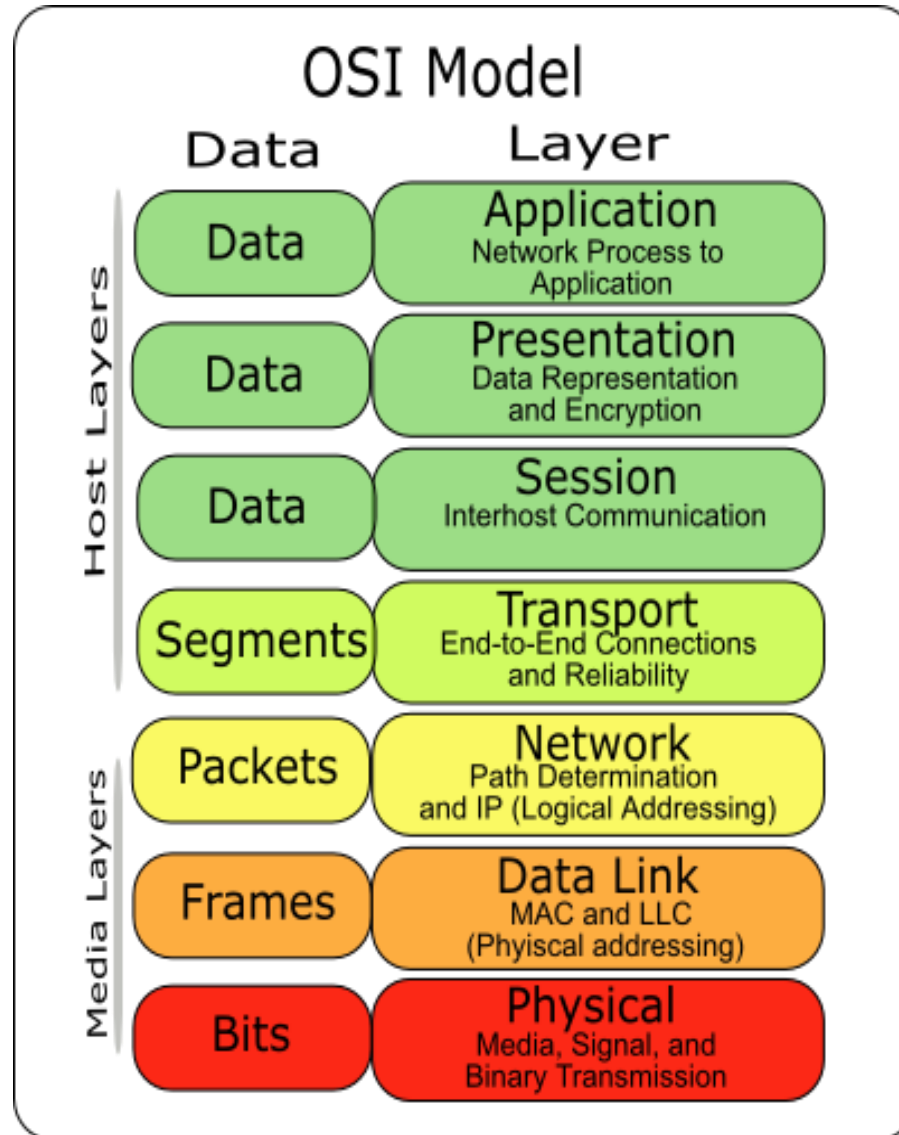


Network Layer

Week 5

Module : Computer Networks
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Office : 324

Network Layer



Network Layer Protocols

Common Network Layer Protocols

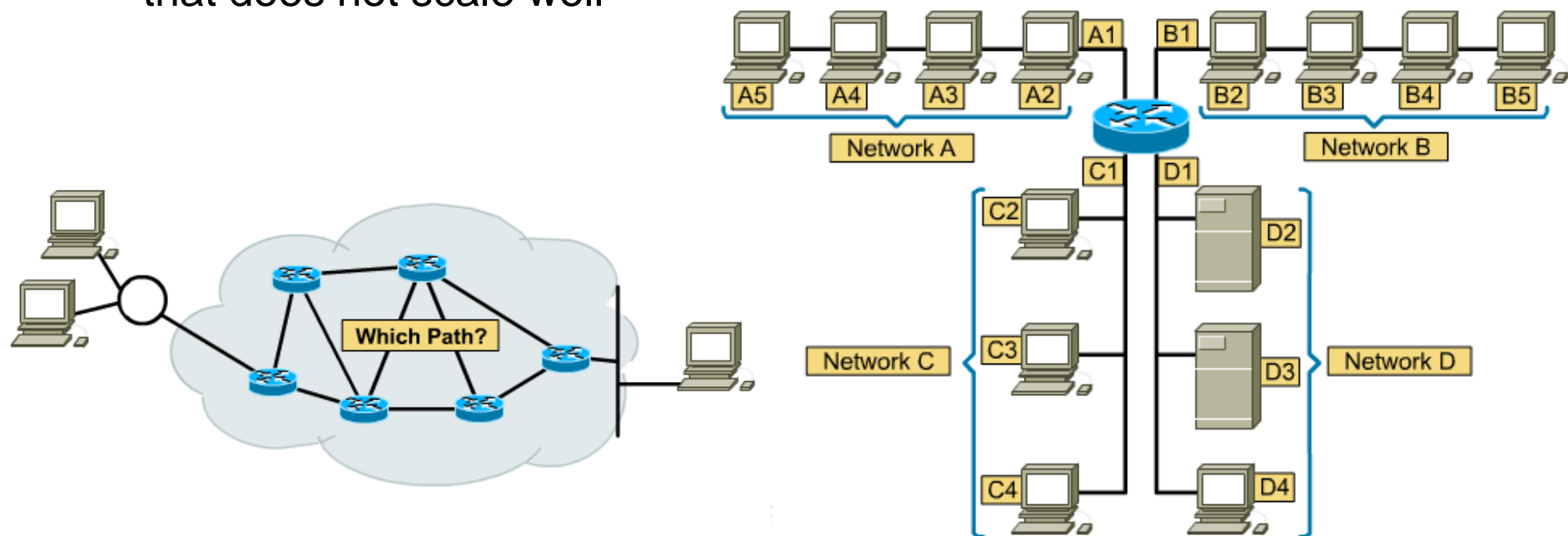
- Internet Protocol version 4 (IPv4)
- Internet Protocol version 6 (IPv6)

