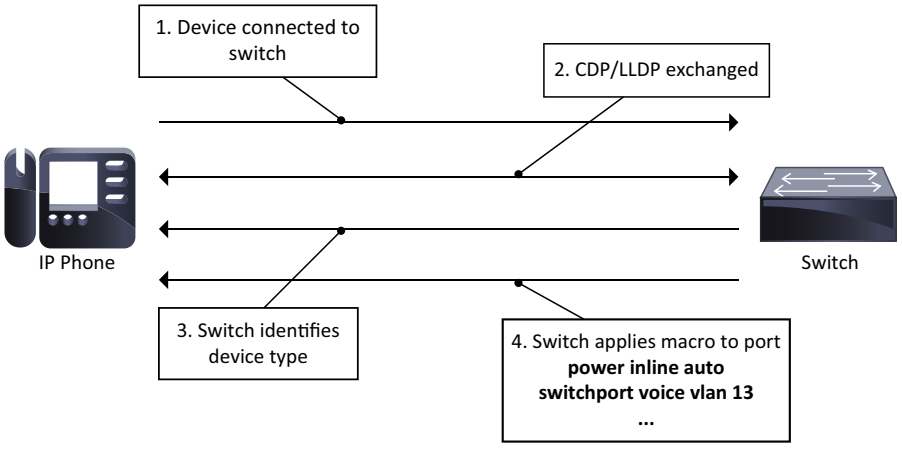

Figure 7-1 *AutoSmart Port discovery process for Cisco IP phone*

One of the main advantages of AutoSmart ports is that the switches contain predefined macros that can be modified to suit your environment. In addition, you can also customize those predefined macros to include all the necessary parameters for your specific environment. Table 7-1 shows a list of some of the predefined device-specific macros that are available in most Cisco Catalyst switches.

Table 7-1 *Device Specific Macros and Descriptions*

Macro Name	Macro Description
access-point	Auto configuration information for the autonomous access point
ip-camera	Auto configuration information for the video surveillance camera
lightweight-ap	Auto configuration information for the lightweight access point
media-player	Auto configuration information for the digital media player
Phone	Auto configuration information for the phone device
Router	Auto configuration information for the router device
Switch	Auto configuration information for the switch device

Enabling AutoSmart Ports on a Cisco Catalyst Switch

In order to enable AutoSmart Ports on a Cisco Catalyst switch, you must follow the steps illustrated in the following example. Another key advantage of this specific automation tool is that it takes a single command to enable to macro functionality.

```
Switch> enable
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# macro auto global processing
Switch(config)# end
Switch#
```

Occasionally, predefined macros contain most of the desired settings that are needed without requiring any modification to the macro. In some cases, however, customizing a macro to fit your needs is a better alternative. Customized macros are commonly deployed when more granular configurations are required. For example, a customized macro may be one that not only changes voice and data VLANs, but can also be used to configure quality of service (QoS) settings and other various options. The following example lists the default settings of the Cisco IP phone macro. This can be seen with the **show macro auto device phone** command.

```
Switch# show macro auto device phone
Device:phone
Default Macro:CISCO_PHONE_AUTO_SMARTPORT
Current Macro:CISCO_PHONE_AUTO_SMARTPORT
Configurable Parameters:ACCESS_VLAN VOICE_VLAN
Defaults Parameters:ACCESS_VLAN=1 VOICE_VLAN=2
Current Parameters:ACCESS_VLAN=1 VOICE_VLAN=2
```

Note To view the entire list of predefined macros that are available in a Cisco Catalyst switch, issue the **show shell functions** command.

The following output illustrates the configuration steps that are necessary to customize and trigger a predefined macro. In this example, the macro, when applied, will change the voice and data VLANs for a port when Cisco IP phone is connected.

```
Switch# configure terminal
Switch(config)# macro auto execute CISCO_PHONE_EVENT builtin CISCO_PHONE_AUTO_
SMARTPORT ACCESS_VLAN=11 VOICE_VLAN=13
Switch(config)# macro auto global processing
Switch(config)# exit
```

To verify this macro is properly modified with the new VLAN assignments, issue the **show shell triggers** command from the EXEC prompt of the CLI. The following snippet shows the output from the **show shell triggers** command.

```
Switch# show shell triggers

User defined triggers
---------------------
Built-in triggers
-----------------
Trigger Id: CISCO_PHONE_EVENT
Trigger description: Event for ip-phone macro
Trigger environment: ACCESS_VLAN=11 VOICE_VLAN=13
Trigger mapping function: CISCO_PHONE_AUTO_SMARTPORT
```

```
Other common event triggers that can be viewed and modified are:
Trigger Id: CISCO_ROUTER_EVENT
Trigger Id: CISCO_SWITCH_EVENT
Trigger Id: CISCO_WIRELESS_AP_EVENT
Trigger Id: CISCO_WIRELESS_LIGHTWEIGHT_AP_EVENT
```

In certain cases, the device you connect to the switch may not be able to use CDP or LLDP to identify itself to the switch. In these instances, you can create a custom macro that uses a BASH-like language syntax. Another interesting use case utilizes the MAC address OUI to identify and properly configure various devices on the switch. The following example shows a custom macro for a printer, using the MAC address OUI as a classifier.

```
Switch(config)# macro auto mac-address-group OUI_PRINTER_PORT
 oui list 0000AA
 exit

Switch(config)# macro auto execute OUI_PRINTER_PORT  {
 if [[ $LINKUP -eq YES ]]
  then conf t
  interface $INTERFACE
  description OUI_PRINTER_PORT macro
  switchport
  switchport mode access
  switchport access vlan data_vlan
  power inline never
  spanning-tree portfast
  exit
  end
 fi
 if [[ $LINKUP -eq NO ]]
  then conf t
  interface $INTERFACE
   switchport access vlan data_vlan
   no spanning-tree portfast
   no description
   exit
  end
 fi
}
```

AutoSmart Ports are a great start to automating specific tasks when it comes to managing your campus LAN. It should be noted that even though AutoSmart Ports are not the most granular way to automate port configurations based on device, it is still a very powerful solution to help reduce some of the more arduous tasks that relate to day-to-day moves, additions, and changes (MACs).

Note For more information on AutoSmart Ports, please visit the following link: www.cisco.com/go/SmartOperations/

AutoConf

Similar to AutoSmart Ports, AutoConf is used to automate various functions within a Cisco Catalyst switch. However, unlike AutoSmart Ports, AutoConf is a template-based solution that is more granular and user friendly. Although these features accomplish similar outcomes, the configurations are applied in a different manner. Interface templates are configured and applied to a specific port or range of ports much like AutoSmart Ports. Table 7-2 lists some of the available predefined interface templates within a Cisco Catalyst switch.

Note AutoConf is available in IOS 15.2(2)E and IOS-XE 3.6 or later.

Table 7-2 *AutoConf Interface Templates and Descriptions*

Template Name	Template Description
AP_INTERFACE_TEMPLATE	Wireless access point interface template
DMP_INTERFACE_TEMPLATE	Digital media player interface template
IP_CAMERA_INTERFACE_TEMPLATE	IP camera interface template
IP_PHONE_INTERFACE_TEMPLATE	IP phone interface template
LAP_INTERFACE_TEMPLATE	Lightweight access point interface template
MSP_CAMERA_INTERFACE_TEMPLATE	Multiservices platform camera interface template
MSP_VC_INTERFACE_TEMPLATE	Multiservices platform VC interface template
PRINTER_INTERFACE_TEMPLATE	Printer interface template
ROUTER_INTERFACE_TEMPLATE	Router interface template
SWITCH_INTERFACE_TEMPLATE	Switch interface template
TP_INTERFACE_TEMPLATE	Telepresence interface template

Some of the key benefits of using templates are as follows:

- Simpler configuration and management than AutoSmart Port macros.
- All interface templates are customizable.
- Templates take up less room in the configuration file than AutoSmart Port macros.
- Template updates apply to all interfaces subscribing to the template.
- Templates can be per session or per port.

The following output shows an example of the built-in IP Phone template by issuing the **show template interface source built-in IP_PHONE_INTERFACE_TEMPLATE** command.

```
Switch# show template interface source built-in IP_PHONE_INTERFACE_TEMPLATE

Template Name       : IP_PHONE_INTERFACE_TEMPLATE
Modified            : No
Template Definition :
 spanning-tree portfast
 spanning-tree bpduguard enable
 switchport mode access
 switchport block unicast
 switchport port-security maximum 3
 switchport port-security maximum 2 vlan access
 switchport port-security violation restrict
 switchport port-security aging time 2
 switchport port-security aging type inactivity
 switchport port-security
 storm-control broadcast level pps 1k
 storm-control multicast level pps 2k
 storm-control action trap
 mls qos trust cos
 service-policy input AUTOCONF-SRND4-CISCOPHONE-POLICY
 ip dhcp snooping limit rate 15
 load-interval 30
 srr-queue bandwidth share 1 30 35 5
 priority-queue out
```

Note To see a list of all the built-in interface templates, issue the **show template interface source built-in all** command.

