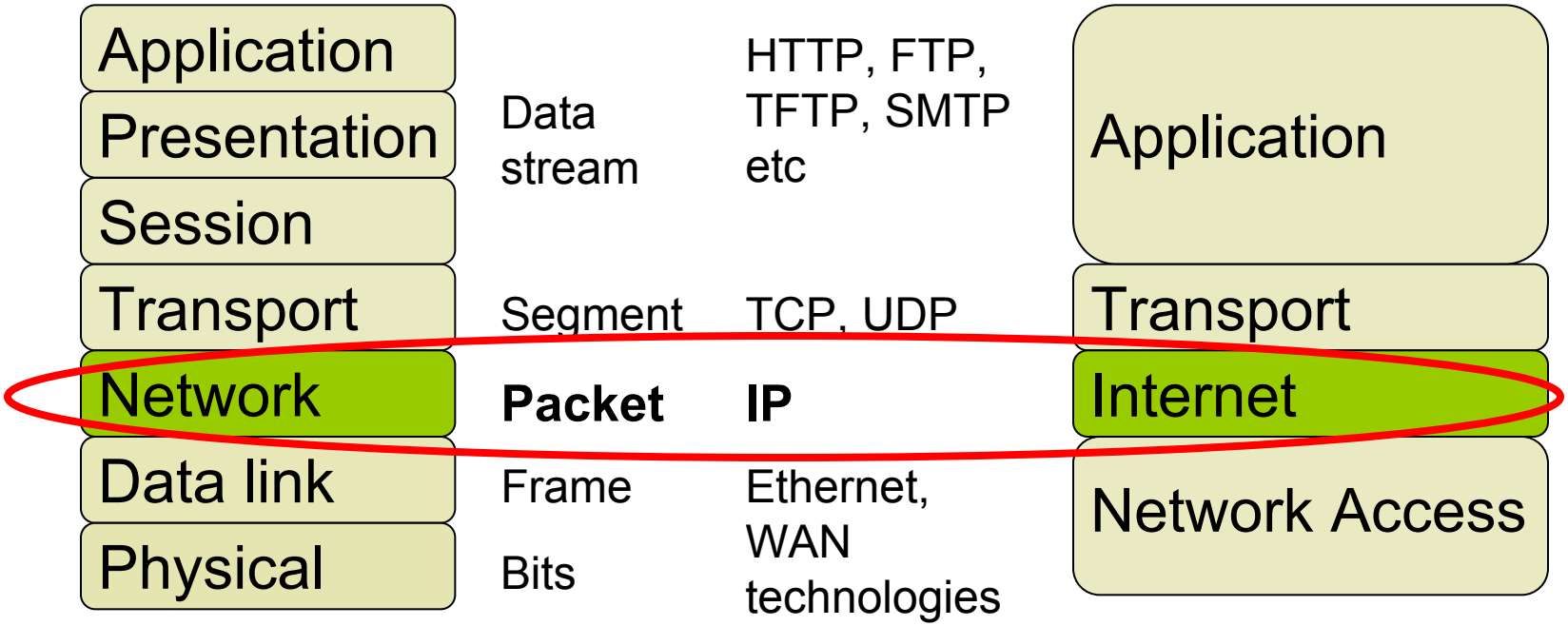
Network Layer

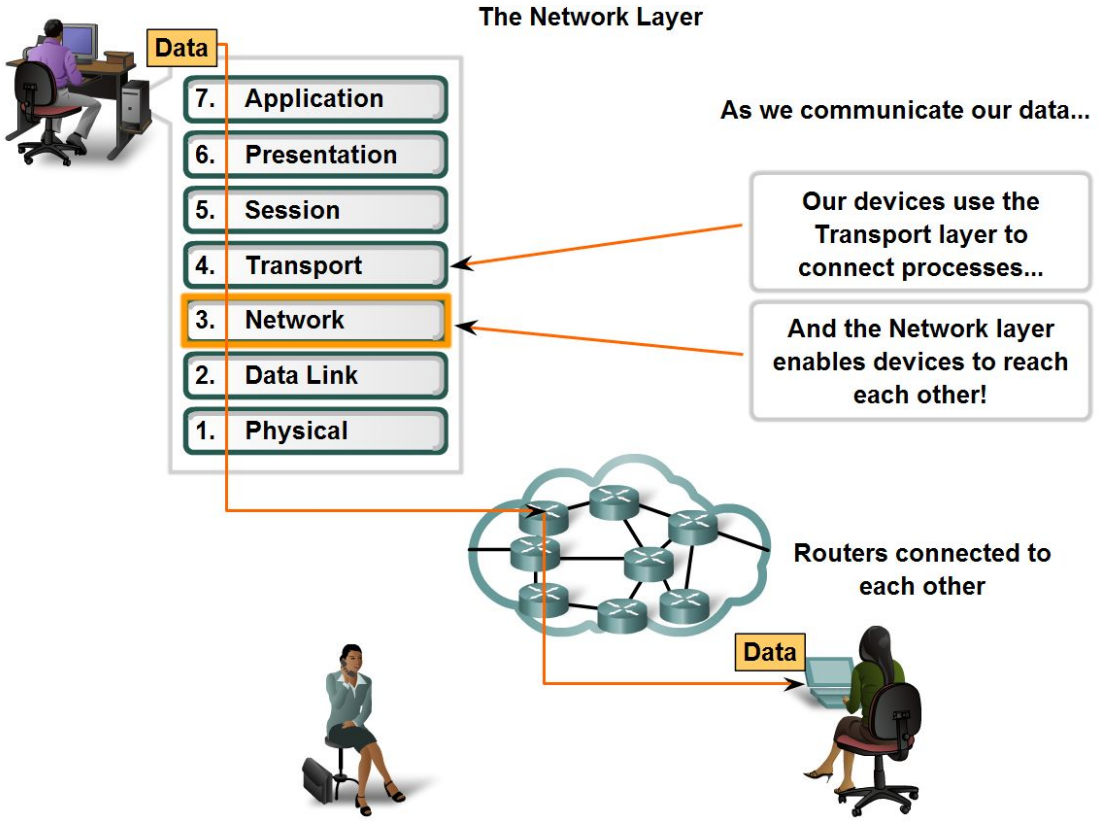
OSI network layer

- OSI model layer 3
- TCP/IP model Internet layer



Network Layer

- **Provides services to exchange the individual pieces of data over the network between identified end devices. .**