Legacy Network Layer Protocols

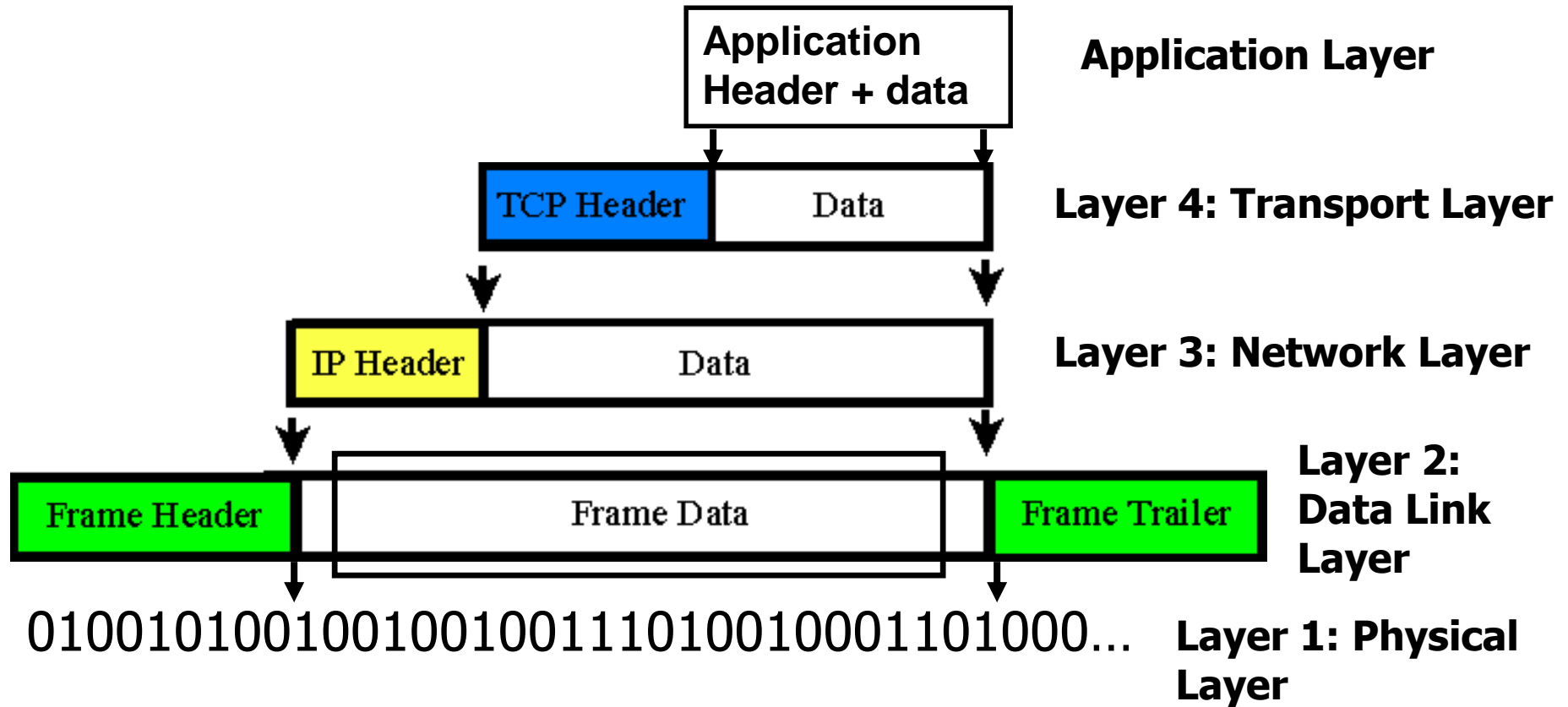
- Novell Internetwork Packet Exchange (IPX)
- AppleTalk
- Connectionless Network Service (CLNS/DECNet)

Identifying Network Users

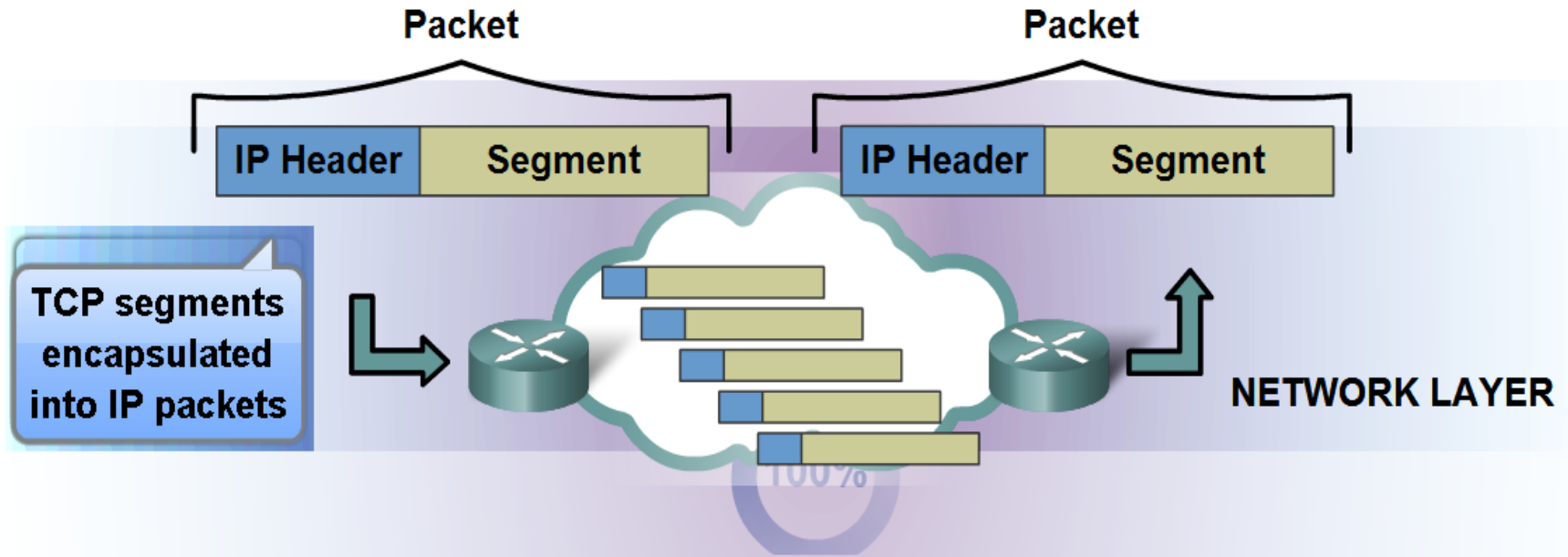
- The **network layer** is responsible for *moving data through a set of networks*.
- **Protocols** that support *network layer* use *hierarchical addressing*
- **Protocols** that have **no network layer** only work on *small internal networks*.
- **Protocols** that have **no network layer** use a *flat addressing scheme* that does not scale well



Data Encapsulation Example



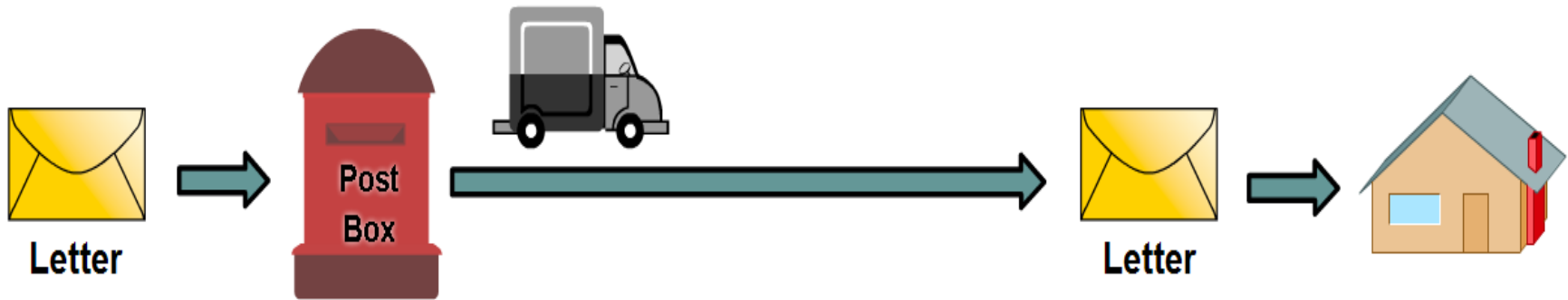
TCP/IP



IP Packets flow through the internetwork.

- **Connectionless** - No connection is established before sending data packets.
- **Best Effort (unreliable)** - No overhead is used to guarantee packet delivery.
- **Media Independent** - Operates independently of the medium carrying the data.

Connectionless Communication



A **letter** is sent.

