

4. Cisco Internet Operating System (IOS)

Just like a general purpose computer, routers run an operating system. The operating system generally is started (*booted*) when a router is powered up. Since routers do not have hard disk drives, the operating system is stored on a flash memory card or nonvolatile RAM (NVRAM). This section gives an overview of the *Internet Operating System (IOS)*, the operating system of Cisco routers. The Cisco routers in the Internet Lab run IOS version 12.0 or higher.

In the Internet Lab, routers are always accessed from the PC via the console port, as discussed in Section 1.2. Once the connection is made, the terminal emulation program *kermit* can be started on a PC to send commands to and receive the output from the router. In the Internet Lab, PC1 is connected to Router1, PC2 to Router2, and so on.

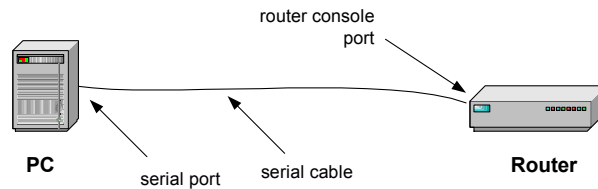


Figure 31. Connecting a cable to a router.

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If one of the interfaces of a router has an IP address configured, an alternative method to access a router is to *telnet* or *secure Shell (ssh)* to the IP address of the configured interface. However, this only works if the router has an interface with a valid IP address.

Deleted: Figure 0.28. Connecting a cable to a router.¶

Once a connection is established, a router shows a command prompt or asks for a login password. After a successful login, a user types commands, similarly as in a Linux Shell. Each router manufacturer has its own command line interface, and the syntax for router commands can be very different across different types of routers. Here, we discuss the command line interface of Cisco IOS.

4.1. The Cisco IOS Command Modes

The command line interface of IOS has a rich syntax. There are hundreds of configuration commands, and some commands have numerous options. Different from a Linux Shell, the command line interface of IOS runs in different modes, and each command requires a certain mode. The Internet Lab features only the most common command modes and, for each command mode, uses only a small subset of available commands. The command modes used in the Internet Lab are the *user EXEC mode*, the *privileged EXEC mode*, the *global configuration mode*, the *interface configuration mode*, and the *router configuration mode*.

Each command mode has a different prompt, and a user can derive the current command mode from the command prompt. The user EXEC Mode is indicated by an angle bracket (>), the privileged EXEC mode by the pound sign (#), and the configuration modes are indicated by an abbreviation of the configuration mode, followed by the pound sign, for example, (config)#, (config-if)#, and (config-router)#. Typing a question mark (?) in any command mode generates a list of all available commands in the current mode.

Table 6 presents a summary of the command modes. [Figure 32](#) illustrates the available transitions between different command modes, and which commands need to be issued. For example, changing from the privileged mode to the global configuration mode is done with the command *configure terminal*. Typing *exit* in this mode returns to the privileged mode.

As shown in [Figure 32](#), it is not feasible to switch arbitrarily from one command mode to another. For example, the global configuration mode cannot be entered from the user EXEC mode.

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IOS command mode	Role of command mode	Command prompt
User EXEC mode	<ul style="list-style-type: none"> Limited command set, e.g., ping, telnet, traceroute No change of system parameters 	Router1 >
Privileged EXEC mode	<ul style="list-style-type: none"> Manage configuration files examine state of router Access control with password (enable secret) 	Router1#
Global configuration mode	<ul style="list-style-type: none"> Change system wide configuration parameters 	Router1 (config) #
Interface configuration mode	<ul style="list-style-type: none"> Modify configuration of a specific interface 	Router1 (config-if) #
Router configuration mode	<ul style="list-style-type: none"> Modify the configuration of a specific routing protocol 	Router1 (config-router) #

Table 6. Cisco IOS Command Modes.

