**Module 6. Cisco’s Internetworking Operating System (IOS)**

**Beginner Question**

**1. Explain router**

A router is [hardware](https://www.computerhope.com/jargon/h/hardware.htm) device designed to receive, analyze and move incoming [packets](https://www.computerhope.com/jargon/p/packet.htm) to another [network](https://www.computerhope.com/jargon/n/network.htm). It may also be used to convert the packets to another network interface, [drop](https://www.computerhope.com/jargon/d/drop.htm) them, and perform other actions relating to a network. The picture shows the Linksys BEFSR11 wireless router and is what many home routers resemble.

**Capabilities of a router:**

A router has a lot more capabilities than other network devices, such as a [hub](https://www.computerhope.com/jargon/h/hub.htm) or a [switch](https://www.computerhope.com/jargon/s/switch.htm) that are only able to perform basic network functions. For example, a hub is often used to transfer data between computers or network devices, but does not analyze or do anything with the data it is transferring. By contrast, routers can analyze the data being sent over a network, change how it is packaged, and send it to another network or over a different network. For example, routers are commonly used in home networks to share a single Internet connection between multiple computers.

**Router types:**

**Wireless (Wi-Fi) router:**

Wireless routers provide [Wi-Fi](https://www.computerhope.com/jargon/w/wifi.htm) access to [smartphones](https://www.computerhope.com/jargon/s/smartphone.htm), [laptops](https://www.computerhope.com/jargon/l/laptop.htm), and other devices with Wi-Fi network capabilities. Also, they may provide standard [Ethernet](https://www.computerhope.com/jargon/e/ethernet.htm) routing for a small number of wired network devices. Some Wi-Fi routers can act as a combination router and [modem](https://www.computerhope.com/jargon/m/modem.htm), converting an incoming [broadband](https://www.computerhope.com/jargon/b/broadban.htm) signal from your [ISP](https://www.computerhope.com/jargon/i/isp.htm).

**Brouter:**

Short for bridge router, a brouter is a networking device that serves as both a [bridge](https://www.computerhope.com/jargon/b/bridge.htm) and a router.

**Core router:**

A core router is a router in a computer network that routes data within a network, but not between networks.

**Edge router:**

For information on an edge router, see our [edge device](https://www.computerhope.com/jargon/e/edge-device.htm) definition page.

**Virtual router:**

A virtual router is a backup router used in a [VRRP](https://www.computerhope.com/jargon/v/vrrp.htm) setup.

**2. Explain Cisco IOS command-line interface (CLI).**

Most Cisco devices (including routers and switches) use a CLI (Command Line Interface) to configure the network device. The CLI is an interface, based on text. You type in configuration commands and use show commands to get the output from the router or switch. There are also GUIs (Graphical User Interface) for the routers, switches and firewalls but the majority of the work is done on the CLI.

This might sound dated but with so many commands that are available to use, the CLI is much easier to work with than any of the graphical interfaces. It’s also much easier to copy entire configurations from one device to another.

Before we can enter any commands, we need access to the CLI. There are three options:

* Console
* Telnet
* SSH

The console is a physical port on the switch that allows access to the CLI. We typically use this the first time we configure the switch. Telnet and SSH are both options for remote access.

**3. Explain and configuring the Cisco Internetwork Operating System (IOS)**

**Cisco Internetwork Operating System (IOS)** is an operating system used on Cisco devices, such as routers and switches. It is a multitasking operating system that implements and controls logic and functions of a Cisco device. Cisco IOS uses a monolithic architecture, which means that it runs as a single image and all processes share the same memory space.

To configure a Cisco device running IOS, the **command-line interface (CLI)** is used. The CLI comes with a predefined number of commands and can be used to configure routing, switching, internetworking, and any other feature supported by a Cisco device that is being configured. The CLI is usually accessed from a remote computer running Telnet or SSH.

IOS has three modes of operation, each with its own set of commands. The modes are:

* user exec mode – when you access an IOS device (using Telnet, SSH, or console access method), you are initially placed in this mode. This mode is mostly used to view statistics and run commands like ping or telnet. It is represented with the > character after the hostname (for example Router\_HQ>).
* privileged exec mode – this mode is accessed by typing the enable command in the user exec mode. This mode is called privileged because it allows you to execute more powerful commands, such as reload. It is represented with the # character after the hostname (for example Router\_HQ#).
* global configuration mode – this mode is accessed by typing the configure terminal command from the privileged exec mode. It is used to make global changes to the device and change its configuration. It is represented with the config keyword after the hostname (for example Router\_HQ(config)).