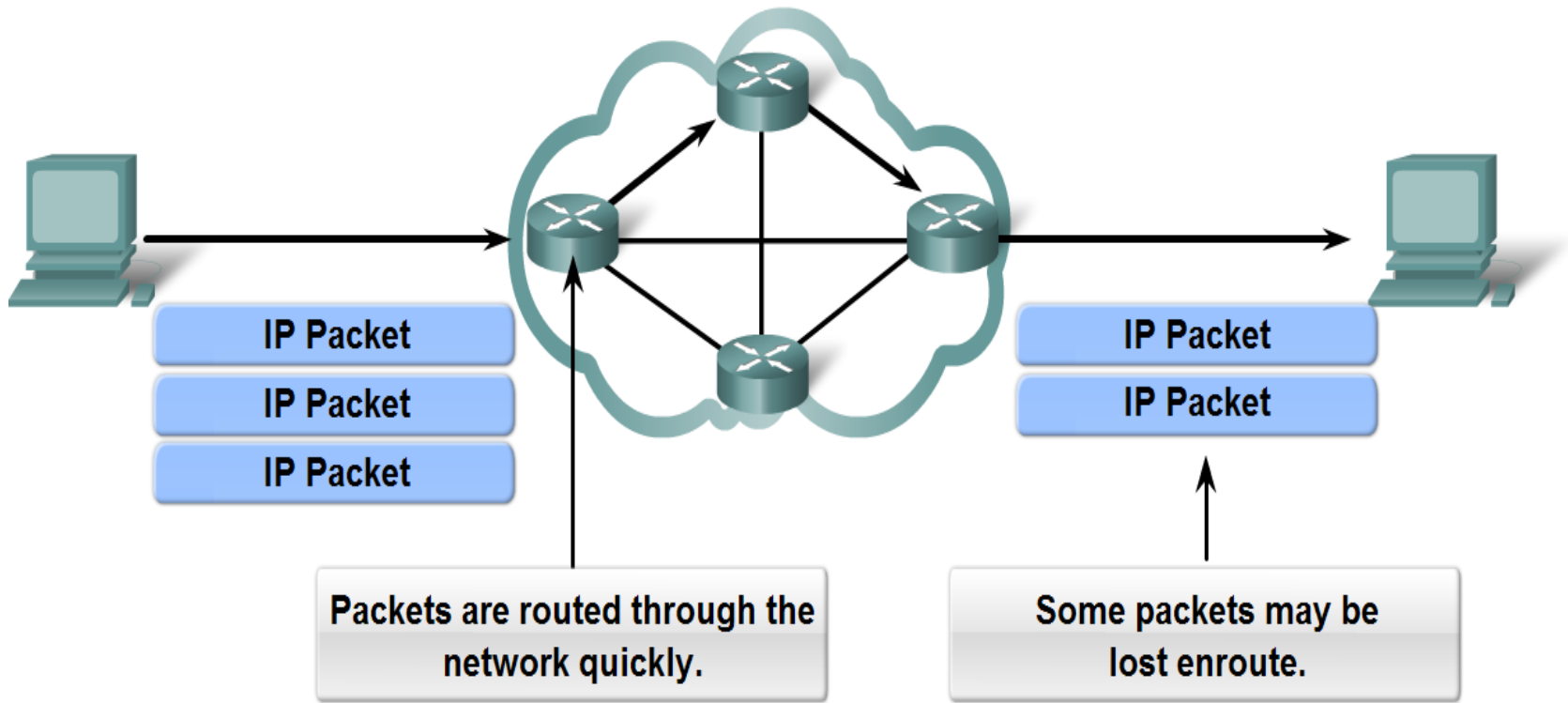
The sender doesn't know:

- 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

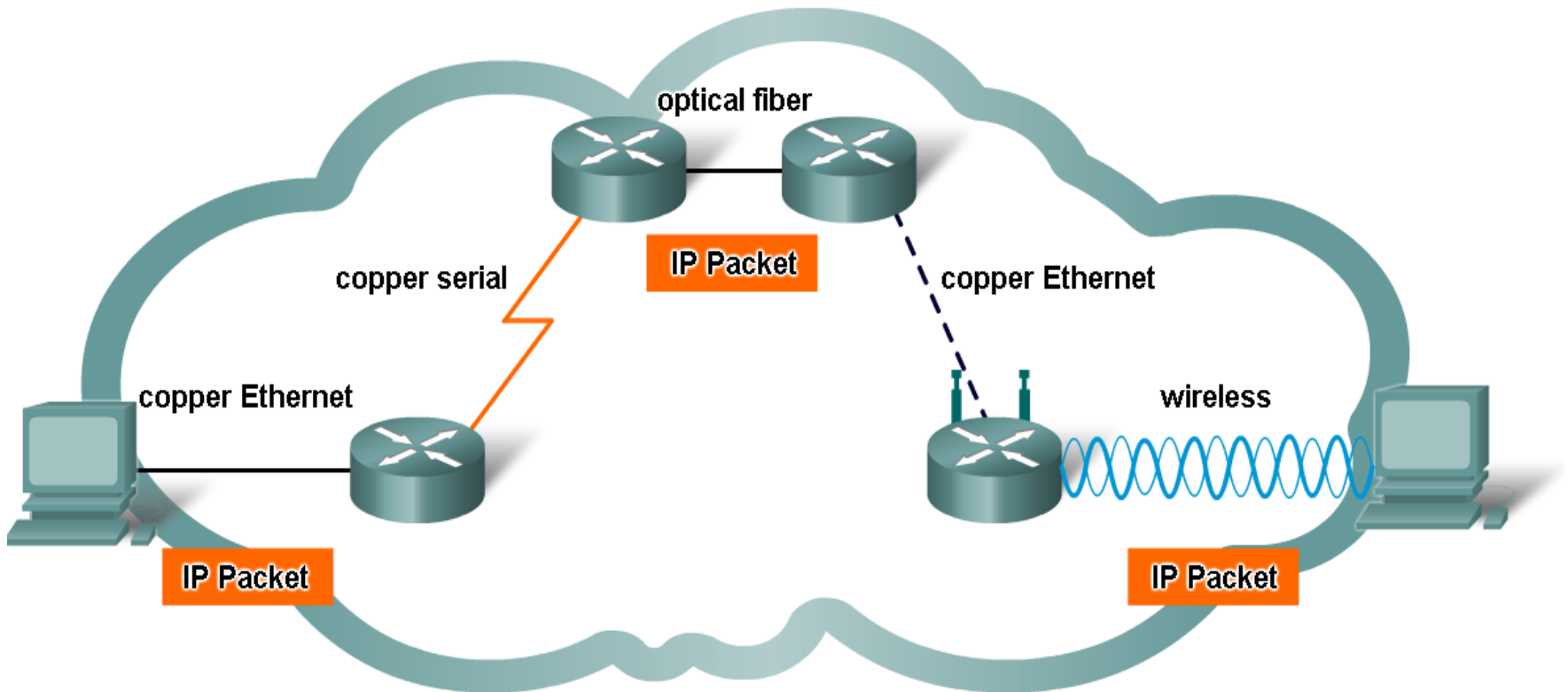
Best Effort



As an unreliable Network layer protocol, IP does not guarantee that all sent packets will be received.

Other protocols manage the process of tracking packets and ensuring their delivery.

Media Independence



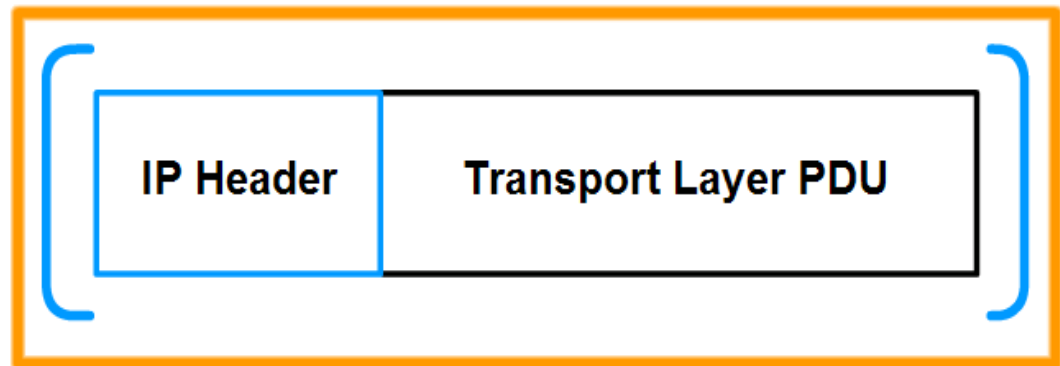
IP packets can travel over different media.