Basic Processes Of Network Layer

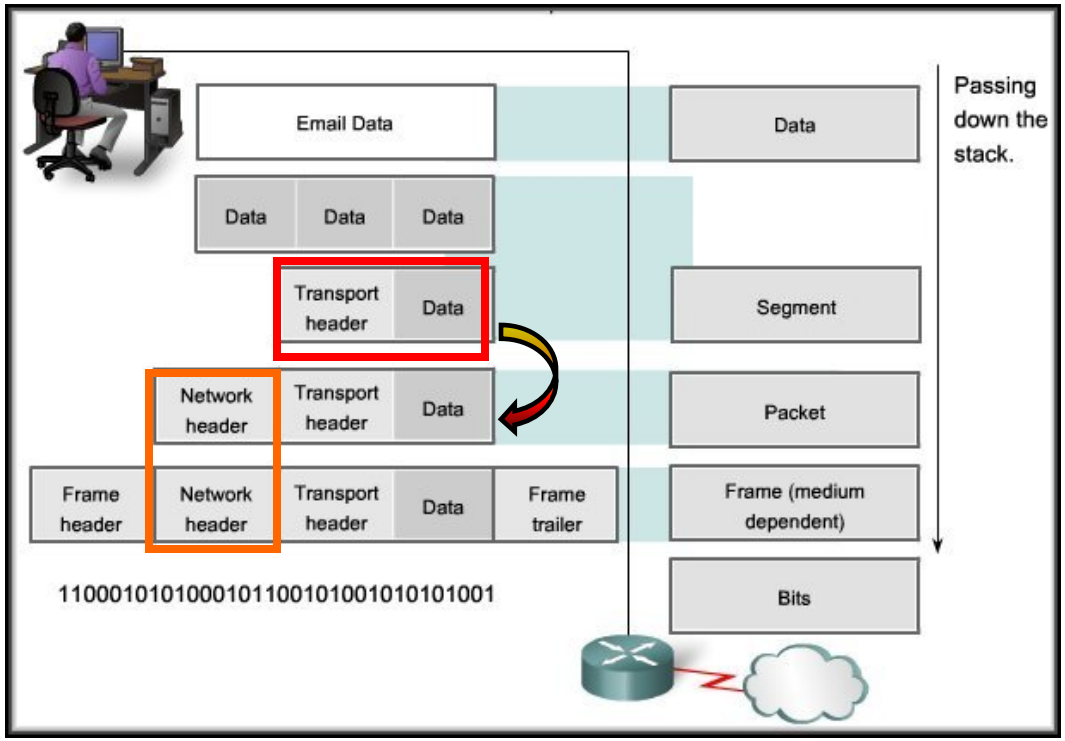
- Addressing
- Encapsulation
- Routing
- Decapsulation

Network layer encapsulation

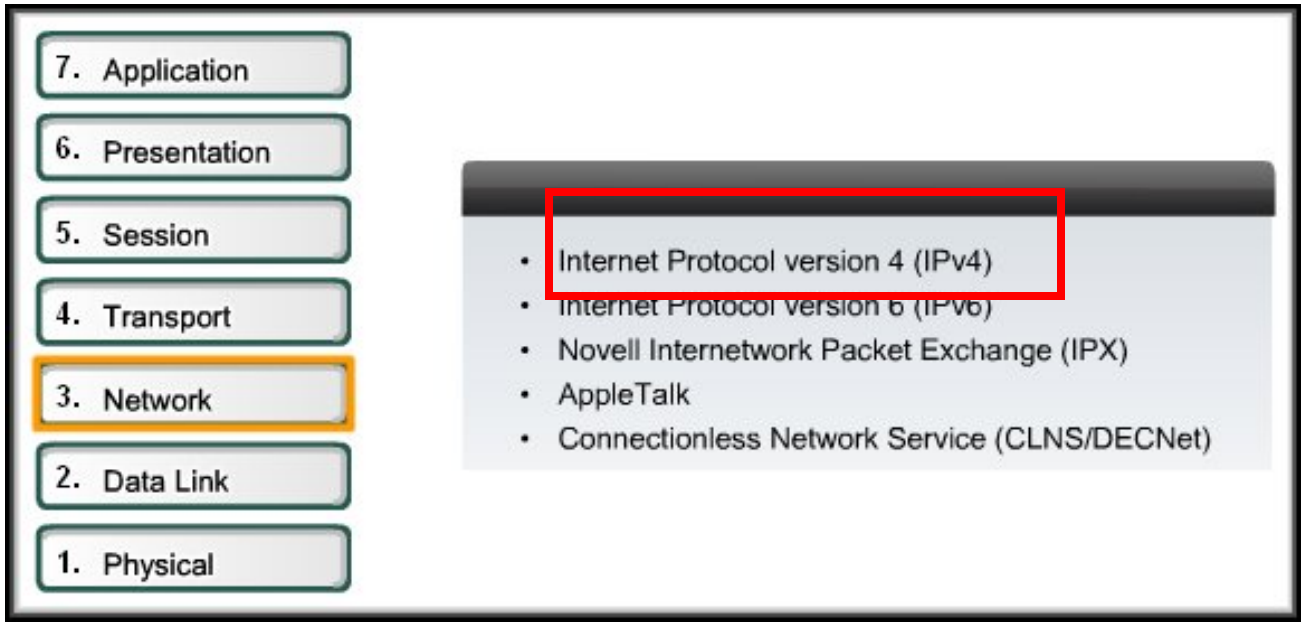
Segment from transport layer.

Packet header added to make IP packet.

Sent to data link layer for further encapsulation into a frame.



Network Layer Protocols

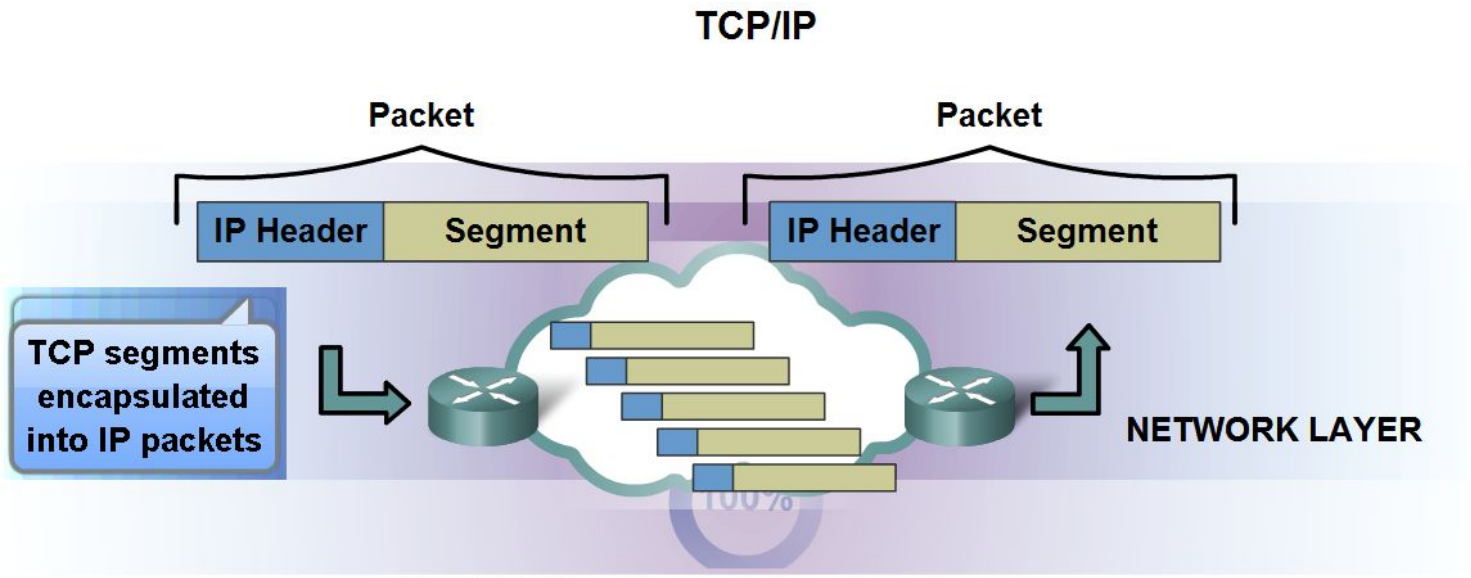


- Internet Protocol Version 4 (IPV4) is the most widely used version of IP.
- Only Layer 3 protocol used on the Internet.
- Focus of this course.