### Configuration files on the router:

### As mentioned earlier, the router is a computer and it the configuration we do determines its operation. The router has two types of memory; volatile and non-volatile memory. The configuration we make is stored in one of these two types of memory depending on the commands we issue.

There are two types of configuration files on the router.

**The startup configuration file (startup-config)** – this is the file that is used during the startup of the router. It is stored in the non-volatile memory which is called the NVRAM. The startup configuration consists of all the commands we have issued and saved in the router. Once the router boots up, this file is loaded from the NVRAM to the RAM where it is used as the running configuration file.

**The running configuration** the operation of the router is determined by the running configuration. Any command that we issue on a router is immediately executed and stored in the running- configuration. This file is stored in the RAM or the volatile memory. This means that if the router loses power, any unsaved changes in this file will be lost. When the running- configuration is saved, it is stored in the NVRAM and becomes the startup-config.

**4. Explain port**



**Intermediate Question**

**1. Find Bringing up a router**

Once you know have the IP address of your router, you can access its configuration pages as follows:

**Login to the Router Setup Page:**

Open your web browser and, in the address bar, type in your router IP address including the dots e.g. 192.168.1.1 then press ENTER.

This should display a window asking you to login with either the admin username and password of your router or else just the password.

Type in the username (if required) and the password then click Login. Your router configuration page should now appear and you can proceed to [set up the router](https://techlogon.com/how-to-set-up-a-cable-wireless-router/) or change settings.

**2. Explain Logging into a router**

**Step 1:**Press the “Windows” key and the “R” key on your keyboard simultaneously (This portion of the tutorial is written specifically for Windows based computers). The “Windows” key usually has a picture of the windows logo. This will bring up the “Run” window. In the text field type in “cmd” (don't include the "")and click “OK”. Once you click “OK”, a new window will pop up. If this method isn't working for you, an alternate method is to type "cmd" into the start menu search bar and then press enter.

**Step 2:**Type in “ipconfig” (again, don't include the "")and press enter on your keyboard. A bunch of information will show up. Scroll down until you find the “Default Gateway” line. The string of numbers at the end of the line (192.168.0.1 in this example) is the IP address of the router.

**Step 3:**Now that we know the IP address of your router, we can login to it. Open up your internet browser, most people use Firefox, Internet Explorer (a.k.a. Windows Exploder), or Chrome. In the address bar at the top of the screen, type in the IP address of the router and press enter. Your browser will take you to the login page of your wireless router.

**Step 4:**At this point you will be asked for the username and password to login to the wireless router. This is not the same password as the one to join your wireless network. This password is almost always left at the default setting. Below is a table of common default router login credentials.

If the above information does not work for you, look in your manual for the login information. If you don’t have a manual, find the model number of your router.

**3. Explain the router prompts**

IP route command is used to configure the static route. Static routes are the most secure way of routing. They will also increase overall network performance. These features are extremely helpful in small network.

We have two commands to configure the static route.

Router(config)# ip route destination\_network\_# [subnet\_mask] IP\_address\_of\_next\_hop\_neighbor [administrative\_distance] [permanent]

And

Router(config)# ip route destination\_network\_# [subnet\_mask] interface\_to\_exit [administrative\_distance] [permanent]

#### ip route:

This is the base command which adds new route in routing table.

#### destination\_network\_#[subnet\_mask]:

This is the first parameter. It specifies the destination network address. We need to provide subnet mask if we are using sub-network. Sub-networks are the smaller networks created from one large network in subnetting. If we are not using sub-network then we can omit the subnet mask value. It will parse automatically.

#### IP\_address\_of\_next\_hop\_neighbor / interface\_to\_exit:

This parameter provides a way to reach the destination network. Both commands use separate way to assign this value. First command provides the IP address of next hop neighbor. It tells router that if it receives a packet for destination [that we set in previous parameter], forward that packet to this next hop neighbor IP address.

Second command also do the same job but in different way. It specifies exit interface instead of next hop IP address. It tells router that if it receives a packet for the destination specified by previous parameter then exits that packet from this interface. Device attached on other end of this interface will take care of the packet.

