



# Programming and Automating Cisco Networks

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

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# Programming and Automating Cisco Networks

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**Cisco Press**

800 East 96th Street

Indianapolis, Indiana 46240 USA

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Ryan Tischer  
Jason Gooley

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Published by:  
Cisco Press  
800 East 96th Street  
Indianapolis, IN 46240 USA

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Printed in the United States of America

First Printing August 2016

Library of Congress Control Number: 2016942372

ISBN-13: 978-1-58714-465-3

ISBN-10: 1-58714-465-4

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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.

## Acknowledgments

### Ryan Tischer:

I'd like to give special recognition to the amazing engineers, managers, sales teams, and customers I have the privilege of working with. I am humbled to be a part of this community, and I fully recognize that without your inspiration, encouragement, and knowledge, this book would not be possible. I have been truly blessed to have managers and co-workers who believe in me, told me when I screwed up, and gave me the opportunity of a lifetime. Special thank you to INSBU for building wickedly-cool products and letting me play.

A big thank you to Joe Clark, Omar Sultan, Brett Bartow, and Eleanor Bru for their amazing work on this book.

Finally, I'd like to thank my co-author Jason Gooley. I approached him with this project at the very last minute, and he's worked very hard to keep the book on time, while not sacrificing technical depth or content.

### Jason Gooley:

First, thank you to Brett Bartow, Eleanor Bru, and the rest of the Cisco Press team for all of the support during creation of this book. It was a pleasure to work with such an amazing group of professionals.

I would like to thank the entire Cisco Commercial Midwest Select Operation for supporting me during this process. Thank you to my manager and all of my teammates on the Illinois Select team for the continued reinforcement of this project.

A special thanks to Anthony Sequeira, Keith Barker, Andre Laurent, and Luke Kaelin for all the mentoring and words of encouragement. I can't thank you enough for all of your support over the years.

Thank you, Ryan, for giving me the opportunity to write this book with you. It has been an absolute blast, and I am honored to be a part of it.

Finally, I would like to thank all my friends and family who have patiently waited for me to finish this project, so I would be able to go outside and play. You know who you are!

## Contents at a Glance

Introduction xviii

### **Section I Getting Started with Network Programmability**

Chapter 1 Introduction: Why Network Programmability 1

Chapter 2 Foundational Skills 13

### **Section II Cisco Programmable Data Center**

Chapter 3 Next-Generation Cisco Data Center Networking 67

Chapter 4 On-Box Programmability and Automation with Cisco Nexus NX-OS 83

Chapter 5 Off-Box Programmability and Automation with Cisco Nexus NX-OS 125

Chapter 6 Network Programmability with Cisco ACI 159

### **Section III Cisco Programmable Campus and WAN**

Chapter 7 On-Box Automation and Operations Tools 215

Chapter 8 Network Automation Tools for Campus Environments 255

Chapter 9 Piecing It All Together 303

Index 307

# Contents

	Introduction	xviii
<b>Section I</b>	<b>Getting Started with Network Programmability</b>	
<b>Chapter 1</b>	<b>Introduction: Why Network Programmability</b>	<b>1</b>
	What Is Network Programmability	3
	Network Programmability Benefits	4
	<i>Simplified Networking</i>	4
	<i>Network Innovation with Programmability</i>	4
	Cloud, SDN, and Network Programmability	6
	SDN	8
	Is Programmability a New Idea?	9
	Network Automation	10
	<i>Automation Example</i>	11
	Summary	11
<b>Chapter 2</b>	<b>Foundational Skills</b>	<b>13</b>
	Introduction to Software Development	13
	Common Constructs—Variables, Flow Control, Functions, and Objects	15
	<i>Variables</i>	15
	<i>Flow Control—Conditions</i>	17
	<i>Flow Control—Loops</i>	18
	<i>Functions</i>	18
	<i>Objects</i>	19
	A Basic Introduction to Python	20
	<i>More on Strings</i>	22
	<i>Help!</i>	23
	<i>Flow Control</i>	24
	<i>Python Conditions</i>	24
	<i>Python Loops</i>	25
	<i>While Loop</i>	26
	<i>Python Functions</i>	28
	<i>Python Files</i>	29
	<i>Importing Libraries</i>	30
	<i>Installing Python Libraries</i>	30
	<i>Using PIP</i>	31

<i>Using Common Python Libraries</i>	31
APIs and SDKs	37
Web Technologies	37
Web Technologies—Data Formatting	38
XML	38
JSON	39
Google Postman	40
<i>Using Postman</i>	40
<i>Using JSON in Python</i>	43
Basic Introduction to Version Control, Git, and GitHub	45
Git—Add a File	47
Creating and Editing Source Code	49
Getting Started with PyCharm	50
<i>Writing Code in PyCharm—Get the Weather</i>	53
<i>Debugging in PyCharm</i>	54
Introduction to Linux	55
<i>Working in Linux</i>	56
<i>Linux Architecture</i>	58
<i>Display Linux Process</i>	59
Using Systemd	61
<i>Linux File System and Permissions</i>	63
<i>Linux Directories</i>	64
<i>Installing Applications on Linux</i>	64
<i>Where to Go for Help</i>	65
Summary	66

**Section II Cisco Programmable Data Center**

**Chapter 3 Next-Generation Cisco Data Center Networking 67**

Cisco Application-Centric Infrastructure (ACI)	70
Nexus Data Broker	74
Use Case—Nexus Data Broker	75
Evolution of Data Center Network Architecture	76
Cisco Data Center Network Controllers	80
Nexus Fabric Manager	80
Virtual Topology System (VTS)	81
Cisco ACI	81
Summary	82

<b>Chapter 4</b>	<b>On-Box Programmability and Automation with Cisco Nexus NX-OS</b>	<b>83</b>
	Open NX-OS Automation—Bootstrap and Provisioning	83
	Cisco POAP	83
	Cisco Ignite	87
	<i>Using Ignite</i>	87
	NX-OS iPXE	88
	Bash	88
	Bash Scripting	89
	Bash Variables, Conditions, and Loops	89
	Bash Arithmetic	90
	Bash Conditions and Flow Control	91
	Bash Redirection and Pipes	94
	Working with Text in Bash	96
	Awk	98
	Bash on Nexus 9000	99
	ifconfig	101
	Tcpdump	101
	ethtool	103
	Run a Bash Script at Startup	103
	<i>Bash Example—Configure NTP Servers at boot</i>	106
	Linux Containers (LXC)	106
	Network Access in Guestshell	109
	<i>Installing Applications in Guestshell</i>	110
	<i>Puppet Agent Installation in Guestshell</i>	111
	<i>NMap Installation in Guestshell</i>	111
	<i>Embedded Nexus Data Broker</i>	111
	<i>Nexus Embedded Event Manager</i>	112
	<i>EEM Variables</i>	113
	On-box Python Scripting	113
	<i>Using the NX-OS Python CLI Library</i>	115
	<i>Using NX-OS Cisco Python Library</i>	116
	<i>Non-Interactive Python</i>	118
	<i>Cisco or CLI Package?</i>	118
	On-Box Python—Use Cases and Examples	118
	EEM Neighbor Discovery	121
	Summary	124

**Chapter 5 Off-Box Programmability and Automation with Cisco Nexus NX-OS 125**

Nexus NX-API	125
NX-API Transport	125
NX-API Message Format	126
NX-API Security	126
NX-API Sandbox	127
<i>Using NX-API in Python</i>	129
<i>Configuring an IP Address with Python and NX-API</i>	130
<i>NX-API REST: An Object-Oriented Data Model</i>	131
<i>NX-API REST Object Model Data</i>	133
<i>Authenticating to NX-API (nxapi_auth cookie)</i>	136
<i>Changing NX-API Objects Data via Postman</i>	138
<i>Modifying NX-API Objects Data via Python</i>	140
<i>NX-API Event Subscription</i>	143
NXTool Kit	146
<i>Using NXTool Kit</i>	146
<i>NXTool Kit BGP Configuration</i>	148
<i>Automation and DevOps Tools</i>	151
Puppet	152
<i>Using Puppet</i>	153
<i>Puppet and Nexus 9000</i>	154
<i>Ansible and Nexus 9000</i>	157
Summary	158
Resources	158

**Chapter 6 Network Programmability with Cisco ACI 159**

Cisco ACI Automation	160
ACI Policy Instantiation	161
A Bit More Python	162
Virtualenv	162
<i>Virtualenv in PyCharm</i>	166
Python Exceptions Handling	166
ACI Fundamentals	169
ACI Management Information Model	169
<i>ACI Object Naming</i>	170
<i>Fault Severity</i>	173
<i>ACI Health Scores</i>	174

ACI Programmability	174
<i>Invoking the API</i>	176
GUI	178
APIC Object Save-as	178
APIC API Inspector	179
APIC Object Store Browser (Visore)	182
APIC API Authentication	185
Using Python to Authenticate to APIC	186
Using Postman to Automate APIC Configurations	188
Using Postman	188
Creating New Postman Calls	189
Programmability Using the APIC RESTful API	192
ACI Event Subscription	196
Cobra SDK	198
Using APIC Cobra	200
Working with Objects	202
Example Cobra SDK—Creating a Complete Tenant Configuration	204
APIC REST Python Adapter (Arya)	207
Using AryaLogger	208
APIC Automation with UCS Director	211
Summary	213

### **Section III Cisco Programmable Campus and WAN**

#### **Chapter 7 On-Box Automation and Operations Tools 215**

Automated Port Profiling	216
AutoSmart Ports	216
Enabling AutoSmart Ports on a Cisco Catalyst Switch	217
AutoConf	220
Enabling AutoConf on a Cisco Catalyst Switch	222
Modifying a Built-in Template	224
Auto Security	227
Enabling Auto Security on a Cisco Catalyst Switch	228
Quality of Service for Campus Architectures	230
AutoQoS on Campus LAN Devices	230
Enabling AutoQoS on a Cisco Catalyst Switch	231

AutoQoS on Campus WAN Devices	233
Enabling AutoQoS on a Cisco ISR Router	234
Automating Management and Monitoring Tasks	236
Smart Call Home	236
Enabling Smart Call Home on an Cisco Catalyst Switch	237
Tcl Shell	243
Embedded Event Manager (EEM)	246
<i>EEM Applets</i>	246
<i>EEM and Tcl Scripts</i>	251
<i>EEM Summary</i>	253
Summary	253

## **Chapter 8 Network Automation Tools for Campus Environments 255**

Data Models and Supporting Protocols	256
YANG Data Models	256
NETCONF	258
ConfD	259
Application Policy Infrastructure Controller Enterprise Module (APIC-EM)	263
APIC-EM Architecture	263
APIC-EM Applications	264
Intelligent WAN (IWAN) Application	264
Plug and Play (PnP) Application	269
Path Trace Application	276
Additional APIC-EM Features	279
Topology	279
Device Inventory	281
Easy Quality of Service (Easy QoS)	283
Dynamic QoS	285
Policy Application	286
APIC-EM Programmability Examples Using Postman	288
Ticket API	288
Host API	291