The IP v4 and IP v6 Protocol

- IP version 6 (IPv6) is developed and being implemented in some areas.
- IPv6 will operate alongside IPv4 and may replace it in the future.
- IP provides
  - Services
  - Packet header structure
  - Contents
- Which is specified by either IPv4 protocol or IPv6 protocol.

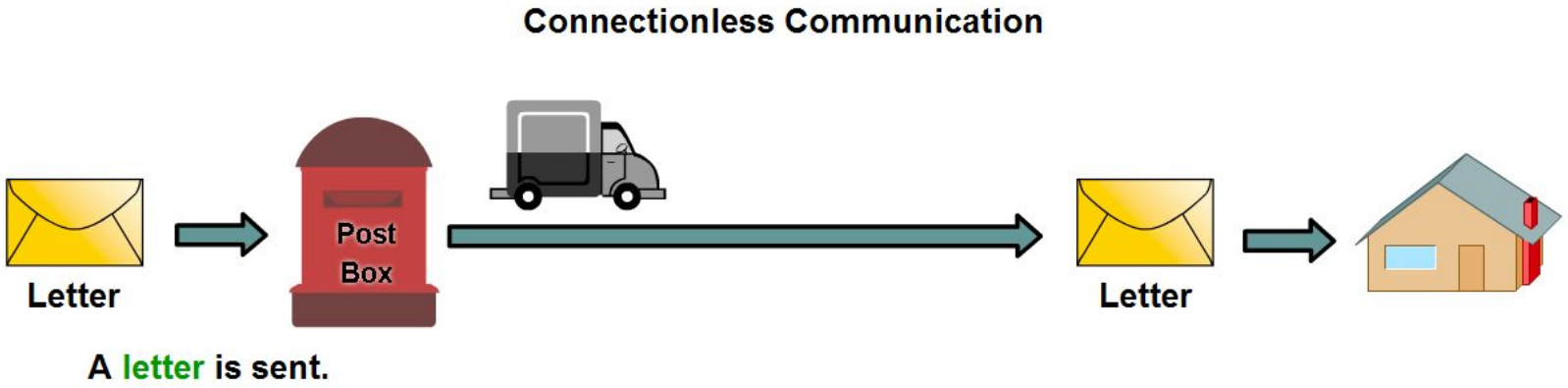
The IP v4 Protocol



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.

The IPv4 Protocol-Connectionless



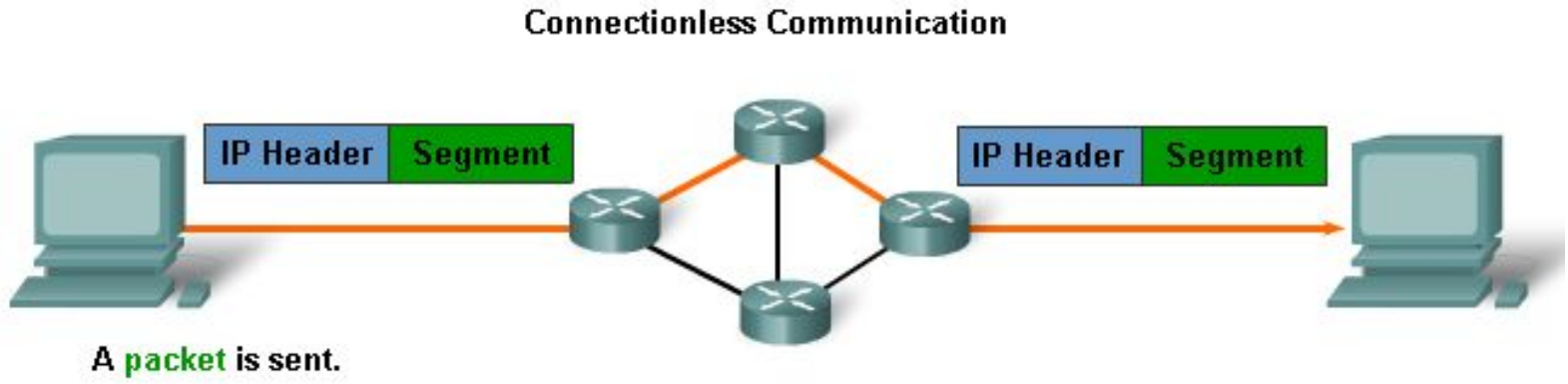
The sender doesn't know:

- 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

The IPv4 Protocol-Connectionless



The sender doesn't know:

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

The receiver doesn't know:

- when it is coming

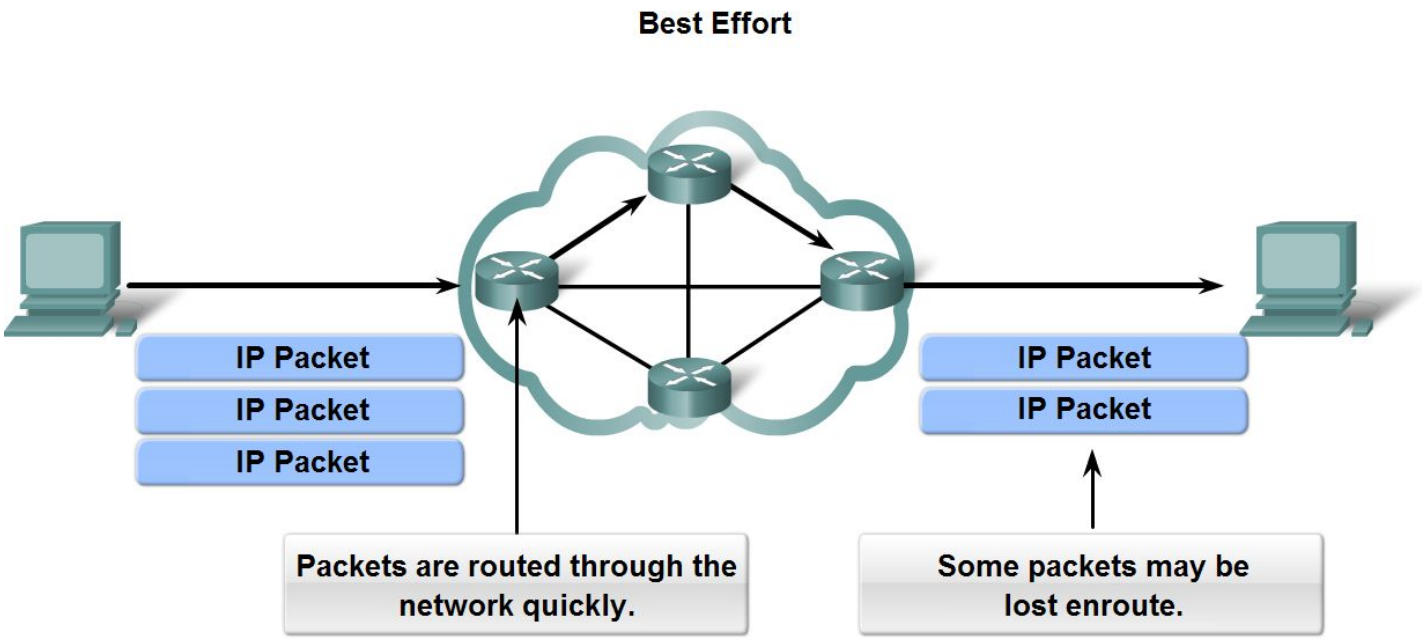
POSTAL ROUTES

DATA NETWORKS

The IPv4 Protocol-Best Effort

- IP does not have the capability to manage, and recover from, undelivered or corrupt packets.
- Protocols at other layers can manage reliability.
- IP then can function very efficiently at the Network layer.