Generating IP Packets

Transport Layer Encapsulation



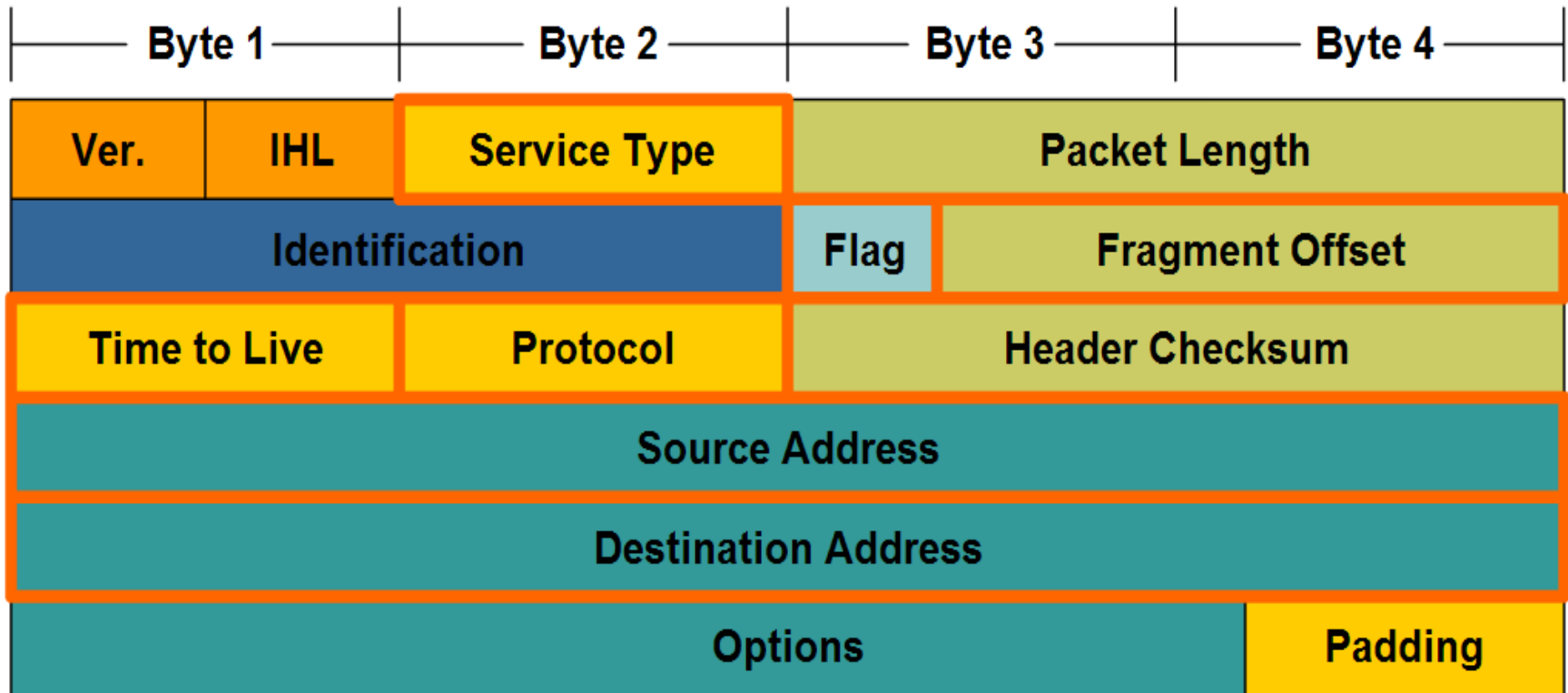
Network Layer Encapsulation



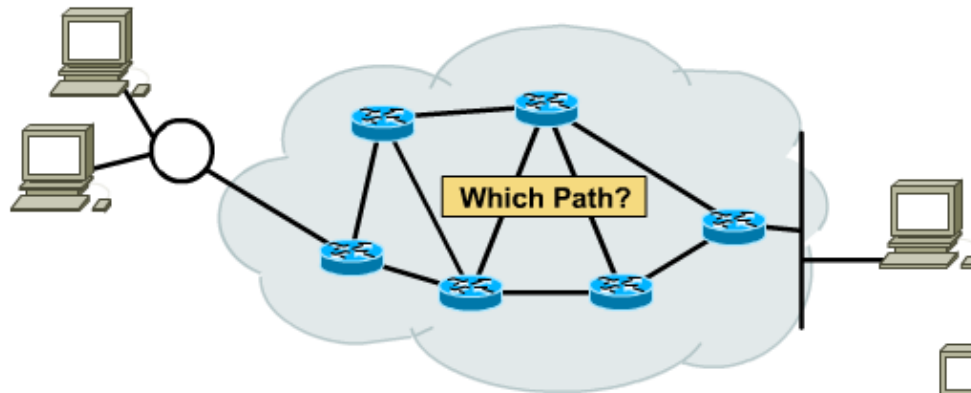
IP Packet

In **TCP/IP** based networks, the Network layer PDU is the **IP** packet.

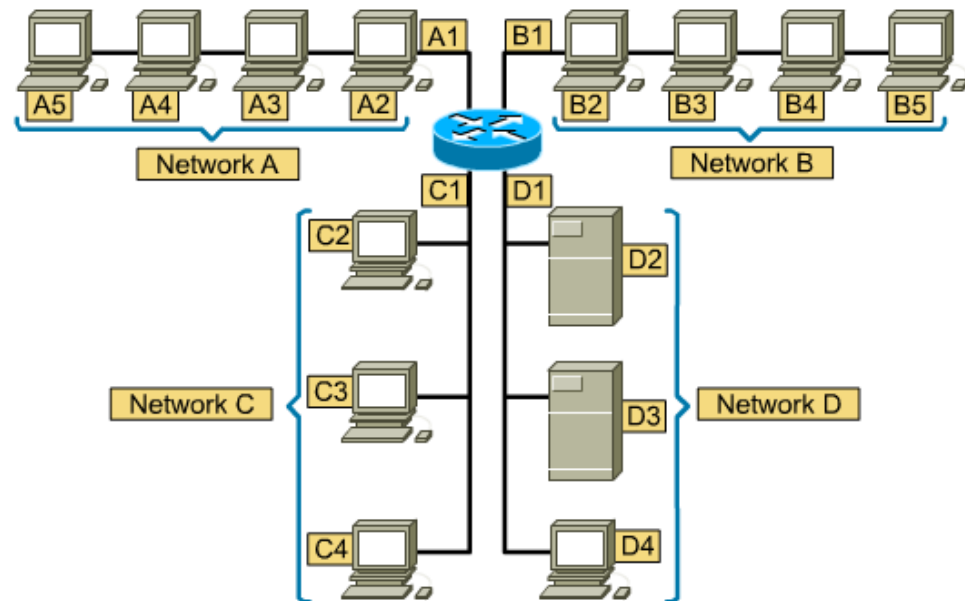
IPv4 Packet Header Fields



Path Determination



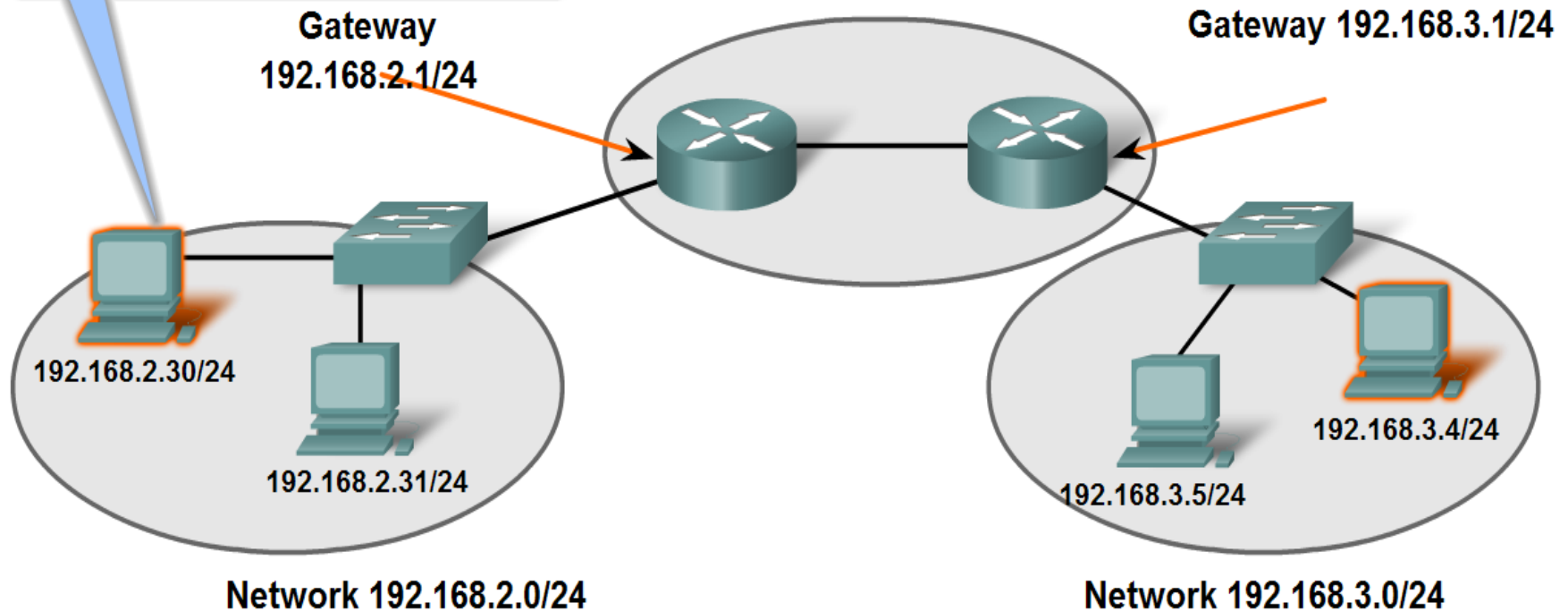
Path determination is determined by Routing Protocols (OSPF, EIGRP, RIP, etc.)



