

## Module 3

### Introduction to Cisco Routers

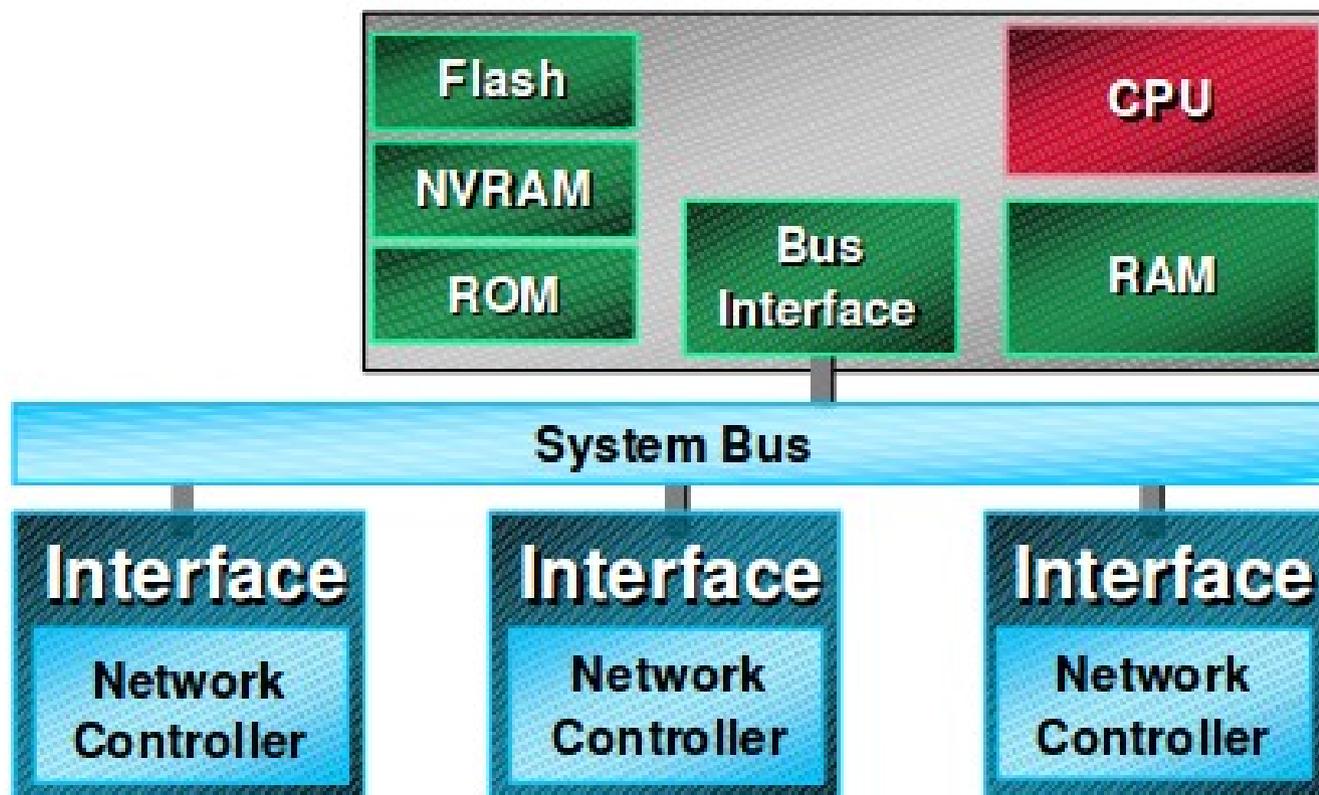
#### Cisco Router Hardware

- >> Started in San Francisco as a Gateway Server hardware in 1984.
- >> There were four types of gateway servers to provide basic LAN-to-WAN and LAN-to-LAN routing utilizing Ethernet, Token Ring;
  - 1) Advanced Gateway Server (AGS)
  - 2) Mid-Range Gateway Server (MGS)
  - 3) Integrated Gateway Server (IGS)
  - 4) Advanced Gateway Server Plus (AGS+)
- >> Cisco router series;