Below is a list of some of the common key points to keep in mind about AutoConf Templates:

- By default, all templates automatically use VLAN 1. This includes any access VLAN, voice VLAN, and native VLAN in regard to trunk ports.
- Templates applied to interfaces are not shown in running configuration. In order to see the configuration applied to an interface, issue the **show derived-config interface <interface>** command.
- EtherChannel interfaces do not support AutoConf interface templates.
- Once AutoConf is enabled globally, it is applied to all interfaces by default. To disable AutoConf on a per-interface basis, issue the **access-session inherit disable autoconf** command.

- The template configuration itself does not show up in the running configuration unless the template is modified. For example, the access VLAN is changed from the default value of VLAN 1.
- All template configuration settings applied to an interface are removed once the device is disconnected from the switch port.

Enabling AutoConf on a Cisco Catalyst Switch

To enable AutoConf, the **autoconf enable** command must be issued from the global configuration mode. The following example illustrates the steps on how to enable AutoConf globally on a Cisco Catalyst Switch.

```
Switch> enable
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# autoconf enable
Switch(config)# end
Switch#
```

AutoConf is now enabled globally on the Catalyst Switch. To verify AutoConf is working properly, a Cisco IP phone is connected into interface GigabitEthernet0/1 on the Catalyst switch. As displayed in the following output, once the phone is connected, AutoConf will apply the IP_PHONE_INTERFACE_TEMPLATE to the interface.

```
Switch# show template binding target gigabitEthernet0/1

Interface Templates
===================
Interface: Gi0/1

Method              Source            Template-Name
------                    ------                 -------------
dynamic             Built-in            IP_PHONE_INTERFACE_TEMPLATE


Service Templates
=================
Interface: Gi0/1

Session             Source            Template-Name
-------                 ------                -------------
```

Based on the previous output, the IP_PHONE_INTERFACE_TEMPLATE was successfully applied to the GigabitEthernet0/1 interface.

Note In general, to see the details of what settings are applied to an interface once a device is connected, issue the **show derived-config interface <interface_name>** command.

Notice that the applied template does not show up in the running configuration of the Catalyst switch. The following snippet shows the output of the **show running-config interface gigabitEthernet0/1** command, illustrating that the interface template is hidden in the running configuration.

```
Switch# show running-config interface gigabitEthernet0/1
Building configuration...

Current configuration : 36 bytes
!
interface GigabitEthernet0/1
end
```

To see the details of what settings were applied to the GigabitEthernet0/1 interface when the Cisco IP phone was connected, issue the **show derived-config interface gigabitEthernet0/1** command as shown in the following output.

```
Switch# show derived-config interface gigabitEthernet0/1
Building configuration...

Derived configuration : 669 bytes
!
interface GigabitEthernet0/1
 switchport mode access
 switchport block unicast
 switchport port-security maximum 3
 switchport port-security maximum 2 vlan access
 switchport port-security violation restrict
 switchport port-security aging time 2
 switchport port-security aging type inactivity
 switchport port-security
 load-interval 30
 srr-queue bandwidth share 1 30 35 5
 priority-queue out
 mls qos trust cos
 storm-control broadcast level pps 1k
 storm-control multicast level pps 2k
 storm-control action trap
 spanning-tree portfast
 spanning-tree bpduguard enable
```

```
 service-policy input AUTOCONF-SRND4-CISCOPHONE-POLICY
 ip dhcp snooping limit rate 15

Switch#
```

Modifying a Built-in Template

Commonly, built-in templates need to be modified to fit the desired configuration model of the environment. Modification of a built-in template allows for the flexibility of having a customized template, based on settings that align with the business needs. The following example lists the steps necessary to modify the built-in IP_PHONE_INTERFACE_TEMPLATE. These configuration steps will change the voice and data VLANs from the default of VLAN 1 to VLANs 11 and 13, respectively, and will add a custom description to the template.

```
Switch> enable
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# template IP_PHONE_INTERFACE_TEMPLATE
Switch(config-template)# switchport access vlan 11
Switch(config-template)# switchport voice vlan 13
Switch(config-template)# description CUSTOM_IP_PHONE_INTERFACE_TEMPLATE
Switch(config-template)# end
Switch#
```

To display the configuration changes made to the template, issue the **show template interface source built-in IP_PHONE_INTERFACE_TEMPLATE** command as shown in the following output.

```
Switch# show template interface source built-in IP_PHONE_INTERFACE_TEMPLATE
Building configuration...

Template Name       : IP_PHONE_INTERFACE_TEMPLATE
Modified            : Yes
Template Definition :
 spanning-tree portfast
 spanning-tree bpduguard enable
 switchport access vlan 11
 switchport mode access
 switchport block unicast
 switchport voice vlan 13
 switchport port-security maximum 3
 switchport port-security maximum 2 vlan access
 switchport port-security violation restrict
 switchport port-security aging time 2
 switchport port-security aging type inactivity
```

```
 switchport port-security
 storm-control broadcast level pps 1k
 storm-control multicast level pps 2k
 storm-control action trap
 mls qos trust cos
 service-policy input AUTOCONF-SRND4-CISCOPHONE-POLICY
 ip dhcp snooping limit rate 15
 load-interval 30
 description CUSTOM_IP_PHONE_INTERFACE_TEMPLATE
 srr-queue bandwidth share 1 30 35 5
 priority-queue out
!
end

Switch#
```

Once an AutoConf template has been modified, the template will now be visible in the running configuration of the Catalyst switch. The following snippet illustrates that the template is now present in the output of the **show running-config** command.

```
Switch# show running-config
Building configuration...
! Output omitted for brevity
!
autoconf enable
!
template IP_PHONE_INTERFACE_TEMPLATE
 spanning-tree portfast
 spanning-tree bpduguard enable
 switchport access vlan 11
 switchport mode access
 switchport block unicast
 switchport voice vlan 13
 switchport port-security maximum 3
 switchport port-security maximum 2 vlan access
 switchport port-security violation restrict
 switchport port-security aging time 2
 switchport port-security aging type inactivity
 switchport port-security
 storm-control broadcast level pps 1k
 storm-control multicast level pps 2k
 storm-control action trap
 mls qos trust cos
 service-policy input AUTOCONF-SRND4-CISCOPHONE-POLICY
 ip dhcp snooping limit rate 15
 load-interval 30
```

```
 description CUSTOM_IP_PHONE_INTERFACE_TEMPLATE
 srr-queue bandwidth share 1 30 35 5
 priority-queue out
!
! Output omitted for brevity
```

Note Even though the template is now visible in the running-config, it still does not list the configuration under the interface(s) that it is applied to.

Although the IP_PHONE_INTERFACE_TEMPLATE is modified and applied, the configuration is still hidden from the interface in the running-config. In order to see the customized configuration that is applied to the interface, the **show derived-config interface gigabitEthernet0/1** command must be used again. The following output shows the modified template that is applied to the gigabitEthernet0/1 interface.

```
Switch# show derived-config interface gigabitEthernet0/1
Building configuration...

!
interface GigabitEthernet0/1
 description CUSTOM_IP_PHONE_INTERFACE_TEMPLATE
 switchport access vlan 11
 switchport mode access
 switchport block unicast
 switchport voice vlan 13
 switchport port-security maximum 3
 switchport port-security maximum 2 vlan access
 switchport port-security violation restrict
 switchport port-security aging time 2
 switchport port-security aging type inactivity
 switchport port-security
 load-interval 30
 srr-queue bandwidth share 1 30 35 5
 priority-queue out
 mls qos trust cos
 storm-control broadcast level pps 1k
 storm-control multicast level pps 2k
 storm-control action trap
 spanning-tree portfast
 spanning-tree bpduguard enable
 service-policy input AUTOCONF-SRND4-CISCOPHONE-POLICY
 ip dhcp snooping limit rate 15
end

Switch#
```

AutoConf is a feature that not only eases the burden of device management and configuration, it also allows for a zero-touch deployment model of commonly connected devices. AutoConf is often used in campus LANs as well as remote branch office deployments. Most organizations enforce a standard when it comes to the type of devices in their environment. Even though make, model, and form factors may differ, AutoConf can assist in reducing the manual configuration tasks needed to deploy different device types such as computers, printers, IP phones, IP cameras, and so forth. If a device supports both AutoConf and AutoSmart ports, it is recommended to use AutoConf first, then AutoSmart ports. However, using both features together could cause undesired results.