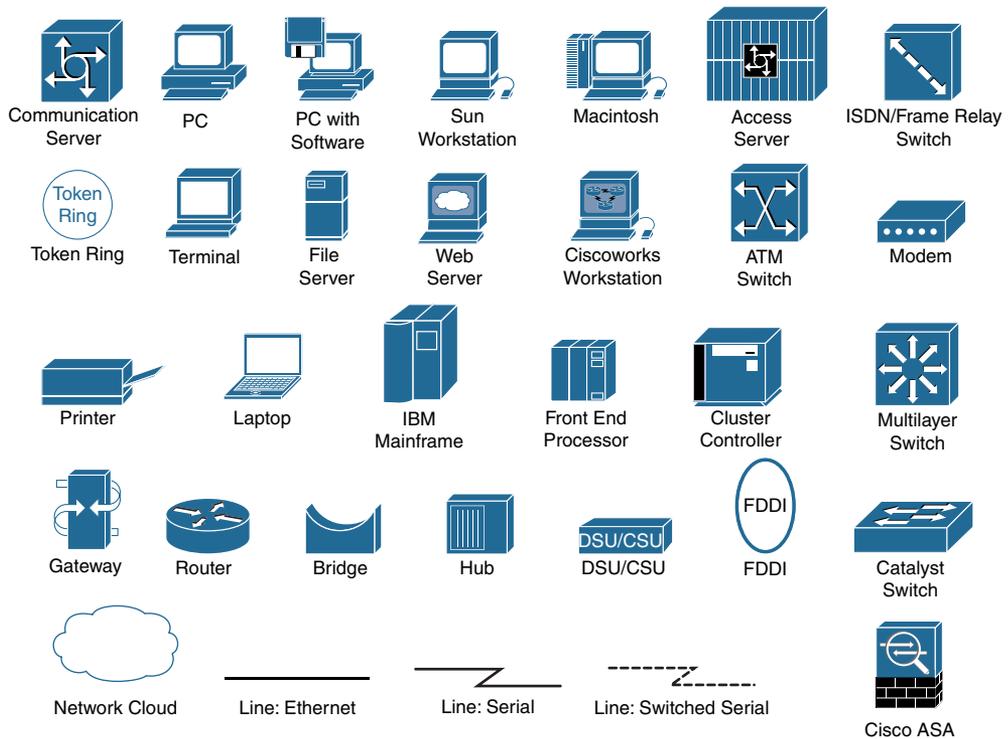
	Network Device API	292
	User API	294
	Available APIC-EM APIs	296
	APIC-EM Programmability Examples Using Python	297
	Ticket API	297
	Host API	299
	Summary	302
<b>Chapter 9</b>	<b>Piecing It All Together</b>	<b>303</b>
	Index	307

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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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## 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:

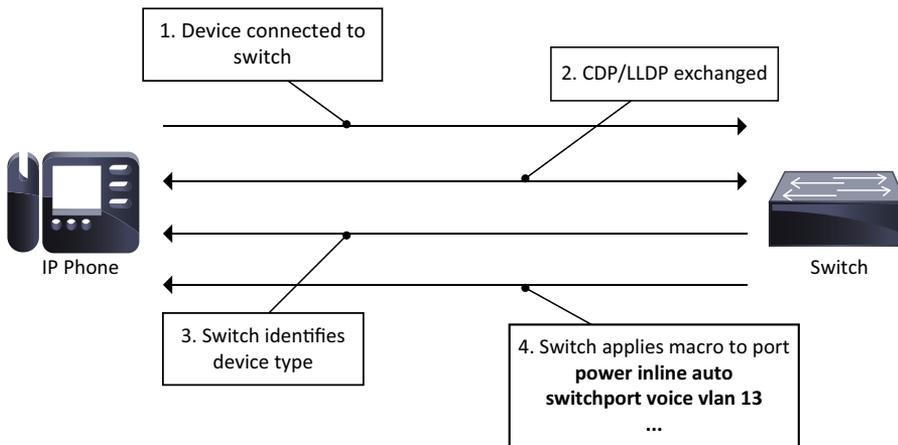
- Power over Ethernet (PoE) settings
- Voice VLAN configuration
- Quality of Service (QoS) settings
- Data VLAN configuration
- Speed/Duplex settings

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/](http://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/xs-360-config/auto\\_sec.pdf](http://www.cisco.com/c/en/us/td/docs/switches/lan/catalyst4500/XE3-6-0E/15-22E/configuration/guide/xs-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](http://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

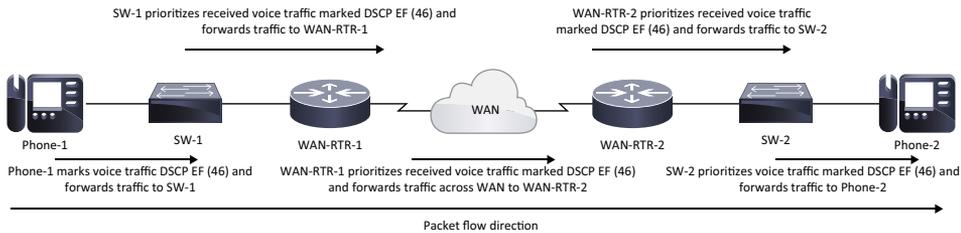
```

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, especially 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 cbQoSCommandDropBitRate.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/Er4wDQYJKoZIhvcNAQEFBQAwwXzELMAkG
A1UEBhMCVVMxZzAVBgNVBAoTDlZlcm1TaWduLCBjb250aW50aW50aW50aW50aW50
cyAzIFB1Ym1yYyBQcm1tYXJ5IENlcnRpZmljYXRpb24gQXV0aG9yaXR5MB4XDTE2
MDEyOTAwMDAwMjI0MDg1MjIzNTk1OVowXzELMAkGA1UEBhMCVVMxZzAVBgNV
BAoTDlZlcm1TaWduLCBjb250aW50aW50aW50aW50aW50aW50cyAzIFB1Ym1yYyBQcm1t
YXJ5IENlcnRpZmljYXRpb24gQXV0aG9yaXR5MIGfMA0GCSqGSIb3DQEBAQUAA4GN
ADCBiQKBggqjDjFme8huKARS0EN8EQNvjV69qRUCPhAwL0TPZ2RHP7gJYHyX3KqHE
BarsAx94f56TuZoAqin9lqyFomNFx3InzPRMxnVx0jnvT0Lwdd8KkMaOIG+YD/Is
I19wKTakyYbnsZogy1Olhec9vn2a/IRFM9x2Fe0PonFkTGUUgWhFpwIDAQABMA0G
CSqGSIb3DQEBAQUAA4GBABBYUqkFFBkyCEHwxWsKzH4PIRnN5GfcX6kb5sroc50i
2JhucwNhkcv8sEVAbkSdjbCxlRnRhLQ2pRdKkKirWmnWXbj9T/UWZYB2oK0z5XqCj
2HUw19JlYD1n1khVdWk/kfVIC0dpImmClr7JyDiGSnoscx1IaU5rfGW/D/xwzoiQ
-----END CERTIFICATE---
-----BEGIN CERTIFICATE-----
MIIE0DCCBDMgAwIBAgIQJQzo4DBhLp8rifcFTXz4/TANBgkqhkiG9w0BAQUFADBfMQswCQ
YDVQoGQGEwJVUzEXBUBGA1UEChMOVmVyaVNPZ24sIEluYy4xNzA1BGNVBAStLkNsYXNzID
Mg
UHViBGljIFB1Ym1yYyBQcm1tYXJ5IENlcnRpZmljYXRpb24gQXV0aG9yaXR5MB4XDTE2
MDEyOTAwMDAwMjI0MDg1MjIzNTk1OVowXzELMAkGA1UEBhMCVVMxZzAVBgNVBAoTDlZlcm1Ta
Wdu
LCBjb250aW50aW50aW50aW50aW50aW50cyAzIFB1Ym1yYyBQcm1tYXJ5IENlcnRpZmljYXRpb24gQX
V0aG9yaXR5MIGfMA0GCSqGSIb3DQEBAQUAA4IBDwAwggEKAoIBAQcVjAgIKXo1
nmAMqudL007cfLw8RRy7K+D+kQL5VwjjZIUUVJ/XxrcgxiV0i6CqppkKzj/i5Vbext0uz/o
9+B1fs70PbZmIVYc9gDaTY3vjgw2IIPVQT60nKWVSFJUurjxuf6/WhkcIzSdhDY2pSS9KP
6HBRTdGJaXvHcPaz3BJ023tdS1bTlR8Vd6Gw9KI18q8ckmcY5fQGBO+QueQA5N06tRn/Ar
r0P07gi+s3i+z016zy9vA9r911ktMZHRxAy3QkGSGT2RT+rCpSx4/VEEnkjWNHidXp8v+
R70rfk/Fla4OndTRQ8Bnc+MUCH71P59zuDMKz10/NieWiu5T6CUVAgMBAAGjggGbmIIBlz
APBgNVHRMBAf8EBTADAQH/MDEGA1UdHwQqMCGwJqAkoCKGIGh0dHA6Ly9jcmwudmVya
XNp
Z24uY29tL3BjYTMuY3J5MA4GA1UdDwEB/wQEAWIBBjA9BGNVHSAENJA0MDIGBFDIAAwKj
AoBggrBgEFBQcCARYcaHR0cHM6Ly93d3cuZmVyaXNpZ24uY29tL2NwczAdBgNVHQ4EFQGU
f9N1p8Ld7LvwManzQzn6Aq8zMTMwbQYIKwYBBQUHAQwEYTBfoV2gWzBZMFcwVRYJaW1h
```

```

Z2
UvZ22lmMCEwHzAHBgUrDgMCGgQUj+XTGoasjY5rw8+AatRIGCx7GS4wJRYjaHR0cDovL2xv
Z28udmVyaXNpZ24uY29tL3ZzbG9nby5naWYwNAYIKwYBBQUHAQEEDAMmCQGCCsGAQU
FBz
ABhhhdHRwOi8vb2NzcC52ZXJpc2lnbi5jb20wPgYDVR01BDcwNQYIKwYBBQUHAwEGCCsG
AQUFBwMCBggrBgEFBQcDAwYJYIZIAYb4QgQBBAQgBMA0GCSqGSIb3DQEBB
Q
UAA4GBABMC3fjohgDyWvj4IAxZiGIHzs73Tvm7WaGY5eE43U68ZhjTresY8g3JbT5K1CDD
PLq9ZVTGr0SzeK0saz6r1we2uIFjxfleLuUqZ87NMwwq141WAYMfs77oOghZtOxFNfeKW/
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](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: XXXXXXXXXXXX
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