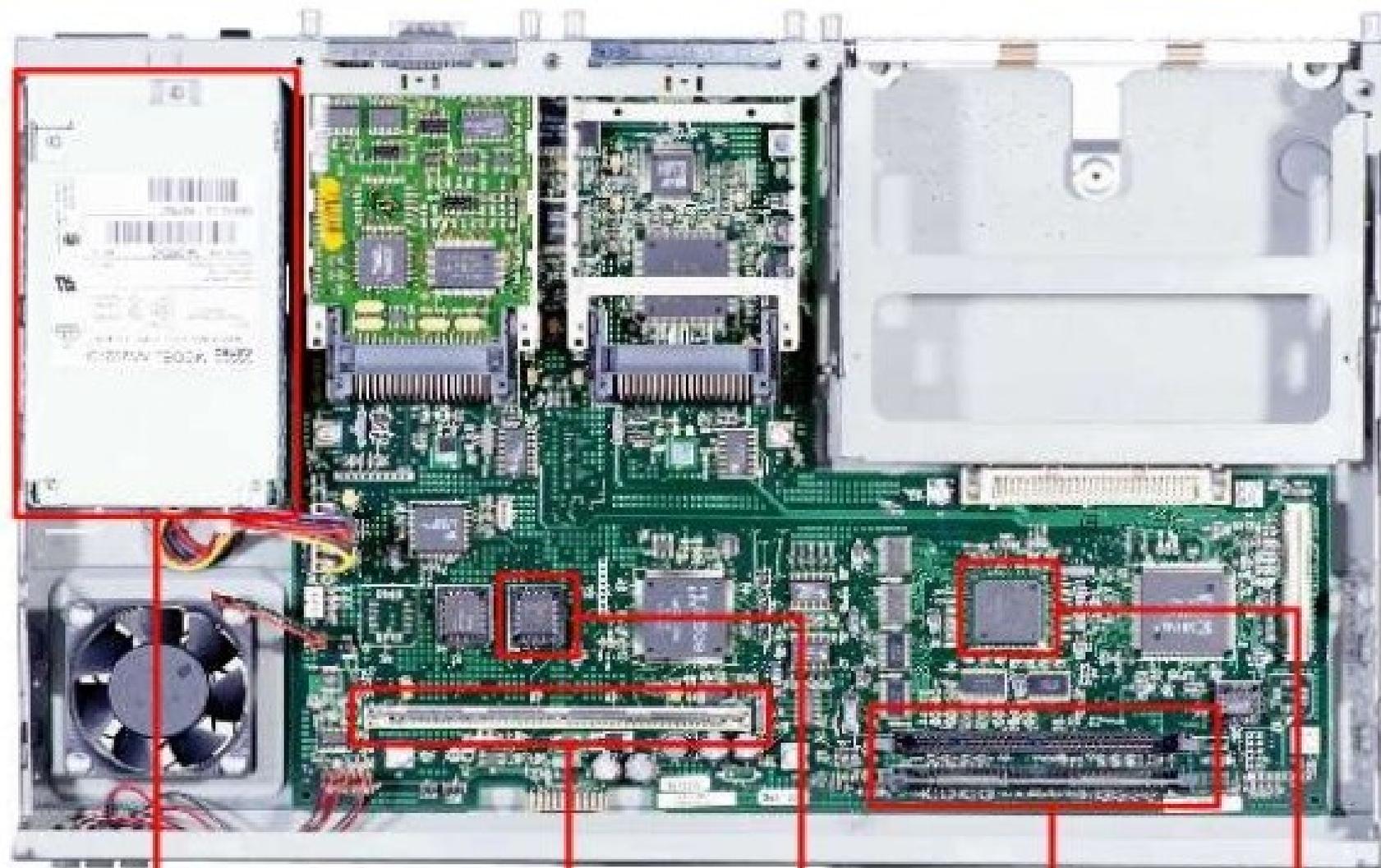
Entry Level	Mid Range	High End
Cisco 16xx	Cisco 26x	Cisco 7xxx
Cisco 25xx	Cisco 36xx	Cisco 4xxx

>> Cisco 1600 series is used for LAN/WAN routing and has such ports. Use built-in 10BASE-T Ethernet interface and synchronous Serial and Integrated CSU/DSU (Channel Service Unit/Data Service Unit) T carrier modular WAN interface cards (WICs). Use Motorola 68030 processor, running at 33MHz.