Gateways Enable Communications between Networks

I only know the addresses of the devices in my network.

If I don't know the address of the destination device, I send the packet to the gateway address by default.

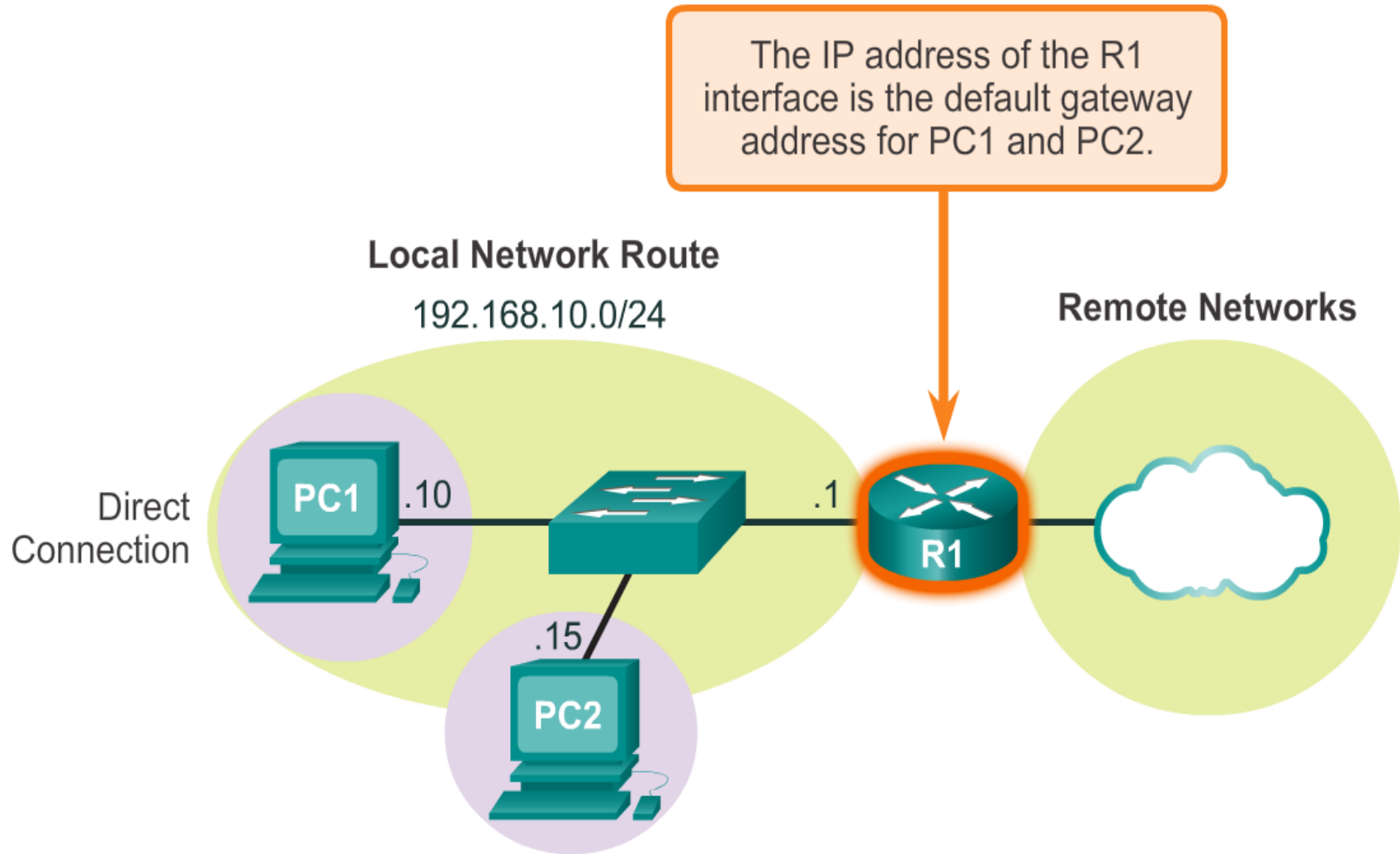


Routing

Host Routing Tables

```
C:\>route print
=====
Interface List
0x1 ..... MS TCP Loopback interface
0x2 ... .. Broadcom NetXtreme 57xx Gigabit Controller - Packet Scheduler Miniport
0x3 ... .. Bluetooth PAN Network Adapter - Packet Scheduler Miniport
0x4 ... .. VirtualBox Host-Only Ethernet Adapter - Packet Scheduler Miniport
=====
Active Routes:
Network Destination    Netmask          Gateway          Interface        Metric
0.0.0.0                0.0.0.0          192.168.100.254  192.168.100.123  20
127.0.0.0              255.0.0.0        127.0.0.1       127.0.0.1        1
169.254.0.0            255.255.0.0     192.168.100.123  192.168.100.123  20
192.168.56.0           255.255.255.0   192.168.56.1    192.168.56.1     20
192.168.56.1           255.255.255.255 127.0.0.1       127.0.0.1        20
192.168.56.255        255.255.255.255 192.168.56.1    192.168.56.1     20
192.168.100.0          255.255.255.0   192.168.100.123  192.168.100.123  20
192.168.100.123       255.255.255.255 127.0.0.1       127.0.0.1        20
192.168.100.255       255.255.255.255 192.168.100.123  192.168.100.123  20
224.0.0.0              240.0.0.0        192.168.56.1    192.168.56.1     20
224.0.0.0              240.0.0.0        192.168.100.123  192.168.100.123  20
255.255.255.255       255.255.255.255 192.168.56.1    192.168.56.1     1
255.255.255.255       255.255.255.255 192.168.56.1    3                 1
255.255.255.255       255.255.255.255 192.168.100.123  192.168.100.123  1
Default Gateway:      192.168.100.254
=====
Persistent Routes:
None
C:\>
```

Host Packet Forwarding Decision



Default Gateway

Hosts must maintain their own, local, 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

```
=====
```

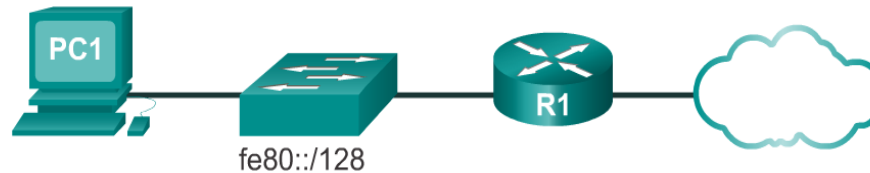
```
<Output omitted>
```

Host Routing Tables

Sample IPv6 Host Routing Table

fe80::2c30:3071:e718:a926/128

2001:db8:9d38:953c:2c30:3071:e718:a926/128



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

```
<Output omitted>
```

```
IPv6 Route Table
```

```
=====
```

```
Active Routes:
```

