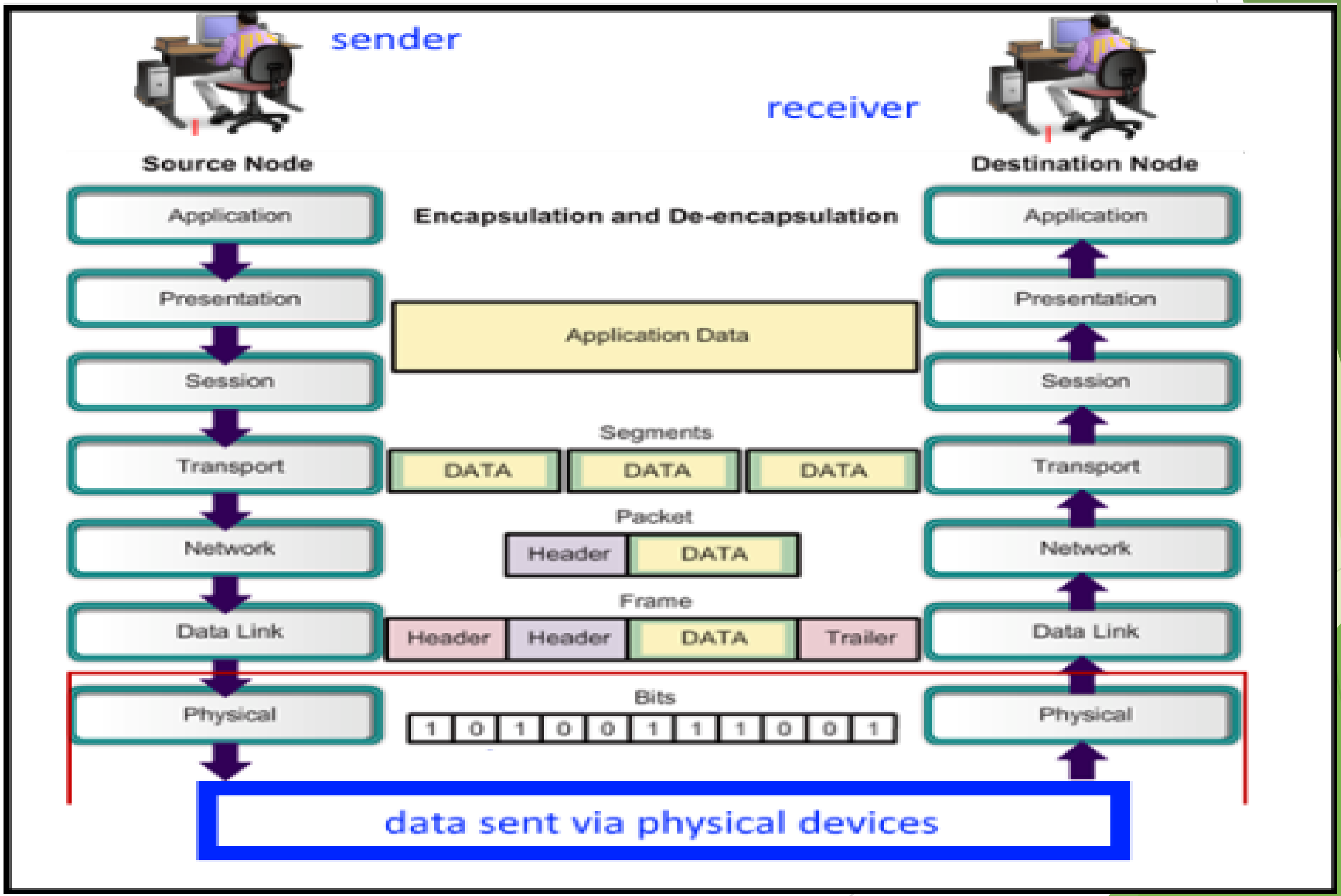
Chapter 6:
Network Layer (Layer 3)



- Network Layer Protocols

The Network Layer

The network layer provides services to allow end devices to exchange data across the network.

Four basic processes used :

- Addressing end devices
- Encapsulation
- Routing
- De-encapsulating

Network Layer Protocols

Protocols are needed for communication.

Common network layer protocols include:

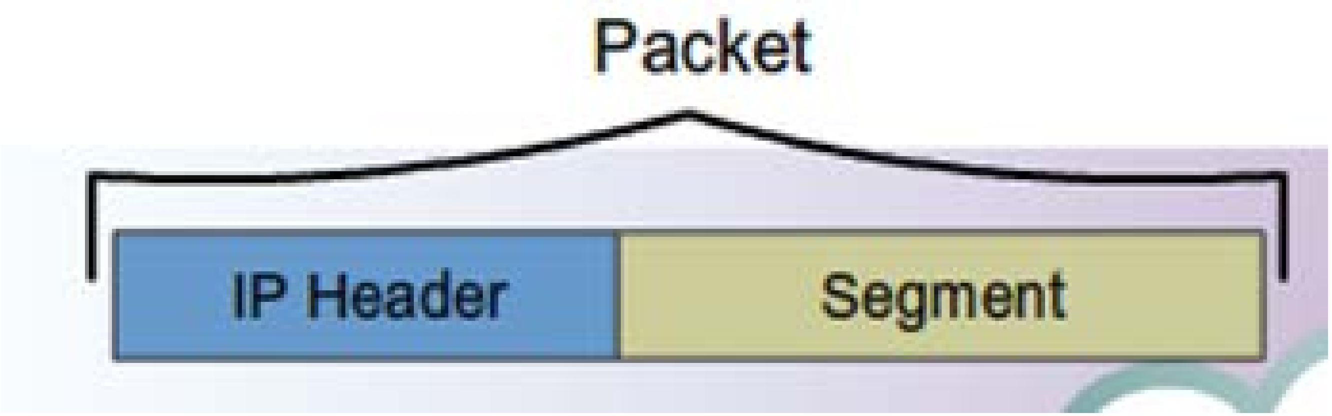
- IP version 4 (IPv4)
- IP version 6 (IPv6)

Non-IP protocols are known as Legacy network layer protocols. They include:

- Novell Internetwork Packet Exchange (IPX)
- AppleTalk
- Connectionless Network Service (CLNS/DECNet)

IP Characteristics
IP Components

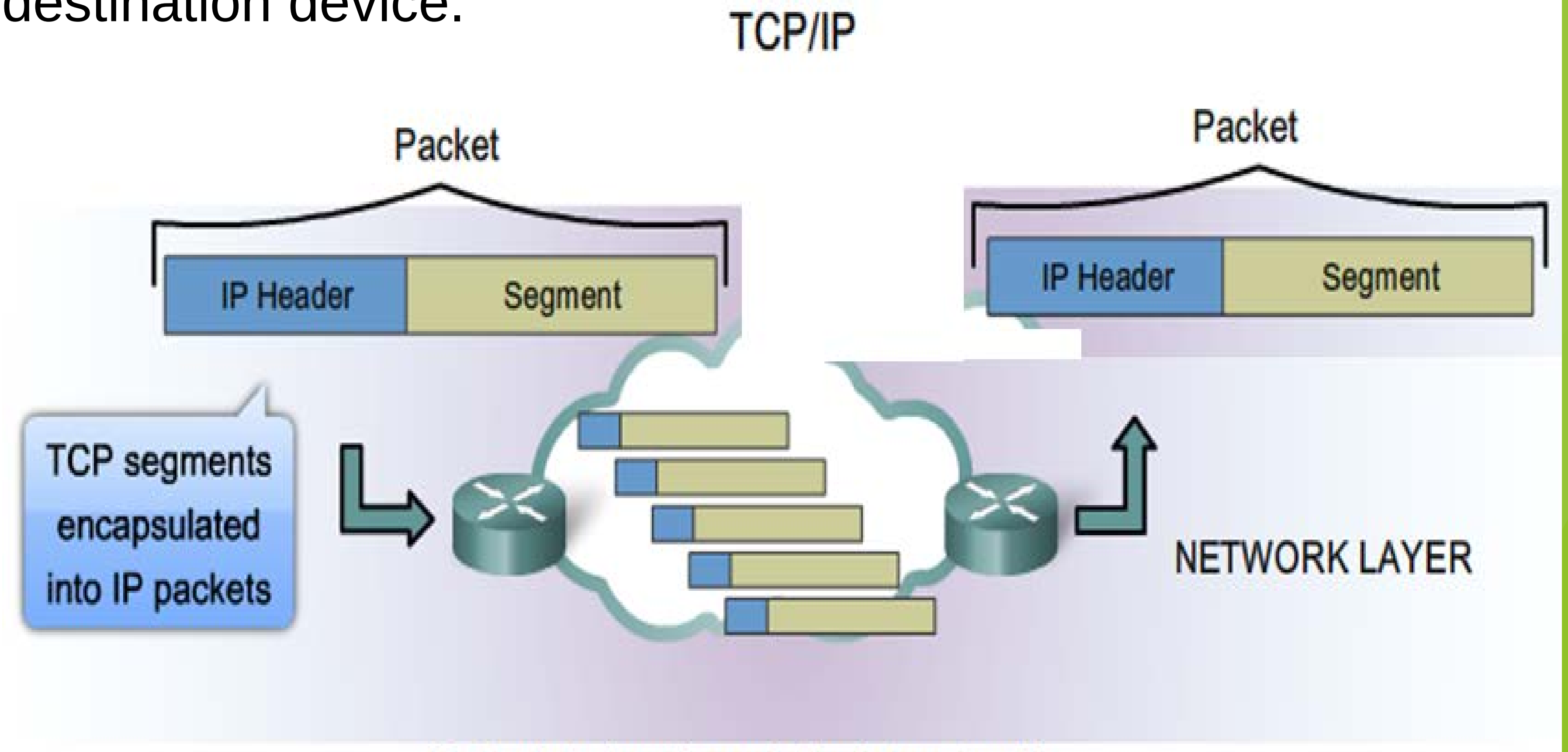
An IP packet consists of an IP header and a segment after encapsulation.