Note For more information on AutoConf templates, please visit: http://www.cisco.com/c/en/us/td/docs/ios-xml/ios/ibns/configuration/15-e/ibns-15-e-book/ibns-autoconf.html

Auto Security

Cisco Auto Security is a feature that, when applied, automatically configures some of the most common baseline campus switching security features. Some of these features include:

- DHCP snooping
- Dynamic ARP inspection (DAI)
- Port Security

DHCP Snooping is a security feature that is designed to protect internally trusted DHCP servers and clients in your environment. DHCP Snooping works by verifying DHCP messages are received from only trusted DHCP servers within your campus environment. All messages from untrusted devices can be filtered or rate-limited, based on the desired configuration parameters. This security mechanism is to keep untrusted hosts from generating DHCP messages that could negatively impact your network. These DHCP messages can be malicious in nature or simply be the product of a misconfiguration. For example, a host computer has a DHCP server feature inadvertently turned on and is providing an unrouteable, incorrect IP address range to various devices in the environment. This will result in end hosts not being able to talk to the rest of the network. However, receiving a DHCP lease from any rogue server could be very problematic even if the IP address ranges are valid in your environment.

When enabled, the DHCP snooping feature keeps track of all devices sending and receiving DHCP messages. This information is stored in a table called the DHCP binding database. When DHCP messages are determined to be legitimate, they are processed normally. If for some reason the intercepted DHCP messages do not meet the proper criteria, the packets are discarded. This helps to protect your environment from DHCP snooping attacks.

Dynamic ARP inspection (DAI) is a feature that is used to prevent address resolution protocol (ARP) spoofing attacks. An ARP spoofing attack is when someone maliciously

injects a duplicate MAC address onto a LAN in an attempt to redirect traffic to an alternate destination. DAI uses the DHCP binding database to verify that there is a valid layer 2 MAC address to layer 3 IP address binding before allowing any traffic to be forwarded on the segment. If it is determined that there is not such a valid mapping, the invalid ARP packets are discarded.

Port Security is a security feature that protects the network by setting dynamic or hard MAC address limits on specific switch ports. For example, the following list provides some of the Port Security features that are available in Catalyst switches.

- Secure ports, based on statically assigned MAC addresses
- Secure ports, based on dynamically learned MAC addresses
- Limit dynamically learned MAC addresses—helps prevent CAM table flooding attacks
- Shut down port when violation occurs
- Restrict port and send SNMP trap when violation occurs

Enabling Auto Security on a Cisco Catalyst Switch

The following example illustrates how to enable Auto Security on a Catalyst switch with a single command.

```
Switch> enable
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# auto security
Switch(config)# end
```

To verify what interfaces the Auto Security configuration has been applied to, issue the **show auto security** command shown in the following output.

```
Switch# show auto security
Auto Security is Enabled globally

AutoSecurity is Enabled on below interface(s):
-----------------------------------------------
   GigabitEthernet0/1

Switch#
```

Because GigabitEthernet0/1 is configured as an access port, the following snippet illustrates the configuration that is visible in the running-config under that specific interface.

```
Switch# show running-config interface GigabitEthernet0/1
Building configuration...
```

```
Current configuration : 85 bytes
!
interface GigabitEthernet0/1
 auto security-port host
 spanning-tree portfast
end

Switch#
```

In order to see the specific configuration that has been automatically applied to the Catalyst switch the **show auto security configuration** command must be issued. The following output depicts the steps necessary to verify the Auto Security configuration.

```
Switch# show auto security configuration
%AutoSecurity provides a single CLI config 'auto security'
 to enable Base-line security Features like
 DHCP snooping, ARP inspection and  Port-Security

Auto Security CLIs applied globally:
---------------------------------
ip dhcp snooping
ip dhcp snooping vlan 2-1005
no ip dhcp snooping information option
ip arp inspection vlan 2-1005
ip arp inspection validate src-mac dst-mac ip


Auto Security CLIs applied on Access Port:
----------------------------------------
switchport port-security maximum 2
switchport port-security maximum 1 vlan access
switchport port-security maximum 1 vlan voice
switchport port-security violation restrict
switchport port-security aging time 2
switchport port-security aging type inactivity
switchport port-security
ip arp inspection limit rate 100
ip dhcp snooping limit rate 100


Auto Security CLIs applied on Trunk Port:
-----------------------------------
ip dhcp snooping trust
ip arp inspection trust
switchport port-security maximum 100
```

```
switchport port-security violation restrict
switchport port-security

Switch#
```

As seen from the above configuration, Auto Security enables an entire baseline of security features on the Catalyst switch. All of these security features and settings have been streamlined into a single command. This automates the deployment of these features, which makes it easier to secure the campus LAN environment.

Note Although many First-Hop Security features have been available in various IOS versions for some time, the Auto Security feature is available in IOS XE 3.6.0E and IOS 15.2(2)E and later.

For more information on Auto Security, please visit: http://www.cisco.com/c/en/us/td/docs/switches/lan/catalyst4500/XE3-6-0E/15-22E/configuration/guide/xe-360-config/auto_sec.pdf

Quality of Service for Campus Architectures

Quality of Service (QoS) is an integral part of any campus environment. QoS allows for the prioritization of specific traffic flows as they traverse over the campus network. For example, it may be desirable to allow voice and video traffic to have priority over bulk FTP traffic during a time of network congestion. One of the most common reasons that QoS is not deployed is due to its complexity. This section will discuss some different ways to automate the deployment of QoS for LAN devices.

Note A base understanding of QoS is assumed. QoS fundamentals are not covered in this chapter. To become more familiar with QoS and its components, please visit: www.cisco.com/go/qos

AutoQoS on Campus LAN Devices

As campus networks continue to grow, more emphasis is being put on the LAN. Today, it is becoming even more important to capitalize on the available LAN bandwidth as much as possible. Often, campus networks are designed with a specific set of goals in mind. For example, the following list are some of the more common business drivers and use cases that put demand on the campus LAN infrastructure:

- Gigabit Ethernet to the desktop
- Campus video communications
- Voice and IP phones

Alternatively, there are some other use cases that are beginning to be more prevalent in enterprise networks. These different, but not uncommon use cases are increasing the demand for connectivity in the LAN:

- Wayfinding devices
- Digital signage
- HVAC systems
- Manufacturing/industrial networks
- Building lighting

All of the above use cases are putting increased demand on the network and, by default, demand on the network engineering team.

Enabling AutoQoS on a Cisco Catalyst Switch

To enable AutoQoS, the following configuration steps must be followed:

Step 1. Enable AutoQoS globally

Step 2. Enable AutoQoS settings under interface

AutoQoS is enabled globally in the following example on the Catalyst switch by issuing the **auto qos global compact** command from the global configuration prompt. Once the feature is enabled globally, it can be verified with the **show auto qos** command.

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# auto qos global compact
Switch(config)# end
Switch# show auto qos

AutoQoS not enabled on any interface

Switch#
```

As you can see from the output of the **show auto qos** command in the following code snippet, there are no interfaces currently configured with any AutoQoS parameters. Once AutoQoS is enabled globally, you must then specify the interface configuration settings. For example, see the following output that illustrates how to enable the AutoQoS settings under a Gigabit Ethernet interface of a Catalyst switch. The configuration shown is for a Cisco IP phone.

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface GigabitEthernet0/1
```

```
Switch(config-if)# auto qos voip cisco-phone
Switch(config-if)# end
Switch#
```

Now that AutoQoS is enabled globally and there is an interface with AutoQoS settings applied to it, the **show auto qos** command is re-issued to verify the configuration as shown in the following snippet. Based on the output of the **show auto qos** command, we see that there is a difference in the information displayed as opposed to output shown previously. When AutoQoS is enabled under the GigabitEthernet0/1 interface, it now includes the interface configuration in the show command.

```
Switch# show auto qos
GigabitEthernet0/1
auto qos voip cisco-phone

Switch#
```

In order to display the actual QoS settings that get applied to the GigabitEthernet0/1 interface when a Cisco IP phone is connected, the **show auto qos interface GigabitEthernet0/1 configuration** command must be issued. The following snippet shows that based on the output of this command, there is an ingress policy named AUTOQOS-PPM-SRND4-CISCOPHONE-POLICY that is applied to the GigabitEthernet0/1 interface. The output also shows that the outbound egress priority queue is enabled and that the interface has been set to automatically trust the DSCP markings from the Cisco IP phone.

```
Switch# show auto qos interface GigabitEthernet0/1 configuration
GigabitEthernet0/1
auto qos voip cisco-phone
Ingress Policy: AUTOQOS-PPM-SRND4-CISCOPHONE-POLICY
Egress Priority Queue: enabled
The port is mapped to qset : 1
Trust device: cisco-phone
```