#### administrative\_distance:

Administrative distance is the trustworthiness of route. Route with the lowest AD value will be chosen while forwarding the packet. By default static route has two AD values depending on the previous parameter. If you have used next hop neighbor IP address, then the default AD value will be 1. If you have used exit interface, then the default AD value will be 0. This parameter allows us to create multiple static routes for the same destination. For example we can create primary and backup path for the destination network. To create backup path, we need to set AD value to higher than default, such as 2 or 3. With this configuration router will use primary path. Due to some reason if primary route fails, the router will start using backup route automatically.

#### Permanent:

When a route goes down router will remove that from routing table. Permanent parameter will keep this route in routing table even if it goes down. Its optional parameter we can omit it. If we omit it, router will remove this route from routing table if it goes down. You might use this parameter for security reason if you never want packets to take another path.

**4. Find the CLI prompts**

The command line, also called the Windows command line, command screen, or text interface, is a [user interface](https://www.computerhope.com/jargon/u/ui.htm) that is navigated by typing commands at [prompts](https://www.computerhope.com/jargon/p/prompt.htm), instead of using the mouse. For example, the Windows [folder](https://www.computerhope.com/jargon/f/folder.htm) in a Windows command line is "C:\Windows>" (as shown in the picture). In [Unix](https://www.computerhope.com/unix.htm) or [Linux](https://www.computerhope.com/jargon/l/linux.htm), it may be "%" or ">" depending on the [shell](https://www.computerhope.com/jargon/s/shell.htm). Unlike a [GUI](https://www.computerhope.com/jargon/g/gui.htm) (graphical user interface) [operating system](https://www.computerhope.com/jargon/o/os.htm), a command line only uses a [keyboard](https://www.computerhope.com/jargon/k/keyboard.htm) to navigate by entering commands and does not utilize a [mouse](https://www.computerhope.com/jargon/m/mouse.htm) for navigating.

**5. Gathering basic routing information**

## Basic IP Routing

* [Variable-Length Subnet Masks](https://www.cisco.com/c/en/us/td/docs/ios-xml/ios/iproute_pi/configuration/xe-3s/iri-xe-3s-book/iri-iprouting.html#GUID-368413E8-0772-49C4-8E6A-B281AE7A5CE4)
* [Static Routes](https://www.cisco.com/c/en/us/td/docs/ios-xml/ios/iproute_pi/configuration/xe-3s/iri-xe-3s-book/iri-iprouting.html#GUID-BDCB762C-7C37-42E9-9AB0-A041BE53447C)
* [Default Routes](https://www.cisco.com/c/en/us/td/docs/ios-xml/ios/iproute_pi/configuration/xe-3s/iri-xe-3s-book/iri-iprouting.html#GUID-474A54CC-F187-47C3-9318-799767560A41)
* [Maximum Number of Paths](https://www.cisco.com/c/en/us/td/docs/ios-xml/ios/iproute_pi/configuration/xe-3s/iri-xe-3s-book/iri-iprouting.html#GUID-8D2873D5-CBA9-4814-A4E3-7E604156FB5A)
* [Multi-Interface Load Splitting](https://www.cisco.com/c/en/us/td/docs/ios-xml/ios/iproute_pi/configuration/xe-3s/iri-xe-3s-book/iri-iprouting.html#GUID-CF485FB2-2440-4DBB-B1C4-B57B29BAA103)
* [Routing Information Redistribution](https://www.cisco.com/c/en/us/td/docs/ios-xml/ios/iproute_pi/configuration/xe-3s/iri-xe-3s-book/iri-iprouting.html#GUID-3E9E5EFB-AA90-4C84-BD24-45E9FBDD1D31)
* [Sources of Routing Information Filtering](https://www.cisco.com/c/en/us/td/docs/ios-xml/ios/iproute_pi/configuration/xe-3s/iri-xe-3s-book/iri-iprouting.html#GUID-EA4ADA27-FAF8-4EF3-8123-DE7BD3E46F64)
* [Authentication Key Management and Supported Protocols](https://www.cisco.com/c/en/us/td/docs/ios-xml/ios/iproute_pi/configuration/xe-3s/iri-xe-3s-book/iri-iprouting.html#GUID-DA3865D7-DDF8-4D33-B3E5-74C671F952AD)

**Advance question**

**1. Setting administrative functions**

The administrative functions that you can configure on a router and switch are:

* Hostnames
* Banners
* Password
* Interface descriptions

None of these will make your routers or switches work better or faster, but your life will be a whole lot better if you just take the time to set these configurations on each of your network devices.