## Cisco Router Hardware



# Internal Components of a 2600 Router



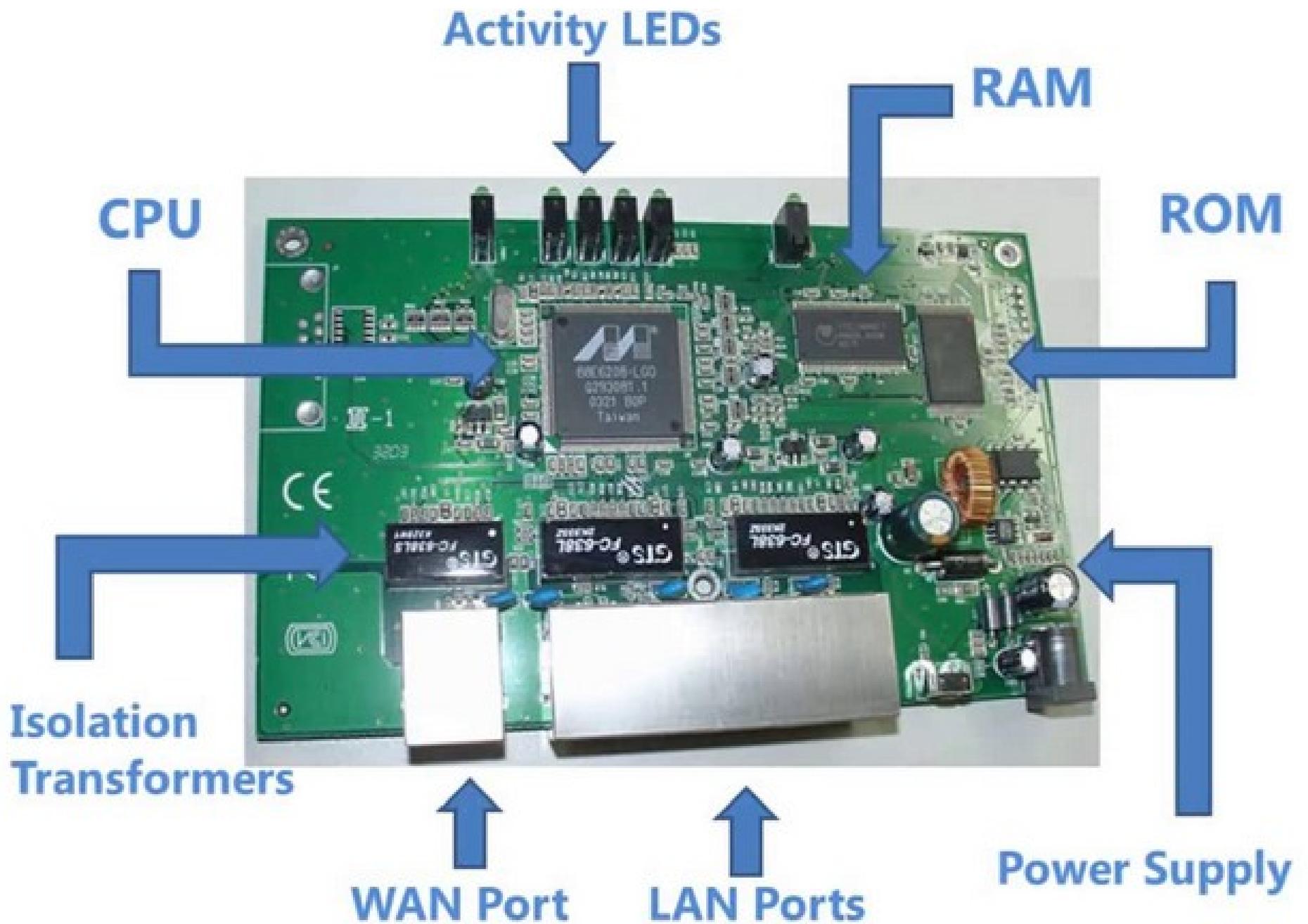
Power Supply

Flash SIMM

Boot ROM

RAM DIMMs

CPU



## Memory on Cisco Routers

- >> There are four types of memory;
  1. Read Only Memory (ROM) – for booting the router
  2. Flash memory – Stores the IOS.
  3. Non-volatile random access memory (NVRAM) – Stores the router's configuration info.
  4. Dynamic random access memory (DRAM) – Performs the routing process.
- >> ROM handles the routers bootstrap process. In some routers, it contains a limited version of IOS. ROMs have just enough space to load the IOS.
- >> Flash memory is rewritable nonvolatile memory. In old days the OS and configuration files were stored in floppy disks. Flash is either mounted on the router's motherboard or installed in a router's PCMCIA slot(s).
- >> NVRAM stores the router's configuration information. It does not lose its contents when the power is lost.
- >> DRAM is used for packet processing and IOS operation. DRAM is partitioned into primary and shared memory.
- >> Primary memory is loaded with the IOS, data tables and running configuration information. For instance, if IP is being routed, the ARP table and IP route tables are stored in primary memory.
- >> The shared memory is used to process datagrams.

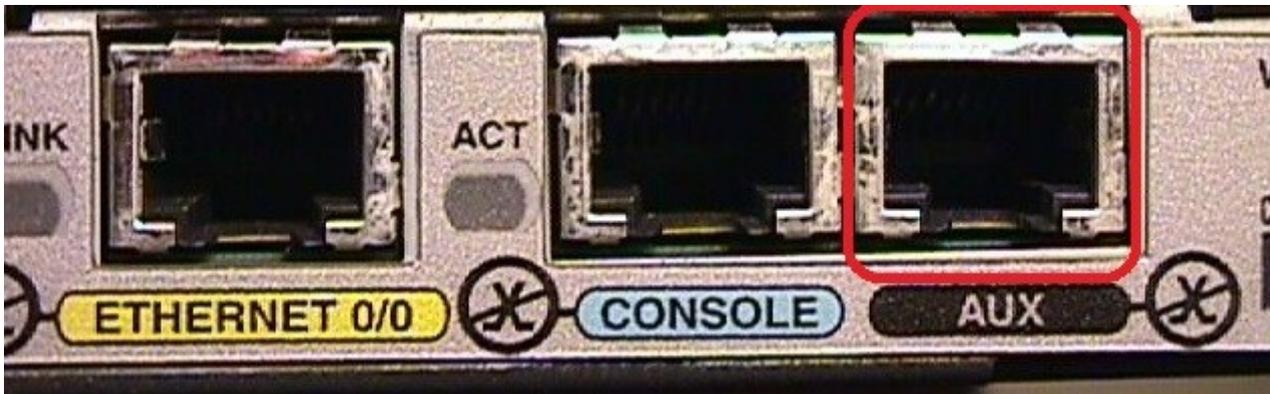
## Memory on Cisco Routers...

- >> There are two primary memory architectures used by Cisco routers:
  - \* Read From Flash (RFF) - Older model. The IOS resides on flash, and IOS data structures are loaded into RAM as needed.
  - \* Read From RAM (RFR) - The IOS image is stored in compressed form on the router's flash. At boot, the IOS's whole image is decompressed from flash to DRAM.
- >> The shared memory is used for datagram processing. By default, the DRAM is partitioned using a 75/25 split of the router's minimum DRAM configuration split.
- >> In some routers, the primary/shared partition cannot be adjusted. On the 2600 and 36x0 series routers, this partition can be readjusted to accommodate different interface configurations.
- >> The 7x00 series does not use partitioned memory architecture. DRAM is used for IOS and routing table storage. Memory used for packet processing is on the interface controller or on the switch processor, depending on the router model.