Next, to further validate the settings within the AUTOQOS-PPM-SRND4-CISCOPHONE-POLICY that is applied to the GigabitEthernet0/1 interface, we issue the show policy-map AUTOQOS-PPM-SRND4-CISCOPHONE-POLICY command as shown in the following output.

```
Switch# show policy-map AUTOQOS-PPM-SRND4-CISCOPHONE-POLICY
  Policy Map AUTOQOS-PPM-SRND4-CISCOPHONE-POLICY
    Class AUTOQOS_PPM_VOIP_DATA_CLASS
      set dscp ef
      police 128000 8000 exceed-action policed-dscp-transmit
    Class AUTOQOS_PPM_VOIP_SIGNAL_CLASS
      set dscp cs3
      police 32000 8000 exceed-action policed-dscp-transmit
```

```
    Class AUTOQOS_PPM_DEFAULT_CLASS
      set dscp default
      police 10000000 8000 exceed-action policed-dscp-transmit
Switch#
```

Based on the previous output, we can see that the following parameters have been set in the QoS policy-map applied to the GigabitEthernet0/1 interface on the Catalyst switch:

- Voice data packets are being marked with the DSCP value of EF (46)
- Policing of the VOIP_DATA_CLASS is set to 128Kbps
- Call signaling packets are being marked with the DSCP value of CS3
- Policing of the VOIP_SIGNAL_CLASS is set to 32Kbps
- All other packets are being marked with DSCP value of DEFAULT (0)
- Policing of the DEFAULT_CLASS is set to 10Mbps

The following snippet illustrates the output of the **show auto qos voip cisco-phone configuration** command, which is an alternate way of displaying the AutoQoS configuration that will be applied to an interface when a Cisco IP phone is connected. This command will also display the DSCP/CoS markings, queuing strategy, and associated thresholds settings that will be applied.

```
Switch# show auto qos cisco-phone configuration
Traffic(DSCP / COS)         IngressQ-Threshold    EgressQ-Threshold
------------------------------------------------------------------------
VoIP(46/5)                          N/A - N/A             01 - 01
Signaling(24/3)                     N/A - N/A             03 - 01
Best-Effort(00/0)                   N/A - N/A             02 - 01
```

All of the QoS settings mentioned above were deployed by issuing only two commands: the **auto qos global compact** global command and the **auto qos voip cisco-phone** interface command. We can begin to see how powerful tools like AutoQoS can be in a campus environment, eEspecially with hundreds to thousands of connected host devices. The following section of this chapter will cover deploying AutoQoS in the campus WAN environment.

AutoQoS on Campus WAN Devices

The best practice in general from a QoS perspective is to mark the traffic closest to the source and carry those markings across your LAN and WAN end-to-end. The biggest reason for this is so that end users and applications have a consistent experience. Marking and prioritizing traffic on the LAN is just one step in a bigger QoS design. Using AutoQoS for the WAN, you can simplify the steps needed to achieve that end-to-end user and application experience. Figure 7-2 illustrates the high level end-to-end QoS design model from an IP phone in one location to an IP phone in another location.

Note Although we will not discuss AutoQoS for WAN in depth in this chapter, the purpose of this section is to inform the readers that there are tools for AutoQoS on Cisco routers.

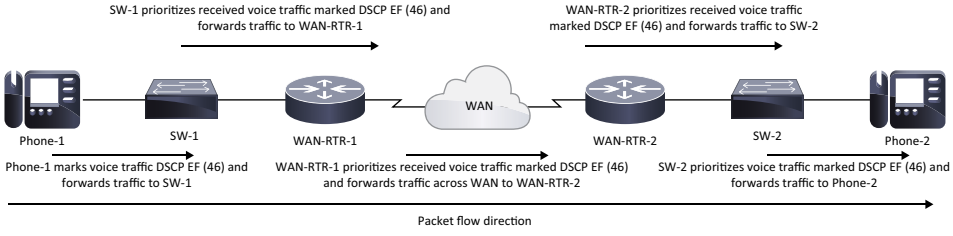

Figure 7-2 *End-to-end QoS example*

As you can see based on Figure 7-2, the QoS markings are kept intact from source to destination across the campus LAN and WAN networks. In this specific case, voice data traffic from Phone-1 to Phone-2 is marked with DSCP EF (46), and those markings are honored on a hop-by-hop basis across the entire network. This is called per-hop behavior (PHB).

Enabling AutoQoS on a Cisco ISR Router

The following example lists the steps that are necessary to enable AutoQoS for the WAN on a Cisco ISR router.

```
Router# configure terminal
Router(config)# interface FastEthernet0/1
Router(config-if)# auto qos voip
Router(config-if)# end
Router#
```

One of the convenient things about AutoQoS for the WAN is that by enabling it on one of the interfaces of the router, it automatically enables the feature globally. Furthermore, it applies all the QoS policy-maps and other settings automatically. The following snippet illustrates an example output of the **show auto qos** command from a Cisco ISR router, illustrating what features AutoQoS will automatically activate when the feature is enabled.

```
Router# show auto qos
 !
 policy-map AutoQoS-Policy-UnTrust
  class AutoQoS-VoIP-RTP-UnTrust
   priority percent 70
   set dscp ef
  class AutoQoS-VoIP-Control-UnTrust
   bandwidth percent 5
```

```
  set dscp af31
 class AutoQoS-VoIP-Remark
  set dscp default
 class class-default
  fair-queue
!
class-map match-any AutoQoS-VoIP-Remark
 match ip dscp ef
 match ip dscp cs3
 match ip dscp af31
!
class-map match-any AutoQoS-VoIP-Control-UnTrust
 match access-group name AutoQoS-VoIP-Control
!
class-map match-any AutoQoS-VoIP-RTP-UnTrust
 match protocol rtp audio
 match access-group name AutoQoS-VoIP-RTCP
!
ip access-list extended AutoQoS-VoIP-RTCP
 permit udp any any range 16384 32767 (6 matches)
!
ip access-list extended AutoQoS-VoIP-Control
 permit tcp any any eq 1720
 permit tcp any any range 11000 11999
 permit udp any any eq 2427
 permit tcp any any eq 2428
 permit tcp any any range 2000 2002
 permit udp any any eq 1719
 permit udp any any eq 5060
!
rmon event 33333 log trap AutoQoS description "AutoQoS SNMP traps for Voice
Drops" owner AutoQoS
rmon alarm 33333 cbQosCMDropBitRate.34.14175073 30 absolute rising-threshold
1 33333 falling-threshold 0 owner AutoQoS

FastEthernet0/1 -
!
interface FastEthernet0/1
 service-policy output AutoQoS-Policy-UnTrust
```

Note AutoQoS for the WAN is platform dependent. To learn more about AutoQoS for WAN and what platforms the feature is supported on, please visit: http://www.cisco.com/c/en/us/products/ios-nx-os-software/autoqos/index.html

AutoQoS, in conjunction with some of the other automation mechanisms discussed earlier in the Automatic Port Profiling section of this chapter, can start to build a very robust and powerful tool set. This tool set can help network engineers ease the operational complexity of managing a constantly changing campus network environment. Chapter 8 "Network Automation Tools for Campus Environments" will highlight another tool set known as the application policy infrastructure controller enterprise module (APIC-EM). APIC-EM offers a wide variety of features that include tools to assist in configuring and automating quality of service in campus environments. We will also discuss some future APIC-EM applications.

Automating Management and Monitoring Tasks

This section will discuss a very robust set of tools that are built-in to many Cisco devices such as:

- Smart Call Home
- Tcl Shell
- Embedded Event Manager (EEM)

These tools are designed to make life a bit easier for the network operations staff by leveraging on-box automation.

Smart Call Home

Cisco's Smart Call Home is a feature that is built into a large number of Cisco devices that allows the devices to automatically reach out to Cisco TAC when there is an issue in your campus environment. Smart Call Home can report a wide variety of different events. For example:

- Generic online diagnostics (GOLD)
- Syslog events
- Environment events and alarms
- Inventory and configuration
- Field notices
- Product security incident response team (PSIRT) notifications

There are three primary ways that Smart Call Home can collect this information from the IOS: Alert Groups and Profiles, collecting show commands, and interaction with the CLI. This information is sent via one of three different transport modes: HTTP(S) direct, HTTP(S) via a transport gateway, or via email through a transport gateway. A transport gateway is a device that securely forwards Call Home messages that are sourced from devices within the network. The information that is gathered and sent to Cisco TAC is then stored in a database within Cisco's data centers. Once the information is collected

and stored in the database, you will be able to view the information from a web portal where you can manage all your devices. Smart Call Home allows TAC to do multiple things with the collected information:

- Automatically create TAC service requests, based on issues with the device(s)
- Notify the Cisco partner should they need to be contacted
- Notify the device owner that there is something going on with the device(s)

This helps make your business more proactive, rather than reactive. An example of Smart Call Home would be if you have a Catalyst 4500 series switch and one of the power supplies failed in the middle of the night. Instead of having to wake up, open a TAC case, and upload the serial number of the switch and the configuration and go through troubleshooting steps, the switch would have used Smart Call Home to contact TAC and upload all the necessary information and a TAC case would have already been opened automatically. In turn, an RMA could be issued automatically for the failed part. This drastically reduces the amount of time and effort engineers have to spend, going through the motions of all the steps mentioned above in order to get a replacement power supply and bring the network back to 100 percent. In addition to this, there is an anonymous reporting feature that allows Cisco to receive minimal error and health information from various devices.