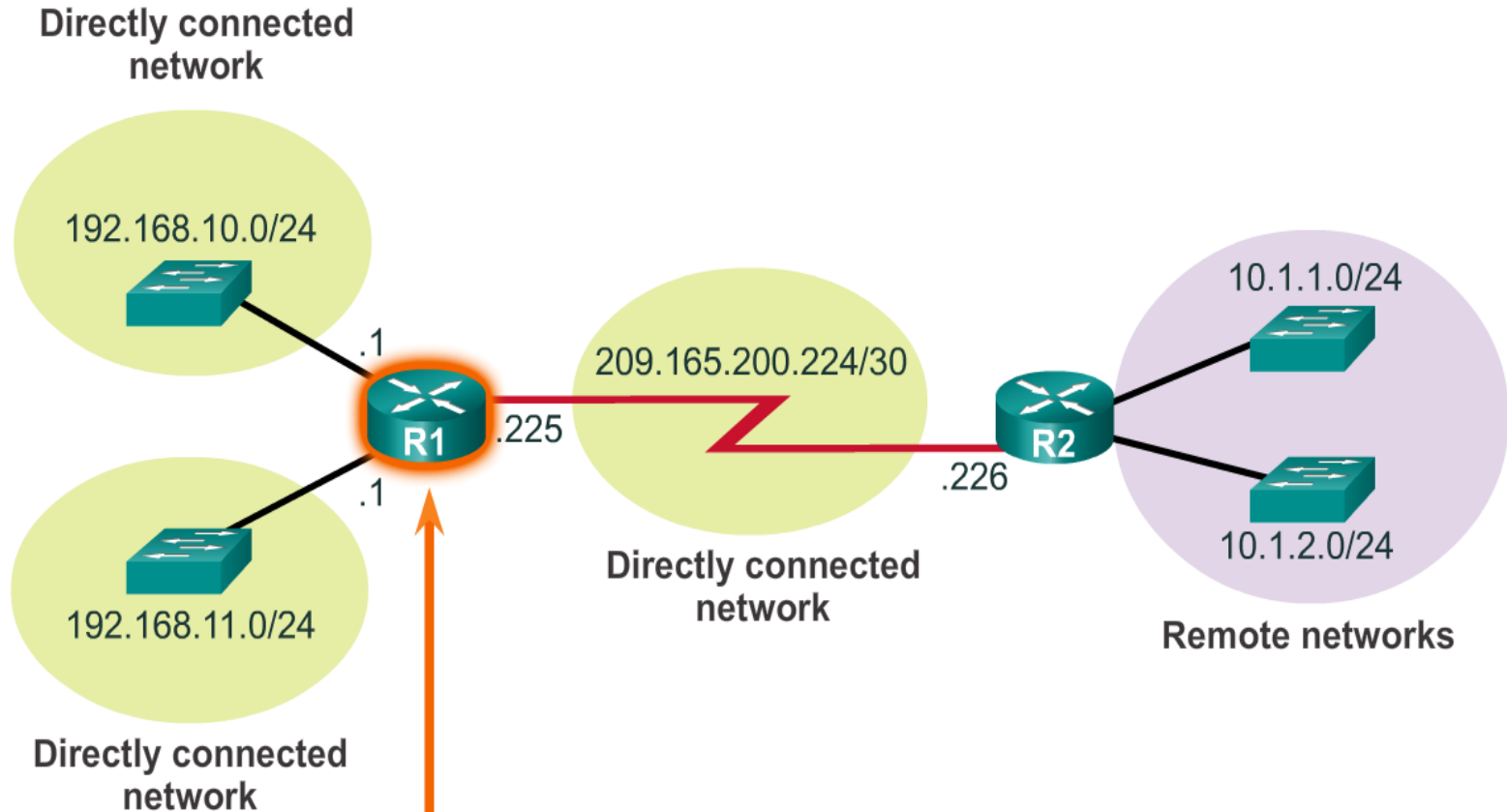
If	Metric	Network	Destination	Gateway
16	58	::/0		On-link
1	306	::1/128		On-link
16	58	2001::/32		On-link
16	306	2001:0:9d38:953c:2c30:3071:e718:a926/128		On-link
15	281	fe80::/64		On-link
16	306	fe80::/64		On-link
16	306	fe80::2c30:3071:e718:a926/128		On-link
15	281	fe80::b1ee:c4ae:a117:271f/128		On-link
1	306	ff00::/8		On-link
16	306	ff00::/8		On-link
15	281	ff00::/8		On-link

```
=====
```

```
<Output omitted>
```

Router Routing Tables

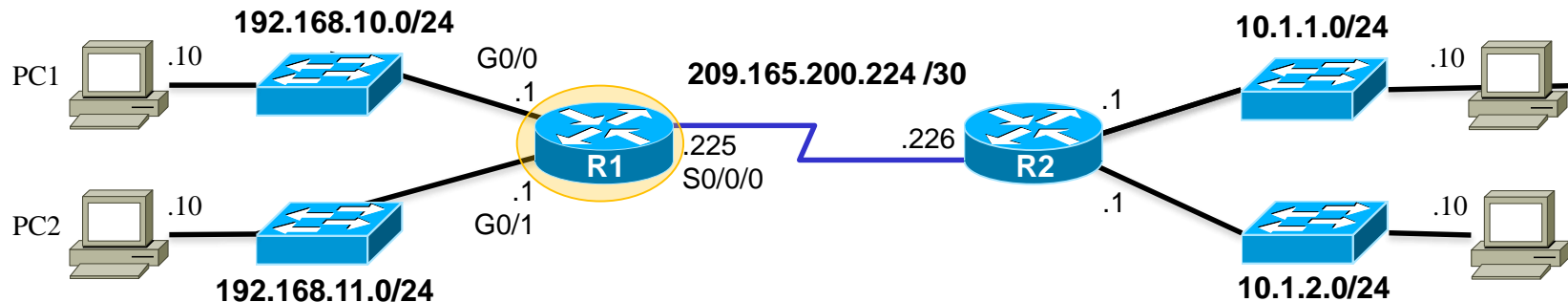
Router Packet Forwarding Decision



R1 has three directly connected networks: 192.168.10.0/24, 192.168.11.0/24, and 209.165.200.224/30. R1 also has two remote networks that it can learn about from R2: 10.1.1.0/24 and 10.1.2.0/24.

Router Routing Tables

IPv4 Router Routing Table



```
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
```

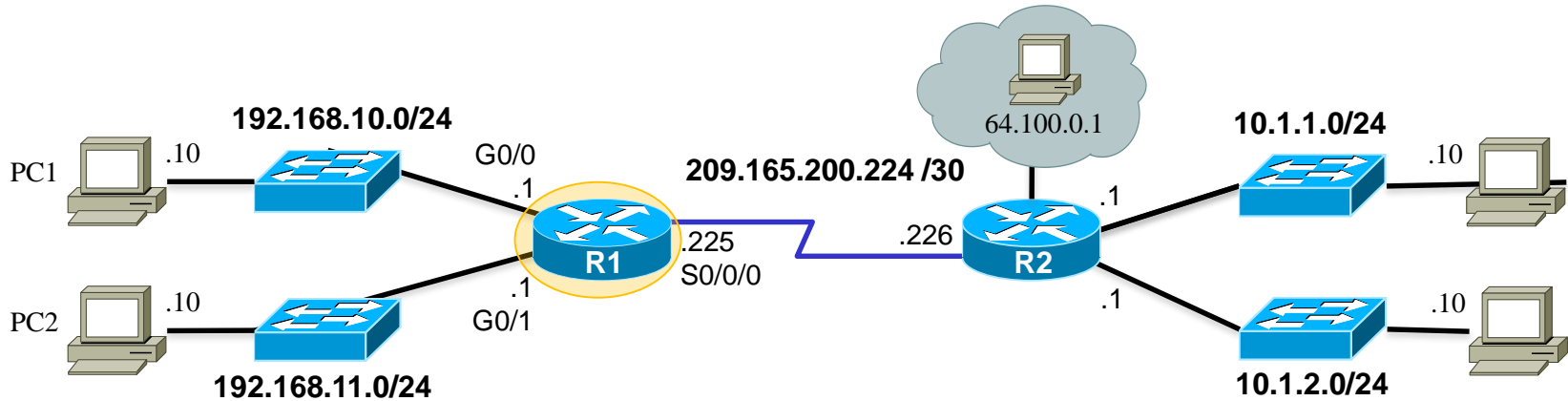
```
Gateway of last resort is not set
```

```
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#
```