The IPv4 Protocol-Best Effort

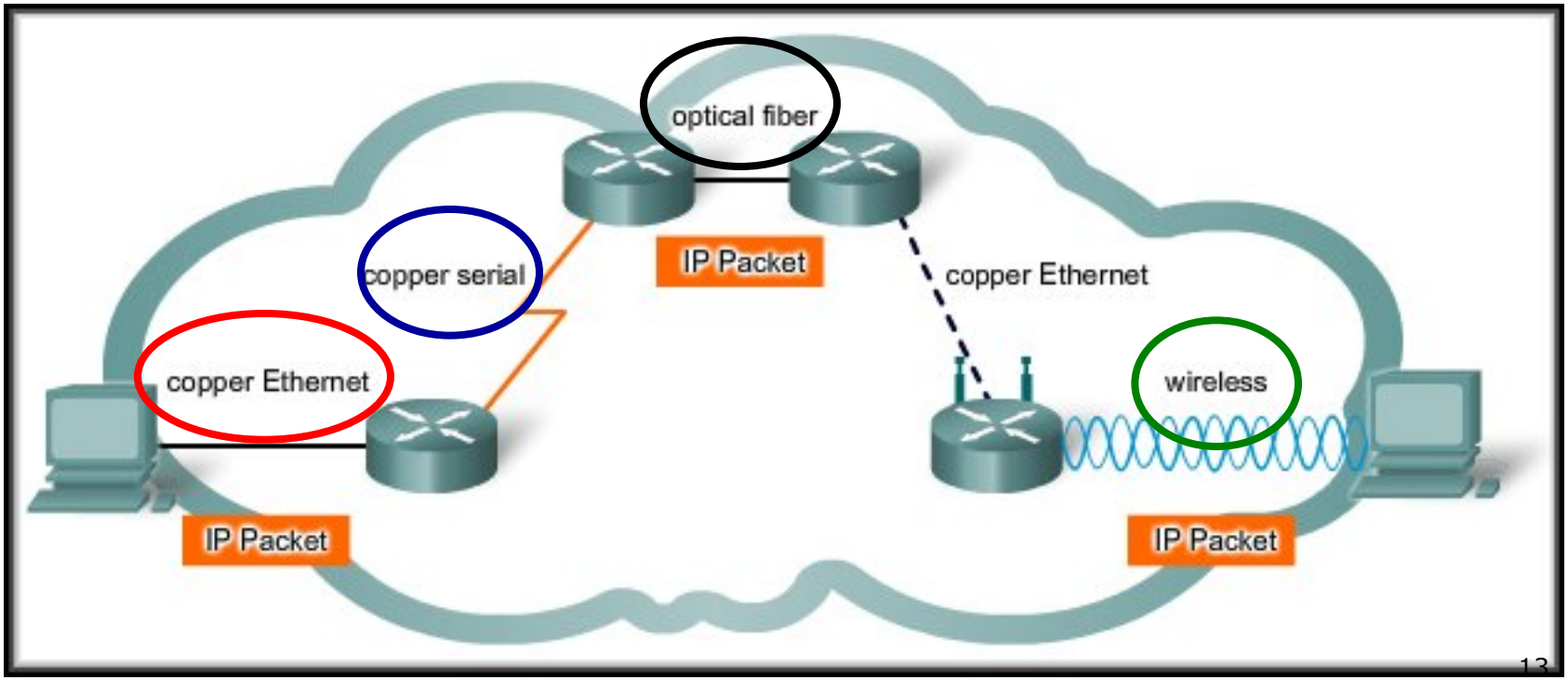


As an unreliable Network layer protocol, IP does not guarantee that all sent packets will be received.

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

The IPv4 Protocol-Media Independent

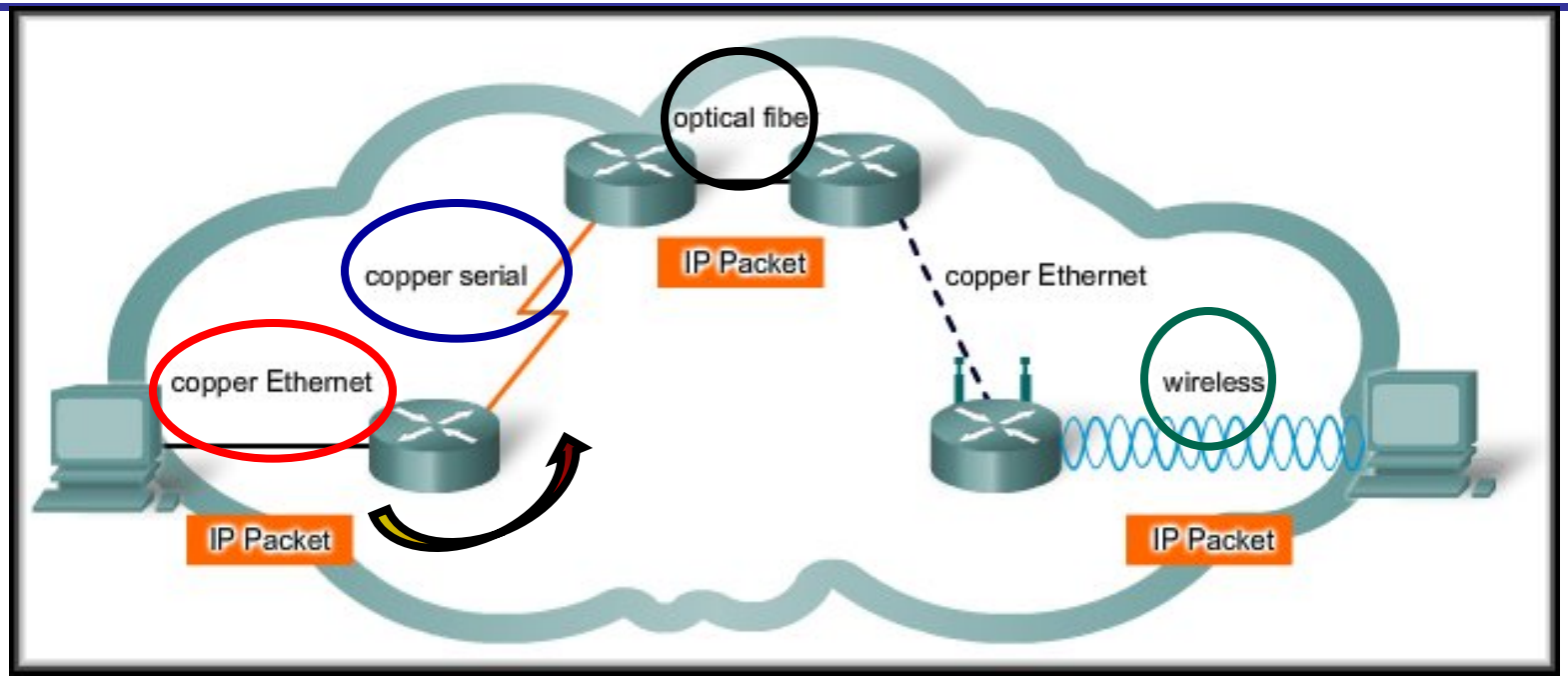
- The transport of IP packets is not limited to any particular medium. Except….