```

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

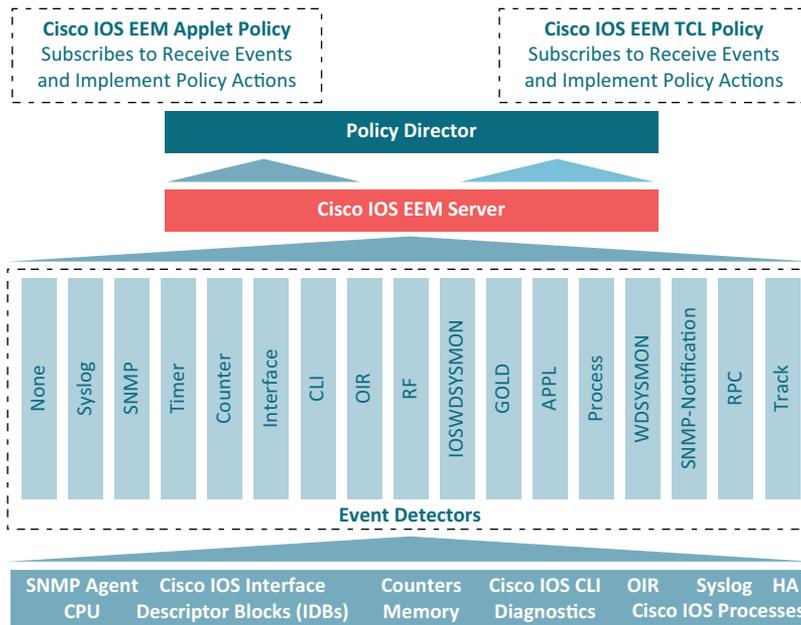
Type escape sequence to abort.
Sending 5, 64-byte ICMP Echos to 192.168.0.2, timeout is 2 seconds:
!!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 4/4/4 ms
Type escape sequence to abort.
Sending 5, 64-byte ICMP Echos to 192.168.0.3, timeout is 2 seconds:
!!!!!!
Success rate is 100 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 “`tcclsh 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 an 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*

<b>EEM Variable</b>	<b>Description</b>	<b>Example</b>
<code>_email_server</code>	SMTP server IP address or DNS name	10.0.0.25 or MAILSVR01
<code>_email_to</code>	Email address to send email to	neteng@yourcompany.com
<code>_email_from</code>	Email address of sending party	no-reply@yourcompany.com
<code>_email_cc</code>	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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# Index

## Symbols

---

\* (asterisk), 32  
\ (backslash), 90  
^ (caret), 32  
./ construct (bash), 90  
\$ (dollar sign), 32  
= (equal sign), 92  
< (left arrow), 92  
. (period), 32, 33  
+ (plus sign), 32  
# (pound sign), 29  
>> redirector, 94  
> (right arrow), 92  
[] (square brackets), 32, 33  
16 nanometer ASIC, 68

## A

---

aaaLogin method, 185  
aaaLogout method, 186  
aaaRefresh method, 185  
aborting pings, 245  
Access Control Lists (ACLs)  
  APIC-EM Policy application,  
  286–287  
  overview, 79  
Access module (Cobra SDK), 200  
accessing  
  dictionaries, 28  
  lists, 27  
  virtual environments, 163–164  
ACI (Application Centric  
  Infrastructure). *See* Cisco  
  ACI (Application Centric  
  Infrastructure)  
ACLs (Access Control Lists)  
  APIC-EM Policy application,  
  286–287  
  benefits of, 79  
actions (EEM), 112–113  
activate command, 163–164  
addresses (IP), 130–131  
ALE (application leaf engine), 67  
ANPs (application network  
  profiles), 72  
Ansible  
  Nexus 9000, 157–158  
  overview, 156–157

- AP\_INTERFACE\_TEMPLATE, 220
- API inspector (APIC), 179–182
- APIC REST Python Adapter (Arya)
  - AryaLogger, 207–208
  - installing, 207–208
  - WebArya, 211
- APIC RESTful API
  - API inspector, 179–182
  - APIC automation with UCS Director, 211
  - APIC configuration automation, 188–191
  - atomic mode, 174–175
  - authentication
    - authentication methods*, 185–186
    - overview*, 182–186
    - with Python*, 186–188
  - Cobra SDK
    - Arya (APIC REST Python Adapter)*, 207–211
    - authentication*, 201
    - documentation*, 198
    - installing*, 199–200
    - libraries*, 200–201
    - modules*, 200
    - objects*, 202–204
    - tenant configuration example*, 204–207
  - components, 175–176
  - event subscription, 196–198
  - forgiving mode, 174–175
  - GUI, 178
  - invoking, 176–178
  - object save-as, 178–179
  - programmability, 192–196
  - read operations, 176
  - Visore, 182–185
  - write operations, 177
- APIC-EM (application policy infrastructure controller enterprise module)
  - APIC-EM Path Trace application, 276–278
  - APIC-EM Plug and Play (PnP)
    - Configuration Upload page*, 275
    - dashboard*, 271–272
    - Device History*, 273
    - overview*, 269–278
    - Pending status information page*, 274
    - project details*, 272–273
    - Software Images tab*, 274–275
    - Unplanned Devices screen*, 275–276
  - authentication via Python
    - Host API*, 299–301
    - Ticket API*, 297–299
  - Device Inventory application, 281–282
  - Dynamic QoS (Quality of Service), 285–286
  - Easy QoS (Quality of Service), 283–285
  - IWAN (Intelligent WAN), 264–269
  - network devices, listing, 292–293
  - overview, 70, 263
  - Policy application, 286–287
  - Postman APIs
    - available APIs*, 296
    - DevNet APIC-EM sandbox*, 288
    - Host API*, 291–292
    - Network Device API*, 292–293

- Ticket API*, 288–291
- User API*, 294–296
- Topology application, 279–281
- users, viewing, 294–296
- APIC-EM-AUTH.py script, 297–299
- APIC-EM-SHOW-HOST.py script, 299–301
- APIs (application programming interfaces)
  - APIC RESTful API. *See also*
    - Cobra SDK
    - API inspector*, 179–182
    - APIC automation with UCS Director*, 211
    - APIC configuration automation*, 188–191
    - atomic mode*, 174–175
    - authentication*, 185–188
    - components*, 175–176
    - event subscription*, 196–198
    - forgiving mode*, 174–175
    - GUI, 178
    - invoking*, 176–178
    - object save-as*, 178–179
    - programmability*, 192–196
    - read operations*, 176
    - Visore*, 182–185
    - write operations*, 177
  - CLI APIs, 115–116
  - ConfD, 261
  - event subscription, 196–198
  - Host API
    - Postman API*, 291–292
    - Python script*, 299–301
  - NX-API
    - authentication*, 136–138
    - automation tools*, 151
    - CLI mode*, 129–130
    - DevOps tools*, 151
    - event subscription*, 143–146
    - IP address configuration*, 130–131
    - message format*, 126
    - NX-API REST*, 131–136
    - NXTool Kit*, 146–151
    - object modification via Postman*, 138–140
    - object modification via Python*, 140–143
    - overview*, 125
    - sandbox*, 127–129
    - security*, 126
    - transport*, 125–126
    - Visore*, 134–136
  - Open Weather Map API, 40–43
  - Postman, 292–293, 294–296
  - Python, 37
  - Ticket API
    - Postman*, 288–291
    - Python script*, 297–299
- applets (EEM), 246–251
- Application Centric Infrastructure (ACI). *See* Cisco ACI (Application Centric Infrastructure)
- application leaf engine (ALE), 67
- application network profiles (ANPs), 72
- application policy infrastructure controller enterprise module. *See* APIC-EM (application policy infrastructure controller enterprise module)
- application programming interfaces. *See* APIs (application programming interfaces)
- Application Spine Engine (ASE), 67

## **Application-Centric Infrastructure (ACI)**

EPGs (end point groups), 72–73

overview, 70–72

policy instantiation, 73–74

**application-level health scores, 174**

## **applications**

installing

*in Guestshell, 110*

*on Linux, 64–65*

open-source applications, 64

**Apt, 65**

## **architecture**

Cisco ACI (Application Centric Infrastructure), 169

Cisco data center, 76–80

Linux, 58

NDB (Nexus Data Broker), 74–76

**arithmetic (Bash), 90–91**

**Arya (APIC REST Python Adapter)**

AryaLogger, 207–208

installing, 207–208

WebArya, 211

**AryaLogger**

installing, 207–208

program example, 207–208

**ASE (Application Spine Engine), 67**

**ASICs, 67–68**

**ASP (AutoSmart Ports)**

availability, 216

device-specific macros and descriptions, 217

enabling on Cisco Catalyst Switch, 217–219

overview, 216–217

website, 220

**asterisk (\*), 32**

**atomic mode (ACI API), 174–175**

**audit trailing (ConfD), 262**

## **authentication**

APIC RESTful API

*authentication methods, 185–186*

*overview, 182–186*

*with Python, 186–188*

APIC-EM authentication

*Host API, 291–292, 299–301*

*Ticket API, 288–291, 297–299*

Cobra SDK, 201

NX-API, 136–138

**auto qos global compact command, 231, 233**

**auto qos voip cisco-phone command, 233**

## **Auto Security**

availability, 230

enabling on Cisco Catalyst Switch, 228–230

overview, 227–228

## **AutoConf**

availability, 220

enabling on Cisco Catalyst Switch, 222–224

interface templates and descriptions, 220–222

template modification, 224–227

website, 227

**autoconf enable command, 222**

## **automated management and monitoring**

EEM (Embedded Event Manager)

*EEM applets, 246–251*

*email variables, 251*

*overview, 246*

*summary, 253*

- Tcl scripts*, 251–252
- website*, 253
- Smart Call Home
  - enabling on Cisco Catalyst Switch*, 237–243
  - overview*, 236–237
  - website*, 239, 243
- Tcl Shell, 243–246
- automated port profiling**
  - ASP (AutoSmart Ports)
    - device-specific macros and descriptions*, 217
    - enabling on Cisco Catalyst Switch*, 217–219
    - overview*, 216–217
    - website*, 220
  - Auto Security
    - availability*, 230
    - enabling on Cisco Catalyst Switch*, 228–230
    - overview*, 227–228
  - AutoConf
    - availability*, 220
    - enabling on Cisco Catalyst Switch*, 222–224
    - interface templates and descriptions*, 220–222
    - template modification*, 224–227
    - website*, 227
  - AutoSmart Ports, 216
    - overview*, 216
- automation tools. See also Cisco**
  - ACI (Application Centric Infrastructure); off-box programmability (NX-OS); on-box programmability (NX-OS)**
  - Ansible
    - Nexus 9000*, 157–158
    - overview*, 156–157
  - APIC-EM (application policy infrastructure controller enterprise module)
    - APIC-EM Plug and Play (PnP)*, 269–278
    - authentication via Python*, 297–301
    - Device Inventory application*, 281–282
    - Dynamic QoS (Quality of Service)*, 285–286
    - Easy QoS (Quality of Service)*, 283–285
    - IWAN (Intelligent WAN)*, 264–269
    - network devices, listing*, 292–293
    - overview*, 263
    - Path Trace application*, 276–278
    - Policy application*, 286–287
    - Postman APIs*, 288–296
    - Topology application*, 279–281
    - users, viewing*, 292–293
  - ASP (AutoSmart Ports)
    - device-specific macros and descriptions*, 217
    - enabling on Cisco Catalyst Switch*, 217–219
    - overview*, 216–217
    - website*, 220
  - Auto Security
    - availability*, 230
    - enabling on Cisco Catalyst Switch*, 228–230
    - overview*, 227–228
  - AutoConf
    - availability*, 220
    - enabling on Cisco Catalyst Switch*, 222–224