**2. Setting hostnames**

Router>

Router>en

Router#

Router#conf t

Enter configuration commands, one per line. End with CNTL/Z.

Router(config)#

Router(config)#

Router(config)#hostn

Router(config)#hostname ?

WORD This system's network name

Router(config)#hostname CiscoTests-BORDER

CiscoTests-BORDER(config)#

**3. Setting banners**

CiscoTests-BORDER>en

CiscoTests-BORDER#

CiscoTests-BORDER#conf t

Enter configuration commands, one per line. End with CNTL/Z.

CiscoTests-BORDER(config)#

CiscoTests-BORDER(config)#bann

CiscoTests-BORDER(config)#banner mot

CiscoTests-BORDER(config)#banner motd ?

LINE c banner-text c, where 'c' is a delimiting character

CiscoTests-BORDER(config)#banner motd #

Enter TEXT message. End with the character '#'.

If you are not authorized to be in CiscoTests.ORG border router,

then you must disconnect immediately!

#

CiscoTests-BORDER(config)#

CiscoTests-BORDER(config)#end

**4. Setting passwords**

Router(config)#

Router(config)#ena

Router(config)#enable ?

last-resort Define enable action if no TACACS servers respond

password Assign the privileged level password

secret Assign the privileged level secret

use-tacacs Use TACACS to check enable passwords

Router(config)#enable sec

Router(config)#enable secret cisco

Router(config)#ena

Router(config)#enable pass

Router(config)#enable password cisco

The enable password you have chosen is the same as your enable secret.

This is not recommended. Re-enter the enable password.

Router(config)#

**5. Setting interface descriptions**

Router#conf t

Enter configuration commands, one per line. End with CNTL/Z.

Router(config)#int fa 0/0

Router(config-if)#

Router(config-if)#desc to ISP - WAN

Router(config-if)#

Router(config-if)#int fa 0/1

Router(config-if)#

Router(config-if)#desc to LAN

Router(config-if)#

Router(config-if)#end

Router#sh run

Building configuration...

...

!

interface FastEthernet0/0

description to ISP - WAN

no ip address

shutdown

duplex auto

speed auto

!

interface FastEthernet0/1

description to LAN

no ip address

shutdown

duplex auto

speed auto

!

ip classless

!

ip http server

no ip http secure-server

!

**6. Performing interface configurations**

Configuring Cisco network devices requires that you enter the Global Configuration mode, but one of the variations in this mode is *Interface Configuration*. When you are working with Global Configuration mode, you may enter an interface for configuration or any number of subconfiguration modes.

At that point in time, any commands you type apply only to the interface. When you are in Interface Configuration mode, your prompt looks something like this,

**Router(configure-if)#**

Each interface or subconfiguration mode has its own list of configuration commands. Here are some of the commands that you see on a network interface:

* **arp**: Sets an interface ARP type or timeout.
* **cdp**: Configures CDP for a specific interface.
* **delay**: Specifies the delay on interface throughput. This is useful for limiting throughput or for simulating slower connections in a lab.
* **description**: Sets a descriptive name for the interface.
* **exit**: Exits Interface mode and returns to Configuration mode.
* **ip**: Configures IP protocol on the interface.
* **logging**: Configures logging for the interface.
* **media-type**: Chooses a media type for interfaces that have the option.
* **mtu**: Sets the interface *maximum transmission unit (MTU),* which limits the size of the Ethernet frame.
* **no**: Negates other commands that have been issued.
* **shutdown**: Disables or shuts down the interface.

**7. Viewing, saving, and erasing configurations**

**Saving:**

To save the running-configuration to NVRAM, you can use the **copy**command in the privileged exec mode. The copy command expects two parameters – the source and the destination. In this case, the source is the running-config and the destination is the startup-config, so the command that you will need to use is copy running-config startup-config as shown below:

myRouter#copy running-config startup-config

Destination filename [startup-config]?

Building configuration…

[OK]

**erasing configurations:**

Log on to your router.