The IPv4 Protocol-Media Independent

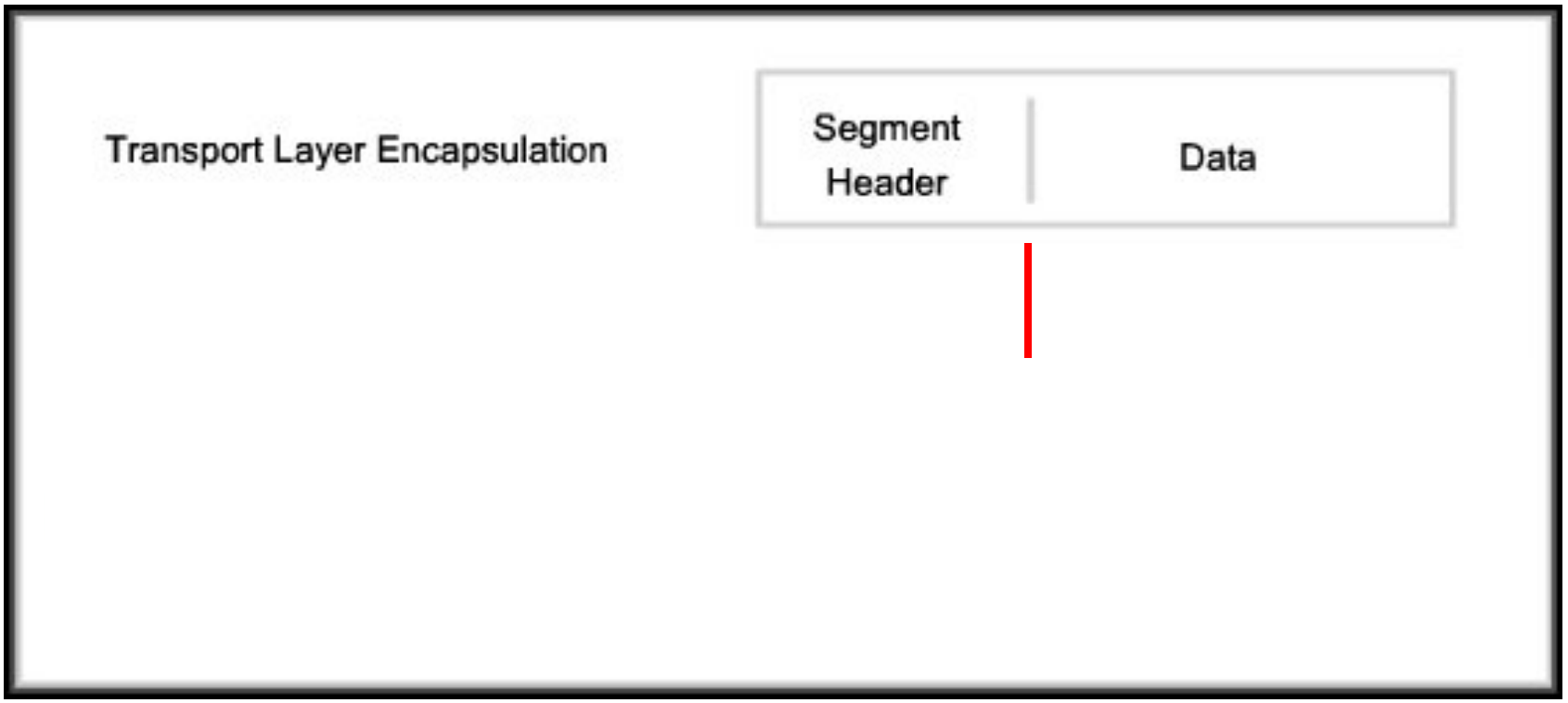
- One major characteristic of the media : **Maximum Transmission Unit (MTU)**.
- The Data Link layer passes the MTU upward to the Network layer.
- In some cases, an intermediary device will need to split up a packet when forwarding with a smaller MTU.
- This process is called fragmenting the packet or **fragmentation.**

Media Independent



- Copper Ethernet: MTU = 1,518 bytes.
- Copper Serial: Frame Relay MTU = 512 bytes.
- Optical Fiber: ATM MTU = 17,966 bytes.
- Wireless: 802.11 MTU = 2272 bytes.

Packaging the Transport Layer PDU

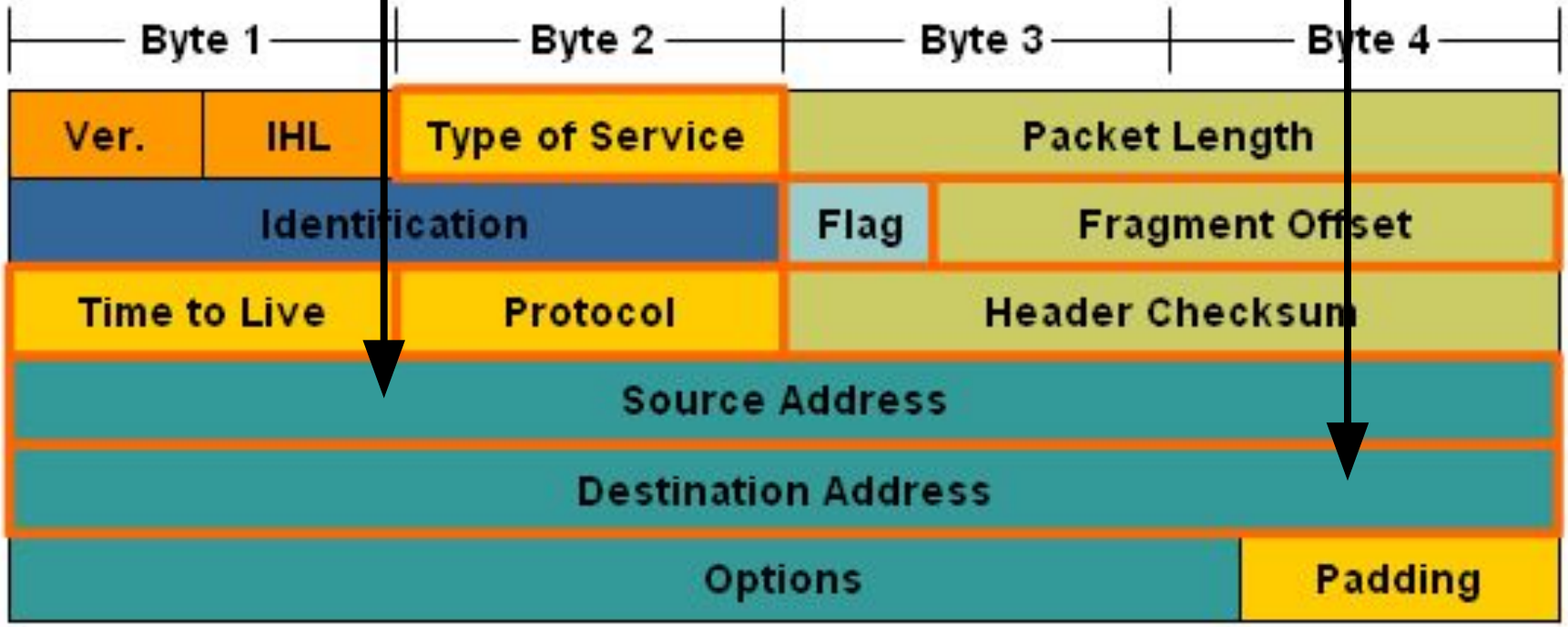


In TCP/IP based networks, the Network Layer PDU is the IP Packet.