IP Characteristics

IP Components

Every packet will flow through the internetwork from source to destination device.



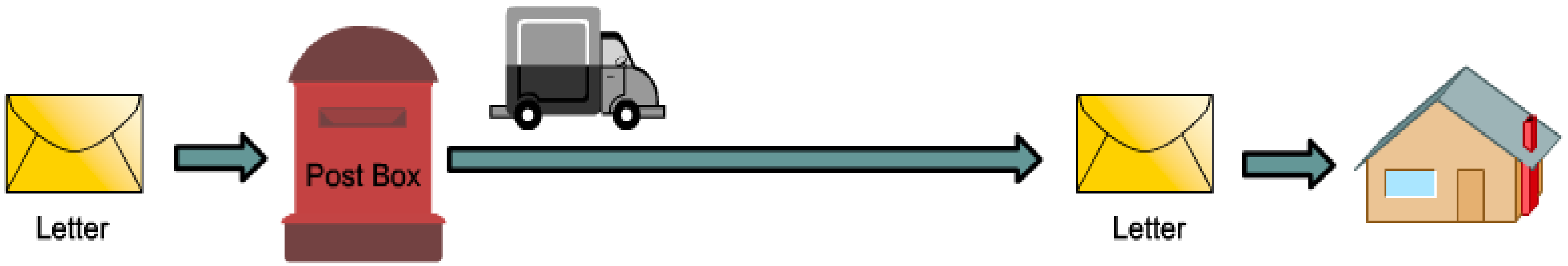
IP Packets flow through the internetwork.

Characteristics of the IP protocol

IP - Connectionless

No connection is made with device while data are sent.

Connectionless Communication



A letter is sent.

The sender doesn't know:

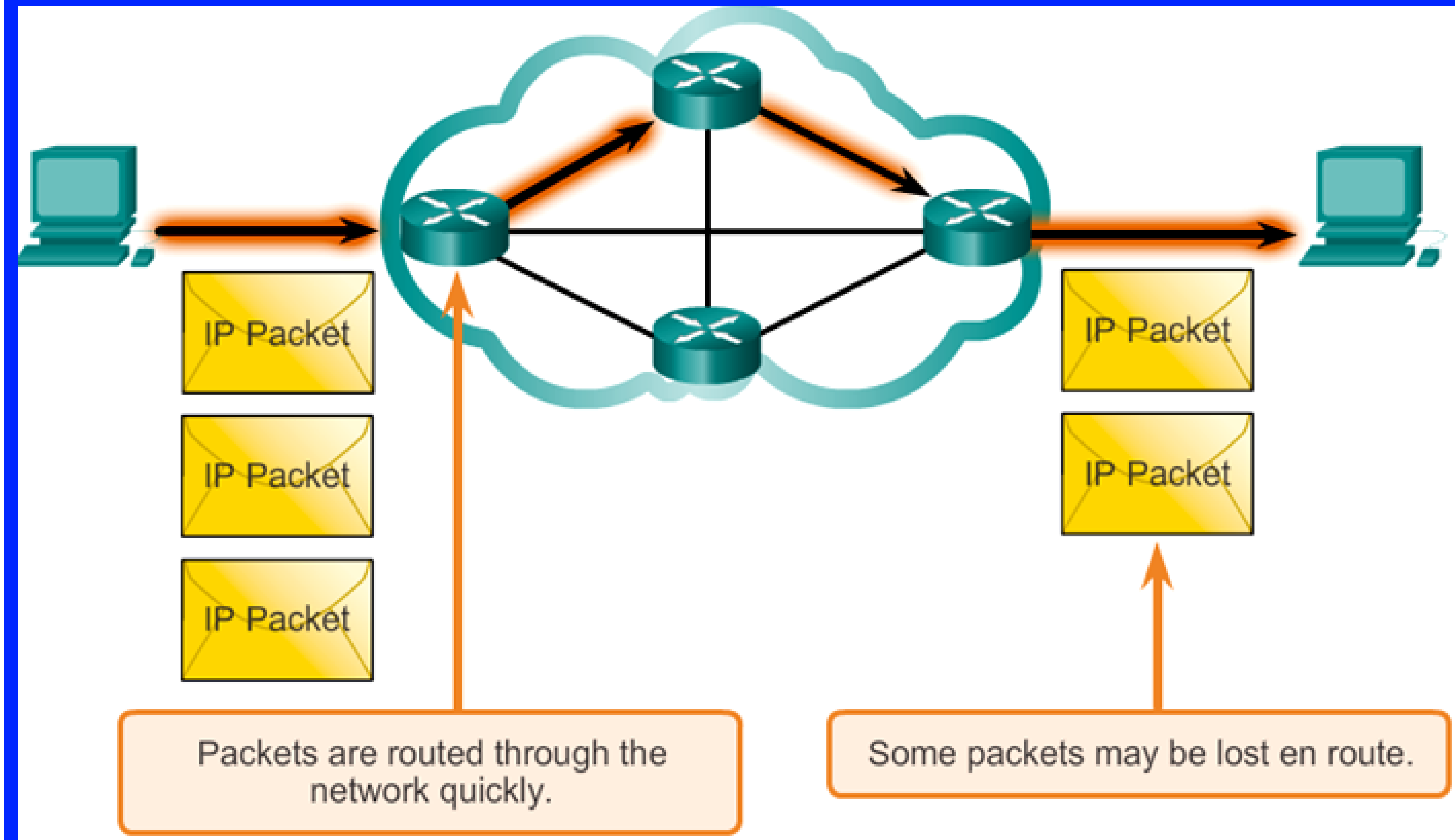
- if the receiver is present
- if the letter arrived
- if the receiver can read the letter

The receiver doesn't know:

- when it is coming

Characteristics of the IP protocol

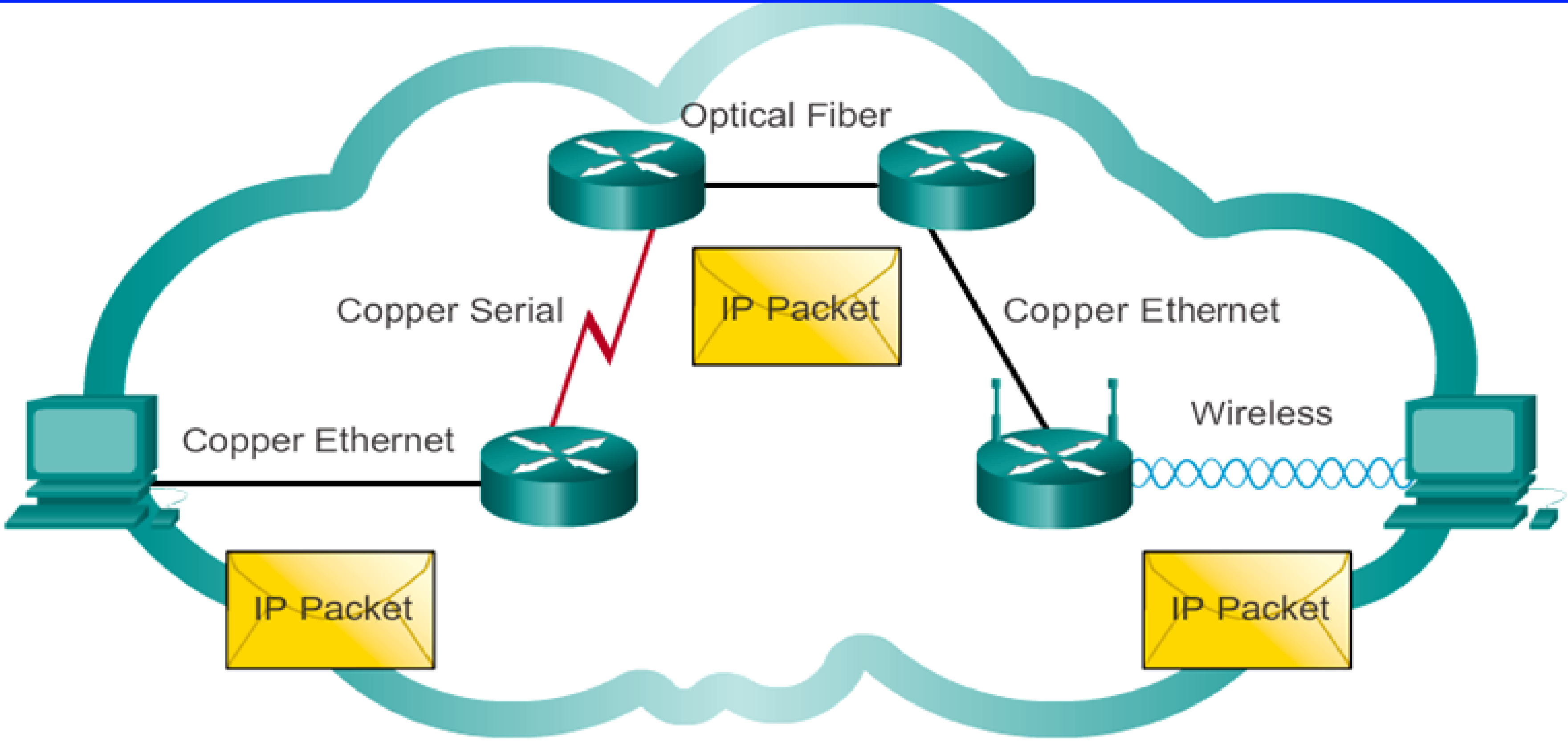
Best Effort Delivery



The IP Network Layer protocol does not guarantee that all packets sent will be received. Other protocols track packets and ensure delivery.

