- **Operating System**: The Cisco IOS (Internetwork Operating System) is copied into RAM during bootup.
- **Running Configuration File**: This is the configuration file that stores the configuration commands that the router IOS is currently using. With few exceptions, all commands configured on the router are stored in the running configuration file, known as *running-config*.
- **IP Routing Table**: This file stores information about directly connected and remote networks. It is used to determine the best path to forward the packet.
- **ARP Cache**: This cache contains the IPv4 address to MAC address mappings, similar to the ARP cache on a PC. The ARP cache is used on routers that have LAN interfaces such as Ethernet interfaces.
- **Packet Buffer**: Packets are temporarily stored in a buffer when received on an interface or before they exit an interface.

RAM is volatile memory and loses its content when the router is powered down or restarted. However, the router also contains permanent storage areas, such as ROM, flash and NVRAM.

ROM

- ROM is a form of permanent storage. Cisco devices use ROM to store:
- The bootstrap instructions
- Basic diagnostic software
- Scaled-down version of IOS
- ROM uses firmware, which is software that is embedded inside the integrated circuit. Firmware includes the software that does not normally need to be modified or upgraded, such as the bootup instructions. ROM does not lose its contents when the router loses power or is restarted.

Flash Memory

Flash memory is nonvolatile computer memory that can be *electrically* stored and erased. Flash is used as permanent storage for the *operating system*, Cisco IOS. In most models of Cisco routers, the IOS is permanently stored in flash memory and copied into RAM during the bootup process, where it is then executed by the CPU. Flash consists of SIMMs or PCMCIA cards, which can be upgraded to increase the amount of flash memory.

Flash memory does not lose its contents when the router loses power or is restarted.

NVRAM

NVRAM (Nonvolatile RAM) does not lose its information when power is turned off. NVRAM is used by the Cisco IOS as permanent storage for the startup configuration file (startup-config). All configuration changes are stored in the running-config file in RAM. To save those changes in case the router is restarted or loses power, the *running-config* must be copied to NVRAM, where it is stored as the *startup-config* file.

Internetwork Operating System

The operating system software used in Cisco routers is known as **Cisco Internetwork Operating System (IOS).** Like any operating system on any computer, Cisco IOS manages the hardware and software resources of the router, including memory allocation, processes, security, and file systems. Cisco IOS is a multitasking operating system that is integrated with routing, switching, internetworking, and telecommunications functions.

Cisco IOS has its own user interface. Although some routers provide a graphical user interface (GUI), the command line interface (CLI) is a much more common method of configuring Cisco routers. The CLI is used throughout this curriculum.