There are six basic steps to enable Cisco's Smart Call Home feature. Those steps are as follows:

- Enable Call Home
- Configure contact email address
- Activate CiscoTAC-1 profile
- Set transport mode
- Install security certificate
- Send a Call Home inventory to start the registration process

Enabling Smart Call Home on an Cisco Catalyst Switch

The following example depicts the process for setting up Smart Call Home on a Catalyst switch.

```
Switch# configure terminal
Switch(config)# service call-home
Switch(config)# call-home
Switch(cfg-call-home)# contact-email-addr neteng@yourcompany.com
Switch(cfg-call-home)# profile CiscoTAC-1
Switch(cfg-call-home-profile)# active
Switch(cfg-call-home-profile)# destination transport-method http
Switch(cfg-call-home-profile)# exit
```

```
Switch(cfg-call-home)# exit
Switch(config)# crypto pki trustpoint cisco
Switch(ca-trustpoint)# enrollment terminal
Switch(ca-trustpoint)# revocation-check crl none
Switch(ca-trustpoint)# exit
Switch(config)# crypto pki authenticate cisco

Enter the base 64 encoded CA certificate.
End with a blank line or the word "quit" on a line by itself

-----BEGIN CERTIFICATE-----
MIICPDCCAaUCEDyRMcsf9tAbDpq40ES/Er4wDQYJKoZIhvcNAQEFBQAwXzELMAkG
A1UEBhMCVVMxFzAVBgNVBAoTDlZlcmlTaWduLCBJbmMuMTcwNQYDVQQLEy5DbGFz
cyAzIFB1YmxpYyBQcmltYXJ5IENlcnRpZmljYXRpb24gQXV0aG9yaXR5MB4XDTk2
MDEyOTAwMDAwMFoXDTI4MDgwMjIzNTk1OVowXzELMAkGA1UEBhMCVVMxFzAVBgNV
BAoTDlZlcmlTaWduLCBJbmMuMTcwNQYDVQQLEy5DbGFzcyAzIFB1YmxpYyBQcmlt
YXJ5IENlcnRpZmljYXRpb24gQXV0aG9yaXR5MIGfMA0GCSqGSIb3DQEBAQUAA4GN
ADCBiQKBgQDJXFme8huKARS0EN8EQNvjV69qRUCPhAwL0TPZ2RHP7gJYHyX3KqhE
BarsAx94f56TuZoAqiN91qyFomNFx3InzPRMxnVx0jnvT0Lwdd8KkMaOIG+YD/is
I19wKTakyYbnsZogy1Olhec9vn2a/iRFM9x2Fe0PonFkTGUugWhFpwIDAQABMA0G
CSqGSIb3DQEBBQUAA4GBABByUqkFFBkyCEHwxWsKzH4PIRnN5GfcX6kb5sroc50i
2JhucwNhkcV8sEVAbkSdjbCxlnRhLQ2pRdKkkirWmnWXbj9T/UWZYB2oK0z5XqcJ
2HUw19JlYD1n1khVdWk/kfVIC0dpImmClr7JyDiGSnoscxlIaU5rfGW/D/xwzoiQ
-----END CERTIFICATE---
-----BEGIN CERTIFICATE-----
MIIE0DCCBDmgAwIBAgIQJQzo4DBhLp8rifcFTXz4/TANBgkqhkiG9w0BAQUFADBfMQswCQ
YDVQQGEwJVUzEXMBUGA1UEChMOVmVyaVNpZ24sIEluYy4xNzA1BgNVBAsTLkNsYXNzID
Mg
UHVibGljIFByaW1hcnkgQ2VydGlmaWNhdGlvbiBBdXRob3JpdHkwHhcNMDYxMTA4MDAwMD
AwWhcNMjExMTA3MjM1OTU5WjCByjELMAkGA1UEBhMCVVMxFzAVBgNVBAoTDlZlcmlTa
Wdu
LCBJbmMuMR8wHQYDVQQLExZWZXJpU2lnbiBUcnVzdCBOZXR3b3JrMTowOAYDVQQLEzEo
Yy
kgMjAwNiBWZXJpU2lnbiwgSW5jLiAtIEZvciBhdXRob3JpemVkIHVzZSBvbmx5MUUwQwYD
VQQDEzxWZXJpU2lnbiBDbGFzcyAzIFB1YmxpYyBQcmltYXJ5IENlcnRpZmljYXRpb24gQX
V0aG9yaXR5IC0gRzUwggEiMA0GCSqGSIb3DQEBAQUAA4IBDwAwggEKAoIBAQCvJAgIKXo1
nmAMqudLO07cfLw8RRy7K+D+KQL5VwijZIUVJ/XxrcgxiV0i6CqqpkKzj/i5Vbext0uz/o
9+B1fs70PbZmIVYc9gDaTY3vjgw2IIPVQT60nKWVSFJuUrjxuf6/WhkcIzSdhDY2pSS9KP
6HBRTdGJaXvHcPaz3BJ023tdS1bTlr8Vd6Gw9KIl8q8ckmcY5fQGBO+QueQA5N06tRn/Ar
r0PO7gi+s3i+z016zy9vA9r911kTMZHRxAy3QkGSGT2RT+rCpSx4/VBEnkjWNHiDxpg8v+
R70rfk/Fla4OndTRQ8Bnc+MUCH7lP59zuDMKz10/NIeWiu5T6CUVAgMBAAGjggGbMIIBlz
APBgNVHRMBAf8EBTADAQH/MDEGA1UdHwQqMCgwJqAkoCKGIGh0dHA6Ly9jcmwudmVya
XNp
Z24uY29tL3BjYTMuY3JsMA4GA1UdDwEB/wQEAwIBBjA9BgNVHSAENjA0MDIGBFUdIAAwKj
AoBggrBgEFBQcCARYcaHR0cHM6Ly93d3cudmVyaXNpZ24uY29tL2NwczAdBgNVHQ4EFgQU
f9Nlp8Ld7LvwMAnzQzn6Aq8zMTMwbQYIKwYBBQUHAQwEYTBfoV2gWzBZMFcwVRYJaW1h
```

```
Z2
UvZ2lmMCEwHzAHBgUrDgMCGgQUj+XTGoasjY5rw8+AatRIGCx7GS4wJRYjaHR0cDovL2xv
Z28udmVyaXNpZ24uY29tL3ZzbG9nby5naWYwNAYIKwYBBQUHAQEEKDAmMCQGCCsGAQU
FBz
ABhhhodHRwOi8vb2NzcC52ZXJpc2lnbi5jb20wPgYDVR0lBDcwNQYIKwYBBQUHAwEGCCsG
AQUFBwMCBggrBgEFBQcDAwYJYIZIAYb4QgQBBgpghkgBhvhFAQgBMA0GCSqGSIb3DQEBB
Q
UAA4GBABMC3fjohgDyWvj4IAxZiGIHzs73Tvm7WaGY5eE43U68ZhjTresY8g3JbT5KlCDD
PLq9ZVTGr0SzEK0saz6r1we2uIFjxfleLuUqZ87NMwwq14lWAyMfs77oOghZtOxFNfeKW/
9mz1Cvxm1XjRl4t7mi0VfqH5pLr7rJjhJ+xr3/

<snip> <Full certificate is issued from link in the Smart Call Home Quick Start
Guide> <snip>

quit
Certificate has the following attributes:
       Fingerprint MD5: EF5AF133 EFF1CDBB 5102EE12 144B96C4
      Fingerprint SHA1: A1DB6393 916F17E4 18550940 0415C702 40B0AE6B

% Do you accept this certificate? [yes/no]: yes
Trustpoint CA certificate accepted.
% Certificate successfully imported

Switch(config)# end
Switch# copy running-config startup-config
```

Note To obtain the proper certificate to paste into the call configuration, please visit the following link to get the Smart Call Home user guide for your model of equipment: http://www.cisco.com/en/US/docs/switches/lan/smart_call_home/user_guides/SCH_Ch6.pdf#G1039385