Characteristics of the IP protocol

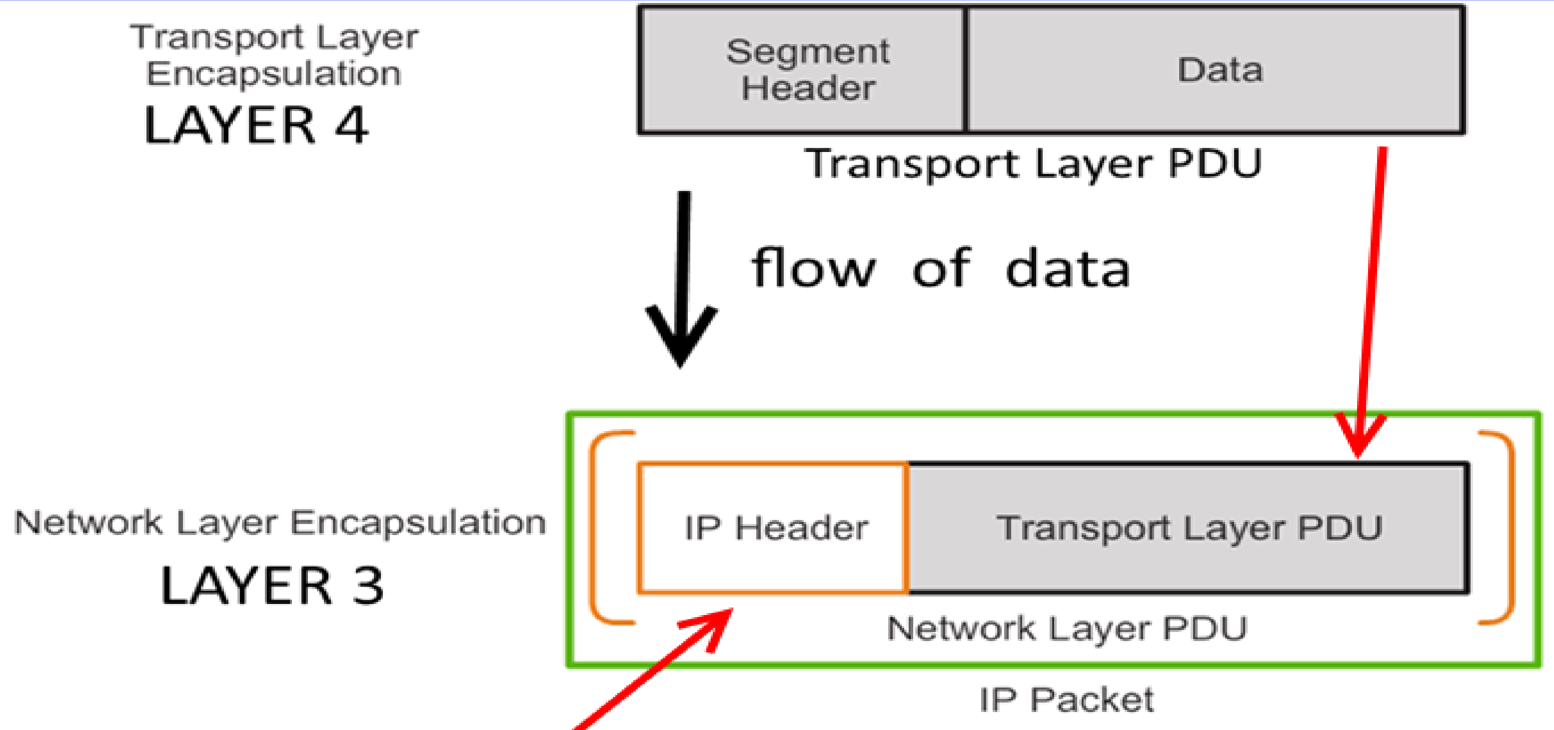
IP – Media Independent



IP packets can travel across different media.
It is thus media-independent.

IPv4 Packet

Encapsulating IP



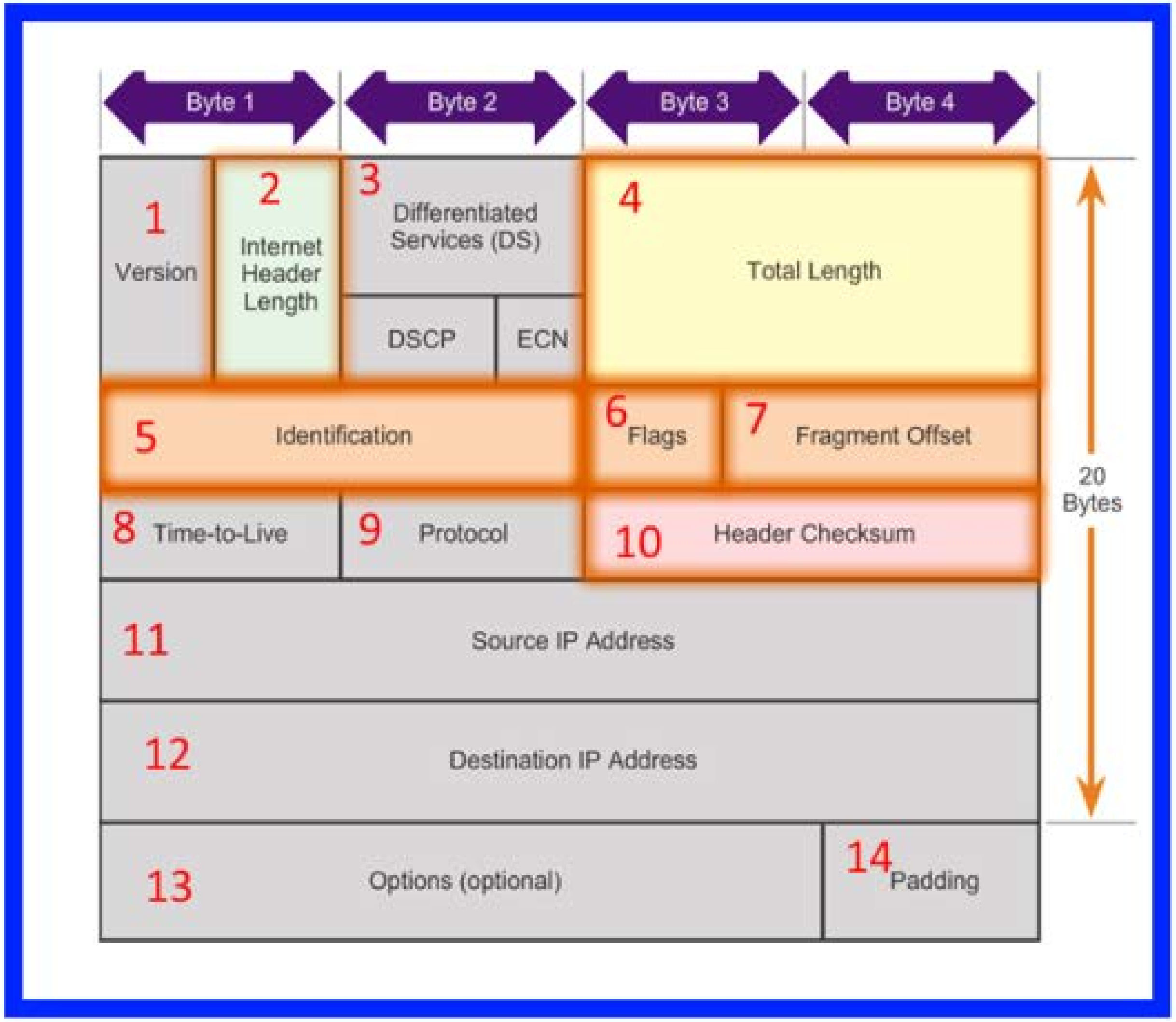
The network layer adds a header so packets can be routed through complex networks and reach their destination. In TCP/IP based networks, the network layer PDU is the IP packet.

IPv4 Packet Header

The IPv4 packet header contains 14 fields;

13 required, 1 option…

Each field has a leng… of 1 byte



Limitations of IPv4

- IP Address depletion
  IPv4 uses 32-bit (four-byte) addresses; this limits the address space to 4294967296 addresses.
- IP v6 was created to overcome this limitation.
- Internet routing table expansion
  Once the number of routing tables reaches 512,000,
  Cisco devices will face problems.
- Lack of end-to-end connectivity
  End-to-end connectivity is a property of the Internet that allows all nodes to send packets to all other nodes , without requiring intermediate network elements to further interpret them.
  IP cannot do that.