Router Routing Tables

Directly Connected Routing Table Entries

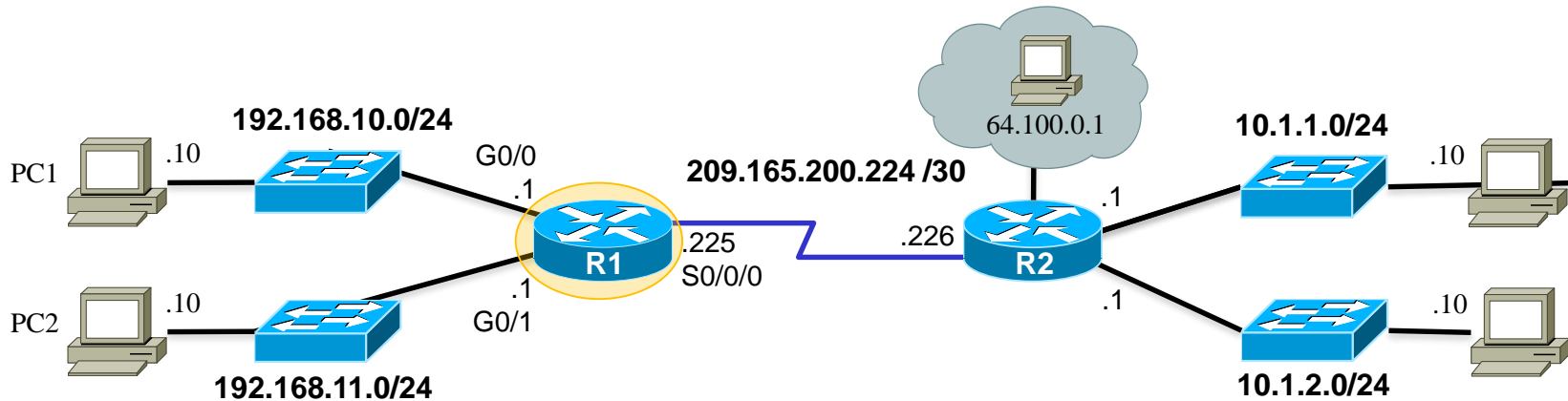


A	B	C
C	192.168.10.0/24 is directly connected,	GigabitEthernet0/0
L	192.168.10.1/32 is directly connected,	GigabitEthernet0/0

A	Identifies how the network was learned by the router.
B	Identifies the destination network and how it is connected.
C	Identifies the interface on the router connected to the destination network.

Router Routing Tables

Remote Network Routing Table Entries

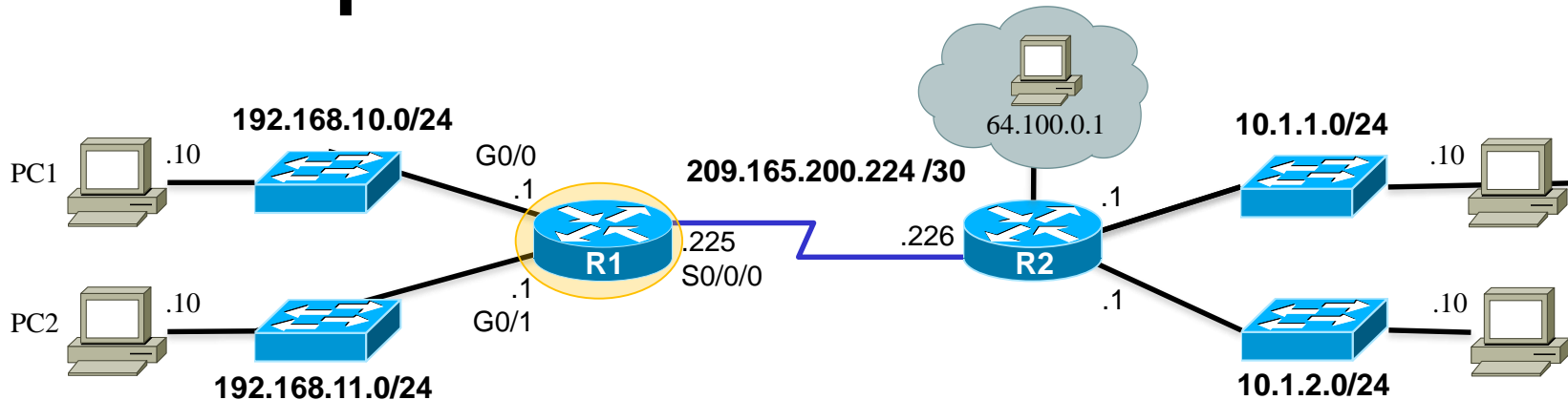


D	10.1.1.0/24	[90/2170112]	via	209.165.200.226	00:00:05	Serial10/0/0
----------	--------------------	---------------------	------------	------------------------	-----------------	---------------------

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



```
R1#show ip route
```

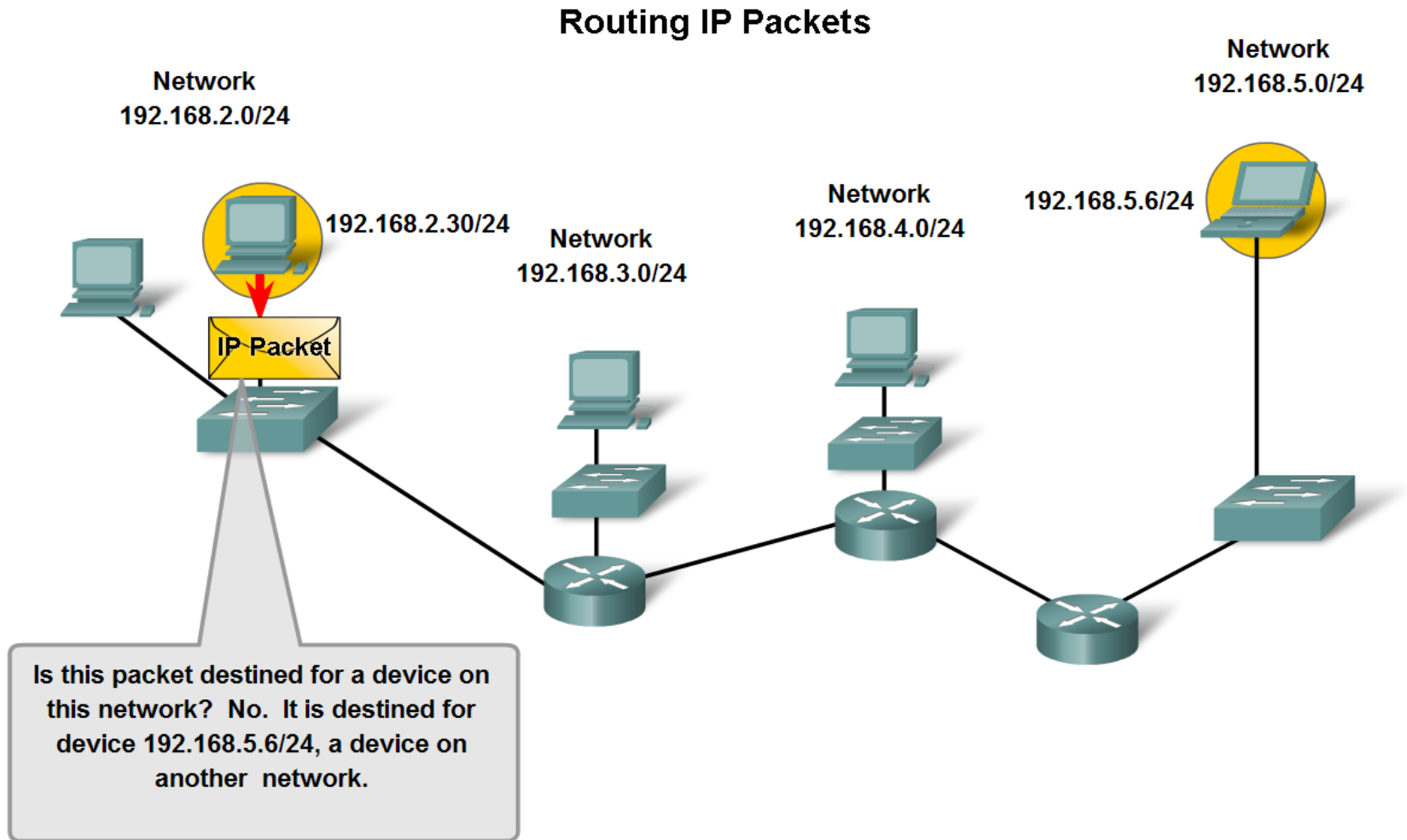
```
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP  
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area  
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2  
E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP  
i - IS-IS, L1 - IS-IS level-1, 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#
```

- The steps of an IP packet as it traverses unchanged via routers from sub network to sub-network



Routing Tables

I want to forward this packet so it can take the next hop towards its destination. I can use the information in my routing table to determine where to forward this message.