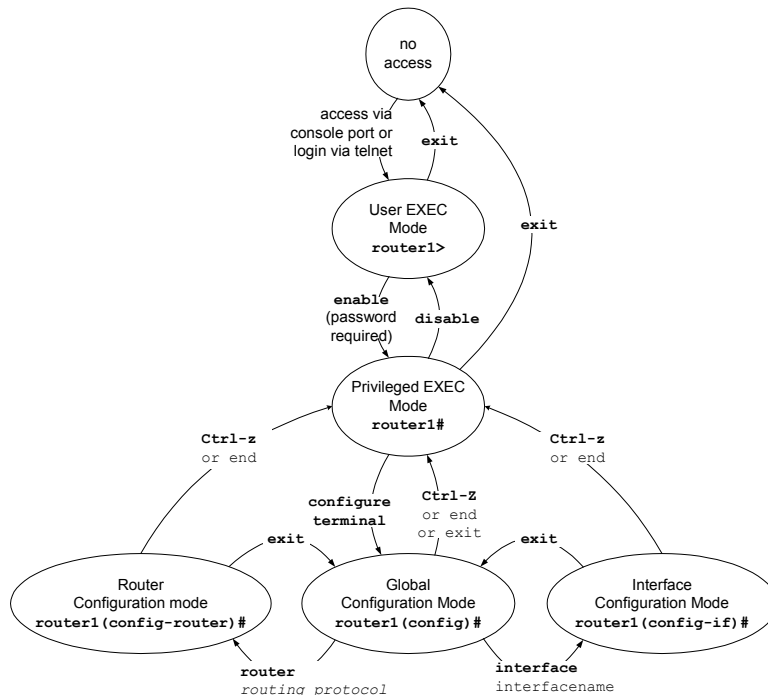


Figure 32 The Cisco IOS Command Modes.

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4.1.1. User EXEC Mode

The user EXEC mode is entered when the router is accessed via a serial connection or when accessing the router via *telnet*.³ The command prompt of the user EXEC mode is

```
Router1>
```

where *Router1* is the name that is assigned to the router. The user EXEC mode only offers a small set of commands, such as *ping*, *telnet*, and *traceroute*. Configuration parameters cannot be read or modified in this mode. Typing

```
Router1>exit
```

logs the user off.

³ Entering the user EXEC mode over a serial connection may require a login password and entering this mode with *telnet* always requires a login password.

4.1.2. Privileged EXEC Mode

To change or view configuration information of a Cisco router, a user must enter a system administrator mode. In IOS, the system administrator mode is called the *privileged EXEC mode*. In the privileged EXEC mode, a user has rights similar to the root account on a Linux system. The privileged EXEC mode is used to read configuration files, reboot the router, and set operating parameters. To modify the configuration of a router, a user must proceed from the privileged EXEC mode to the global configuration mode, and, from there, to other configuration modes.

Entering the privileged EXEC mode requires to type a password, called the *enable secret*. The privileged EXEC mode is entered from the user EXEC mode by typing the command

```
Router1>enable  
Password : <enable secret>
```

Typing the correct password displays the following command prompt:

```
Router1#
```

To change the command mode back to the user EXEC mode, the user types

```
Router1#disable
```

Typing *exit* logs the user off.

4.1.3. Global Configuration Mode

The global configuration mode is used to modify system wide configuration parameters, such as routing algorithms and routing tables. The global configuration mode can only be entered from the privileged EXEC mode. This is done by typing

```
Router1#configure terminal
```

No additional password is required to enter this mode. The argument *terminal* tells the router that the configuration commands will be entered from a terminal. The alternatives are to issue configuration commands from a configuration file or from a remote machine via a file transfer. The command prompt in the global configuration mode is

```
Router1(config)#
```

Global configuration commands include commands that enable or disable IP forwarding and that set static routing table entries. For example, the command

```
Router1(config)#ip routing
```

enables IP forwarding on the router, and the command

```
Router1(config)#ip route 20.0.1.0/24 10.1.1.1
```

adds a network route for destination address 20.0.1.0/24 via gateway 10.1.1.1 to the routing table. Typing *CTRL-z* as in

```
Router1(config)#CTRL-z
```

changes from the global configuration to the privileged EXEC mode.

4.1.4. Interface Configuration Mode

To modify the configuration parameters of a specific interface, for example, the IP address, a user must enter the interface configuration mode. The interface configuration mode, which can only be entered from the global configuration mode, for a network interface is entered by typing the keyword *interface* followed by the interface name.

In IOS, each network interface is associated with a name, which specifies an interface type, a slot number, and a port number. Examples of interface types that are used in the Internet Lab are serial WAN interface (*Serial*), 10 Mbps Ethernet (*Ethernet*), and 100 Mbps Ethernet (*FastEthernet*). Other types of interfaces are FDDI Token Ring (*FDDI*), and Asynchronous Transfer Mode (*ATM*). The slot number indicates the slot into which the interface card is inserted. The port number identifies a port on the interface card. For example, on a Cisco 2611, the interface name Ethernet0/0 identifies port 0 on a 10 Mbps Ethernet card, which is located in slot 0 of the router. Ethernet0/1 identifies port 1 on the same card. On routers which have a fixed number of interfaces and which do not have a slotted chassis, the slot number is omitted. For example, on a Cisco 2514 router, which has two Ethernet interfaces and two serial WAN interfaces, the interface names are *Ethernet0*, *Ethernet1*, *Serial0*, and *Serial1*. Throughout this book, we use the syntax for interface cards for slotted router chassis. For other routers, such as Cisco 2500 series routers, the names of the interfaces need to be changed appropriately. IOS assigns interface names automatically without intervention by a user. The privileged EXEC commands *show protocols* or *show interfaces* lists the names of all interfaces on a router.