Introducing IPv6

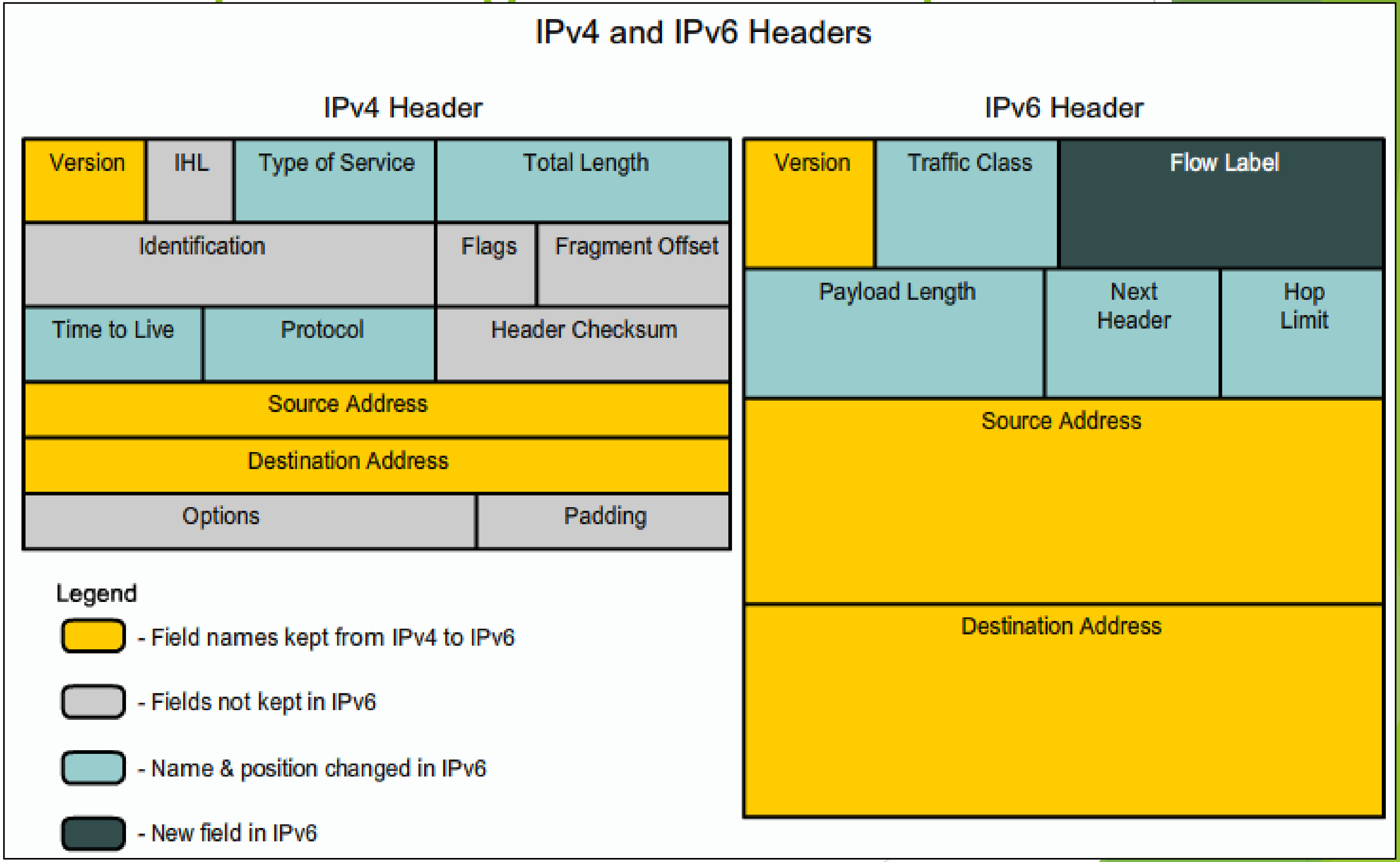
To overcome the limitations of IPv4, IPv6 was introduced.

It offers the following benefits:

- Increased address space compared to IPv4
- Improved packet handling compared to IPv4.
- Eliminates the need for NAT (Network Address Translation).
- Integrated security
- IPv4 offers 4294967296 addresses

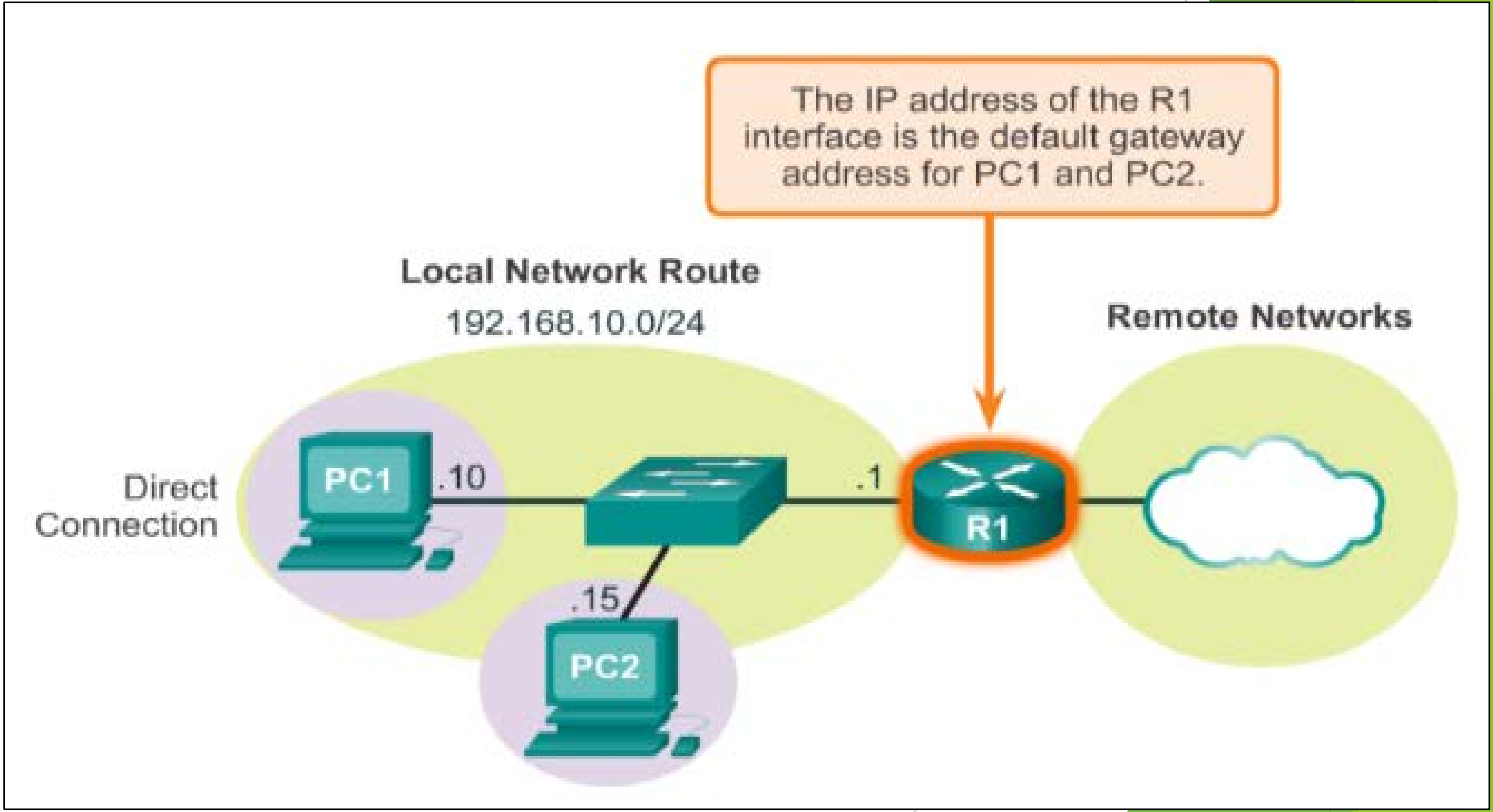
IPv6 Packet

Encapsulating IPv6 is simpler



Host Routing Tables

Host Packet Forwarding Decision



Routing Table

A routing table is a data table stored in a router or a networked computer.

Routing refers to finding the best path.

It lists the routes to particular network destinations.

The primary function of a router is to forward a packet toward its destination destination IP address.

To do this, a router needs to search the routing information stored in its routing table.