Once you complete the certificate import process, you must then initiate a call home to begin the registration process for the device. Before we begin the call home process, we will enable the **debug event manager action cli** command as the following snippet depicts. This will show the steps that the call-home feature is taking. It is important to remember that call-home uses embedded event manager (EEM) to function. The following example also shows the **call-home** command that is used to initiate the call-home and registration process on a Cisco Catalyst switch.

```
Switch# debug event manager action cli
Debug EEM action cli debugging is on
Switch# call-home send alert-group inventory profile CiscoTAC-1
Sending inventory info call-home message ...
Please wait. This may take some time ...
```

```
Switch#
Dec  7 22:48:38.089: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : CTL : cli_open
called.
Dec  7 22:48:38.089: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : Switch>
Dec  7 22:48:38.089: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : IN  :
Switch>enable
Dec  7 22:48:38.099: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : Switch#
Dec  7 22:48:38.099: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : IN  : Switch#show
version
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : Cisco IOS
Software, C3560CX Software (C3560CX-UNIVERSALK9-M), Version 15.2(3)E, RELEASE
SOFTWARE (fc4)
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : Technical
Support: http://www.cisco.com/techsupport
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT :
Copyright (c) 1986-2014 by Cisco Systems, Inc.
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : Compiled
Sun 07-Dec-14 13:15 by prod_rel_team
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(c
Translating "tools.cisco.com"… domain server (X.X.X.X)li_lib) : : OUT :
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : ROM:
Bootstrap program is C2960X boot loader
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : BOOTLDR:
C3560CX Boot Loader (C3560CX-HBOOT-M) Version 15.2(3r)E1, RELEASE SOFTWARE (fc1)
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT :
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : Switch
uptime is 1 day, 6 hours, 9 minutes
Dec  7 22:48:38.120 [OK]
i: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : System returned to ROM by
power-on
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : System
restarted at 16:38:44 UTC Sun Dec 6 2015
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : System
image file is "flash:/c3560cx-universalk9-mz.152-3.E/c3560cx-universalk9-mz
.152-3.E.bin"
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : Last reload
reason: power-on
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT :
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT :
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT :
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : This
product contains cryptographic features and is subject to United
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : States and
local country laws governing import, export, transfer and
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : use.
Delivery of Cisco cryptographic products does not imply
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : third-party
authority to import, export, distribute or use encryption.
Dec  7 22:48:38.120: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : CTL : 20+ lines
read from cli, debug output truncated
```

```
Dec  7 22:48:38.620: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : IN  : Switch#show
inventory oid
Dec  7 22:48:38.634: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : NAME: "1",
DESCR: "WS-C3560CX-8PC-S"
Dec  7 22:48:38.638: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : PID:
WS-C3560CX-8PC-S  , VID: V01  , SN: XXXXXXXXXXX
Dec  7 22:48:38.638: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : OID:
1.3.6.1.4.1.9.12.3.1.3.1593
Dec  7 22:48:38.638: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT :
Dec  7 22:48:38.638: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT :
Dec  7 22:48:38.638: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : Switch#
Dec  7 22:48:39.137: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : IN  : Switch#show
env power
Dec  7 22:48:39.155: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : SW  PID
Serial#     Status           Sys Pwr  PoE Pwr  Watts
Dec  7 22:48:39.155: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : --  -------
-----------  ----------  ---------------  -------  -------  -----
Dec  7 22:48:39.155: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT :  1
Built-in                                          Good
Dec  7 22:48:39.155: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT :
Dec  7 22:48:39.155: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : OUT : Switch#
Dec  7 22:48:39.658: %HA_EM-6-LOG: callhome : DEBUG(cli_lib) : : CTL : cli_close
called.
Dec  7 22:48:39.658:
Dec  7 22:48:39.658: tty is now going through its death sequence
Switch#
```

Now that this step is complete, an email will be sent to the email address used in the CiscoTAC-1 profile as shown in Figure 7-3. In this case, that email address is neteng@yourcompany.com. Once that email is received, to complete the registration process you must follow the directions in the email. You must also have a valid contract associated to the device you are trying to register to the Smart Call Home portal. Following the link will redirect you to the Smart Call Home Web Portal as shown in Figure 7-4. Once logged into the portal, the device registration process can be completed.

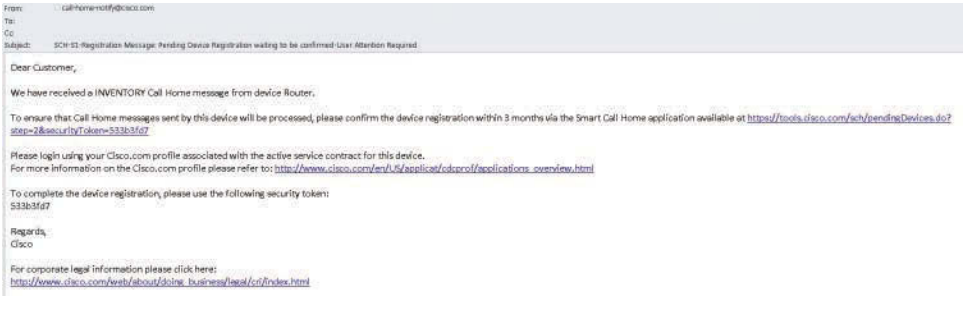

Figure 7-3 *Email from Cisco Smart Call Home Tool*

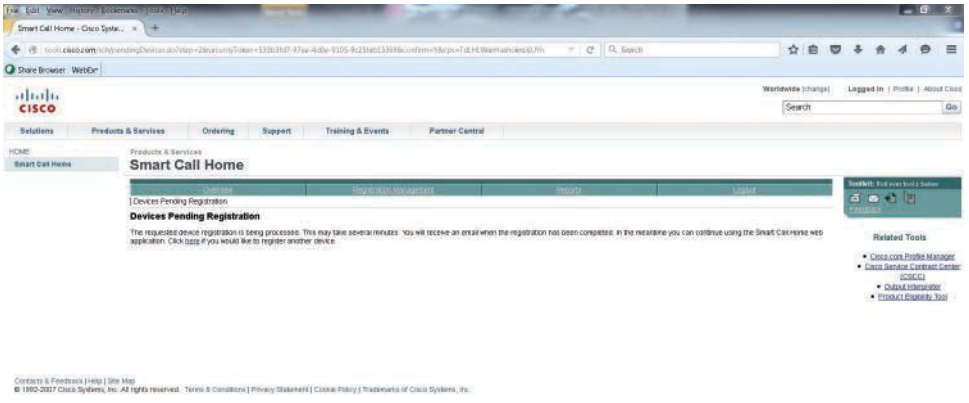

Figure 7-4 *Smart Call Home Web Portal*

To verify that Smart Call Home is running on your device, issue the **show call-home** command from the privileged exec prompt. The following snippet displays the output from the **show call-home** command on a Cisco Catalyst Switch. There are many different options that can be configured with Smart Call Home. The following alert groups are enabled automatically when configuring Smart Call Home with the **call-home send alert-group inventory profile CiscoTAC-1** command:

- Configuration
- Diagnostic
- Environment
- Inventory
- Syslog

```
Switch# show call-home
Current call home settings:
    call home feature : enable
    call home message's from address: Not yet set up
    call home message's reply-to address: Not yet set up

    vrf for call-home messages: Not yet set up

    contact person's email address: neteng@yourcompany.com

    contact person's phone number: Not yet set up
    street address: Not yet set up
    customer ID: Not yet set up
    contract ID: Not yet set up
    site ID: Not yet set up
```

```
    source ip address: Not yet set up
    source interface: Not yet set up
    Mail-server: Not yet set up
    Rate-limit: 20 message(s) per minute

Available alert groups:
    Keyword                  State   Description
    ------------------------ ------- -------------------------------
    configuration            Enable  configuration info
    diagnostic               Enable  diagnostic info
    environment              Enable  environmental info
    inventory                Enable  inventory info
    syslog                   Enable  syslog info

Profiles:
    Profile Name: CiscoTAC-1

Switch#
```

Note For more information on Smart Call Home, please visit: https://supportforums.cisco.com/community/4816/smart-call-home

Tcl Shell

Tcl Shell is a feature that is built into Cisco routers and switches that allows engineers to interact directly with the device by using various Tcl scripts. Tcl scripting has been around for quite some time and is a very useful scripting language. Tcl provides many ways to streamline different tasks that can help with day-to-day operations and monitoring of a network. Some of the following are tasks that can be automated by using these scripts:

- Verify IP and IPv6 reachability, using ping
- Verify IP and IPv6 reachability, using Traceroute
- Check interface statistics
- Retrieve SNMP information by accessing MIBs
- Send email messages containing CLI outputs from Tcl scripts

Most often, basic Tcl scripts are entered line by line within the Tcl shell, although, for some of the more advanced scripting methods, you can load the script into the flash of the device you are working on and execute the script from there. These scripts have to be in a specific Tcl format as shown in the following examples. The following example illustrates how to enter the Tcl shell on a Cisco router and execute a simple ping script.

```
Router# tclsh
Router(tcl)# foreach address {
+>(tcl)# 192.168.0.2
>(tcl)# 192.168.0.3
+>(tcl)# 192.168.0.4
+>(tcl)# 192.168.0.5
+>(tcl)# 192.168.0.6
+>(tcl)# } { ping $address
+>(tcl)# }
Type escape sequence to abort.
Sending 5, 64-byte ICMP Echos to 192.168.0.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/4/4 ms
Type escape sequence to abort.
Sending 5, 64-byte ICMP Echos to 192.168.0.3, timeout is 2 seconds:

!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/4/4 ms
Type escape sequence to abort.
Sending 5, 64-byte ICMP Echos to 192.168.0.4, timeout is 2 seconds:
….
Success rate is 0 percent (0/5)
Type escape sequence to abort.
Sending 5, 64-byte ICMP Echos to 192.168.0.5, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
Type escape sequence to abort.
Sending 5, 64-byte ICMP Echos to 192.168.0.6, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/3/4 ms
Router(tcl)# tclquit
Router#
```