Memory	Volatile / Non-Volatile	Stores
RAM	Volatile	<ul style="list-style-type: none"><li>• Running IOS</li><li>• Running configuration file</li><li>• IP routing and ARP tables</li><li>• Packet buffer</li></ul>
ROM	Non-Volatile	<ul style="list-style-type: none"><li>• Bootup instructions</li><li>• Basic diagnostic software</li><li>• Limited IOS</li></ul>
NVRAM	Non-Volatile	<ul style="list-style-type: none"><li>• Startup configuration file</li></ul>
Flash	Non-Volatile	<ul style="list-style-type: none"><li>• IOS</li><li>• Other system files</li></ul>

## Talking to Your Cisco Router (Through the Console)

- >> Console is required for access to the operating system for initial setup and configuration.
- >> After the router is online, Telnet can be used to access a virtual router terminal port.
- >> After the router is online, Simple Network Management Protocol (SNMP) can be an alternative to the router's Command-Line Interface (CLI) to make changes and gather information about the router.
- >> SNMP can be used only if TCP/IP is enabled.
  
- >> There will be at least two Async Serial line ports, which are labeled "CONSOLE" and "AUX." Both are configured as data terminal equipment (DTE).
- >> The CONSOLE port is the only means of direct access to the router's CLI, and it functions as the router's primary configuration access port when the router is unconfigured.
- >> CONSOLE port: either RJ-45 or RS232C (9-pin or 25-pin) interface.
- >> The console port is also the default output display for all the router's system messages.



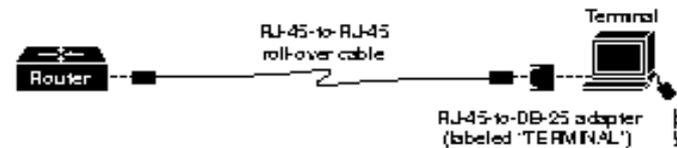
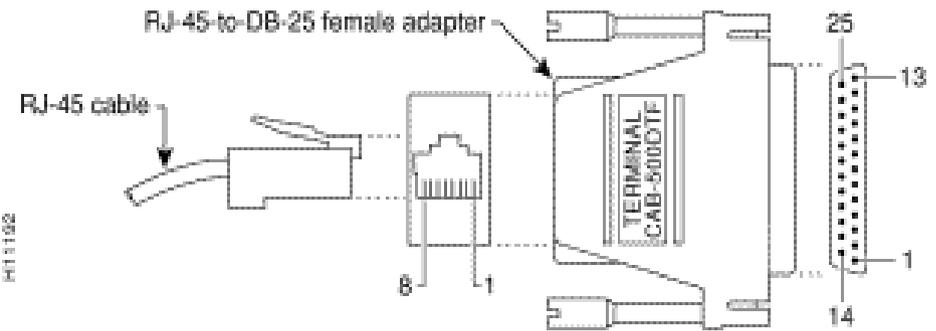
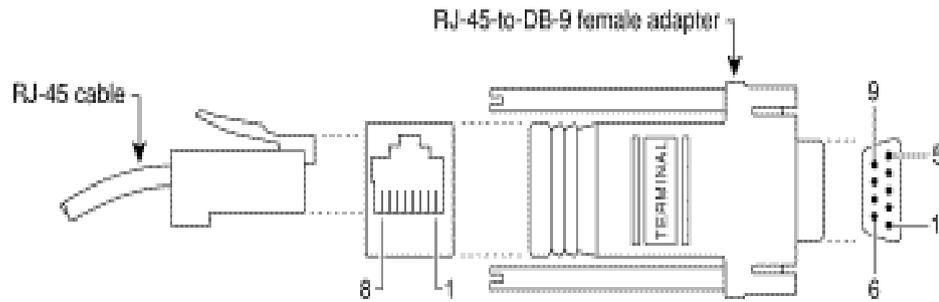
## Talking to Your Cisco Router (Through the Console)...

- >> The AUX port is a standard async port and can be configured to
  - \* provide a second console port for out-of-band (dial-in) access to the router.
  - \* provide remote network access over PPP or SLIP (Serial Line Internet Protocol).
  - \* function as a backup link for a dedicated WAN connection.
- >> The AUX port is not used for initial configuration and system messaging.
- >> AUX port: either RJ-45 or RS232C (9-pin or 25-pin) interface.

# Talking to Your Cisco Router (Through the Console)...

## >> Console Port Connection to a PC

To connect a PC terminal to the console port, use the RJ-45-to-RJ-45 rollover cable, and either the RJ-45-to-DB-25 female DTE adapter or the RJ-45-to-DB-9 female DTE adapter (labeled "TERMINAL").