Routing Table

How a routing table looks like:

```
C:\Users\PC1>netstat -r

<Output omitted>

IPv4 Route Table
===========================================================================
Active Routes:
Network Destination        Netmask          Gateway       Interface  Metric
          0.0.0.0          0.0.0.0     192.168.10.1    192.168.10.10     25
        127.0.0.0        255.0.0.0         On-link         127.0.0.1    306
        127.0.0.1  255.255.255.255         On-link         127.0.0.1    306
  127.255.255.255  255.255.255.255         On-link         127.0.0.1    306
     192.168.10.0    255.255.255.0         On-link     192.168.10.10    281
    192.168.10.10  255.255.255.255         On-link     192.168.10.10    281
   192.168.10.255  255.255.255.255         On-link     192.168.10.10    281
        224.0.0.0        240.0.0.0         On-link         127.0.0.1    306
        224.0.0.0        240.0.0.0         On-link     192.168.10.10    281
  255.255.255.255  255.255.255.255         On-link         127.0.0.1    306
  255.255.255.255  255.255.255.255         On-link     192.168.10.10    281
===========================================================================

<Output omitted>
```

Default Gateway

Host Routing Table

Hosts must maintain their own routing table to ensure that network layer packets are directed to the correct destination network. The local table of the host typically contains:

- Direct connection
- Local network route
- Local default route

Host Routing Tables

Sample IPv4 Host Routing Table


```
C:\Users\PC1> netstat -r
<Output omitted>
IPv4 Route Table
===========================================================================
Active Routes:
Network Destination        Netmask          Gateway       Interface  Metric
          0.0.0.0          0.0.0.0     192.168.10.1   192.168.10.10     25
        127.0.0.0        255.0.0.0         On-link        127.0.0.1    306
        127.0.0.1  255.255.255.255         On-link        127.0.0.1    306
  127.255.255.255  255.255.255.255         On-link        127.0.0.1    306
     192.168.10.0    255.255.255.0         On-link    192.168.10.10    281
    192.168.10.10  255.255.255.255         On-link    192.168.10.10    281
   192.168.10.255  255.255.255.255         On-link    192.168.10.10    281
        224.0.0.0        240.0.0.0         On-link        127.0.0.1    306
        224.0.0.0        240.0.0.0         On-link    192.168.10.10    281
  255.255.255.255  255.255.255.255         On-link        127.0.0.1    306
  255.255.255.255  255.255.255.255         On-link    192.168.10.10    281
===========================================================================
<Output omitted>
```

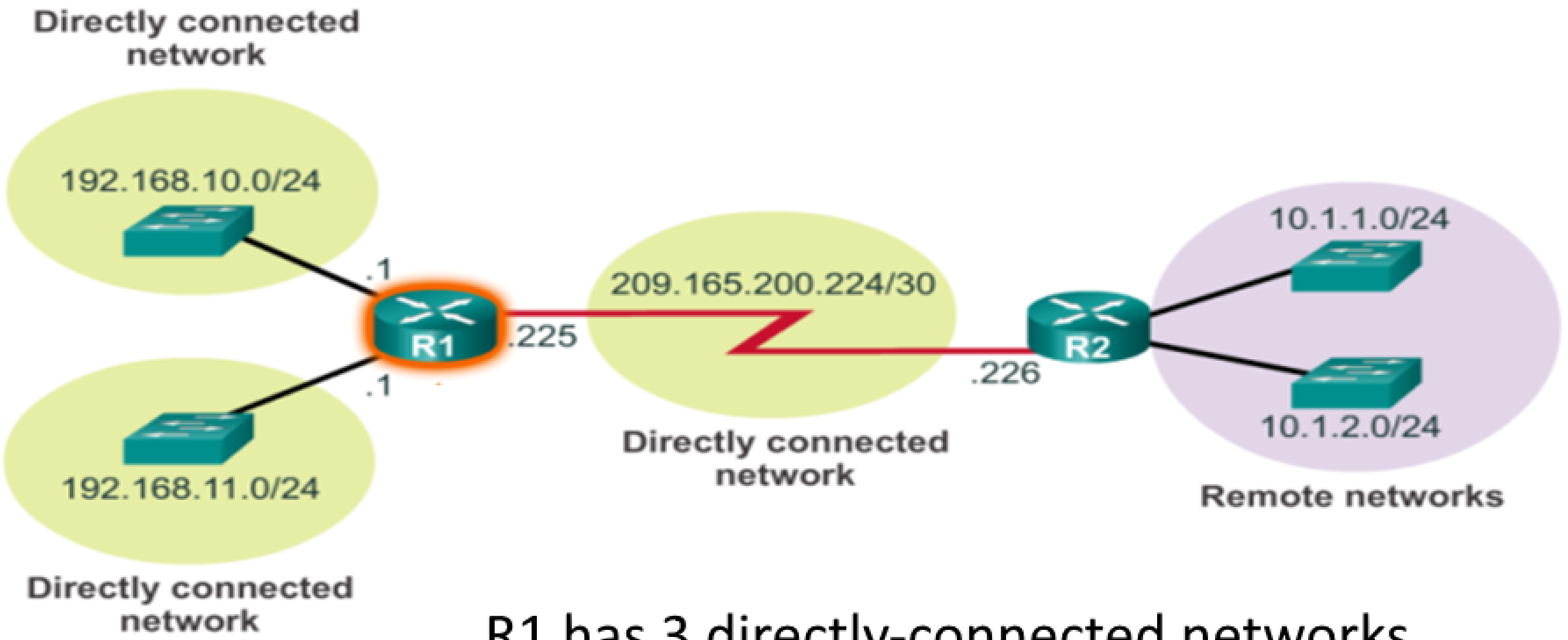
Sample IPv6 Host Routing Table


```
C:\Users\PC1> netstat -r

<Output omitted>

IPv6 Route Table
===========================================================================
Active Routes:
 If Metric Network Destination      Gateway
 16     58 ::/0                     On-link
  1    306 ::1/128                  On-link
 16     58 2001::/32                On-link
 16    306 2001:0:9d38:953c:2c30:3071:e718:a926/128
                                    On-link
 15    281 fe80::/64                On-link
 16    306 fe80::/64                On-link
 16    306 fe80::2c30:3071:e718:a926/128
                                    On-link
 15    281 fe80::b1ee:c4ae:a117:271f/128
                                    On-link
  1    306 ff00::/8                 On-link
 16    306 ff00::/8                 On-link
 15    281 ff00::/8                 On-link
===========================================================================
<Output omitted>
```

Router Routing Tables

A device can have 2 types of networks:

- Directly-connected networks and
- Remote networks



R1 has 3 directly-connected networks, and 2 remote networks

Router Routing Tables

Remote Network Routing Table Entries

Meaning of parts of a table entry

```
D        10.1.1.0/24 [90/2170112] via 209.165.200.226, 00:00:05, Serial0/0/0
```

A	Identifies how the network was learned by the router.
B	Identifies the destination network.
C	Identifies the administrative distance (trustworthiness) of the route source.
D	Identifies the metric to reach the remote network.
E	Identifies the next hop IP address to reach the remote network.
F	Identifies the amount of elapsed time since the network was discovered.
G	Identifies the outgoing interface on the router to reach the destination network.

Router Routing Tables

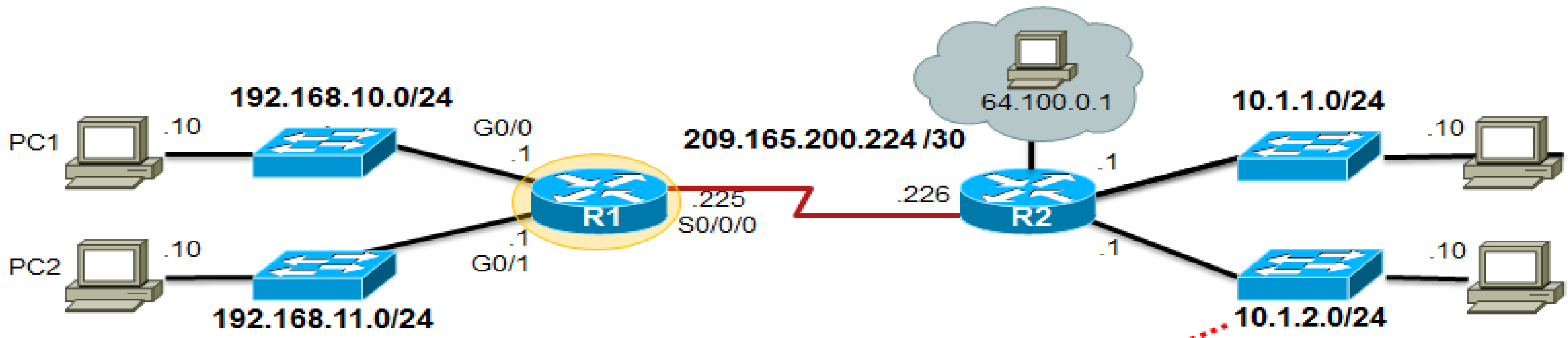
Next-Hop Address

The **next hop** is the **next** possible destination for a data packet.

next hop is an IP **address** entry in a router's routing table.