IPv4 packet header fields

IP address of source host, needed so reply can be sent.

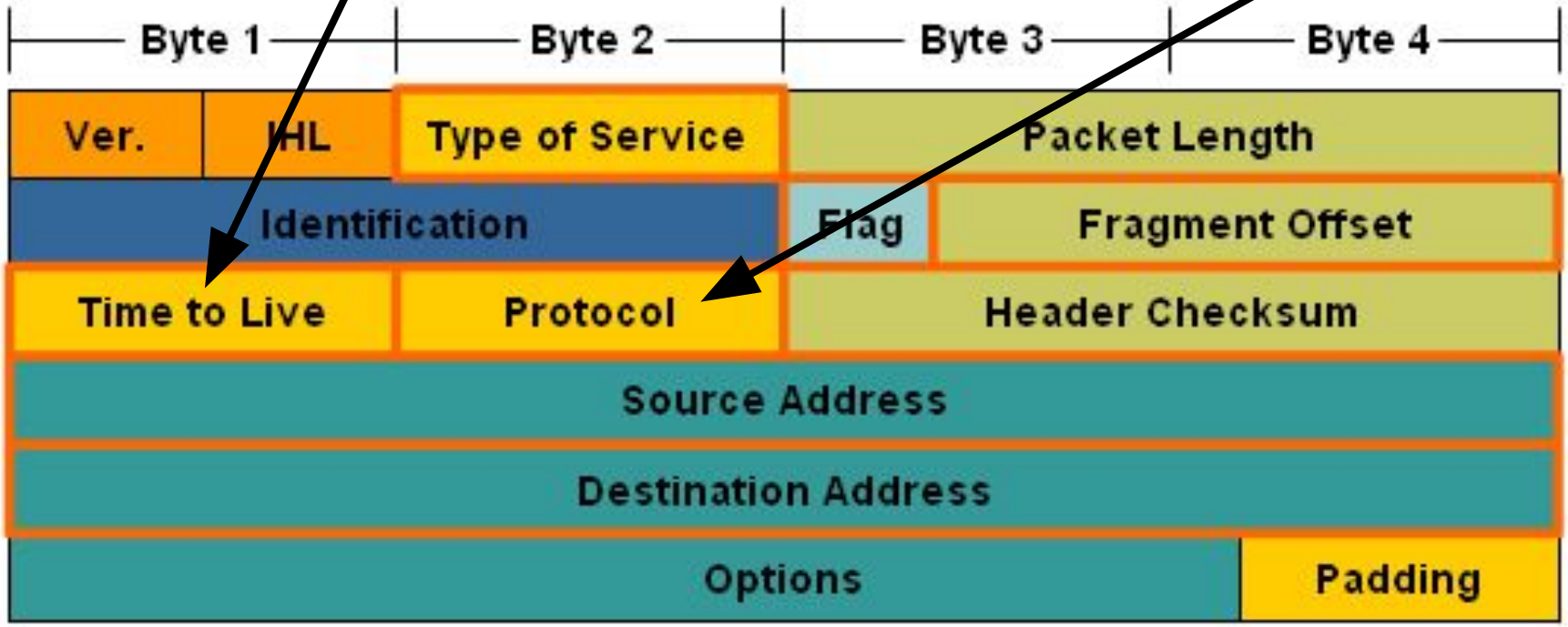
IP address of destination host, needed so routers can find route.



IPv4 packet header fields

Reduced by 1 at each router. Packet dropped if it goes to 0.

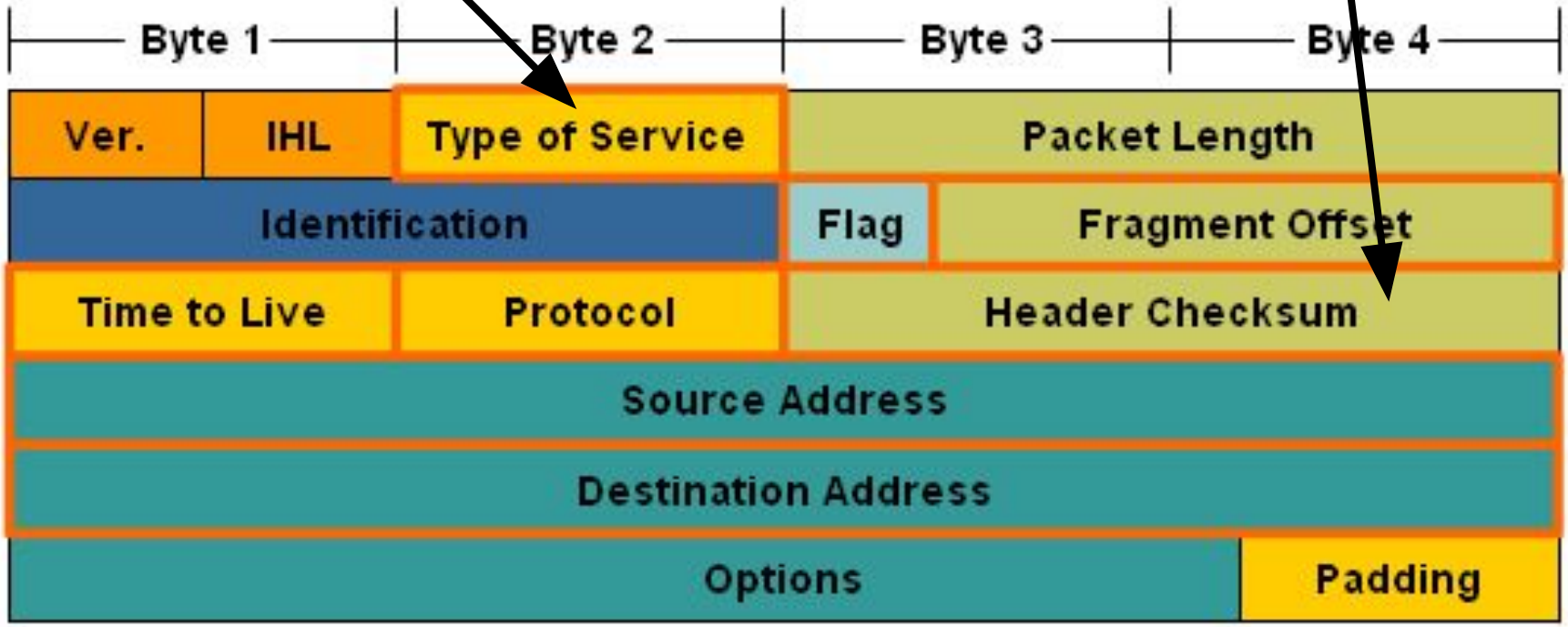
TCP or UDP used in Transport layer.



IPv4 packet header fields

Priority for QoS. E.g. voice data has higher priority than e-mail.