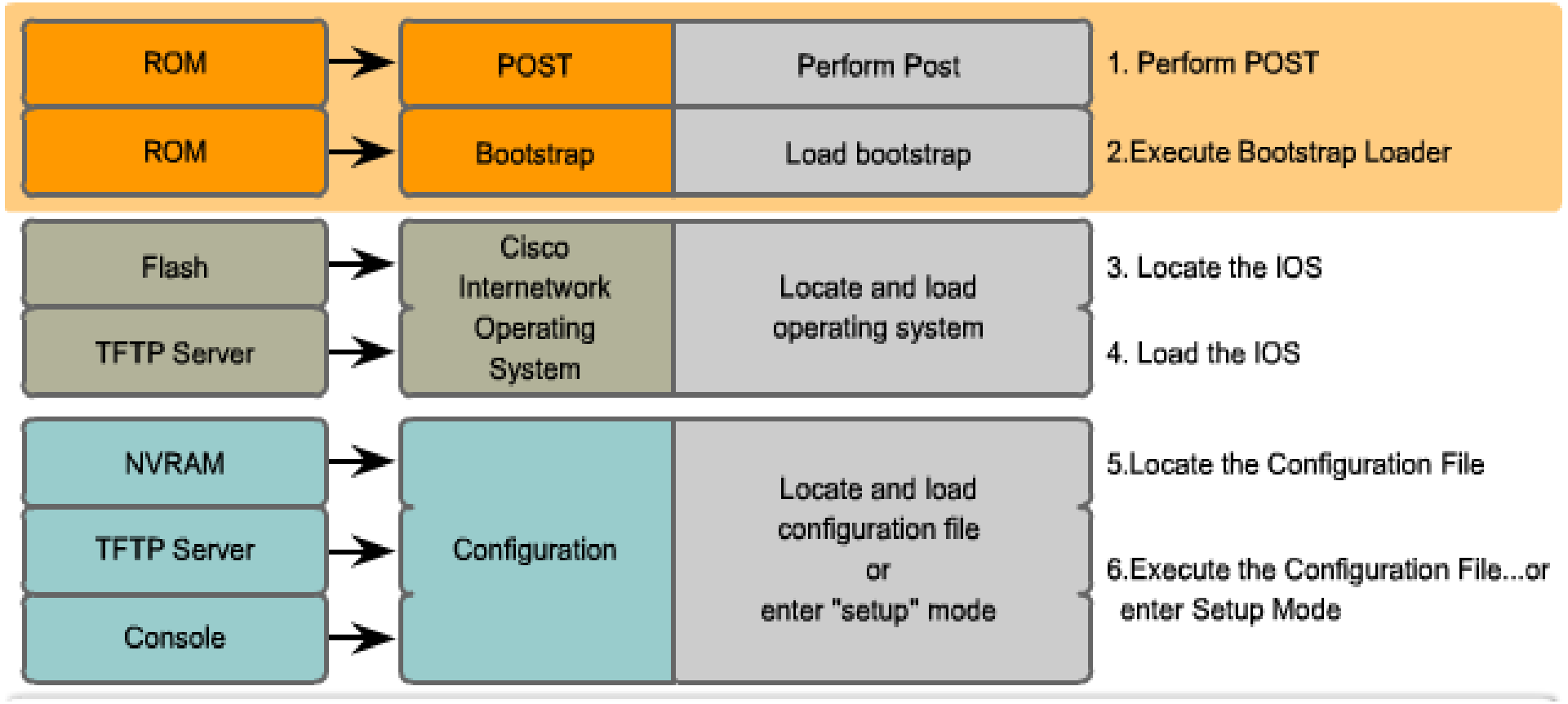
Upon bootup, the *startup-config file* in *NVRAM* is copied into *RAM* and stored as the *running-config file*. IOS executes the configuration commands in the running-config. Any changes entered by the network administrator are stored in the running-config and are immediately implemented by the IOS.

Bootup Process

There are four major phases to the bootup process:

1. Performing the POST
2. Loading the bootstrap program
3. Locating and loading the Cisco IOS software
4. Locating and loading the startup configuration file or entering setup mode

How a Router Boots Up



If a full IOS image can not be located, a scaled-down version of the IOS is copied from ROM into RAM. This version of IOS is used to help diagnose any problems and can be used to load a complete version of the IOS into RAM.

Locating the Startup Configuration File

After the IOS is loaded, the bootstrap program searches for the startup configuration file, known as *startup-config*, in NVRAM. This file has the previously saved configuration commands and parameters including:

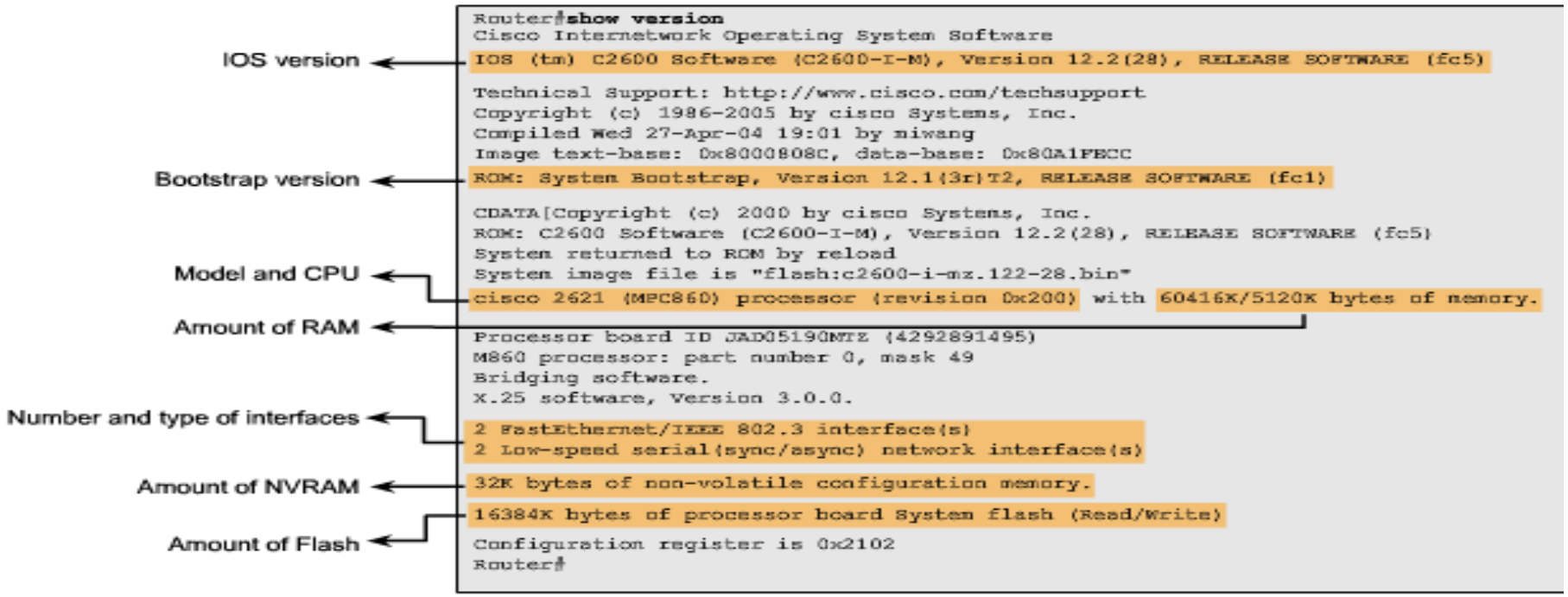
- interface addresses
- routing information
- passwords
- any other configurations saved by the network administrator.