Router Routing Tables

Next-Hop Address



Next hop address

```
R1#show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
D       10.1.1.0/24 [90/2170112] via 209.165.200.226, 00:00:05, Serial0/0/0
D       10.1.2.0/24 [90/2170112] via 209.165.200.226, 00:00:05, Serial0/0/0
     192.168.10.0/24 is variably subnetted, 2 subnets, 3 masks
C       192.168.10.0/24 is directly connected, GigabitEthernet0/0
L       192.168.10.1/32 is directly connected, GigabitEthernet0/0
     192.168.11.0/24 is variably subnetted, 2 subnets, 3 masks
C       192.168.11.0/24 is directly connected, GigabitEthernet0/1
L       192.168.11.1/32 is directly connected, GigabitEthernet0/1
     209.165.200.0/24 is variably subnetted, 2 subnets, 3 masks
C       209.165.200.224/30 is directly connected, Serial0/0/0
L       209.165.200.225/32 is directly connected, Serial0/0/0
R1#
```

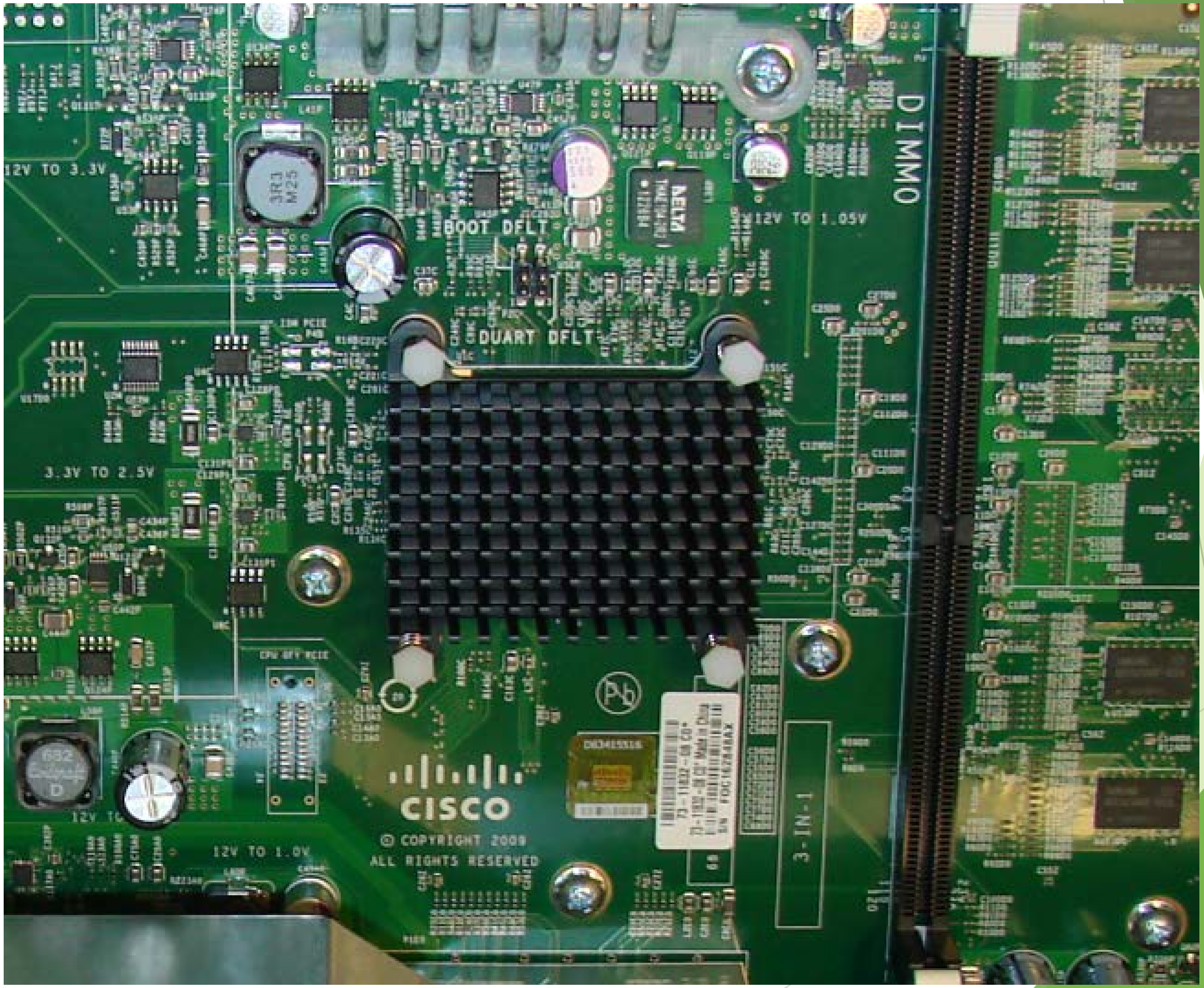
ROUTERS

Anatomy of a Router

A Router is basically a Computer

Anatomy of a Router

Router CPU and OS



Anatomy of a Router

Router Memory

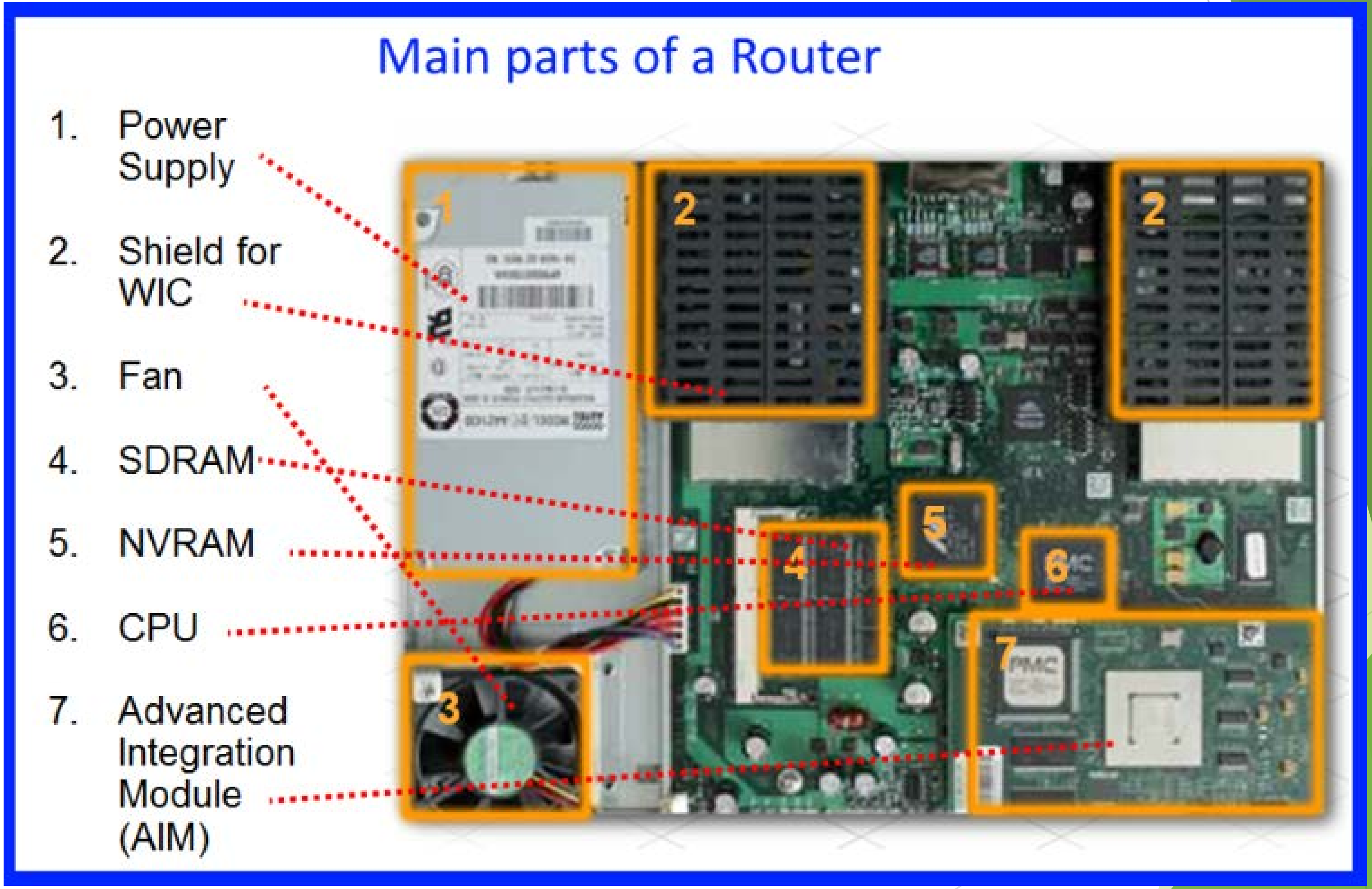
There are 4 types of memory used in a router:

- RAM
- ROM
- NVRAM
- Flash

Memory Type	Volatile / Non-Volatile	What are Stored in the Memory
RAM	Volatile	• Running IOS • Running configuration file • IP routing and ARP tables • Packet buffer
ROM	Non-Volatile	• Bootup instructions • Basic diagnostic software • Limited IOS
NVRAM	Non-Volatile	• Startup configuration file
Flash	Non-Volatile	• IOS • Other system files