- interface templates and descriptions, 220–222*
  - template modification, 224–227*
  - website, 227*
  - automation example, 11
  - AutoQoS on LAN devices
    - enabling on Cisco Catalyst Switch, 231–233*
    - overview, 230–231*
  - AutoQoS on WAN devices
    - enabling on Cisco ISR routers, 234–236*
    - overview, 233–234*
  - AutoSmart Ports, 216
  - ConfD, 259–263
  - DevOps, 304
  - EEM (Embedded Event Manager)
    - EEM applets, 246–251*
    - email variables, 251*
    - overview, 246*
    - summary, 253*
    - Tcl scripts, 251–252*
    - website, 253*
  - importance of, 303
  - NETCONF (network configuration protocol), 258–259
  - NX-OS support for, 151
  - overview, 255–256
  - Puppet
    - ciscopuppet, 154–156*
    - Nexus 9000, 154–157*
    - overview, 152–153*
  - Smart Call Home
    - enabling on Cisco Catalyst Switch, 237–243*
    - overview, 236–237*
    - website, 239, 243*
  - Tcl Shell, 243–246
    - when to use, 10
  - YANG (yet another next generation)
    - data models, 256–258
  - automation versus orchestration, 6
  - AutoSmart Ports. *See* ASP (AutoSmart Ports)
  - Awk, 98–99
- ## B
- 
- backslash (\), 90
  - bandwidth allocation, 285
  - Bash scripts
    - arithmetic, 90–91
    - Awk, 98–99
    - commands
      - boot\_config.sh, 106*
      - chkconfig, 105–106*
      - man, 99–100*
    - conditions, 91–94
    - ethtool, 103
    - flow control, 91–94
    - ifconfig, 101
    - loops, 93–94
    - Nexus 9000, 99–100
    - NTP server configuration, 106
    - operators, 91–92
    - overview, 56, 88–89
    - redirection, 94–96
    - running at startup, 103–106
    - Sed text editor, 96–98
    - tcpdump, 101–103
    - variables, 89–90
  - BGP configuration with NXTool Kit, 148–151
  - /bin directory, 64

boot, configuring NTP servers at, 106  
 /boot directory, 64  
 boot order pxe bootflash  
 command, 88  
 boot\_config.sh command, 106  
 /bootflash directory, 118  
 BPDUs (bridge protocol data  
 units), 78  
 bridge protocol data units  
 (BPDUs), 78  
 Broadcom, NFE (network forwarding  
 engine), 67  
 browsers, Visore, 134–136  
 BUM traffic, 80

## C

---

call-home command, 239–241  
 call-home send alert-group inventory  
 profile CiscoTAC-1 command,  
 242–243  
 calling functions, 29  
 calls (Postman), creating, 189–191  
 campus environments, automation  
 tools for  
 APIC-EM (application policy  
 infrastructure controller  
 enterprise module)  
*APIC-EM Plug and Play (PnP)*,  
 269–278  
*authentication via Python*,  
 297–301  
*Device Inventory application*,  
 281–282  
*Dynamic QoS (Quality of  
 Service)*, 285–286  
*Easy QoS (Quality of Service)*,  
 283–285  
*IWAN (Intelligent WAN)*,  
 264–269  
*network devices, listing*,  
 292–293  
*overview*, 263  
*Path Trace application*,  
 276–278  
*Policy application*, 286–287  
*Postman APIs*, 288–296  
*Topology application*,  
 279–281  
*users, viewing*, 292–293  
 ConfD, 259–263  
 NETCONF (network configuration  
 protocol), 258–259  
 overview, 255–256  
 YANG (yet another next generation)  
 data models, 256–258  
 capturing IP packet headers,  
 101–103  
 caret (^), 32  
 case sensitivity (Cisco ACI API), 177  
 case statement, 92–93  
 cat command, 57  
 catalogs, Cisco Prime Service  
 Catalog, 213  
 Catalyst Switch. *See* Cisco  
 Catalyst Switch, enabling  
 automation tools on  
 cd command, 57  
 CDB Database (ConfD), 261  
 cdp\_neighbor.py, 121–123  
 changing dictionary data, 28  
 Chef, 151  
 chkconfig, 105–106  
 chmod command, 29, 57, 64  
 chown command, 57  
 chvrf command, 109  
 CI/CD (continuous integration/  
 continuous deployment), 2

**Cisco ACI (Application Centric Infrastructure)**

advantages of, 304

APIC RESTful API

*API inspector, 179–182*

*APIC automation with UCS Director, 211*

*APIC configuration automation, 188–191*

*atomic mode, 174–175*

*authentication, 185–188*

*components, 175–176*

*event subscription, 196–198*

*forgiving mode, 174–175*

*GUI, 178*

*invoking, 176–178*

*object save-as, 178–179*

*programmability, 192–196*

*read operations, 176*

*Visore, 182–185*

*write operations, 177*

architecture, 169

automation, 160–161

Cobra SDK

*Arya (APIC REST Python Adapter), 207–211*

*authentication, 201*

*documentation, 198*

*installing, 199–200*

*libraries, 200–201*

*modules, 200*

*objects, 202–204*

*tenant configuration example, 204–207*

EPGs (end point groups), 72–73

event subscription, 196–198

management information model

*fault lifecycle, 171–173*

*fault severity, 173–174*

*health scores, 174*

*MIT (management information tree), 169–170*

*MOs (managed objects), 169–170*

*object names, 170*

overview, 8–9, 70–72, 81, 159

policy instantiation, 73–74, 161–162

Python exception handling

*definition of, 162*

*examples, 166–168*

*virtual environments, 163–165*

*virtualenv installation, 162–163*

**Cisco APIC Python SDK (Cobra)**

Arya (APIC REST Python Adapter)

*installing, 207–211*

*WebArya, 211*

authentication, 201

documentation, 198

installing, 199–200

libraries, 200–201

modules, 200

objects, 202–204

tenant configuration example, 204–207

**Cisco Application Spine Engine (ASE), 67****Cisco Auto Security**

availability, 230

enabling on Cisco Catalyst Switch, 228–230

overview, 227–228

**Cisco Catalyst Switch, enabling automation tools on**

- ASP (AutoSmart Ports), 217–219
- Auto Security, 228–230
- AutoConf, 222–224
- AutoQoS on LAN devices, 231–233
- Smart Call Home, 237–243
- Cisco Data Center (GitHub), 123, 207**
- Cisco data center networking**
  - ACI (Application Centric Infrastructure). *See* Cisco ACI (Application Centric Infrastructure)
  - Cisco Nexus Fabric Manager, 80–81
  - Cisco VTS (Virtual Topology System), 81
  - network architecture, 76–80
  - Nexus 9000, 67–70
  - Nexus Data Broker (NDB)
    - architecture*, 74–76
    - RESTful API*, 75
    - use case*, 75–76
  - NX-OS. *See* Cisco Nexus NX-OS
- Cisco DevNet**
  - APIC-EM sandbox, 288
  - website, 204
- Cisco Ignite, 87–88**
- Cisco ISR routers, enabling AutoQoS on, 234–236**
- Cisco IWAN (Intelligent WAN), 264–269**
- Cisco Merchant + strategy, 67**
- Cisco Netflow Generation Appliance, 75**
- Cisco Nexus Fabric Manager, 80–81**
- Cisco Nexus NX-OS**
  - Ansible
    - Nexus 9000*, 157–158
    - overview*, 156–157
  - Bash scripts
    - arithmetic*, 90–91
    - Awk*, 98–99
    - conditions*, 91–94
    - ethtool*, 103
    - flow control*, 91–94
    - ifconfig*, 101
    - loops*, 93–94
    - Nexus 9000*, 99–100
    - NTP server configuration*, 106
    - operators*, 91–92
    - overview*, 88–89
    - redirection*, 94–96
    - running at startup*, 103–106
    - Sed text editor*, 96–98
    - tcpdump*, 101–103
    - variables*, 89–90
  - Cisco Ignite, 87–88
  - Cisco libraries, importing, 113–115
  - EEM (Embedded Event Manager)
    - actions*, 112–113
    - leveraging Python scripts from*, 121–123
    - neighbor discovery*, 121–123
    - system events*, 112
    - variables*, 113
  - Guestshell
    - application installation*, 110
    - network access*, 109–110
    - NMap installation*, 111
    - overview*, 108–109
    - Puppet agent installation*, 111
  - iPXE, 88
  - LXC (Linux Containers), 106–107
  - NDB (Nexus Data Broker), 111–112
  - NX-API
    - authentication*, 136–138

- automation tools*, 151
- CLI mode*, 129–130
- DevOps tools*, 151
- event subscription*, 143–146
- IP address configuration*, 129–130
- message format*, 126
- NX-API REST*, 131–136
- NXTool Kit*, 146–151
- object modification via Postman*, 138–140
- object modification via Python*, 140–143
- overview*, 125
- sandbox*, 127–129
- security*, 126
- transport*, 125–126
- Visore*, 134–136
- overview, 69, 83
- POAP (power-on auto provisioning), 83–87
- Puppet
  - Nexus 9000*, 154–157
  - overview*, 152–153
- Python scripts
  - Cisco Python package*, 116–117
  - CLI APIs*, 115–116
  - leveraging from EEM syslog event*, 121–123
  - non-interactive Python*, 118
  - Reload\_in Pseudocode*, 118–121
- Cisco POAP (power-on auto provisioning), 83–87
- Cisco Prime Service Catalog, 213
- Cisco Python package, 116–117
- Cisco Smart Call Home
  - enabling on Cisco Catalyst Switch, 237–243
  - overview, 236–237
  - website, 239, 243
- Cisco Smart Install (SMI) Proxy, 271
- Cisco Switched Port Analyzer (SPAN), 74
- Cisco UCS (Unified Computing System) Manager, 7
- Cisco Validated Designs (CVDs), 266
- Cisco VTS (Virtual Topology System), 81
- ciscopuppet
  - documentation, 156
  - installing, 154
  - NX-OS configurations, 155–156
  - verifying, 154
- cisco.vrf module, 116–117
- clear command, 57
- cleared faults, 174
- cli(), 115
- CLI APIs, 115–116
- CLI mode (NX-API), 129–130
- `$_cli_result` keyword, 247
- clid(), 115
- clip(), 115
- Cliqr, 7
- cloning Git repositories, 44–47
- cloud operational models
  - network programmability, 304
  - overview, 6–8
- cmd dictionary value, 129
- Cobra SDK
  - Arya (APIC REST Python Adapter)
    - installing*, 207–211
    - WebArya*, 211
  - authentication, 201