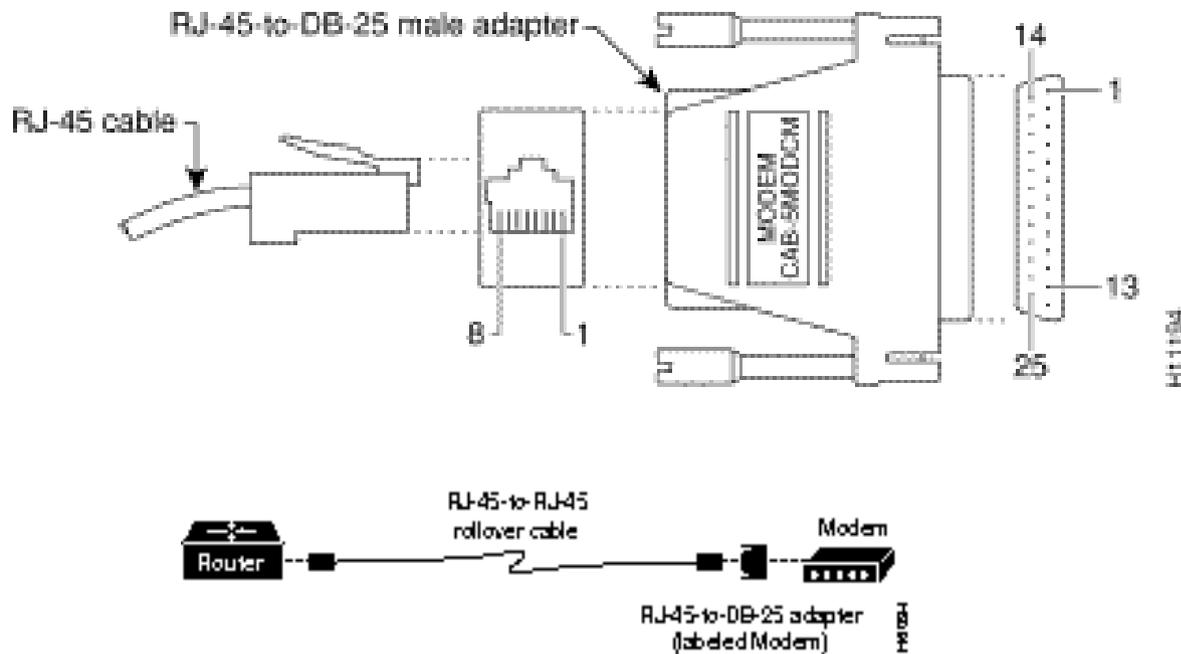


## Talking to Your Cisco Router (Through the Console)...

### >> Auxiliary Port Connection to a Modem

In order to connect a PC terminal to the router, use the RJ-45-to-RJ-45 roll-over cable and either the RJ-45-to-DB-25 female DTE adapter or the RJ-45-to-DB-9 female DTE adapter (labeled "TERMINAL").

In order to connect a modem to the auxiliary port, use the RJ-45-to-RJ-45 rollover cable and the RJ-45-to-DB-25 male DCE adapter (labeled "MODEM").





DB-9

Connect to laptop



Connect to router

RJ-45



## **Talking to Your Cisco Router (Through the Console)...**

- >> After the console connection, a terminal emulation software is needed to access the CLI.
- >> Such softwares include PuTTY, HyperTerminal, etc.
- >> When the router is powered on, it is possible to enter into the CLI and configure the router.

## Cisco IOS

- >> Internetwork Operating System
  - >> Multi-platform, feature-rich, efficient and routing-centric OS.
  - >> Uses standard as well as proprietary routing protocols.
  - >> Reliability and security enhancements.
  - >> Cisco IOS is the standard by which other routing implementations are compared.
  - >> Based on the TOPS-20 (a proprietary OS by Digital Equipment Corporation, DEC) command shell interface.
  - >> The current version is 12.4
  - >> Depending on the hardware platform, IOS comes in three flavors;
    - 1) IP only - Comes in several variations. These variations provide additional services such as data encryption, firewalls, and Network Address Translation (NAT).
    - 2) IP/IPX/AT/DEC—Provides multiprotocol support.
    - 3) ENTERPRISE—Provides support for all the IOS enhanced features.
- Note: IPX (Internetwork Packet Exchange) is a networking protocol from Novell that interconnects networks that use Novell's NetWare clients and servers.
- AT protocol is used for the communication between the host and the modem.
- >> IOS versions are upgradable, but be concious about the hardware support.

## Cisco IOS...

>> Different IOS versions

- 1) Major release (MR): There have been five major IOS releases: 8.0, 9.0, 10.0, 11.0, and 12.0. Only 10.0 through 12.0 are still supported. An IOS MR evolves from an early deployment release to a general deployment status.
- 2) Early deployment release (ED) is an enhancement to a MR, providing support for a new hardware or software feature.
- 3) Deferred releases (DR) are old EDs that have been replaced by a newer ED.
- 4) General deployment (GD) indicates that the IOS has reached a mature stable phase and is recommended for general use.
- 5) Limited deployment (LD) is the halfway mark of an IOS version between MR and general deployment.

## Cisco IOS...

- >> All Cisco routers have at least two configuration files on Cisco routers: startup and running.
- >> Initial configuration dialog: Appears when the router is turned on for the first time.
- >> This is shown when there is no startup configuration in the NVRAM.
- >> The startup configuration is the configuration file the router stores in NVRAM and is read into RAM when the router boots up.
- >> The running configuration is a copy of the router's stored configuration that is loaded into the router's RAM when the router boots up. The administrator can make changes in this configuration.
- >> Both the configurations are stored as collections of binary representations and the IOS converts them into text representations.
- >> All configurations are done through the IOS CLI shell which is called the EXEC shell.
- >> The EXEC shell of a router can be accessed through direct line (through console port) or virtual terminal line.
- >> Direct mode is through the Console port
- >> Once IP is configured on the router, it can be accessed through Virtual Terminal Lines (VTY – eg: Telnet sessions).