An alternate to entering the DNS node names or IP addresses in a line-by-line fashion, you can also enter some of the script commands on a single line within the Tcl shell. For instance, the following example shows a similar ping script to the one entered before, but now it is executed on the same line within the Tcl shell.

```
Router# tclsh
Router(tcl)# foreach address {192.168.0.2 192.168.0.3 192.168.0.4} {ping $address}

Type escape sequence to abort.
Sending 5, 64-byte ICMP Echos to 192.168.0.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/4/4 ms
Type escape sequence to abort.
```

```
Sending 5, 64-byte ICMP Echos to 192.168.0.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/4/4 ms
Type escape sequence to abort.
Sending 5, 64-byte ICMP Echos to 192.168.0.4, timeout is 2 seconds:
…..
Success rate is 0 percent (0/5)
Router(tcl)# tclquit
Router#
```

Note To abort a ping that is timing out while running a script, press and hold the CTRL+Shift keys and press the 6 key for each failing ping, then release all keys. This speeds up the script to keep processing past the node(s) that are not responding and does not stop the script from running.

To execute Tcl Scripts from the local flash memory, you would need to store the script in flash and then call the script by file name. Scripts can be stored on the device's local flash, USB flash, or compact flash. Tcl scripts can be transferred into the IOS File System (IFS) by using SCP, TFTP, FTP, or RCP. From a security perspective, SCP is preferred due to its use of SSH. To execute a locally stored script, the **source** command from within the Tcl shell prompt can be used. The following example illustrates the steps to call a script named *ping.tcl* from the local flash on a device. This script is an example of the same ping script that was shown earlier in this chapter.

Note The scripts that are stored locally to the device should be named in the following manner: filename.tcl

```
Router# tclsh
Router(tcl)# source flash:ping.tcl

Type escape sequence to abort.
Sending 5, 64-byte ICMP Echos to 192.168.0.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/4/4 ms
Type escape sequence to abort.
Sending 5, 64-byte ICMP Echos to 192.168.0.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/4/4 ms
Type escape sequence to abort.
Sending 5, 64-byte ICMP Echos to 192.168.0.4, timeout is 2 seconds:
…..
Success rate is 0 percent (0/5)
Router(tcl)# tclquit
Router#
```

Note The previous script that is stored locally in flash can also be executed by simply issuing the "tclsh flash:ping.tcl command.

Embedded Event Manager (EEM)

Embedded Event Manager (EEM) is a very flexible and powerful tool within Cisco IOS. EEM allows engineers to build software applets that can automate many tasks. EEM also derives some of its power from the fact that you can build custom scripts using Tcl so that they automatically execute, based on the output of an action or an event on a device. One of the main benefits of EEM is that it is all contained within the local device. There is no need to rely on an external scripting engine or monitoring device in most cases. Figure 7-5 illustrates some of the event detectors and how they interact with the IOS subsystem.

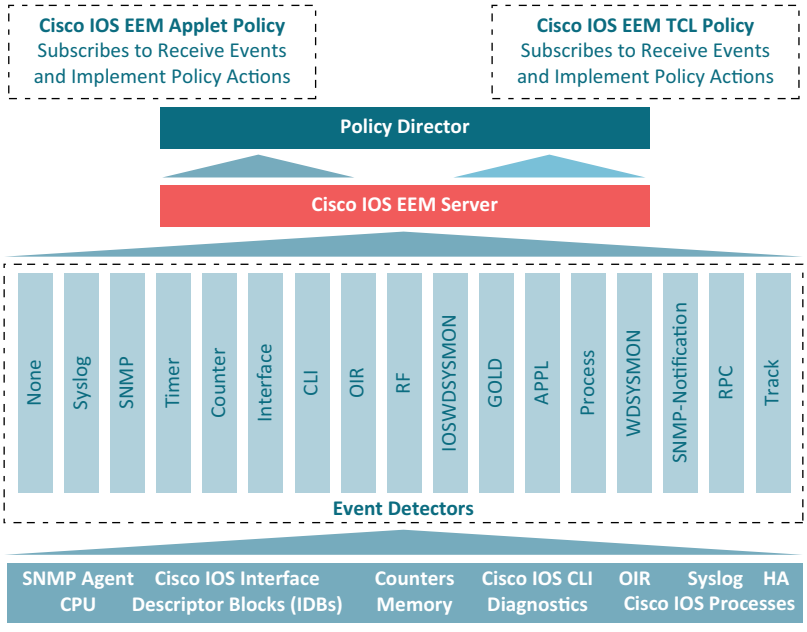

Figure 7-5 *EEM Event Detectors*

EEM Applets

EEM applets are comprised of multiple building blocks. In this chapter, we will focus on the two of the primary building blocks that make up EEM applets. Those building blocks are called events and actions. These EEM applets use a similar logic to the *if-then* statements found in some of the more common programming languages. For instance, *if* an event happens, *then* an action is taken. In the following example, we illustrate a very common EEM applet that is monitoring syslog messages on a router. This particular

applet is looking for a specific syslog message, stating that the Loopback0 interface went down. The specific syslog message is matched using regular expressions. This is a very powerful and granular way of matching patterns. If this specific syslog pattern is matched (an event) at least once, then the following actions will be taken:

- The Loopback0 interface will be shutdown and brought back up (**shutdown**, then **no shutdown**)
- The router will generate a syslog message that says "I've fallen, and I can't get up!"
- An email message will be sent to the network administrator that includes the output of the **show interface loopback0** command.

```
event manager applet LOOP0
 event syslog pattern "Interface Loopback0.* down" period 1
 action 1.0 cli command "enable"
 action 2.0 cli command "config terminal"
 action 3.0 cli command "interface loopback0"
 action 4.0 cli command "shutdown"
 action 5.0 cli command "no shutdown"
 action 5.5 cli command "show interface loopback0"
 action 6.0 syslog msg "I've fallen, and I can't get up!"
 action 7.0 mail server 10.0.0.25 to neteng@yourcompany.com from
 no-reply@yourcompany.com subject "Loopback0 Issues!" body "The Loopback0
interface was
 bounced. Please monitor accordingly. "$_cli_result"
```

Note Remember to include the **enable** and **configure terminal** commands at the beginning of actions within your applet. This is necessary as the applet assumes you are in exec mode, not privileged exec or config mode. In addition, if you are using AAA command authorization, you will want to include the **event manager session cli username** ***username*** command. Otherwise, the CLI commands in the applet will fail. It is also good practice to use decimal labels similar to 1.0, 2.0, and so forth when building applets. This allows you to insert and action between other actions in the future. For example, 1.5 will allow you to insert an action between 1.0 and 2.0. Remember that labels are parsed as strings, which means 10.0 would come after 1.0, not 9.0.