- documentation, 198
  - installing, 199–200
  - libraries, 200–201
  - modules, 200
  - objects, 202–204
  - tenant configuration example, 204–207
  - cobra.mit library, 201**
  - cobra.model library, 201**
  - collections, 188
  - comments (Python), 29
  - committing files to GitHub, 48
  - concatenating strings, 23
  - conditions
    - Bash scripting, 91–94
    - explained, 17
    - Python conditions, 24–25
  - conf command, 130**
  - ConfD, 259–263**
  - config false command, 258**
  - ConfigRequest(), 202**
  - configuration**
    - ACI tenant configuration with Cobra, 204–207
    - APIC configuration automation, 188–191
    - BGP configuration with NXTool Kit, 148–151
    - IP addresses, 130–131
    - NTP server, 106
    - POAP (power-on auto provisioning), 83–87
    - Puppet, 155
  - Configuration Upload page (APIC-EM PnP), 275**
  - configure terminal command, 218, 247**
  - consumption model (DevOps), 304**
  - continuous integration/continuous deployment (CI/CD), 2**
  - converting variables to strings, 23**
  - cookies, nxapi\_auth, 126, 136–138**
  - Core Engine (ConfD), 261**
  - cp command, 57**
  - critical faults, 173**
  - custom tags, 170**
  - customized virtual environments, 163**
  - CVDs (Cisco Validated Designs), 266**
- ## D
- 
- DAI (Dynamic ARP inspection), 227–228**
  - dashboard (APIC-EM PnP), 271–272**
  - data center networking. *See* Nexus data center networking**
  - data management engine (DME), 133, 174**
  - data models, YANG (yet another next generation), 256–258**
  - Data Provider API, 261**
  - data types, 15–16, 27–28**
  - data-encoding formats**
    - JSON (Javascript Object Notation), 39–45
    - XML (Extensible Markup Language), 38–39
  - datetime library, 30, 35–36**
  - deactivate command, 163–164**
  - debug event manager action cli command, 239–241, 247**
  - debug event manager action mail command, 249**
  - debug event manager all command, 249**

**debugging**

HTML APIC GUI, 178

PyCharm, 54–55

**deep packet inspection (DPI) tool, 4****def keyword, 29****defining**

functions, 29

variables, 15–16

**DELETE method, 37****development. *See* software development****Device History (APIC-EM PnP), 273****Device Inventory application (APIC-EM), 281–282****DevNet**

APIC-EM sandbox, 288

website, 66

**DevOps**

network consumption model, 304

NX-OS support for, 151

**df command, 57****DHCP (Dynamic Host Configuration Protocol)**

DHCP Snooping, 227

POAP configuration, 84–85

**dictionaries, 28****dir command, 147–148****directories**

/bin, 64

/boot, 64

/bootflash, 118

/etc, 64

/etc/passwd, 57

/home, 64

overview, 64, 118

/sbin, 64

/usr, 64

/var/log, 64

**discovery**

EEM (Embedded Event Manager), 121–123

MOs (managed objects), 178

**displaying**

APIC-EM users, 294–296

Linux processes, 59–61

**distinguished names (DNs), 133, 170****DME (data management engine), 133, 174****DMP\_INTERFACE\_TEMPLATE, 220****DNs (distinguished names), 133, 170****documentation**

ciscopuppet, 156

Cobra SDK, 198

man documentation, 99

NFM (Nexus Fabric Manager), 82

Python, 24

VTS (Virtual Topology System), 82

**dohost command, 109****dollar sign (\$), 32****downloading Git, 45****DPI (deep packet inspection) tool, 4****Dynamic ARP inspection (DAI), 227–228****Dynamic Host Configuration Protocol. *See* DHCP (Dynamic Host Configuration Protocol)****Dynamic QoS (Quality of Service), 285–286**

---

**E****Easy QoS (Quality of Service), 283–285****ECMP (Equal Cost Multiple Path), 77**

**editing**

JSON editor, 178

source code, 49–50

text in Bash

*Awk*, 98–99

*Sed text editor*, 96–98

**editors**

JSON editor, 178, 191

Sed, 96–98

**EEM (Embedded Event Manager)**

actions, 112–113

EEM applets, 246–251

email variables, 251

leveraging Python scripts from,  
121–123

neighbor discovery, 121–123

overview, 246

summary, 253

system events, 112

Tcl scripts, 251–252

variables, 113

website, 253

**.egg files, 198****else statements**

overview, 17

Python, 24–25

**email variables (EEM), 251****Embedded Event Manager. *See* EEM (Embedded Event Manager)****enable command**

Auto Security, 228

AutoConf, 224

AutoSmart Ports, 217

EEM applets, 247

**enabling**

ASP (AutoSmart Ports), 217–219

Auto Security, 228–230

AutoConf, 222–224

AutoQoS on LAN devices, 231–233

AutoQoS on WAN devices, 234–236

Smart Call Home, 237–243

**end point groups (EPGs)**

assigning interfaces to, 193–196

definition of, 72–74, 161–162

**environments. *See* campus**

**environments, automation tools  
for; virtual environments**

**EPGs (end point groups)**

assigning interfaces to, 193–196

definition of, 72–74, 161–162

**eq operator, 91****Equal Cost Multiple Path (ECMP), 77****equal sign (=), 92****errors. *See* exception handling**

*/etc* directory, 64

*/etc/passwd* file, 57

**Ethernet VPNs (EVPNs), 80–81****ethtool, 103**

event manager run command,  
251–252

event manager session cli username  
command, 247

event none command, 251–252

**events**

Cisco ACI event subscription,  
196–198

EEM (Embedded Event  
Manager), 112

NX-API event subscription,  
143–146

**eVPN, 80****EVPNs (Ethernet VPNs), 80–81****exception handling**

definition of, 162

examples, 166–168

- virtual environments, 163–165
- virtualenv installation, 162–163
- exiting virtual environments, 163–164
- expressions, regular
  - Python, 31–37
  - Sed support for, 96
- Extensible Markup Language (XML), 38–39

## F

---

- Fabric Manager, 80–81
- faults
  - lifecycle, 171–173
  - severity, 173–174
  - states, 172–173
- fields (Path Trace), 277
- FIFO (first-in, first-out), 176
- file prompt quiet command, 250
- file system, 63–64
- files
  - .egg files, 198
  - adding to GitHub, 47–48
  - .py files, 29
  - Python files, 29
- filters, tcpdump, 102
- find method, 22
- first-in, first-out (FIFO), 176
- flow control
  - Bash scripting, 91–94
  - conditions
    - explained*, 17
    - Python conditions*, 24–25
  - loops
    - explained*, 18
    - Python loops*, 25–28

- forgiving mode (ACI API), 174–175
- formatted data. *See* data-encoding formats
- formatting tools (JSON), 178, 191
- freezing virtual environments, 164–165
- functions
  - calling, 29
  - defining, 29
  - overview, 18–19, 28–29

## G

---

- gateways, transport, 236–237
- General Public License (GPL), 56
- GET method, 37
- Git
  - commands, 49
  - downloading, 45
  - files, adding to repositories, 47–48
  - overview, 45
  - resources, 49
  - git add command, 47–48, 49
  - git clone command, 44–47, 49
  - git commit command, 48, 49
  - git pull command, 49
  - git push command, 48, 49
  - git status command, 47
- GitHub
  - Cisco Data Center page, 123, 207
  - overview, 45
  - repository creation, 45–47
  - repository updates, 47–48
  - resources, 49
- Google Postman, 40–43
- GPL (General Public License), 56
- grep command, 57

gt operator, 91

## Guestshell

application installation, 110

network access, 109–110

NMap installation, 111

overview, 108–109

Puppet agent installation, 111

GUI (APIC), 178

## H

---

handling exceptions. *See* exception handling

hashes, 17

health scores, 174

hello\_world (Bash), 104–105

## help

help command, 147–148

help method, 23

Linux, 65–66

Python, 23–24, 116–117

help command, 147–148

help method, 23

/home directory, 64

\$HOME variable, 89

## Host API

Postman API, 291–292

Python script, 299–301

human language versus machine language, 8–9

## I

---

IaaS (infrastructure as a service), 6–7

## if statements

Bash scripting, 91–92

if-else, 17, 24–25

if-then, 246–247

overview, 17

Python, 24–25

ifconfig, 101

if-else statements, 17, 24–25

if-then statements, 246–247

Ignite, 87–88

import command, 30

## imports

Cisco libraries, 113–115

Cobra SDK libraries, 200–201

NXTool Kit, 146

Python libraries, 30

info faults, 174

information technology as a service (ITaaS), 213

infrastructure as a service (IaaS), 6–7

innovation (network), 4–6

## installation

applications

*in Guestshell, 110*

*on Linux, 64–65*

Arya (APIC REST Python Adapter), 207–208

AryaLogger, 207–208

ciscopuppet, 154

Cobra SDK, 200

libraries into virtual environments, 164

NDB (Nexus Data Broker), 111–112

NMap in Guestshell, 111

NXTool Kit, 146

Puppet agents in Guestshell, 111

Python, 20

Python libraries, 30–31

virtualenv, 162–163

**instantiation**

ACI (Application Centric Infrastructure) policy, 73–74, 161–162

objects, 20

Intelligent WAN (IWAN), 264–269

interface command, 130

interface status, checking, 101

**interfaces**

assigning to EPGs (end point groups), 193–196

AutoConf interface templates, 220–222

invoking APIC RESTful API, 176–178

IP address configuration, 130–131

IP packet headers, capturing, 101–103

IP phone port profiling. *See* port profiling

IP\_CAMERA\_INTERFACE\_TEMPLATE, 220

IP\_PHONE\_INTERFACE\_TEMPLATE, 220

iPXE, 88

ISR routers, enabling AutoQoS on, 234–236

ITaaS (information technology as a service), 213

IWAN (Intelligent WAN), 264–269

**J**

---

Javascript Object Notation. *See* JSON (Javascript Object Notation)