Enter the privileged EXEC by typing enable command.

At privileged EXEC mode type write erase, which will erase the NVRAM file system and removes all files.

Confirm that you want to erase all files at prompt.

After the complete execution of “step 4” enter reload, and type no when prompted whether to save the configuration.

UpaaeRouter1# write erase

UpaaeRouter1# reload // these two commands will erase both running and startup configurations.

**Viewing:**

you can view the files you save on the running config by typing the command show running-config or show startup-config from the router privileged mode. The sh run command, which is the shortcut for show running-config, tells us that we are viewing the current configuration on the router.

Router#sh run

Building configuration…

Current configuration:

!

version 12.0

service timestamps debug uptime

service timestamps log uptime

no service password-encryption

!

hostname Router

ip subnet-zero

frame-relay switching

!

**8. Verifying routing configurations**

**EIGRP:**

**Topology:** Router 1 (R1) (e0/0: 10.0.0.1/24)-------(e0/1: 10.0.1.2/24) Router 2 (R2)

**R1:**  
interface Ethernet0/0  
 ip address 10.0.0.1 255.255.255.0  
  
router eigrp 100  
 network 10.0.0.1 0.0.0.0  
  
**R2:**  
interface Ethernet0/0  
 ip address 10.0.1.2 255.255.255.0  
  
router eigrp 100  
 network 10.0.1.2 0.0.0.0

**RIP:**

!--- RIP Configuration

router rip

network 10.0.0.0

version 2

**OSPF:**

Device> enable

Device# configure terminal

Device(config)# router ospf 109

Device(config-router)# network 192.168.129.16 0.0.0.3 area 20

Device(config-router)# end

**9. Cisco IOS command-line interface (CLI)**

The Cisco IOS command-line interface (CLI) is the primary user interface used for configuring, monitoring, and maintaining Cisco devices. This user interface allows you to directly and simply execute Cisco IOS commands, whether using a router console or terminal, or using remote access methods.

Additional user interfaces includeSetup mode (used for first-time startup), the Cisco Web Browser, and user menus configured by a system administrator. For information about Setup mode, see Using Setup Mode to Configure a Cisco Networking Device and Using AutoInstall to Remotely Configure Cisco Networking Devices. For information on issuing commands using the Cisco Web Browser, see “Using the Cisco Web Browser User Interface”. For information on user menus, see “Managing Connections, Menus, and System Banners”.

To aid in the configuration of Cisco devices, the Cisco IOS XE command-line interface is divided into different command modes. Each command mode has its own set of commands available for the configuration, maintenance, and monitoring of router and network operations. The commands available to you at any given time depend on the mode you are in. Entering a question mark (**?**) at the system prompt (router prompt) allows you to obtain a list of commands available for each command mode.

The use of specific commands allows you to navigate from one command mode to another. The standard order that a user would access the modes is as follows: user EXEC mode; privileged EXEC mode; global configuration mode; specific configuration modes; configuration submodes; and configuration subsubmodes.

When you start a session on a router, you generally begin in *user* *EXEC* *mode*, which is one of two access levels of the EXEC mode. For security purposes, only a limited subset of EXEC commands are available in user EXEC mode. This level of access is reserved for tasks that do not change the configuration of the router, such as determining the router status.

In order to have access to all commands, you must enter *privileged* *EXEC* *mode*, which is the second level of access for the EXEC mode. Normally, you must enter a password to enter privileged EXEC mode. In privileged EXEC mode, you can enter any EXEC command, because privileged EXEC mode is a superset of the user EXEC mode commands.

Most EXEC mode commands are one-time commands, such as **show** or **more** commands, which show the current configuration status, and **clear** commands, which clear counters or interfaces. EXEC mode commands are not saved across reboots of the router.

From privileged EXEC mode, you can enter*global configuration mode*. In this mode, you can enter commands that configure general system characteristics. You also can use global configuration mode to enter specific configuration modes. Configuration modes, including global configuration mode, allow you to make changes to the running configuration. If you later save the configuration, these commands are stored across router reboots.

From global configuration mode you can enter a variety of protocol-specific or feature-specific configuration modes. The CLI hierarchy requires that you enter these specific configuration modes only through global configuration mode. As an example, this chapter describes *interface* *configuration* *mode*, a commonly used configuration mode.