If the startup configuration file, startup-config, is located in NVRAM, it is copied into RAM as the running configuration file, running-config.

Verifying Router Bootup Process

The **show version** command can be used to help verify and troubleshoot some of the basic hardware and software components of the router.

How a Router Boots Up



Router Interfaces (Management Ports)

Routers have physical connectors that are used to manage the router. These connectors are known as management ports. Unlike Ethernet and serial interfaces, management ports are not used for packet forwarding. The most common management port is the **console port**. The console port is used to connect a terminal, or most often a PC running *terminal emulator software*, to configure the router without the need for network access to that router. The console port must be used during *initial configuration of the router*.

Another management port is the **auxiliary port**. Not all routers have auxiliary ports. At times the auxiliary port can be used in ways similar to a console port. It can also be used to attach a modem.

Router Interfaces

The term interface on Cisco routers refers to a physical connector on the router whose main purpose is to receive and forward packets. Routers have multiple interfaces that are used to connect to multiple networks. Typically, the interfaces connect to various types of networks, which means that different types of media and connectors are required. Often a router will need to have different types of interfaces. For example, a router usually has **FastEthernet** interfaces for connections to different LANs and various types of **WAN** interfaces to connect a variety of serial links including T1, DSL and ISDN. The figure shows the FastEthernet and serial interfaces on the router.