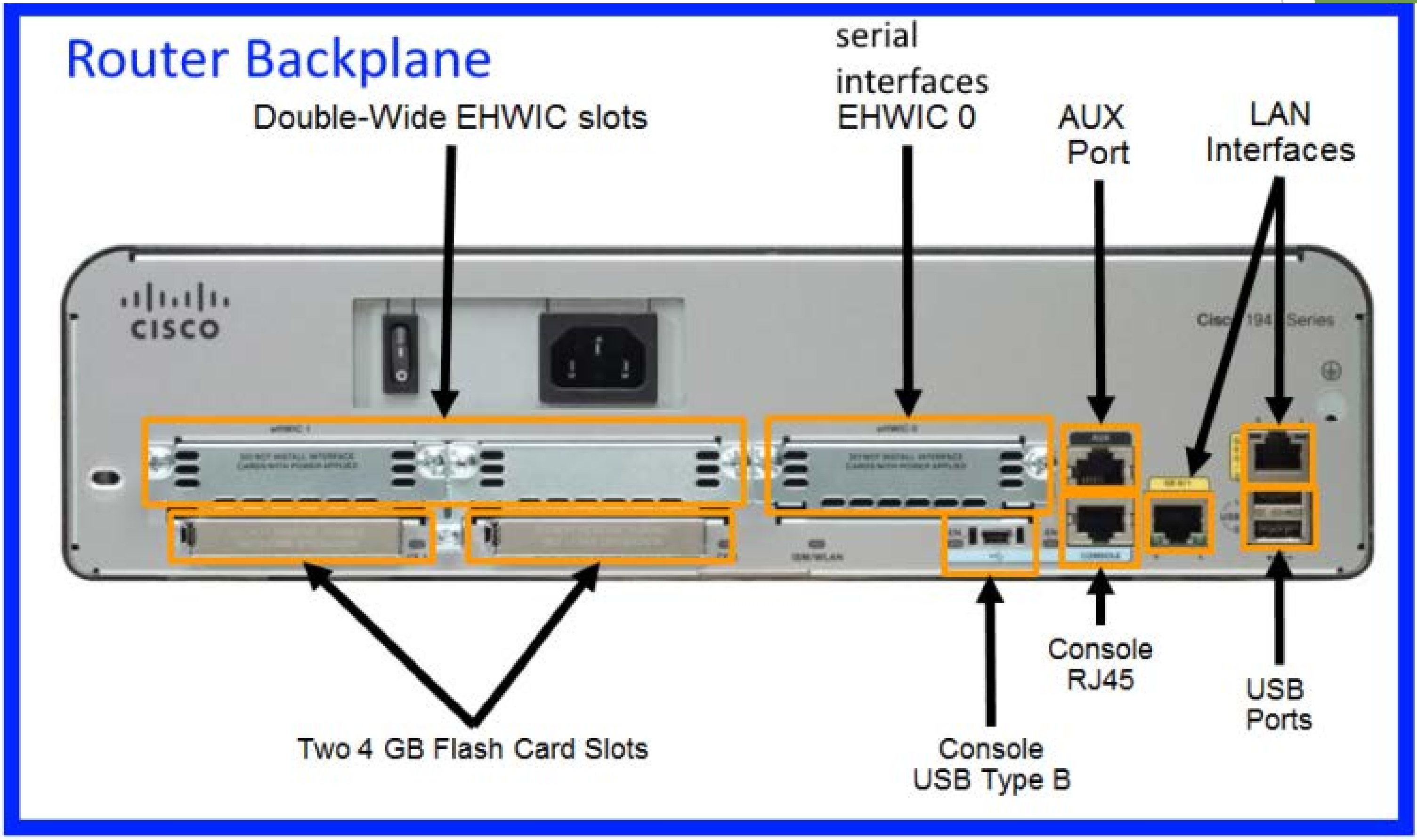
Anatomy of a Router

Inside a Router



Router Backplane

On the backplane of the router, there are different ports for different connections.



Cisco IOS

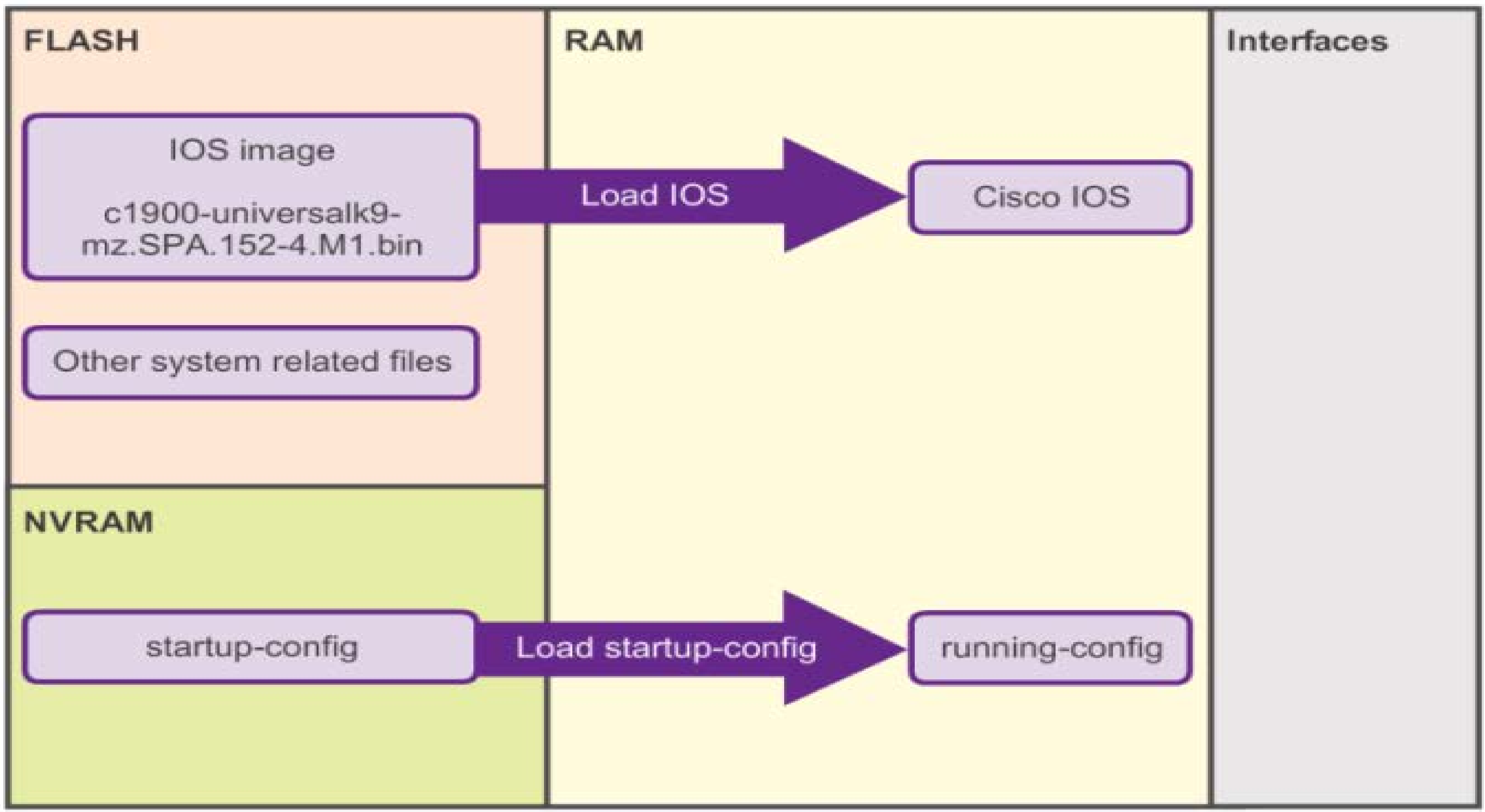
Cisco IOS for routers provides the following:

- Addressing
- Interfaces
- Routing
- Security
- QoS
- Resources Management

Router Boot-up

Bootset Files

Different files are stored in different memory spaces.



Configuring a Router

- When a Cisco router is booted for the first time, some basic configuration has already been performed. This is the default configuration.
- To check the configuration details, we can use the command ‘show running-config’ at the CLI.
- It may need to be re-configured to suit the network it is used in.

Configuring a Router

CLI commands to enter into configuration mode.

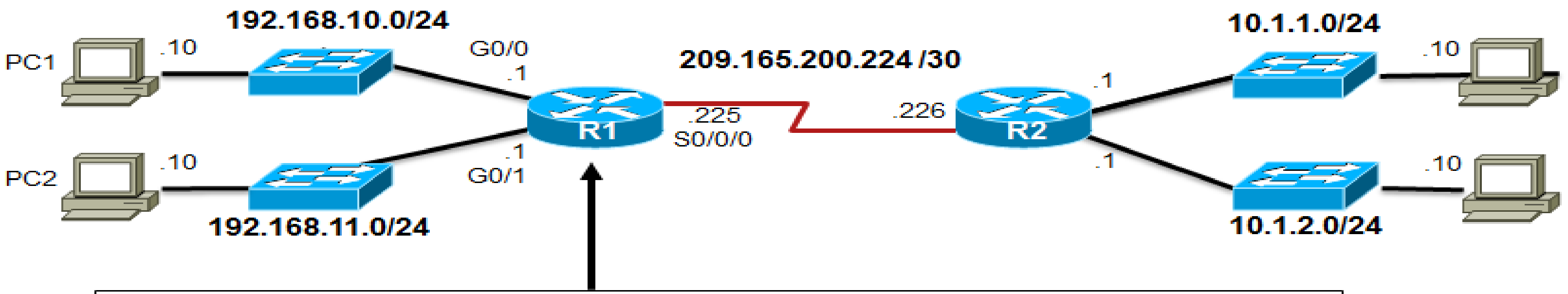
```
Router> enable
Router# configure terminal
Enter configuration commands, one per line.
End with CNTL/Z.
Router(config)# hostname R1
R1(config)#
```