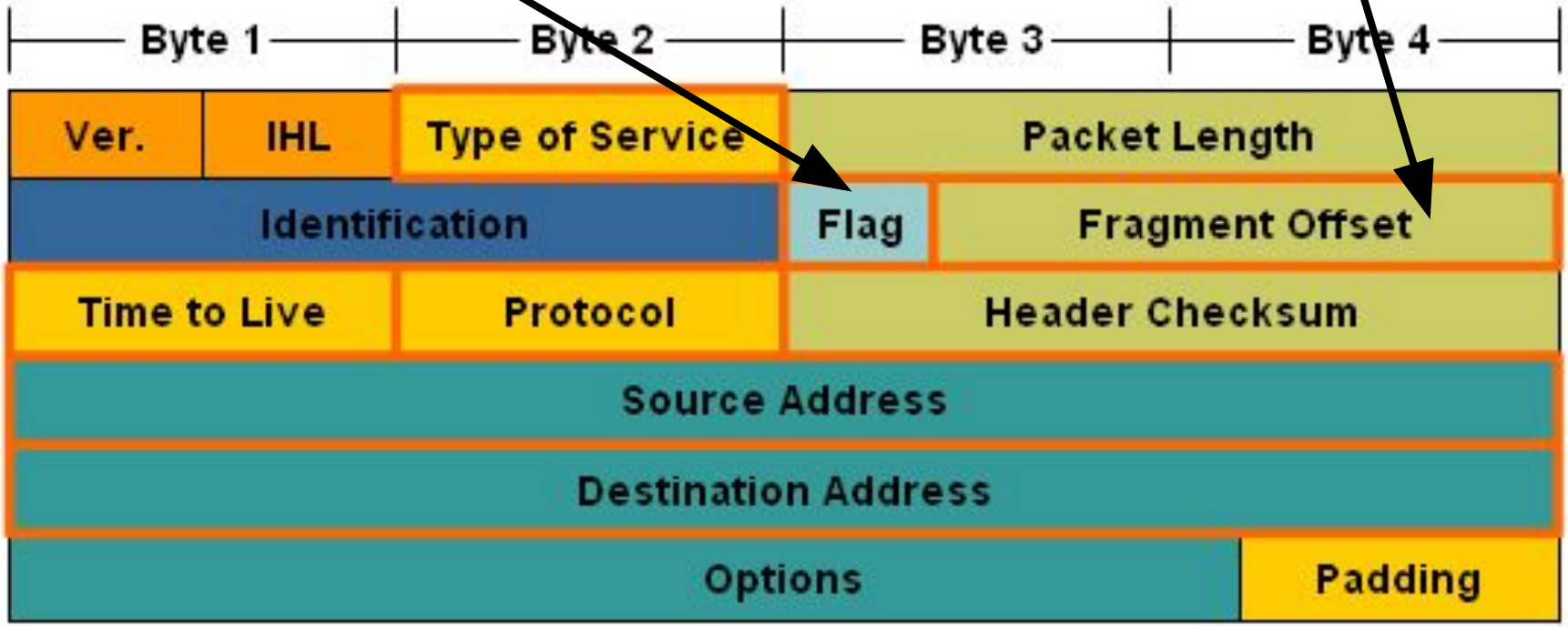
For checking if header has been corrupted.



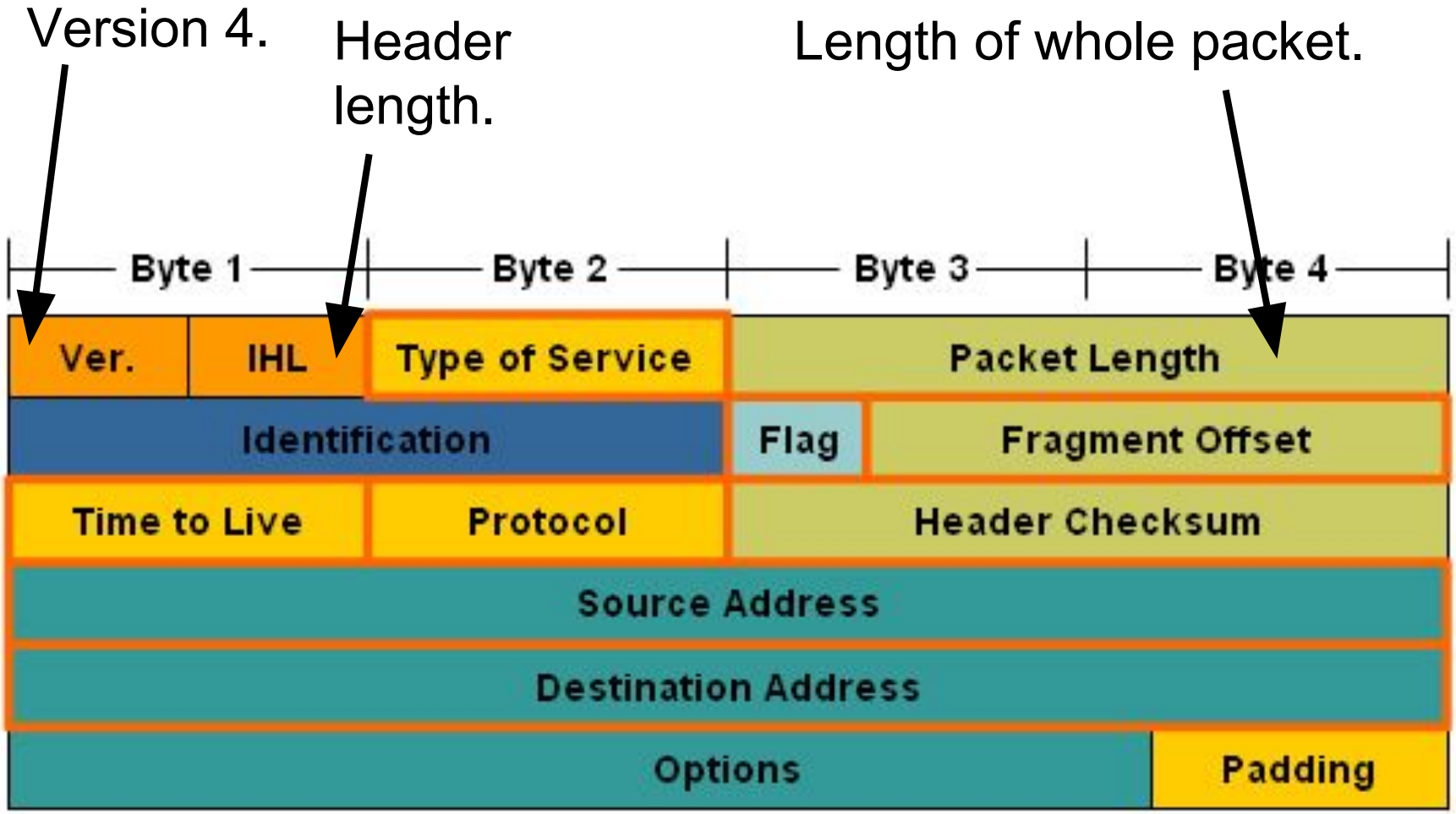
IPv4 packet header fields

Shows if packet has been fragmented or must not be fragmented.