The interface configuration mode for the network interface on port 1 of a 10 Mbps Ethernet card inserted in slot 0 of the router is entered with the command

```
Router1(config)#interface Ethernet0/1
```

The command prompt of the interface configuration mode is

```
Router1(config-if)#
```

To return to the global configuration mode one types

```
Router1(config-if)#exit
```

When a global configuration command is typed in the interface configuration mode, then IOS changes to the global configuration command.

4.1.5. Router Configuration Mode

The router configuration mode is used to configure the parameters for a specific routing protocol. When entering the router configuration mode, the name of the routing protocol must be specified as an argument. IOS supports numerous routing protocols, including the *Routing Information Protocol (RIP)*, *Open Shortest Path First (OSPF)*, and *Border Gateway Protocol (BGP)*, and many more. The command to enter the routing router configuration mode for the routing protocol RIP from the global configuration mode is

```
Router1(config)#router rip
```

The command prompt for the router configuration protocol is

```
Router1(config-router)#
```

Typing

```
Router1(config-if)#exit
```

changes to the global configuration mode.

4.2. IOS Commands for Interface Configuration

We next discuss the IP configuration of a network interface in IOS. Consider a router with a 10 Mbps Ethernet (*Ethernet*) interface card with two ports which is located in slot 0 of the router, with names *Ethernet0/0* and *Ethernet0/1*. The following sequence of IOS commands configures port 0 with IP address 10.0.2.1/24 and port 1 with IP address 10.0.3.1/24. In addition, the commands enable IP forwarding on the router.

```
Router1> enable  
Password: <enable secret>  
Router1# configure terminal  
Router1(config)# no ip routing  
Router1(config)# ip routing  
Router1(config)# interface Ethernet0/0  
Router1(config-if)# no shutdown  
Router1(config-if)# ip address 10.0.2.1 255.255.255.0  
Router1(config-if)# interface Ethernet0/1  
Router1(config-if)# no shutdown  
Router1(config-if)# ip address 10.0.3.1 255.255.255.0  
Router1(config-if)# end
```

The first two commands change to the privileged EXEC mode and, from there, to the global configuration mode. The command *no ip routing*, which is the command to disable IP forwarding, is used to reset the contents of the routing table. The next command, *ip routing*, enables IP forwarding on the router. Then, the interface configuration mode is entered for interface *Ethernet0/0*. The command *no shutdown* enables the interface, and the

command `ip address 10.0.3.1 255.255.255.0` sets the IP address to 10.0.3.1/24. The commands to configure the second interface are similar. Note that the interface configuration mode for interface `Ethernet0/1` is entered without returning to the global configuration mode. The last command (`end`) returns to the privileged EXEC mode.

The following list summarizes the IOS commands for enabling IP forwarding and for configuring IP addresses.

IOS mode: Global configuration

ip routing

Enables IP forwarding.

no ip routing

Disables IP forwarding. This command also deletes the content of the routing table.

IOS: Interface configuration

no shutdown

Disables network interface.

shutdown

Enables a network interface.

ip address *IPaddress mask*

Sets the IP address and netmask of an interface to *IPaddress* and *netmask*.

bandwidth *bw*

Assigns the bandwidth *bw* to an interface. The bandwidth is used as a cost metric by some routing protocols. The bandwidth does not impose a limit on the transmission rate of a network interface.

The routers in the Internet Lab have two Ethernet interfaces, of type *Ethernet* or *FastEthernet*, and one or more serial WAN interfaces of type *Serial*. The names of the interface depend on the types of routers used. On routers with a slotted chassis, the names of the interfaces additionally depend on the slot location of the interface card. The interface names of a router are displayed with the privileged EXEC commands `show interfaces` or `show protocols`. For example, on a Cisco 2611 router, where a *FastEthernet* card with two ports is inserted in slot 0 and a serial card with two ports is inserted in slot 1, the interface names are:

Interfaces on a Cisco 2611 router (with a FastEthernet interface card in slot 0 and a

WAN serial interface card in slot 1):

FastEthernet0/0, FastEthernet0/1, Serial1/0, Serial1/1

On routers with fixed interfaces cards, the interface names do not list a slot number. For example, on a Cisco 2514, the interface names are:

Interfaces on a Cisco 2514 router:

Ethernet0, Ethernet1, Serial0, Serial1

4.3. IOS Commands to Display the Configuration and other Information

IOS maintains two configuration files, which are called *startup configuration* and *running configuration*. The configuration files consists of a sequence of IOS commands. The startup configuration is kept in a file on Nonvolatile RAM (NVRAM), and contains the IOS commands that are executed when IOS is booted. To reboot IOS, one can turn the power switch off and then on again. Alternatively, a reboot of IOS is enforced when typing the privileged EXEC command *reload*. When IOS is booted up, the running configuration is set to the startup configuration. The running configuration stores the currently active configuration of the router, and issuing IOS configuration commands modifies the running configuration. The running configuration is kept in RAM and is lost when the router is powered off or when IOS is rebooted. To make changes to the running configuration permanent, the command *copy running-config starting-config* can be used to save the running configuration as the startup configuration.

The commands that display the configuration files are entered from the privileged EXEC mode, and are as given below.

IOS mode: Privileged EXEC

write term

show running-config

Displays the current configuration of the router. Both commands are identical.

show config

show startup-config

Displays the startup configuration of the router. Both commands are identical.

reload

Forces a reboot of IOS. This command discards the running configuration and reloads the startup configuration.

copy running-config starting-config

Saves the current configuration as the startup configuration. The new startup configuration will be used the next time IOS is rebooted.

In Section 4.5, we show the output of the *show startup-config* command for a Cisco 2514 router. In addition to configuration files, various commands are available to display information about the router. Below we list some frequently used commands.

IOS mode: Privileged EXEC

show version

Displays the version of IOS.

show protocols

Displays the IP configuration of the interfaces of the router. Also, indicates if IP forwarding is enabled or disabled.

show ip route

Displays the routing table.

show ip cache

Displays the routing cache.

show interfaces

show interfaces *interfacename*

Displays information about all network interfaces. When an interface name is given as argument, for example, *Ethernet0/1*, information is displayed only for the specified interface.

show ip arp

Displays the contents of the ARP cache.

The *show protocols* command gives a concise overview of the IP configuration of the interfaces of the router.

```
router1#show protocols
Global values:
  Internet Protocol routing is enabled
Ethernet0 is up, line protocol is up
  Internet address is 10.0.2.1/24
Ethernet1 is up, line protocol is up
  Internet address is 10.0.3.1/24
Serial0 is administratively down, line protocol is down
Serial1 is administratively down, line protocol is down
```

From this output, we can tell that IP forwarding is enabled on the router, that the Ethernet interfaces *Ethernet0* and *Ethernet1* are configured with IP addresses, and that the serial

interfaces are currently not used. More extensive information about the interfaces can be displayed with the *show interfaces* command. The output of this and other commands is shown in Section 4.5.

4.4. Navigating the IOS Command Line Interface

IOS provides a few features that make typing commands more convenient. We already mentioned that typing a question mark (?) in a given command mode generates a list of all available commands in the current command mode. For example,

```
Router1(config-if)#?
```

lists the available commands in the interface configuration mode. Since IOS commands can only be executed in a certain command mode, this command helps to determine if a command can be executed in the current mode. The question mark can also be used to determine the list of available options of a command. For example,

```
Router1#configure ?
```

lists all options that are available for the command *configure*.

When typing commands or the names of network interfaces, it is sufficient to type just enough characters so that IOS can interpret the input without ambiguity. The following shows how some abbreviations are interpreted.

```
conf          configure
w t          write terminal
int e0/0      interface Ethernet0/0
```

When the Tab key (<Tab>) is typed in the command line interface, IOS attempts to complete the command. Command completion is successful only if enough characters are typed so that the prefix can be completed without ambiguity. Here are some examples of command line completions.

```
conf <Tab>          configure
conf <Tab> t <Tab>  configure terminal
```

An interesting feature of IOS, is that putting a “no” in front of some command often creates a valid command. For example, if a certain command enables a feature of a router than adding a “no” in front of that command disables the same feature. Sometimes it is the other way around, that is, the command to enable a feature uses the command to disable the feature preceded by a “no”. The following are a set of examples.

```
Enable IP forwarding :    ip routing
Disable IP forwarding:    no ip routing
Add a routing table entry: ip route 10.0.2.0 255.255.255.0 10.0.3.1
Delete a routing table entry: no ip route 10.0.2.0 255.255.255.0 10.0.3.1
```

Disable a network interface: **shutdown**
Enable a network interface: **no shutdown**