JSON (Javascript Object Notation)

formatting tools, 178, 191

JSON-RPC, 126

overview, 39–45

json library, 30, 44–45

jsoneditoronline.org, 139

**K**

---

keywords. *See also* statements

\$\_cli\_result, 247

def, 29

kill command, 57

**L**

---

L2-based network architecture, 77–79

LANs, AutoQoS on LAN devices

enabling on Cisco Catalyst Switch, 231–233

overview, 230–231

LAP\_INTERFACE\_TEMPLATE, 220

layer 2-based network architecture, 77–79

Lean IT, 303

less command, 57

**libraries**

Cisco libraries, importing, 113–115

Cobra SDK, 200–201

installing into virtual environments, 164

Python libraries

*datetime*, 35–36

*importing*, 30

*installing*, 30–31

*json*, 44–45

*requests*, 43–44

*sys*, 34–35

lifecycle of faults, 171–173

**Linux**

architecture, 58

bash, 56

commands

- chmod*, 64
  - command summary*, 56–58
  - ls*, 63
  - systemd*, 61–62
  - top*, 61
  - directories, 64
  - file system, 63–64
  - GPL (General Public License), 56
  - help, 65–66
  - installing applications on, 64–65
  - LXC (LinuX Containers), 62
  - overview, 55–56
  - permissions, 63–64
  - processes, displaying, 59–61
  - ps tool, 59
  - resources, 65–66
  - systemd, 61–62
  - yum tool, 65
  - LinuX Containers (LXC)**, 62, 106–107. *See also* Guestshell
  - list command**, 107
  - lists**
    - list command, 107
    - overview, 16
    - in Python, 27
  - lookupByClass method**, 202–203
  - lookupByDN method**, 202–204
  - for loops**
    - Bash scripting, 93
    - overview, 18
    - in Python, 25–26
  - loops**
    - Bash scripting, 93–94
    - explained, 18, 93–94
    - looping through dictionaries, 28
    - for loops
      - Bash scripting*, 93
      - overview*, 18
      - Python loops*, 25–26
    - while loops
      - Bash scripting*, 94
      - overview*, 18
      - Python loops*, 26–27
  - ls command**, 57, 63
  - lt operator**, 91
  - LXC (LinuX Containers)**, 62, 106–107. *See also* Guestshell
- ## M
- 
- M2M (machine-to-machine interactions)**, 9–10
  - machine language versus human language**, 8–9
  - machine-to-machine interactions (M2M)**, 9–10
  - MACs (moves, additions, and changes)**, 216
  - major faults**, 173
  - man command**, 57, 99
  - man documentation**, 99
  - Managed Object API**, 261
  - Managed Object module (Cobra SDK)**, 200
  - managed objects (MOs)**
    - Cobra SDK Managed Object module, 200
    - definition of, 133, 169–170
    - discovering, 178
    - health scores, 174
    - Managed Object API, 261
  - management information model (Cisco ACI)**
    - fault lifecycle, 171–173

- fault severity, 173–174
- health scores, 174
- MIT (management information tree), 169–170
- MOs (managed objects), 169–170
- object names, 170
- management information tree (MIT), 169–170**
- management tasks**
  - EEM (Embedded Event Manager)
    - EEM applets, 246–251*
    - email variables, 251*
    - overview, 246*
    - summary, 253*
    - Tcl scripts, 251–252*
    - website, 253*
  - Smart Call Home
    - enabling on Cisco Catalyst Switch, 237–243*
    - overview, 236–237, 243*
    - website, 239*
  - Tcl Shell, 243–246
- MD5 hash, 86**
- Merchant + strategy (Cisco), 67**
- message format (NX-API), 125–126**
- methods**
  - aaaLogin, 185
  - aaaLogout, 186
  - aaaRefresh, 185
  - APIC authentication methods, 185–186
  - ConfigRequest(), 202
  - find, 22
  - help, 23
  - lookupByClass, 202–203
  - lookupByDN, 202–204
  - re.findall, 32
  - re.match, 33
  - re.search, 33–34
  - re.sub, 34
  - split, 22
- minor faults, 173**
- MIT (management information tree), 169–170**
- mkdir command, 57**
- models, YANG (yet another next generation), 256–258**
- modification**
  - NX-API objects
    - via Postman, 138–140*
    - via Python, 140–143*
- modifying AutoConf templates, 224–227**
- modules (Cobra SDK), 200**
- monitoring tasks**
  - EEM (Embedded Event Manager)
    - EEM applets, 246–251*
    - email variables, 251*
    - overview, 246*
    - summary, 253*
    - Tcl scripts, 251–252*
    - website, 253*
  - Smart Call Home
    - enabling on Cisco Catalyst Switch, 237–243*
    - overview, 236–237*
    - website, 239, 243*
  - Tcl Shell, 243–246
- more command, 252**
- MOs (managed objects)**
  - Cobra SDK Managed Object module, 200

definition of, 133, 169–170  
 discovering, 178  
 health scores, 174  
 Managed Object API, 261  
 moves, additions, and changes (MACs), 216  
**MSP\_CAMERA\_INTERFACE\_TEMPLATE**, 220  
**MSP\_VC\_INTERFACE\_TEMPLATE**, 220  
 mutability of data in Python, 27  
 mv command, 57

## N

---

**names**  
 object names, 170  
 variables, 15–16  
**Naming module (Cobra SDK)**, 200  
**NDB (Nexus Data Broker)**  
 architecture, 74–76  
 overview, 111–112  
 RESTful API, 75  
 use case, 75–76  
**ne operator**, 91  
**neighbor discovery (EEM)**, 121–123  
**NETCONF (network configuration protocol)**, 258–259  
**Netflow Generation Appliance**, 75  
**network automation tools**  
 APIC-EM (application policy infrastructure controller enterprise module)  
*APIC-EM Plug and Play (PnP)*, 269–278  
*authentication via Python*, 297–301  
*Device Inventory application*, 281–282

*Dynamic QoS (Quality of Service)*, 285–286  
*Easy QoS (Quality of Service)*, 283–285  
*IWAN (Intelligent WAN)*, 264–269  
*network devices, listing*, 292–293  
*overview*, 263  
*Path Trace application*, 276–278  
*Policy application*, 286–287  
*Postman APIs*, 288–296  
*Topology application*, 279–281  
*users, viewing*, 292–293  
 automation example, 11  
 ConfD, 259–263  
 DevOps, 304  
 importance of, 303  
 NETCONF (network configuration protocol), 258–259  
 overview, 255–256  
 when to use, 10  
 YANG (yet another next generation) data models, 256–258  
**network configuration protocol (NETCONF)**, 258–259  
**network consumption model (DevOps)**, 304  
**network controllers. *See also***  
 Cisco ACI (Application Centric Infrastructure)  
 Cisco Nexus Fabric Manager, 80–81  
 Cisco VTS (Virtual Topology System), 81  
**Network Device API**, 292–293  
**network devices (APIC-EM)**, listing, 292–293  
**network engineers, skill set needed by**, 303–304

**network forwarding engine (NFE), 67**

**network innovation, 4–6**

**network programmability**

automation tools. *See* network automation tools

benefits of

*network innovation, 4–6*

*simplified networking, 4*

Cisco ACI (Application Centric Infrastructure). *See* Cisco ACI (Application Centric Infrastructure)

cloud operational models, 6–8, 304

definition of, 3

importance of, 303–305

off-box programmability (NX-OS). *See* off-box programmability (NX-OS)

on-box automation tools. *See* on-box programmability (NX-OS)

origin of, 9–10

overview, 1–2

SDN (software-defined networking), 8–9

**network programmability user group (NPUG), 66**

**Nexus 9000**

Ansible, 157–158

Bash scripting, 99–100

network architecture, 76–80

overview, 67–70

Puppet, 154–157

**Nexus 9200K, 68**

**Nexus 9300EX, 68**

**Nexus Data Broker (NDB)**

architecture, 74–76

overview, 111–112

RESTful API, 75

use case, 75–76

**Nexus data center networking.**

*See also* Cisco ACI (Application Centric Infrastructure)

Cisco Nexus Fabric Manager, 80–81

Cisco VTS (Virtual Topology System), 81

network architecture, 76–80

Nexus 9000, 67–70

Nexus Data Broker (NDB)

*architecture, 74–76*

*RESTful API, 75*

*use case, 75–76*

NX-OS. *See* Cisco Nexus NX-OS

**Nexus Fabric Manager, 80–81**

**Nexus NX-OS. *See* Cisco Nexus NX-OS**

**NFE (network forwarding engine), 67**

**NFM (Nexus Fabric Manager), 80–81**

**NMap agent installation, 111**

**no shutdown command, 247**

**non-interactive Python, 118**

**NPUG (network programmability user group), 66**

**NTP server configuration, 106**

**NX-API**

Ansible, 156–157

authentication, 136–138

automation tools, 151

CLI mode, 129–130

DevOps tools, 151

event subscription, 143–146

IP address configuration, 129–130

message format, 126

NX-API REST

*CLI versus object model, 131–132*

*logical hierarchy, 132–133*

*overview, 131–136*

**NXTool Kit***BGP configuration, 148–151**importing, 146**installing, 146**usage example, 146–148*object modification via Postman,  
138–140object modification via Python,  
140–143

overview, 69, 125

sandbox, 127–129

security, 126

transport, 125–126

Visore, 134–136

**NX-API REST**

CLI versus object model, 131–132

logical hierarchy, 132–133

overview, 131–136

**nxapi\_auth cookie, 126, 136–138****NX-OS. See Cisco Nexus NX-OS****NXTool Kit***BGP configuration, 148–151**importing, 146**installing, 146**usage example, 146–148***O**

---

**Object Identifiers (OIDs), 258****object modification (NX-API)**

via Postman, 138–140

via Python, 140–143

**object save-as (APIC), 178–179****object store browser (APIC),  
182–185****object-oriented data models**

CLI versus object model, 131–132

logical hierarchy, 132–133

overview, 131–136

**objects**

Cobra SDK, 202–204

instantiating, 20

MOs (managed objects)

*definition of, 133, 169–170**discovering, 178**health scores, 174*

names, 170

overview, 19–20

**off-box programmability (NX-OS)**

Ansible

*Nexus 9000, 157–158**overview, 156–157*

definition of, 125

NX-API

*authentication, 136–138**automation tools, 151**CLI mode, 129–130**DevOps tools, 151**event subscription, 143–146**IP address configuration,  
129–130**message format, 126**NX-API REST, 131–136**NXTool Kit, 146–151**object modification via  
Postman, 138–140**object modification via Python,  
140–143**overview, 125**sandbox, 127–129**security, 126**transport, 125–126**Visore, 134–136*