Packet destined for Network 10.1.1.0/24



192.168.2.1/24

192.168.2.2/24

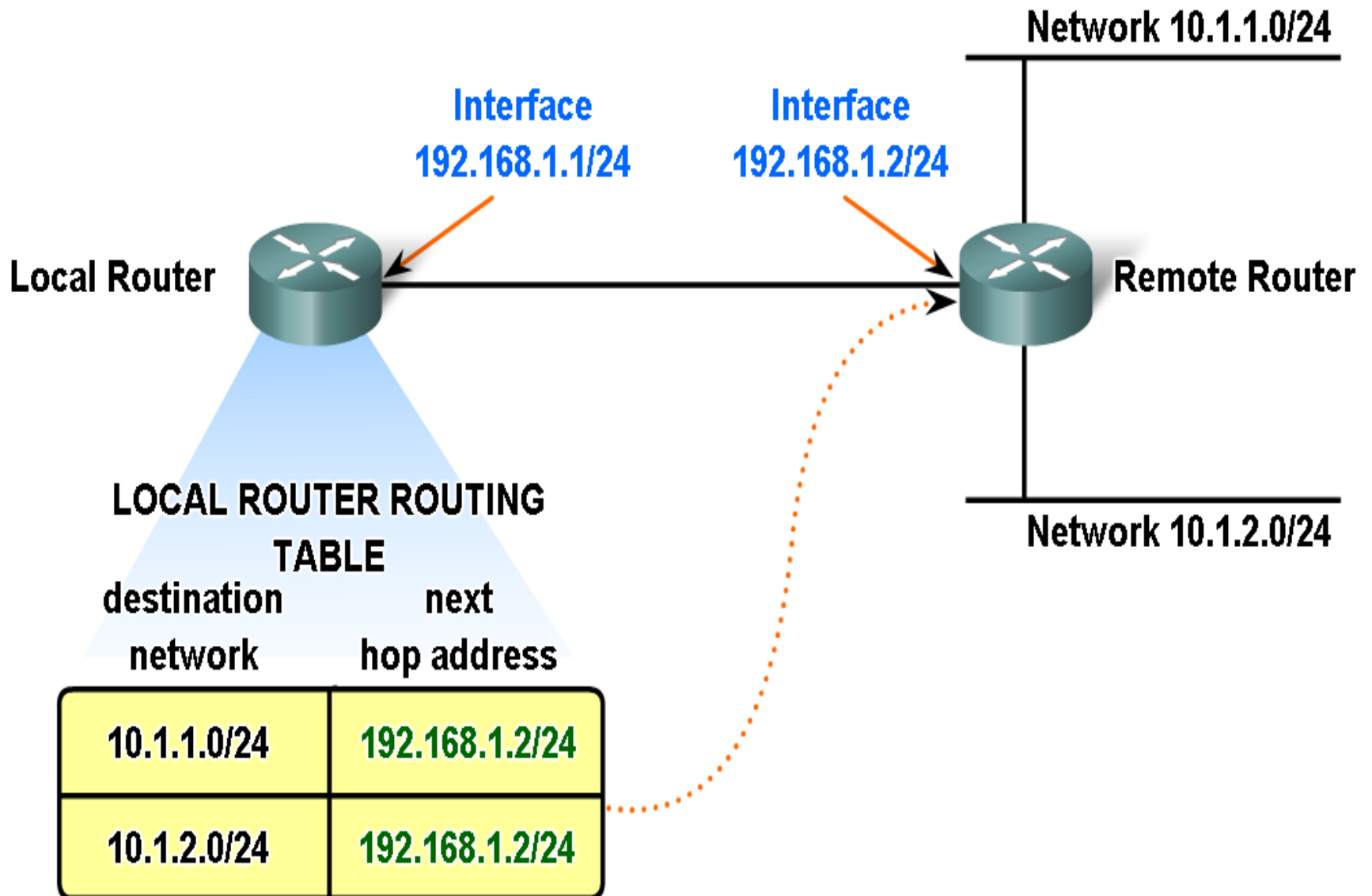
Network 10.1.1.0/24

Remote Router

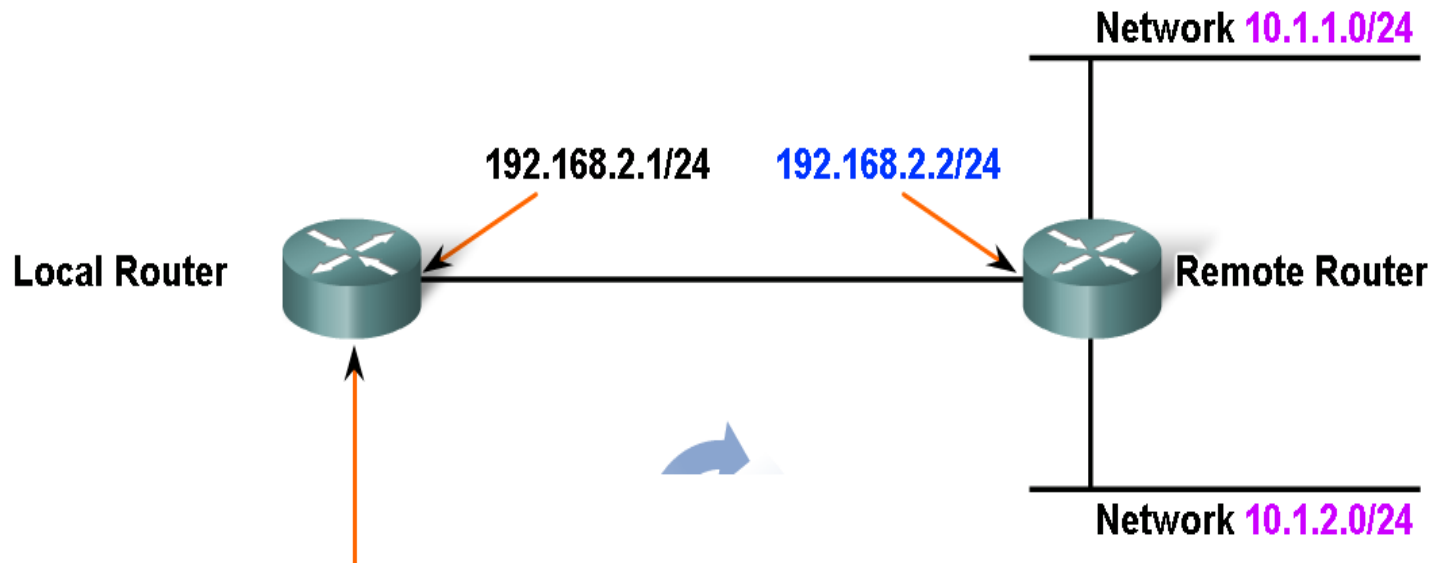
Network 10.1.2.0/24

ROUTING TABLE

Local Router Routing Table



Confirming the Gateway and Route



```
10.0.0.0/24 is subnetted, 2 subnets
R    10.1.1.0 [120/1] via 192.168.2.2, 00:00:08, FastEthernet0/0
R    10.1.2.0 [120/1] via 192.168.2.2, 00:00:08, FastEthernet0/0
C 192.168.1.0/24 is directly connected, FastEthernet0/0
```

This is the routing table output of Local Router when the **"show ip route"** is issued.

The next hop for networks 10.1.1.0/24 and 10.1.2.0/24 from Local Router is 192.168.2.2.