## Cisco IOS...

- >> When the router boots up, it enters into a shell.
- >> The shell is called EXEC shell and has three major modes based on the security level and access control.
- >> The EXEC modes are: User EXEC, Privileged EXEC and Configuration EXEC modes.

## User EXEC mode

- >> Initial mode; distinguished by a > prompt.
- >> security level 0
- >> It basically allows the user to establish connections from the EXEC shell to other TCP/IP hosts (such as Telnet or rlogin ) or start up a network transport session (PPP, etc).
- >> The <ping> and <traceroute> applications are also available in user EXEC.
- >> To enter the privileged EXEC mode, use the **<enable>** user EXEC command.

```
Router> enable
```

```
Router#
```

## Cisco IOS...

### Privileged EXEC mode

- >> Enables complete control over the router.
- >> Distinguished by # prompt.
- >> Commonly called enable mode because it is invoked with the user EXEC command <enable>.
- >> Highest IOS security level (15) by default; just like the root or the administrator.
- >> This mode should be password protected, but it is not by default.
- >> The enable passwords are set using the <enable password> and <enable secret> commands.
- >> Enable secret is the preferred mode of password protection because it is stored in the configuration information in an encrypted form.
- >> IOS allows multiple privileged EXEC levels to be defined with different security levels to control the access to specific commands.
- >> Most useful command in this mode is the **show** command, which is used to show different parameter/configurations in the router.
  - <show interfaces [ type ] [ number ]> - Shows information about router interfaces.
  - <show running-config> - Shows the router's current configuration.
  - <show startup-config> - Shows the router's NVRAM stored configuration.
- >> <configure terminal> command is used to enter the configuration EXEC mode.

## Cisco IOS...

### Configuration EXEC mode

- >> Only for creating and modifying the router's configuration files.
- >> It is entered from a privileged EXEC mode with a security level of 1 or higher.
- >> All configuration changes are active changes, so when a change is made, they are in effect.
- >> When changes occur, they are made to the running configuration. Hence if any error occurs, just reboot the router and the startup configuration is reloaded.
- >> There are four configuration options.
  - \* <configure terminal> provides the only direct access used to the configuration EXEC CLI. No router status information can be retrieved while in this mode. Therefore, if you want to check something about the router's configuration, you need to exit out. To disable a command, use <no> before the command.
  - \* <configure memory> Reloads the startup-config into DRAM, overwriting any changes made to the running-config that are contained in the original startup-config (just in case you made a mistake). Additional changes made to the running-config, which are not contained in the startup-config, will not be altered.
  - \* <overwrite-network>— Erases the running-config before reloading the startup-config. This returns configuration to the router to its boot or last saved state.
  - \* <configure network> loads a file from a defined source, then loads it into DRAM and appends it to the running configuration.

## Cisco IOS...

### Configuration EXEC mode...

- >> When enter into the configuration EXEC CLI, this mode is also called global configuration mode.
- >> Global mode commands are used to set most of the router's global operational parameters and basic network protocol services.
- >> Some of the parameters are;
  - Time and date settings
  - Security privileges and enable passwords
  - User accounts and authentication
  - Configuration register settings
  - Boot parameters
- >> From global mode, we can enter into different interface specific modes.
- >> After setting up the router, the running configuration must be stored into the NVRAM in order to retain the changes even after the router is switched off. This can be done by the command <copy running-config startup-config>

## Configuring Router with <copy> and TFTP

>> CLI is not sufficient for large configuration changes such as static routing table or ACL maintenance.

>> <copy> command is used to copy configuration files on and off the router's NVRAM, DRAM, and flash file systems.

>> The <copy> command is used with the syntax <copy> <from> <to>

>> The common use of <copy> command is to store/load running/startup configurations

>> *Router#copy running-config startup-config*

>> Router#copy ?

flash:	Copy from flash: file system
ftp:	Copy from ftp: file system
running-config	Copy from current system configuration
startup-config	Copy from startup configuration
tftp:	Copy from tftp: file system

>> Some other uses of <copy> command is as follows

1. Using <copy> to Erase File Systems
2. Using <copy> with Flash Memory
3. Using <copy> with TFTP

## 1. Using <copy> to Erase File Systems:

The <copy /erase> command in conjunction with the [null] file system will erase a memory partition.

Eg: to erase NVRAM, the command <write erase> would be used or,

```
Router#copy /erase null: nvram:startup-config
```

```
Destination filename [startup-config]?
```

```
Erasing the nvram filesystem will remove all files! Continue? [confirm]
```

```
[OK]
```

```
Erase of nvram: complete
```

```
Router#
```

>> The command <erase> will do the same.

```
Router#erase ?
```

```
Flash: Filesystem to be erased
```

```
NVram: Filesystem to be erased
```

```
Startup-config: Erase contents of configuration memory
```

## 2. Using <copy> with Flash Memory

>> The [flash:] target is used to represent all flash memory installed on a router's motherboard and installed in PCMCIA slots. The specific PCMCIA slots are represented by *slot0:*, *slot1:*, etc.