4.5. Displaying IOS Configuration Information

This section shows the output of configuration information from a Cisco 2514 router.

```
router1#show version
Cisco Internetwork Operating System Software
IOS (tm) 2500 Software (C2500-D-L), Version 12.0(17), RELEASE
SOFTWARE (fc1)
Copyright (c) 1986-2001 by cisco Systems, Inc.
Compiled Mon 16-Apr-01 17:52 by nmasa
Image text-base: 0x03038A64, data-base: 0x00001000

ROM: System Bootstrap, Version 11.0(10c), SOFTWARE
BOOTFLASH: 3000 Bootstrap Software (IGS-BOOT-R), Version
11.0(10c), RELEASE SOFTWARE (fc1)

Router1 uptime is 3 weeks, 6 days, 9 hours, 15 minutes
System restarted by power-on
System image file is "flash:c2500-d-l.120-17"

cisco 2500 (68030) processor (revision L) with 14336K/2048K
bytes of memory.
Processor board ID 07668449, with hardware revision 00000000
Bridging software.
X.25 software, Version 3.0.0.
2 Ethernet/IEEE 802.3 interface(s)
2 Serial network interface(s)
32K bytes of non-volatile configuration memory.
8192K bytes of processor board System flash (Read ONLY)

Configuration register is 0x2102
```

```
router1#show interfaces Ethernet0
Ethernet0 is up, line protocol is up
  Hardware is Lance, address is 00e0.b06a.4eb8 (bia
00e0.b06a.4eb8)
  Internet address is 10.0.2.1/24
  MTU 1500 bytes, BW 10000 Kbit, DLY 1000 usec, rely 255/255,
load 1/255
  Encapsulation ARPA, loopback not set, keepalive set (10 sec)
  ARP type: ARPA, ARP Timeout 04:00:00
  Last input 00:00:28, output 00:00:00, output hang never
  Last clearing of "show interface" counters never
  Queueing strategy: fifo
  Output queue 0/40, 0 drops; input queue 0/75, 0 drops
  5 minute input rate 0 bits/sec, 1 packets/sec
```

```
5 minute output rate 0 bits/sec, 0 packets/sec
5557 packets input, 1540509 bytes, 0 no buffer
Received 5035 broadcasts, 0 runts, 0 giants, 0 throttles
0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0
abort
0 input packets with dribble condition detected
247651 packets output, 16613143 bytes, 0 underruns
187763 output errors, 0 collisions, 77 interface resets
0 babbles, 0 late collision, 0 deferred
187763 lost carrier, 0 no carrier
0 output buffer failures, 0 output buffers swapped out
```

```
router1#show interfaces Serial0
Serial0 is administratively down, line protocol is down
Hardware is HD64570
MTU 1500 bytes, BW 1544 Kbit, DLY 20000 usec, rely 255/255, load
1/255
Encapsulation HDLC, loopback not set, keepalive set (10 sec)
Last input never, output never, output hang never
Last clearing of "show interface" counters never
Queueing strategy: fifo
Output queue 0/40, 0 drops; input queue 0/75, 0 drops
5 minute input rate 0 bits/sec, 0 packets/sec
5 minute output rate 0 bits/sec, 0 packets/sec
0 packets input, 0 bytes, 0 no buffer
Received 0 broadcasts, 0 runts, 0 giants, 0 throttles
0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored, 0 abort
0 packets output, 0 bytes, 0 underruns
0 output errors, 0 collisions, 2 interface resets
0 output buffer failures, 0 output buffers swapped out
0 carrier transitions
DCD=down DSR=down DTR=down RTS=down CTS=down
```

```
router1#show startup-config
Using 825 out of 32762 bytes
!
version 12.0
service timestamps debug uptime
service timestamps log uptime
no service password-encryption
!
hostname router1
!
enable secret 5 $1$94pd$J.oTq5ujOU6Zko00pndrA/
enable password rootroot
!
ip subnet-zero
!
!
```

```
!
interface Ethernet0
 ip address 10.0.1.1 255.255.255.0
 no ip directed-broadcast
 no ip mroute-cache
!
interface Ethernet1
 ip address 10.0.2.1 255.255.255.0
 ip helper-address 10.0.1.21
 no ip directed-broadcast
 no ip mroute-cache
!
interface Serial0
 no ip address
 no ip directed-broadcast
 no ip mroute-cache
 shutdown
 no fair-queue
!
interface Serial1
 no ip address
 no ip directed-broadcast
 no ip mroute-cache
 shutdown
!
ip classless
!
dialer-list 1 protocol ip permit
dialer-list 1 protocol ipx permit
!
line con 0
 transport input none
line aux 0
line vty 0 4
 password rootroot
 login
!
end
```

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