Puppet, 152–157

**OIDs (Object Identifiers), 258****on-box automation tools**

## ASP (AutoSmart Ports)

*device-specific macros and descriptions, 217*

*enabling on Cisco Catalyst Switch, 217–219*

*overview, 216–217*

*website, 220*

## Auto Security

*availability, 230*

*enabling on Cisco Catalyst Switch, 228–230*

*overview, 227–228*

## AutoConf

*availability, 220*

*enabling on Cisco Catalyst Switch, 222–224*

*interface templates and descriptions, 220–222*

*template modification, 224–227*

*website, 227*

## AutoQoS on LAN devices

*enabling on Cisco Catalyst Switch, 231–233*

*overview, 230–231*

## AutoQoS on WAN devices

*enabling on Cisco ISR routers, 234–236*

*overview, 233–234*

## AutoSmart Ports, 216

## EEM (Embedded Event Manager)

*EEM applets, 246–251*

*email variables, 251*

*overview, 246*

*summary, 253*

*Tcl scripts, 251–252*

*website, 253*

*overview, 215*

## Smart Call Home

*enabling on Cisco Catalyst Switch, 237–243*

*overview, 236–237*

*website, 239, 243*

## Tcl Shell, 243–246

**on-box programmability (NX-OS)**

## Bash scripts

*arithmetic, 90–91*

*Awk, 98–99*

*conditions, 91–94*

*ethtool, 103*

*flow control, 91–94*

*ifconfig, 101*

*loops, 93–94*

*Nexus 9000, 99–100*

*NTP server configuration, 106*

*operators, 91–92*

*overview, 88–89*

*redirection, 94–96*

*running at startup, 103–106*

*Sed text editor, 96–98*

*tcpdump, 101–103*

*variables, 89–90*

## Cisco Ignite, 87–88

## EEM (Embedded Event Manager)

*actions, 112–113*

*leveraging Python scripts from, 121–123*

*neighbor discovery, 121–123*

*system events, 112*

*variables, 113*

## Guestshell

*application installation, 110*

*network access, 109–110*

*NMap installation, 111*

- overview, 108–109*
  - Puppet agent installation, 111*
  - iPXE, 88
  - LXC (LinuX Containers), 106–107
  - NDB (Nexus Data Broker), 111–112
  - overview, 83
  - POAP (power-on auto provisioning), 83–87
  - Python scripts
    - Cisco libraries, importing, 113–115*
    - Cisco Python package, 116–117*
    - CLI APIs, 115–116*
    - leveraging from EEM syslog event, 121–123*
    - non-interactive Python, 118*
    - Reload\_in Pseudocode, 118–121*
  - online resources
    - ciscopuppet, 156
    - Git, 49
    - Linux, 65–66
    - Python, 36–37
  - Open NX-OS, 6
  - Open Weather Map API example, 40–43
  - open-source applications, 64
  - operators
    - Bash, 91–92
    - Python, 25
  - orchestration, 6
  - os library, 30
- ## P
- 
- package management tool. *See* PIP (package management tool)
  - packets
    - IP packet headers, capturing, 101–103
    - VXLAN packets, 79–80
  - Path Trace application (APIC-EM), 276–278
  - path traces, 276–278
  - \$PATH variable, 89
  - Pending status information page (APIC-EM PnP), 274
  - per-hop behaviors (PHBs), 285
  - period (.), 32, 33
  - permissions (Linux), 63–64
  - PHBs (per-hop behaviors), 285
  - pings, aborting, 245
  - PIP (package management tool)
    - overview, 30–31
    - virtual environments
      - freezing, 164–165*
      - installing, 164*
      - recreating, 165*
      - sharing, 165*
  - pip freeze command, 165
  - pip install command, 31, 165, 208
  - pip list command, 165
  - pip search command, 31
  - pip show command, 31
  - platform as a service (PaaS), 6–7
  - Plug and Play (PnP)
    - APIC-EM Plug and Play (PnP)
      - Configuration Upload page, 275*
      - dashboard, 271–272*
      - overview, 269–271, 269–278*

PaaS (platform as a service), 6–7

- Pending status information page, 274*
- project details, 272–273*
- Software Images tab, 274–275*
- Unplanned Devices screen, 275–276*
- Device History, 273
- plus sign (+), 32**
- PnP (Plug and Play)**
  - APIC-EM Plug and Play (PnP)
    - Configuration Upload page, 275*
    - dashboard, 271–272*
    - Device History, 273*
    - overview, 269–271, 269–278*
    - Pending status information page, 274*
    - project details, 272–273*
    - Software Images tab, 274–275*
    - Unplanned Devices screen, 275–276*
- POAP (power-on auto provisioning), 83–87**
- Policy application (APIC-EM), 286–287**
- policy instantiation**
  - ACI (Application Centric Infrastructure), 73–74
  - Cisco ACI (Application Centric Infrastructure), 161–162
- port profiling**
  - ASP (AutoSmart Ports)
    - device-specific macros and descriptions, 217*
    - enabling on Cisco Catalyst Switch, 217–219*
    - overview, 216–217*
  - Auto Security
    - availability, 230*
    - enabling on Cisco Catalyst Switch, 228–230*
    - overview, 227–228*
- AutoConf
  - enabling on Cisco Catalyst Switch, 222–224*
  - interface templates and descriptions, 220–222*
  - template modification, 224–227*
- overview, 216
- Port Security, 228**
- POST method, 37**
- Postman**
  - APIC configuration automation, 188–191
  - APIC-EM APIs
    - available APIs, 296*
    - DevNet APIC-EM sandbox, 288*
    - Host API, 291–292*
    - Network Device API, 292–293*
    - Ticket API, 288–291*
    - User API, 294–296*
  - calls, creating, 189–191
  - collections, 188
  - NX-API object modification, 138–140
  - Open Weather Map API example, 40–43
- pound sign (#), 29**
- power-on auto provisioning. *See* POAP (power-on auto provisioning)**
- Prime Service Catalog, 213**
- print command, 21, 128–129**
- PRINTER\_INTERFACE\_TEMPLATE, 220**
- processes (Linux), displaying, 59–61**
- profiling ports. *See* port profiling**

- programmability. *See* network programmability; off-box programmability (NX-OS); on-box programmability (NX-OS)
- project details (APIC-EM PnP), 272–273
- provisioning. *See* POAP (power-on auto provisioning)
- ps tool, 59
- pseudocode, 14
- Puppet
  - agent installation in Guestshell, 111
  - ciscopuppet
    - documentation*, 156
    - installing*, 154
    - NX-OS configurations*, 155–156
    - verifying*, 154
  - Nexus 9000, 154–157
  - overview, 152–153
- PUT method, 37
- pwd command, 57
- \$PWD variable, 89
- .py filename extension, 29
- PyCharm
  - debugging, 54–55
  - interface, 50–53
  - virtualenv, 166
  - writing code in, 53
- Python
  - APIC authentication, 186–188
  - APIC-EM authentication
    - Host API*, 299–301
    - Ticket API*, 297–299
  - APIs (application programming interfaces), 37
  - commands
    - chmod*, 29
    - dir*, 147–148
    - help*, 147–148
    - import*, 30
    - pip install*, 31
    - pip search*, 31
    - pip show*, 31
    - print*, 21
    - str*, 23
  - comments, 29
  - conditions, 24–25
  - dictionaries, 28
  - documentation, 24
  - exception handling
    - definition of*, 162
    - examples*, 166–168
    - virtualenv*, 162–166
  - files, 29
  - functions, 28–29
  - help, 23–24, 116–117
  - installing, 20
  - libraries
    - Cisco libraries, importing*, 113–115
    - Cisco Python package*, 116–117
    - CLI APIs*, 115–116
    - datetime*, 35–36
    - importing*, 30
    - installing*, 30–31
    - json*, 44–45
    - requests*, 43–44
    - sys*, 34–35
  - lists, 27
  - loops
    - for loop*, 25–26
    - while loop*, 26–27

## methods

*find*, 22  
*help*, 23  
*re.findall*, 32  
*re.match*, 33  
*re.search*, 33–34  
*re.sub*, 34  
*split*, 22

## non-interactive Python, 118

## NX-API in

*authentication*, 136–138  
*CLI mode*, 129–130  
*event subscription*, 143–146  
*IP address configuration*,  
 130–131  
*object modification*, 140–143

## online resources, 36–37

## operators, 25

## overview, 20–21

PIP (package management tool),  
30–31

## PyCharm

*debugging*, 54–55  
*interface*, 50–53  
*writing code in*, 53

## regular expressions, 31–37

## scripts

*cdp\_neighbor.py*, 121–123  
*leveraging from EEM syslog  
 event*, 121–123  
*Reload\_in Pseudocode*,  
 118–121  
*scheduling*, 57  
*SimpleMath.py example*, 36  
*WebSoc.py*, 144–145

## SDKs (software development kits), 37

## tuples, 27

## variables

*converting to strings*, 23  
*overview*, 20–21  
*strings*, 22–23

## web technologies

*Google Postman*, 40–43  
*JSON (Javascript Object  
 Notation)*, 39–45  
*REST (Representational State  
 Transfer)*, 37–38  
*XML (Extensible Markup  
 Language)*, 38–39

## python command, 20

## Q

---

**QoS (Quality of Service)**

## AutoQoS on LAN devices

*enabling on Cisco Catalyst  
 Switch*, 231–233  
*overview*, 230–231

## AutoQoS on WAN devices

*enabling on Cisco ISR routers*,  
 234–236  
*overview*, 233–234

## on box-by-box basis, 259–260

Dynamic QoS (Quality of Service),  
285–286Easy QoS (Quality of Service),  
283–285network programmability and, 4  
website, 230**Quality of Service. See QoS (Quality  
of Service)**

## R

---

**raised state (faults), 172**

raised-clearing state (faults), 173  
 \$RANDOM variable, 89  
 re library, 30  
 read operations (Cisco ACI), 176  
 recreating virtual environments, 165  
 Redhat Package Manager (RPM), 64  
 redirection (Bash), 94–96  
 re.findall method, 32  
 registering your book, A00.0102  
 regular expressions
 

- Python, 31–37
- Sed support for, 96

 relative names (RNs), 170  
 reload in command, 118–121  
 Reload\_in Pseudocode, 118–121  
 re.match method, 33  
 Remote Procedure Call (RPC),  
     JSON-RPC, 126  
 repositories (GitHub)
 

- cloning, 44–47
- creating, 45–47
- updating, 47–48

 Representational State Transfer.  
     *See* REST (Representational State  
     Transfer)  
 Request module (Cobra SDK), 200  
 requests library, 30, 43–44  
 re.search method, 33–34  
 resources
 

- ciscopuppet, 156
- Git, 49
- Linux, 65–66
- Python, 36–37
- software development, 65–66

 REST (Representational State  
 Transfer). *See also* APIC RESTful  
 API; NX-API

Google Postman, 40–43  
 JSON (Javascript Object Notation),  
     39–45  
     overview, 37–38  
     XML (Extensible Markup Language),  
     38–39  
 re.sub method, 34  
 retaining state (faults), 173  
 return on investment (ROI) for  
     software development, 13–14  
 reverse path traces, 278  
 rm command, 57  
 RNs (relative names), 170  
 ROI (return on investment) for  
     software development, 13–14  
 roles (ConfD), 262  
 rollback management (ConfD), 262  
 ROUTER\_INTERFACE\_TEMPLATE,  
     220  
 routers, enabling AutoQoS on,  
     234–236  
 RPC (Remote Procedure Call),  
     JSON-RPC, 126  
 RPM (Redhat Package Manager), 64  
 run guestshell command, 108  
 running
 

- Bash scripts at startup, 103–106
- Python files, 29

## S

---

SaaS (software as a service), 6–7  
 SaltStack, 151  
 sandbox (NX-API), 127–129  
 /sbin directory, 64  
 scheduling Python scripts, 57  
 scores (health), 174  
 scrapy library, 30

**scripts**

## Bash

- arithmetic*, 90–91
- Awk*, 98–99
- conditions*, 91–94
- ethtool*, 103
- flow control*, 91–94
- ifconfig*, 101
- loops*, 93–94
- Nexus 9000*, 99–100
- NTP server configuration*, 106
- operators*, 91–92
- overview*, 88–89
- redirection*, 94–96
- running at startup*, 103–106
- Sed text editor*, 96–98
- tcpdump*, 101–103
- variables*, 89–90