>> Eg: *router#copy run slot0:* copies the running configuration to slot0 so that it can be copied to another router.

## 3. Using <copy> with TFTP (Trivial File Transfer Protocol)

>> TFTP is mostly used for IOS upgradation.

>> TFTP is a UNIX routine used in conjunction with BOOTP, which provides a file transfer mechanism for loading OS and configuration information for disk less workstations.

>> TFTP has no security, and files can be copied back and forth with no authentication.

>> After the router has an IP address, TFTP can be used to load the rest of the router's Configuration.

>> Using <copy> with a TFTP server works the same as copying from a memory file system.

>> Eg: Router#copy running-config tftp

Remote host [ ]? 192.168.0.2

Name of configuration file to write [router-config]?

Write file router-confg on host 192.168.0.2? [confirm]

Building configuration...

Writing router-config !! [OK]

## Basic Cisco Router Configuration

- >> Deals with configuring Layer 2 and Layer 3 protocols.
- >> When a new router is switched on, there will be nothing in the NVRAM and hence ask the user whether to enter the Initial Configuration Mode (yes/no).

>> 'Yes' will help to make a limited configuration and 'No' will enter directly into EXEC mode.

>> User can view the Interfaces (type, slot, and port Information) in the Privileged EXEC mode.

```
Router#show ip interface brief
```

>> User can set the interfaces at Configuration EXEC mode.

>> We can set the router name here

```
Router(config)# hostname GPTC
```

```
GPTC(config)#
```

>> If there is are DNS servers, they can be specified by the command

```
<ip name-server [ip address of the DNS server]>
```

```
Router(config)# ip name-server 192.168.12.2
```

>> From configuration EXEC mode, it is possible to enter *interface* modes where interface parameters such as IP addresses can be set for each interface.

```
Router(config)# interface fastethernet 0
```

```
Router(config-if)# ip address 192.1.12.51 255.255.255.0
```

```
Router(config-if)# no shutdown
```

## Basic Cisco Router Configuration...

>> Static routing tables and dynamic routing tables (RIP - Routing Information Protocol) are stated in Configuration EXEC mode.

Static routing syntax:

```
Router(config)# <ip route> <to_network> <to_network_mask> <through_interface_ip>
```

```
Eg: GPTC(config)# ip route 192.168.1.0 255.255.0.0 10.10.10.2
```

Dynamic routing:

```
Eg: GPTC(config)#router rip
```

```
GPTC(config-router)#version 2
```

```
GPTC(config-router)#network 192.168.1.1
```

>> <show ip route> command at user or privileged mode will show the routing table.

## What is rommon? (ROM Monitor)

>> ROMMON or also known as bootstrap program is a mini operating system in the Cisco devices that helps to initialize the processor hardware and boot the operating system software (Cisco IOS).

>> Since it's only a mini OS that has a very limited set of commands you can't do any configuration such as configuring routing, ip addressing, etc from ROMMON.

>> But the power of the ROMMON is that you can do very useful things such as password recovery procedure when you forgot your password to the devices, downloading softwares through serial connection, and upgrading the Cisco IOS.

>> You can only access the ROMMON using the console connection i.e. through terminal monitor. And not through networks (AUX).

>> You can access the ROMMON mode using the break button on the keyboard.

## Disaster Recovery

- >> There may be disasters like IOS corruption, password loss etc.
- >> It is possible to reload IOS and reset password.
- >> This is done by changing the **bootstrap behaviour**.
- >> The bootstrap behaviour can be changed by changing the **configuration register** (16-bit).

## Cisco routers basic boot sequence:

- 1) The router is powered up.
- 2) It checks its configuration register settings.
- 3) It checks the NVRAM for boot loader information.
- 4) It loads the IOS.
- 5) It loads the NVRAM config.

## WHAT IS A CONFIGURATION REGISTER?

>> The configuration register is a 16-bit number, represented in hexadecimal, which controls everything from the way in which a CISCO router boots to whether or not it will process the contents of the startup configuration file. By default, the configuration register on a router is set to a value of 0x2102. The "0x" portion represents the value as hexadecimal, while the "2102" portion is the hexadecimal representation of the 16-bit value.

## WHAT IS THE PURPOSE OF CONFIGURATION REGISTER?

>> The configuration register can be used to change router behavior in several ways, such as:

- how the router boots (into ROMmon, NetBoot)
- options while booting (ignore configuration, disable boot messages)
- console speed (baud rate for a terminal emulation session)
- Set and display the configuration register value
- Force the router into the ROM monitor (bootstrap program)
- Select a boot source and default boot filename
- Enable or disable the Break function
- Control broadcast addresses
- Load operating software from ROM

>> To view the current Configuration Register value, use the <show version> command, and check the last line of the result.

“....

*Configuration register is 0x2102”*

>> To get the CISCO Router into Setup mode, the global Configuration mode and type

*Router(config)#config-register <16-bit value>*

>> *Router#reload* will reboot the system with the new config register value.

## **Some config-register values are;**

0x2102 is the factory-default configuration register value. By default, console break option is disabled once the IOS is loaded.

0x2142 boots from flash without using NVRAM contents; good for password recovery.