OR

```
Router> en
Router# conf t
Enter configuration commands, one per line.
End with CNTL/Z.
Router(config)# ho R1
R2(config)#
```

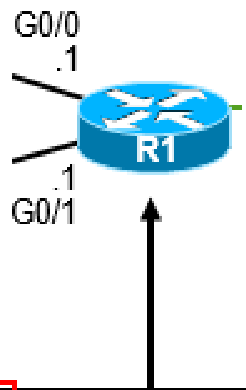
Configure LAN Interfaces

Routers need to be configured to the LAN used.




```
R1# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#
R1(config)# interface gigabitethernet 0/0
R1(config-if)# ip address 192.168.10.1 255.255.255.0
R1(config-if)# description Link to LAN-10
R1(config-if)# no shutdown
%LINK-5-CHANGED: Interface GigabitEthernet0/0, changed state to up
%LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/0,
changed state to up
R1(config-if)# exit
R1(config)#
R1(config)# int g0/1
R1(config-if)# ip add 192.168.11.1 255.255.255.0
R1(config-if)# des Link to LAN-11
R1(config-if)# no shut
%LINK-5-CHANGED: Interface GigabitEthernet0/1, changed state to up
%LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/1,
changed state to up
R1(config-if)# exit
R1(config)#
```

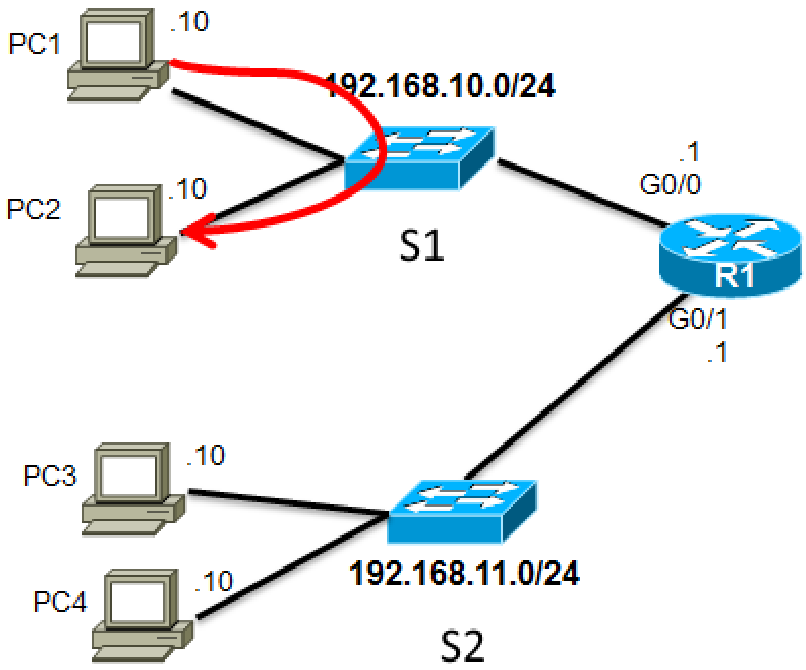
Verify Interface Configuration



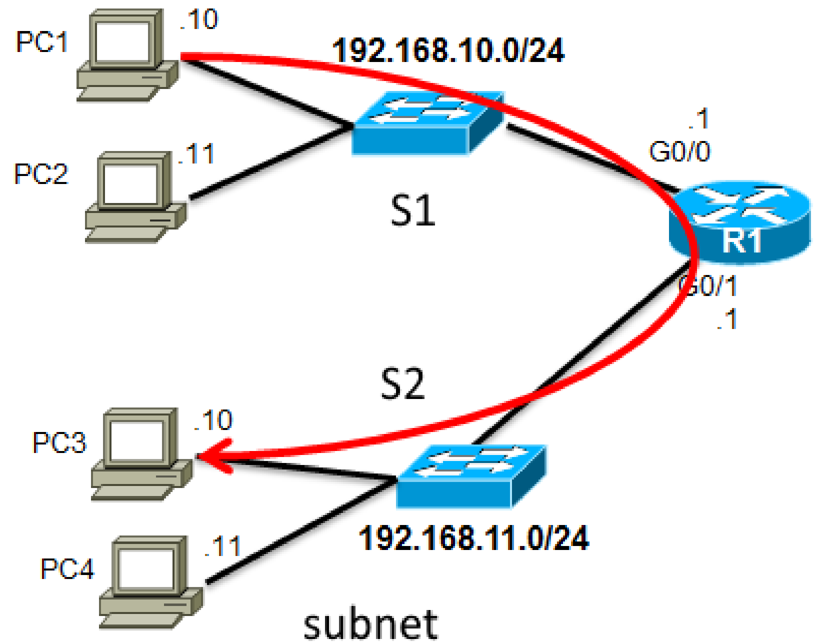

```
R1# show ip interface brief
Interface              IP-Address      OK? Method Status                Protocol

GigabitEthernet0/0     192.168.10.1    YES manual up                    up
GigabitEthernet0/1     192.168.11.1    YES manual up                    up
Serial0/0/0            209.165.200.225 YES manual up                    up
Serial0/0/1            unassigned      YES NVRAM  administratively down down
Vlan1                  unassigned      YES NVRAM  administratively down down
R1#
R1# ping 209.165.200.226

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 209.165.200.226, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/9 ms

R1#
```

Default Gateway on a Host

Default Gateway
not needed

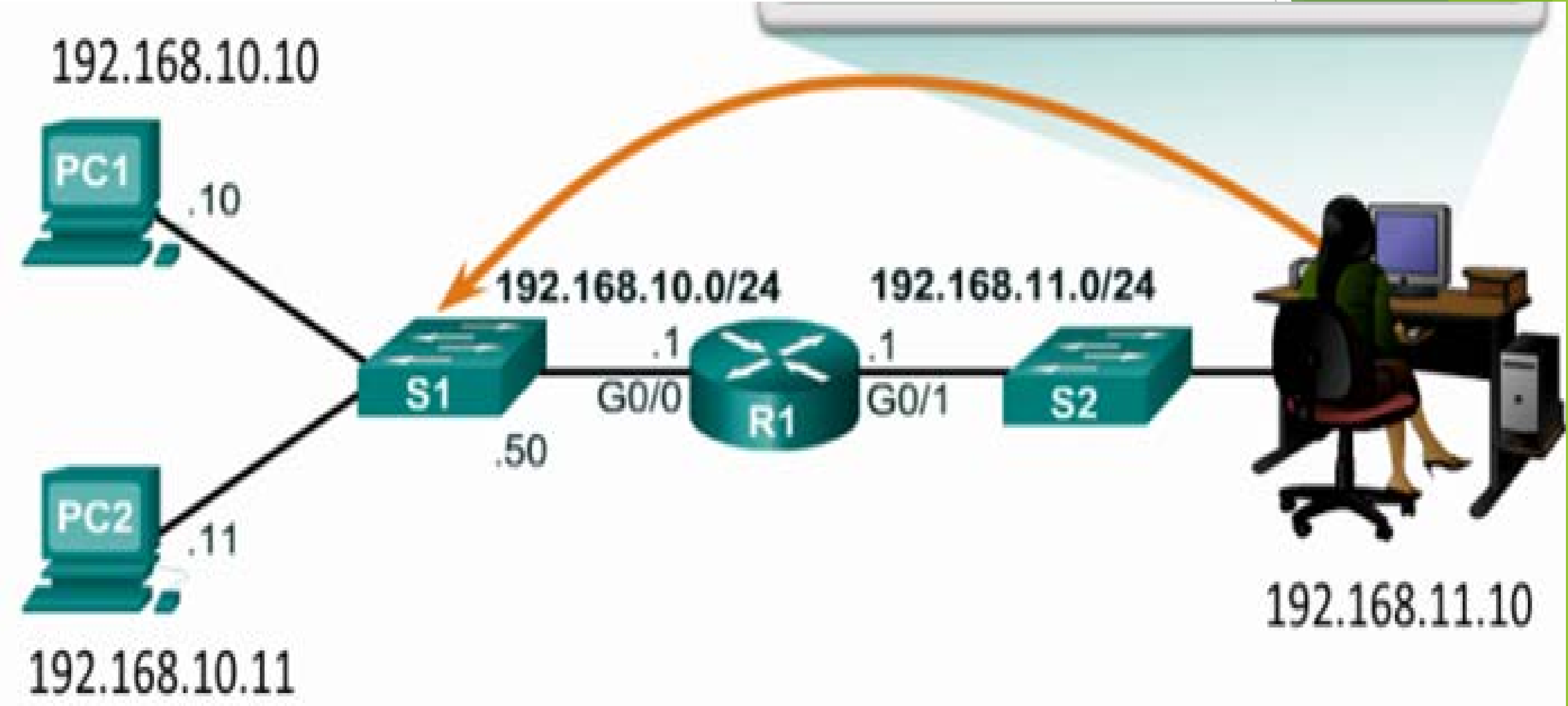


Default Gateway is needed in a switch when packets are sent to/from another subnet



Configuring the Default Gateway

Default Gateway on a Switch



If the default gateway was not configured on S1, response packets from S1 would not be able to reach the administrator at 192.168.11.10. The administrator would not be able to manage the device remotely.

END