Router Interfaces - Physical Representation

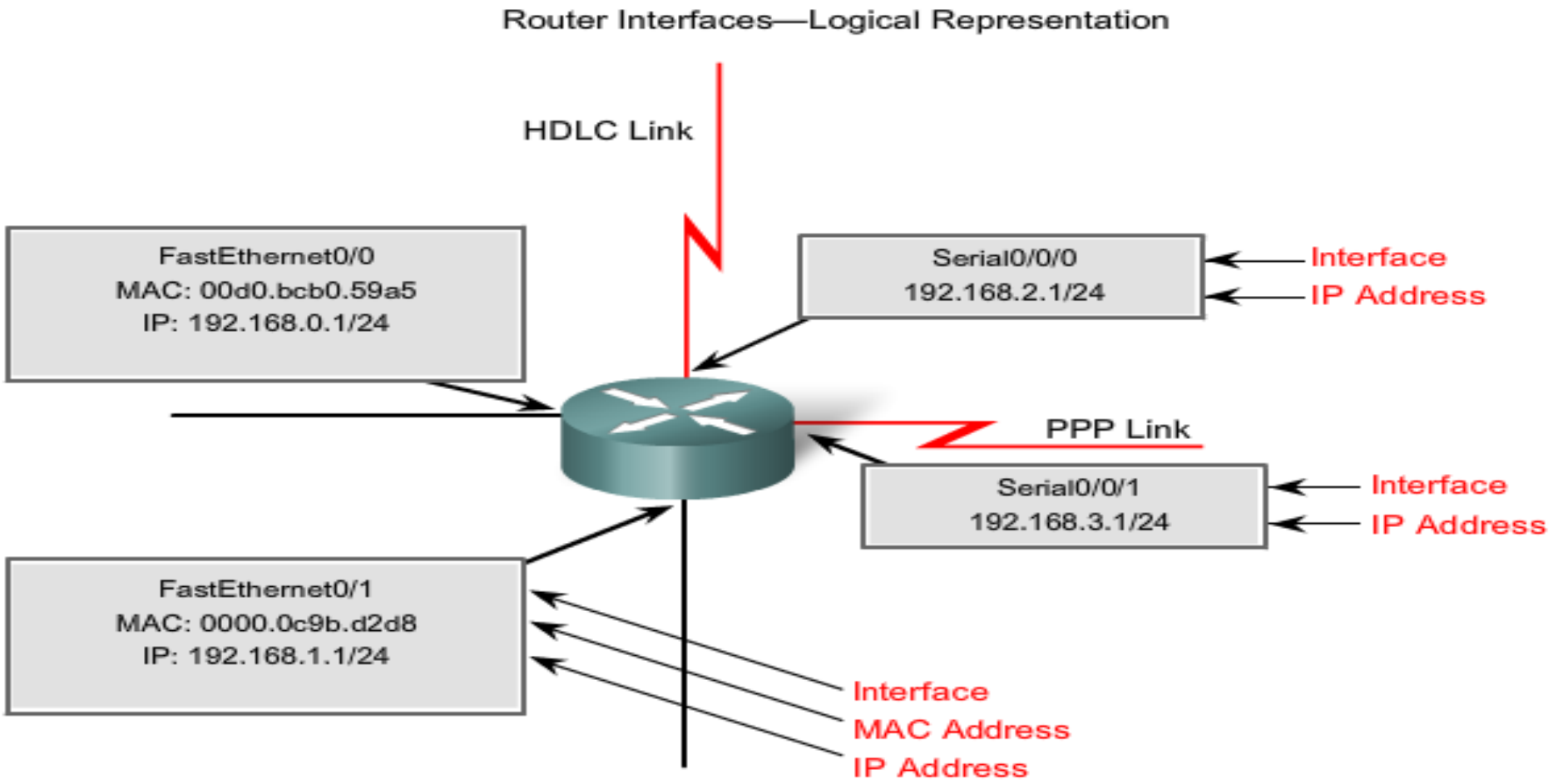
Each individual interface connects to a different network. Thus each interface has an IP address/mask from that network.

Interfaces Belong to Different Networks

Router interfaces can be divided into two major groups:

1- LAN interfaces - such as Ethernet and FastEthernet

2- WAN interfaces - such as serial, ISDN, and Frame Relay


Router Interfaces—Logical Representation
HDLC Link
FastEthernet0/0
MAC: 00d0.bcb0.59a5
IP: 192.168.0.1/24
Serial0/0/0
192.168.2.1/24
Interface
IP Address
PPP Link
Serial0/0/1
192.168.3.1/24
Interface
IP Address
FastEthernet0/1
MAC: 0000.0c9b.d2d8
IP: 192.168.1.1/24
Interface
MAC Address
IP Address

LAN interfaces: are used to connect the router to the LAN.

WAN Interfaces: are used to connect routers to external networks. The Layer 2 encapsulation can be of different types, such as PPP, Frame Relay, and HDLC (High-Level Data Link Control).

Note: MAC addresses are used on LAN interfaces, such as Ethernet, and are not used on WAN interfaces. However, WAN interfaces use their own Layer 2 addresses depending on the technology.

Routers and the Network Layer

A router is considered a Layer 3 device because its primary forwarding decision is based on the information in the Layer 3 IP packet, specifically the destination IP address. This process is known as **routing**.

Routers Operate at Layers 1, 2, and 3

A router makes its primary forwarding decision at Layer 3, it participates in Layer 1 and Layer 2 processes as well. After a router has examined the destination IP address of a packet and consulted its routing table to make its forwarding decision, it can forward that packet out the appropriate interface toward its destination. The router encapsulates the Layer 3 IP packet into the data portion of a Layer 2 data link frame appropriate for the exit interface. The type of frame can be an Ethernet, HDLC, or some other Layer 2 encapsulation - whatever encapsulation is used on that particular interface. The Layer 2 frame is encoded into the Layer 1 physical signals that are used to represent bits over the physical link.