## Python

- APIC-EM-AUTH.py*, 297–299
- APIC-EM-SHOW-HOST.py*, 299–301
- cdp\_neighbor.py*, 121–123
- Cisco libraries, importing*, 113–115
- Cisco Python package*, 116–117
- CLI APIs*, 115–116
- leveraging from EEM syslog event*, 121–123
- non-interactive Python*, 118
- Reload\_in Pseudocode*, 118–121
- scheduling*, 57
- WebSoc.py*, 144–145

**SDKs (software development kits)**

## Cobra SDK

- Arya (APIC REST Python Adapter)*, 207–211

- authentication*, 201
- documentation*, 198
- installing*, 200
- libraries*, 200–201
- modules*, 200
- objects*, 202–204
- tenant configuration example*, 204–207

## Python, 37

- SDN (software-defined networking)**, 8–9, 304

- SD-WAN (software-defined WAN)**, 264–269

- searching, strings**, 22

- secure unique device identification (SUDI)**, 270

**security**

## Auto Security

- availability*, 230
- enabling on Cisco Catalyst Switch*, 228–230
- overview*, 227–228

## NX-API, 126

- Sed text editor**, 96–98

- Services module (Cobra SDK)**, 200

- Session module (Cobra SDK)**, 200

- set command**, 89

- severity of faults**, 173–174

- sharing virtual environments**, 165

- shells, Tcl Shell**, 243–246

- show auto qos command**, 231–232, 234–235

- show auto qos voip cisco-phone configuration command**, 233

- show auto security command**, 228

- show auto security configuration
  - command, 229–230
- show call-home command, 242–243
- show derived-config interface
  - command, 221, 223–225, 226
- show interface command, 128, 247
- show log command, 273
- show macro auto device phone
  - command, 218
- Show Reverse button (Path Trace application), 278
- show running-config command, 225–226, 273
- show running-config interface
  - command, 223
- show shell functions command, 218
- show shell triggers command, 218–219
- show template interface source built-in all command, 221
- show template interface source built-in IP\_PHONE\_INTERFACE\_TEMPLATE command, 221
- shutdown command, 247
- silicon transistors, 68
- SimpleAciUiLogServer, 208
- SimpleMath.py, 36
- simplified networking, 4
- Smart Call Home
  - enabling on Cisco Catalyst Switch, 237–243
  - overview, 236–237
  - website, 239, 243
- SMI (Cisco Smart Install) Proxy, 271
- SMPs (symmetric multiprocessors), NX-OS support for, 69
- SNMP (Simple Network Management Protocol), 258
- soaking state (faults), 172
- soaking-clearing state (faults), 172
- software as a service (SaaS), 6–7
- software development
  - common constructs
    - conditions*, 17
    - functions*, 18–19
    - loops*, 18
    - objects*, 19–20
    - variables*, 15–17
  - Linux
    - architecture*, 58
    - commands*, 56–58
    - directories*, 64
    - file system*, 63–64
    - installing applications on*, 64
    - overview*, 55–56
    - permissions*, 63–64
    - processes, displaying*, 59–61
    - systemd*, 61–62
  - overview, 13–15
  - pseudocode, 14
  - with Python. *See* Python
  - resources, 65–66
  - return on investment (ROI), 13–14
  - source code, editing
    - overview*, 49–50
    - PyCharm*, 50–55
  - version control with Git/GitHub
    - Git commands*, 49
    - overview*, 45
    - repository creation*, 45–47
    - repository updates*, 47–48
- software development kits (SDKs), 37
- Software Images tab (APIC-EM PnP), 274–275

software-defined networking (SDN), 8–9, 304

software-defined WAN (SD-WAN), 264–269

source code, editing

- overview, 49–50
- PyCharm
  - debugging*, 54–55
  - interface*, 50–53
  - writing code in*, 53

source command, 245

SPAN (Switched Port Analyzer), 74

spanning tree protocol (STP), 78

spine/leaf architecture, 76–77

split method, 22

splitting strings, 22

square brackets ([ ]), 32, 33

startup, running Bash scripts at, 103–106

stateless access control lists (ACLs), 79

statements

- case, 92–93
- else, 17, 24–25
- if
  - Bash scripting*, 91–92
  - overview*, 17
  - Python*, 24–25
- if-else
  - overview*, 17
  - Python*, 24–25
- traceback statements, 167

states (faults), 171–173

status of interfaces, checking, 101

STP (spanning tree protocol), 78

str command, 23

stream editor (Sed), 96–98

strings

- concatenating, 23
- converting variables to, 23
- overview, 16
- Python, 22–23
- searching, 22
- splitting, 22

su command, 57

subscriptions

- Cisco ACI event subscription, 196–198
- NX-API event subscription, 143–146

SUDI (secure unique device identification), 270

SWITCH\_INTERFACE\_TEMPLATE, 220

Switched Port Analyzer (SPAN), 74

switches. *See* Cisco Catalyst Switch, enabling automation tools on

symmetric multiprocessors (SMPs), NX-OS support for, 69

sys library, 30, 34–35

system events, 112

systemd, 61–62

system-wide health scores, 174

## T

---

T2 network forwarding engine, 67

tail command, 57, 58

tar command, 57

Tcl scripts, EEM (Embedded Event Manager) and, 251–252

Tcl Shell, 243–246

tcpdump, 101–103

templates, AutoConf

- interface templates and descriptions, 220–222
- template modification, 224–227
- tenant configuration (ACI), 204–207**
- tenant health scores, 174**
- testing POAP (power-on auto provisioning) files, 87**
- text, editing in Bash**
  - Awk, 98–99
  - Sed, 96–98
- Ticket API**
  - Postman API, 288–291
  - Python script, 297–299
- tools (automation)**
  - APIC-EM (application policy infrastructure controller enterprise module)
    - APIC-EM Plug and Play (PnP), 269–278*
    - APIC-EM Topology application, 279–281*
    - authentication via Python, 297–301*
    - Device Inventory application, 281–282*
    - Dynamic QoS (Quality of Service), 285–286*
    - Easy QoS (Quality of Service), 283–285*
    - IWAN (Intelligent WAN), 264–269*
    - network devices, listing, 292–293*
    - overview, 263*
    - Path Trace application, 276–278*
    - Policy application, 286–287*
    - Postman APIs, 288–296*
    - users, viewing, 292–293*
  - ASP (AutoSmart Ports)
    - availability, 216*
    - enabling on Cisco Catalyst Switch, 217–219*
  - Auto Security
    - availability, 230*
    - enabling on Cisco Catalyst Switch, 228–230*
    - overview, 227–228*
  - AutoConf
    - availability, 220*
    - enabling on Cisco Catalyst Switch, 222–224*
    - interface templates and descriptions, 220–222*
    - template modification, 224–227*
    - website, 227*
  - AutoQoS on LAN devices
    - enabling on Cisco Catalyst Switch, 231–233*
    - overview, 230–231*
  - AutoQoS on WAN devices
    - enabling on Cisco ISR routers, 234–236*
    - overview, 230–231, 233–234*
  - ConfD, 259–263
  - device-specific macros and descriptions, 217
  - NETCONF (network configuration protocol), 258–259
  - overview, 216–217, 255–256
  - YANG (yet another next generation) data models, 256–258
- top command, 61**
- top of rack (TOR) switches, 75**

Topology application (APIC-EM),  
279–281

TOR (top of rack) switches, 75

touch command, 47, 57

TP\_INTERFACE\_TEMPLATE, 220

traceback statements, 167

tracing path, 276–278

traffic classification, 285

transactions (NETCONF), 259

transistors, 68

transport gateways, 236–237

Trident 2 network forwarding engine  
(NFE), 67

tuples, 27

types, 15–16, 27–28

## U

---

UCS (Unified Computing System)  
Manager, 7

UCS Director (UCS-D), 211

UCS-D (UCS Director), 211

Unicode, 44

Unified Computing System (UCS)  
Manager, 7

Unplanned Devices screen (APIC-EM  
PnP), 275–276

updating GitHub repositories, 47–48

USC-Director, 7

use cases (NDB), 75–76

User API

available APIs, 296

Postman API, 294–296

users, viewing, 294–296

/usr directory, 64

## V

---

validation (ConfD), 262

variables

Bash scripting, 89–90

EEM (Embedded Event Manager), 113

Python variables

*converting to strings*, 23

*defining*, 15–16

*explained*, 20–21

*hashes*, 17

*lists*, 16

*names*, 16

*passing to functions*, 19

*strings*, 16, 22–23

/var/log directory, 64

varying cash flows, 251

verifying ciscopuppet, 154

version control with Git/GitHub

Git commands, 49

overview, 45

repository creation, 45–47

repository updates, 47–48

View Small button (Path Trace  
application), 278

viewing

APIC-EM users,  
294–296

Linux processes, 59–61

virtual environments

accessing, 163–164

creating, 163

customizing, 163

exiting, 163–164

freezing, 164–165

installing libraries into, 164

overview, 163–165

in PyCharm, 166

- recreating, 165
- sharing, 165
- Virtual Extensible LANs (VXLANs), 79–80**
- Virtual Topology System (VTS), 81**
- virtualenv**
  - installing, 162–163
  - in PyCharm, 166
  - virtual environments, 163–165
- virtual-service commands, 107**
- Visore, 134–136, 182–185**
- vsh command, 99–100**
- VTS (Virtual Topology System), 81**
- VXLANs (Virtual Extensible LANs), 79–80**

## W

---

- WAN, IWAN (Intelligent WAN), 264–269**
- WANs, AutoQoS on WAN devices**
  - enabling on Cisco ISR routers, 234–236
  - overview, 233–234
- warning faults, 173**
- weather, checking, 53**
- web technologies**
  - Google Postman, 40–43
  - JSON (Javascript Object Notation), 39–45
  - REST (Representational State Transfer), 37–38
  - XML (Extensible Markup Language), 38–39
- WebArya, 211**
- websites**
  - APIC-EM (application policy infrastructure controller enterprise module), 278

- ASP (AutoSmart Ports), 220
- AutoConf, 227
- Cisco DevNet, 204
- Cisco IWAN (Intelligent WAN), 269
- EEM (Embedded Event Manager), 253
- jsoneditoronline.org, 139
- NFM (Nexus Fabric Manager), 82
- QoS (Quality of Service), 230
- RESTful API, 75
- Smart Call Home, 239, 243
- VTS (Virtual Topology System), 82
- WebSoc.py, 144–145**
- while loops**
  - Bash scripting, 94
- overview, 18, 27–28**
  - in Python, 26–27
- Wind River, 69**
- wireless LAN controller (WLC), 277**
- WLC (wireless LAN controller), 277**
- write operations (Cisco ACI), 177**

## X-Y-Z

---

- XML (Extensible Markup Language), 38–39**
- YAML (yet another mark-up language), 156**
- YANG (yet another next generation) data models, 256–258**
- yet another mark-up language (YAML), 156**
- yet another next generation (YANG) data models, 256–258**
- Yocto project, 69**
- yum tool, 65**