From configuration modes, you can enter configuration submodes. Configuration submodes are used for the configuration of specific features within the scope of a given configuration mode. As an example, this chapter describes the *subinterface* *configuration* *mode*, a submode of the interface configuration mode.

*ROM* *monitor* *mode* is a separate mode used when the router cannot boot properly. If your system (router, switch, or access server) does not find a valid system image to load when it is booting, the system will enter ROM monitor mode. ROM monitor (ROMMON) mode can also be accessed by interrupting the boot sequence during startup.

| Command | Purpose |
| --- | --- |
| (prompt  )# **help** | Displays a brief description of the help system. |
| (prompt  )#  abbreviated-command-entry**?** | Lists commands in the current mode that begin with a particular character string. |
| (prompt  )# abbreviated-command-entry  <**Tab**> | Completes a partial command name. |
| (prompt  )# **?** | Lists all commands available in the command mode. |
| (prompt  )# command**?** | Lists the available syntax options (arguments and keywords) for the command. |
| (prompt  )# command  keyword **?** | Lists the next available syntax option for the command. |

**10. Explain Routing Protocol Configurations**

Hundreds of different [network protocols](https://www.lifewire.com/definition-of-protocol-network-817949) have been created for supporting [communication between computers](https://www.lifewire.com/internet-networking-and-security-4781467) and other types of electronic devices. So-called routing protocols are the family of network protocols that enable computer [routers](https://www.lifewire.com/what-is-a-router-2618162) to communicate with each other and in turn to intelligently forward traffic between their respective networks. The protocols described below each enable this critical function of routers and computer networking.

## Five Most Popular Routing Protocols

## RIP

Researchers developed **Routing Information Protocol**in the 1980s for use on small- or medium-sized internal networks that connected to the early Internet. RIP is capable of routing messages across networks up to a maximum of 15 [hops](https://www.lifewire.com/packet-switching-on-computer-networks-817938).

RIP-enabled routers discover the network by first sending a message requesting router tables from neighboring devices. Neighbor routers running RIP respond by sending the full routing tables back to the requestor, whereupon the requestor follows an algorithm to merge these updates into its own table. At scheduled intervals, RIP routers then periodically send out their router tables to their neighbors so that any changes can be propagated across the network.

## OSPF

**Open Shortest Path First** was created to overcome some of its limitations of RIP including:

* 15 hop count restriction
* Inability to organize networks into a routing hierarchy, important for manageability and performance on large internal networks
* Significant spikes of network traffic generated by repeatedly re-sending full router tables at scheduled intervals.

As the name suggests, OSPF is an open public standard with widespread adoption across many industry vendors. OSPF-enabled routers discover the network by sending identification messages to each other followed by messages that capture specific routing items rather than the entire routing table. It is the only link-state routing protocol listed in this category.

## EIGRP and IGRP

Cisco developed **Internet Gateway Routing Protocol**as another alternative to RIP. The newer **Enhanced IGRP** (EIGRP) made IGRP obsolete starting in the 1990s. EIGRP supports classless IP [subnets](https://www.lifewire.com/internet-protocol-tutorial-subnets-818378) and improves the efficiency of the routing algorithms compared to older IGRP. It does not support routing hierarchies, like RIP. Originally created as a proprietary protocol runnable only on Cisco family devices, EIGRP was designed with the goals of easier configuration and better performance than OSPF.

## IS-IS

The **Intermediate System to Intermediate System**protocol functions similarly to OSPF. While OSPF became the more popular choice overall, IS-IS remains in widespread use by service providers who have benefitted from the protocol being more easily adaptable to their specialized environments. Unlike the other protocols in this category, IS-IS does not run over [Internet Protocol (IP)](https://www.lifewire.com/internet-protocol-explained-3426713) and uses its own addressing scheme.

## BGP and EGP

The **Border Gateway Protocol**is the Internet standard External Gateway Protocol (EGP). BGP detects modifications to routing tables and selectively communicates those changes to other routers over [TCP/IP](https://www.lifewire.com/transmission-control-protocol-and-internet-protocol-816255).

Internet providers commonly use BGP to join their networks together. Additionally, larger business sometimes also use BGP to connect multiple internal networks. Professionals consider BGP the most challenging of all routing protocols to master due to its configuration complexity.