Based on the output from the **debug event manager action cli**, you can see the actual actions taking place when the applet is running. The following example shows the applet being engaged when we issue the **shutdown** command on the Loopback0 interface. It also shows that there was an error when trying to connect to the SMTP server to send the email to the administrator. This is because the actual SMTP server we are using for this test is not configured. Notice that because we used the **$_cli_result** keyword in the configuration, it will include the output of any CLI commands that were issued in the applet. In this case, the output of the **show interface Loopback0** command will be included in the debug and the mail message.

```
Switch#
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# interface loopback0
Switch(config-if)# shutdown
Switch(config-if)#
Dec  6 17:21:59.214: %LINK-5-CHANGED: Interface Loopback0, changed state to
administratively down
Dec  6 17:21:59.217: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : CTL : cli_open
called.
Dec  6 17:21:59.221: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT : Switch>
Dec  6 17:21:59.221: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : IN  : Switch>enable
Dec  6 17:21:59.231: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT : Switch#
Dec  6 17:21:59.231: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : IN  : Switch#show
interface loopback0
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT : Loopback0 is
administratively down, line protocol is down
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :   Hardware is
Loopback
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :   MTU 1514
bytes, BW 8000000 Kbit/sec, DLY 5000 usec,
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :
reliability 255/255, txload 1/255, rxload 1/255
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :
Encapsulation LOOPBACK, loopback not set
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :   Keepalive
set (10 sec)
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :   Last input
never, output never, output hang never
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :   Last
clearing of "show interface" counters never
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :   Input queue:
0/75/0/0 (size/max/drops/flushes); Total output drops: 0
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :   Queueing
strategy: fifo
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :   Output
queue: 0/0 (size/max)
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :   5 minute
input rate 0 bits/sec, 0 packets/sec
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :   5 minute
output rate 0 bits/sec, 0 packets/sec
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :      0 packets
input, 0 bytes, 0 no buffer
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :
Received 0 broadcasts (0 IP multicasts)
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :
0 runts, 0 giants, 0 throttles
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :      0 input
errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :      0 packets
output, 0 bytes, 0 underruns
```

```
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :      0 output
errors, 0 collisions, 0 interface resets
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :      0 unknown
protocol drops
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : CTL : 20+ lines read
from cli, debug output truncated
Dec  6 17:21:59.252: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : IN  : Switch#config
terminal
Dec  6 17:21:59.266: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT : Enter
configuration commands, one per line.  End with CNTL/Z.
Dec  6 17:21:59.266: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :
Switch(config)#
Dec  6 17:21:59.266: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : IN  :
Switch(config)#interface loopback0
Dec  6 17:21:59.277: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :
Switch(config-if)#
Dec  6 17:21:59.277: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : IN  :
Switch(config-if)#shutdown
Dec  6 17:21:59.287: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :
Switch(config-if)#
Dec  6 17:21:59.287: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : IN  :
Switch(config-if)#no shutdown
Dec  6 17:21:59.298: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : OUT :
Switch(config-if)#
Dec  6 17:21:59.298: %HA_EM-6-LOG: LOOP0: I've fallen and I can't get up!
Dec  6 17:22:01.293: %LINK-3-UPDOWN: Interface Loopback0, changed state to up
Dec  6 17:22:11.314: %HA_EM-3-FMPD_SMTP: Error occurred when sending mail to SMTP
server: 10.0.0.25 : error in connecting to SMTP server
Dec  6 17:22:11.314: %HA_EM-3-FMPD_ERROR: Error executing applet LOOP0 statement
7.0
Dec  6 17:22:11.314: %HA_EM-6-LOG: LOOP0 : DEBUG(cli_lib) : : CTL : cli_close
called.
```

Note For troubleshooting purposes, using the **debug event manager all** command will show all the outputs for the configured actions while the applet is being executed. For instance, it will show the same output as shown above but will include more details on all the other actions. To specifically troubleshoot the mail configuration and related error messages in an EEM Applet, the **debug event manager action mail** command is most useful as it filters out all the other unnecessary debug messages while you are trying to troubleshoot the mail configuration. This will allow you to focus on SMTP errors as shown in the previous example.

Another very useful aspect of EEM applets is that CLI patterns can be matched as an event. This means that when certain commands are entered into the router via CLI, they can trigger an EEM event within an applet. Then the configured actions will take place as a result of the CLI pattern being matched. The following example uses another common

EEM applet to match the CLI pattern "wr mem". Once the applet is triggered, the following actions will be invoked:

- The router will generate a syslog message that says "Configuration File Changed!"
- The startup-config will be copied to a TFTP server.
- Generate a syslog message stating that the configuration has been successfully saved.

```
event manager environment filename Router.cfg
event manager environment tftpserver tftp://10.1.200.29/
event manager applet BACKUP-CONFIG
 event cli pattern "write mem.*" sync yes
 action 1.0 cli command "enable"
 action 2.0 cli command "configure terminal"
 action 3.0 cli command "file prompt quiet"
 action 4.0 cli command "end"
 action 5.0 cli command "copy start $tftpserver$filename"
 action 6.0 cli command "configure terminal"
 action 7.0 cli command "no file prompt quiet"
 action 8.0 syslog priority informational msg "Configuration File Changed! TFTP
backup successful."
```

Note The **file prompt quiet** command disables the IOS confirmation mechanism that asks you to confirm your actions.

Note The priority and facility of the Syslog messages can be changed to fit your environment's alerting structure. For example, we used informational in the previous example.

As seen in the previous examples there are multiple ways to call out specific EEM environment values. The first example illustrated that you can use a single line to configure the mail environment and send messages with CLI output results. Using the event manager environment variables shown in the second example, you can statically set different settings that you can call on from multiple actions instead of calling them out individually on a single line. Although you can create custom names and values that are arbitrary and can be set to anything, it is good practice to use common and descriptive variables. Table 7-3 lists some of the most commonly used email variables in EEM.

Table 7-3 *Common EEM Email Variables*

EEM Variable	Description	Example
_email_server	SMTP server IP address or DNS name	10.0.0.25 or MAILSVR01
_email_to	Email address to send email to	neteng@yourcompany.com
_email_from	Email address of sending party	no-reply@yourcompany.com
_email_cc	Email address of additional email receivers	helpdesk@yourcompany.com

EEM and Tcl Scripts

Using an EEM applet to call Tcl scripts is another very powerful aspect of EEM. We have covered multiple ways to use EEM applets. In this section, we will discuss how to call a Tcl script from an EEM applet. The previous sections on EEM showed multiple ways of executing actions, based on the automatic detection of specific events when they are happening. This example shows how to manually execute an EEM applet that will, in turn, execute a Tcl script that is locally stored in the device's flash memory.
It is important to understand that there are many different ways to use EEM and that manually triggered applets are also a very useful tool. The following example depicts an EEM script that is configured with the **event none** command. This means that there is no automatic event that the applet is monitoring and that this applet will only run when it is triggered manually. To manually run an EEM applet, the **event manager run** command must be used as illustrated in second output.

```
event manager applet Ping
 event none
 action 1.0 cli command "enable"
 action 1.1 cli command "tclsh flash:/ping.tcl"


Router# event manager run Ping
Router#
Dec  6 19:32:16.564: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : CTL : cli_open
called.
Dec  6 19:32:16.564: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : Router>
Dec  6 19:32:16.568: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : IN  : Router>enable
Dec  6 19:32:16.578: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : Router#
Dec  6 19:32:16.578: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : IN  : Router#tclsh
flash:/ping.tcl
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : Type escape
sequence to abort.
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : Sending 5,
100-byte ICMP Echos to 192.168.0.2, timeout is 2 seconds:
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : !!!!!
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : Success rate is
100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : Type escape
sequence to abort.
```

```
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : Sending 5,
100-byte ICMP Echos to 192.168.0.3, timeout is 2 seconds:
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : !!!!!
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : Success rate is
100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : Type escape
sequence to abort.
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : Sending 5,
100-byte ICMP Echos to 192.168.0.4, timeout is 2 seconds:
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : !!!!!
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : Success rate is
100 percent (5/5), round-trip min/avg/max = 1/1/3 ms
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : Type escape
sequence to abort.
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : Sending 5,
100-byte ICMP Echos to 192.168.0.5, timeout is 2 seconds:
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : !!!!!
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : Success rate is
100 percent (5/5), round-trip min/avg/max = 1/1/4 ms
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : Type escape
sequence to abort.
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : Sending 5,
100-byte ICMP Echos to 192.168.0.6, timeout is 2 seconds:
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : !!!!!
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : OUT : Success rate is
100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : CTL : 20+ lines read
from cli, debug output truncated
Dec  6 19:32:16.711: %HA_EM-6-LOG: Ping : DEBUG(cli_lib) : : CTL : cli_close called.
```

For reference, see the following snippet for the exact content of the ping.tcl script used in the manually triggered EEM applet in the previous example. To see the contents of a TCL script that resides in flash, issue the **more** command followed by the file location and filename. The **more** command can be used to view all other text based files stored in the local flash as well.

```
Router# more flash:ping.tcl
foreach address {
192.168.0.2
192.168.0.3
192.168.0.4
192.168.0.5
192.168.0.6
} { ping $address}
```

EEM Summary

There are many ways to utilize EEM. From applets to scripting, the possibly use cases can only be limited by the engineer's imagination. EEM provides on-box monitoring of various different components based on a series of events. Once an event is detected, an action can take place. This helps make some of the network monitoring more proactive, rather than reactive. This can also reduce the load on the network and improve efficiency from the monitoring system because now the devices can simply report when there is something wrong instead of continually asking the devices if there is anything wrong.

Note For information on EEM and its robust features, please visit http://www.cisco.com/c/en/us/products/ios-nx-os-software/ios-embedded-event-manager-eem/index.html

Summary

By automating daily configuration tasks, you gain some of the following benefits:

- Increased agility
- Reduced Opex
- Lower overall TCO
- Streamlined management
- Reduction of human error
- Increased visibility

Keeping the above in mind, then adding the fact that many organizations are dealing with lean IT problems and high turnover, network engineers are being asked to do more with less. Utilizing some of the tools that were covered in this chapter can help alleviate some of the pressure put on IT staff by offloading some of the more tedious, time-consuming, and repetitious tasks. This will allow the network engineer to focus more on critical mission responsibilities like network design and growth planning.

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