0x2141 boots from boot ROM and ignores NVRAM contents; used when the IOS image is damaged, or if you need to perform an IOS upgrade on an RFF and have no local TFTP server.

0x2101 loads the IOS from ROM, and the NVRAM configuration is loaded into RAM as the running configuration.

0x2010 configures the router to check NVRAM and boot directly into ROM monitor.

0x141, which disables the Break key, ignores the NVRAM configuration, and boots the default system image from ROM.

## Setting the conf-reg Value in ROM Monitor

>> '**rommon**' mode can be used to set the config-register if the global mode is not accessible due to some reason, such as IOS failure.

>> While the router is booting, press the *pause/break* button on the keyboard to enter 'rommon'.

>> This mode can be identified either by "**rommon x >**" or simply ">" prompt. (x may be 1,2,3..)

>> In 2500 series routers, > prompt can be seen. Then type *O/R <hex value>* to change the config-reg value; then press "i" to enter the initialization mode.

>> In most other routers, use the command *<confreg hexvalue>*

>> Use the command *<reset>* to restart the router with the new config-reg value.

>> If the *confreg* is set to 0x2142, the reboot will load IOS skipping the NVRAM. Here we can enter the privileged EXEC and global configuration mode without password and reset the password or give a new password in global configuration mode. Thus we can recover the router **when the password is lost**.

## Upgrading Your Router's IOS

>> Easiest method is TFTP (Trivial File Transfer Protocol).

>> TFTP sever must be in the same local network.

>> On RFF (Read From Flash) routers (1600, 2500 series), since the router boots with the flash in read-only mode, the IOS cannot be altered. Here to upgrade IOS, the router must be configured to boot from TFTP server.

>> On RFR (Read From RAM) routers (1600-R, 2600, 36x0, 4x00, and 7x00 series), the router's flash is in read/write mode all the time because the IOS is loaded into DRAM at boot. IOS can be upgraded while the router is in operation.

>> Problems occur if the new IOS image is corrupt or any improper IOS version for the model.

>> For RFF or RFR routers, TFTP booting is the best option to updrade IOS.

## Setting Up TFTP Boot

>> By default, the IOS uses the first IOS image it finds on the flash filesystem.

>> It can be changed by the gobal config command `<boot system [source] [filename]>`

>> For TFTP boot, use the command `<boot system tftp [filename] [IP address]>`

>> Eg: *Router(config)#boot system tftp c2500-enter40-l.113-9.bin 192.168.0.2*

*Router(config)#^Z*

*Router#reload*

>> *It will load the specified IOS version (c2500-enter40-l.113-9.bin) from the defined TFTP server (192.168.0.2)*

## Installing the New IOS

>> After the router is up again, the IOS can be loaded using the <copy> privileged EXEC command:

```
Router#copy tftp flash
```

>> If there are multiple flash, the system will ask for which flash to be used.

>> If you have enough flash space, it is possible to store different IOS versions and use the <boot> command to define which IOS version will be loaded at boot time.

>> If you do not have enough flash, you can always use TFTP.

>> If there is an additional flash, it can hold an additional IOS.

>> If both are erased, they will see as a single partition.

## Configuring the Router's Clock

>> Clock is not important for routing, but essential for logging, accounting, and SNMP.

>> Set either manually each time the router reboots, or by using the Network Time Protocol (NTP).

>> Cisco 7x00 series routers use a hardware clock. On all other models when the system boots up the clock is set to March 1, 1993.

>> IOS uses Universal Time Coordinated (UTC), more commonly known as Greenwich Mean Time (GMT). Hence offset must be provided to make it for different locale.

To set your time zone, use the global configuration command `<clock timezone>`

*clock timezone zone hours-offset [minutes-offset]*

Eg: Router(config)#clock timezone I 5 30                   *(I for India – from cisco website)*

>> To set the router's system clock **manually**, use the privileged EXEC command `<clock set>`. The convention is *hour:min:second day month year*:

Eg: Router#clock set 14:00:15 29 Jan 2018

>> **Automatic** time update can be done using NTP. IOS provides the facility for the router to act as an NTP client, an NTP server, or an NTP peer. As an NTP client, the router contacts the defined NTP server, then verifies and synchronizes its system clock. As an NTP server, the router can be used by other systems on the network as their NTP server. In a peer scenario, the router and the NTP source exchange time synchronization information.

## To set an NTP client...

>> The commands are;

```
router(config)#ntp server 128.4.1.1
```

```
router(config)#interface FastEthernet1/0
```

```
router(config-if)#ntp broadcast client
```

>> To see if NTP is working correctly, use the privileged EXEC command <show ntp status>.

```
Router#sh ntp status
```

```
Clock is synchronized, stratum 3, reference is 130.140.55.216
```

```
nominal freq is 250.0000 Hz, actual freq is 250.0000 Hz, precision is 2**24
```

```
reference time is BB0FC7AA.95E93186 (14:25:46.585 EDT Mon Jun 14 1999)
```

```
clock offset is 7.3012 msec, root delay is 21.21 msec
```

```
root dispersion is 65.20 msec, peer dispersion is 37.78 msec
```

```
Router#
```

>> To see the status of the NTP server relationships between the router and its defined NTP servers, use the privileged EXEC command <show ntp associations>.

```
Router#show ntp associations
```