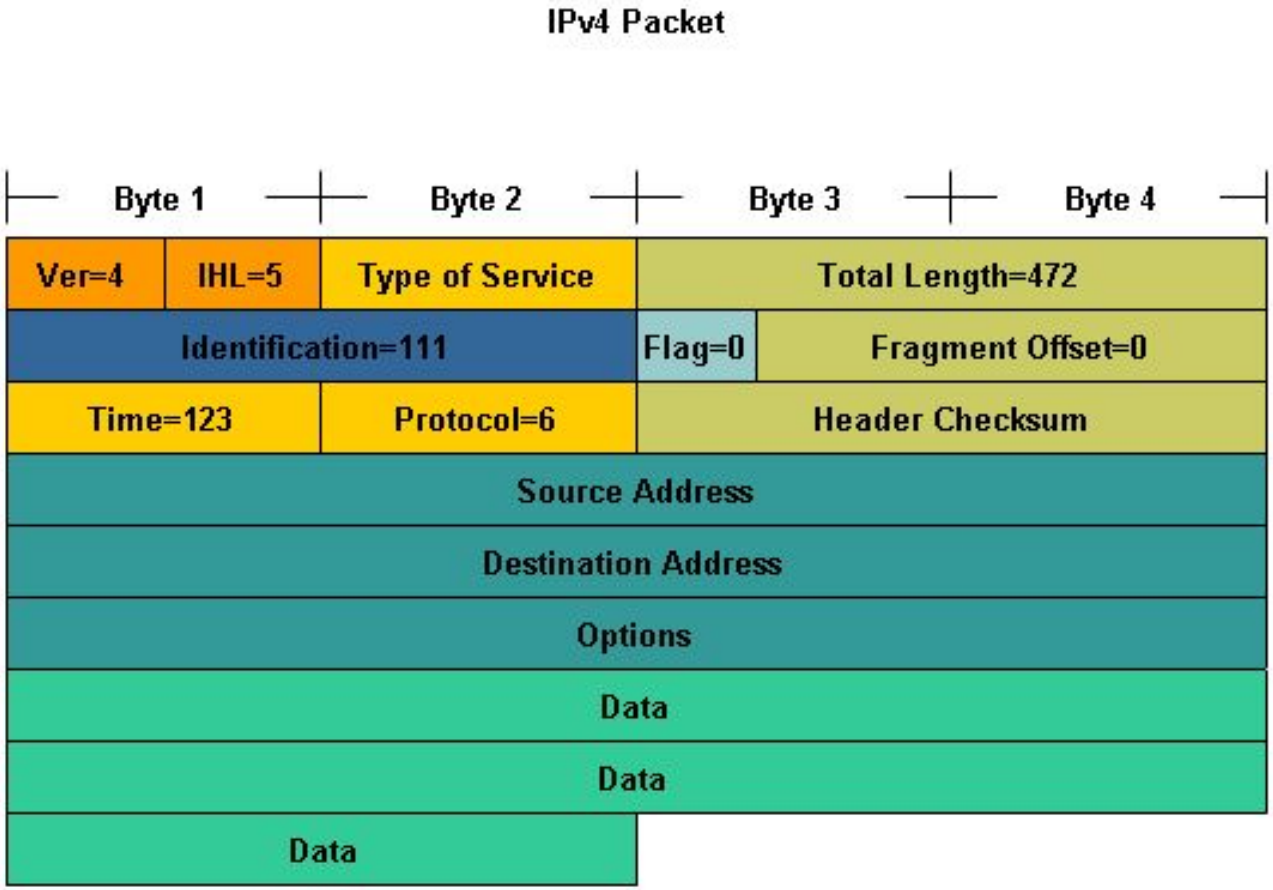
If router has to split a packet, this gives order for putting pieces together.



IPv4 packet header fields

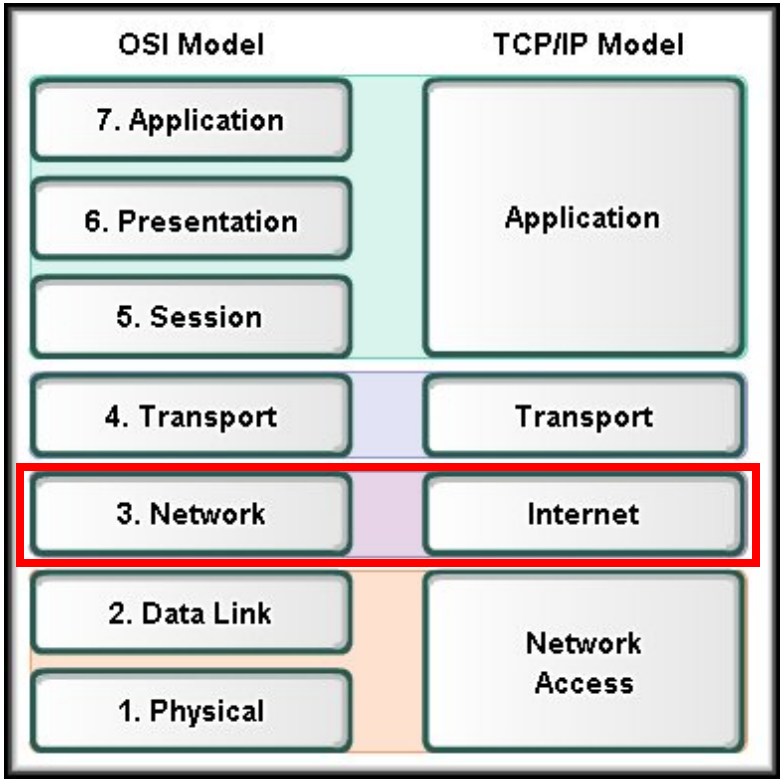


Typical IPv4 Packet

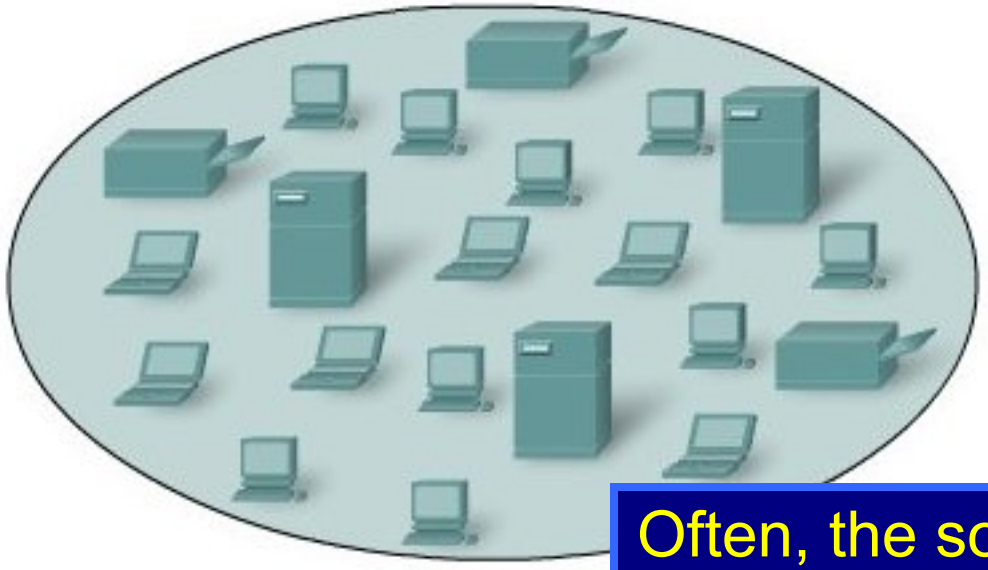


OSI Network Layer

Networks: Dividing Hosts into Groups



Dividing Hosts into Groups



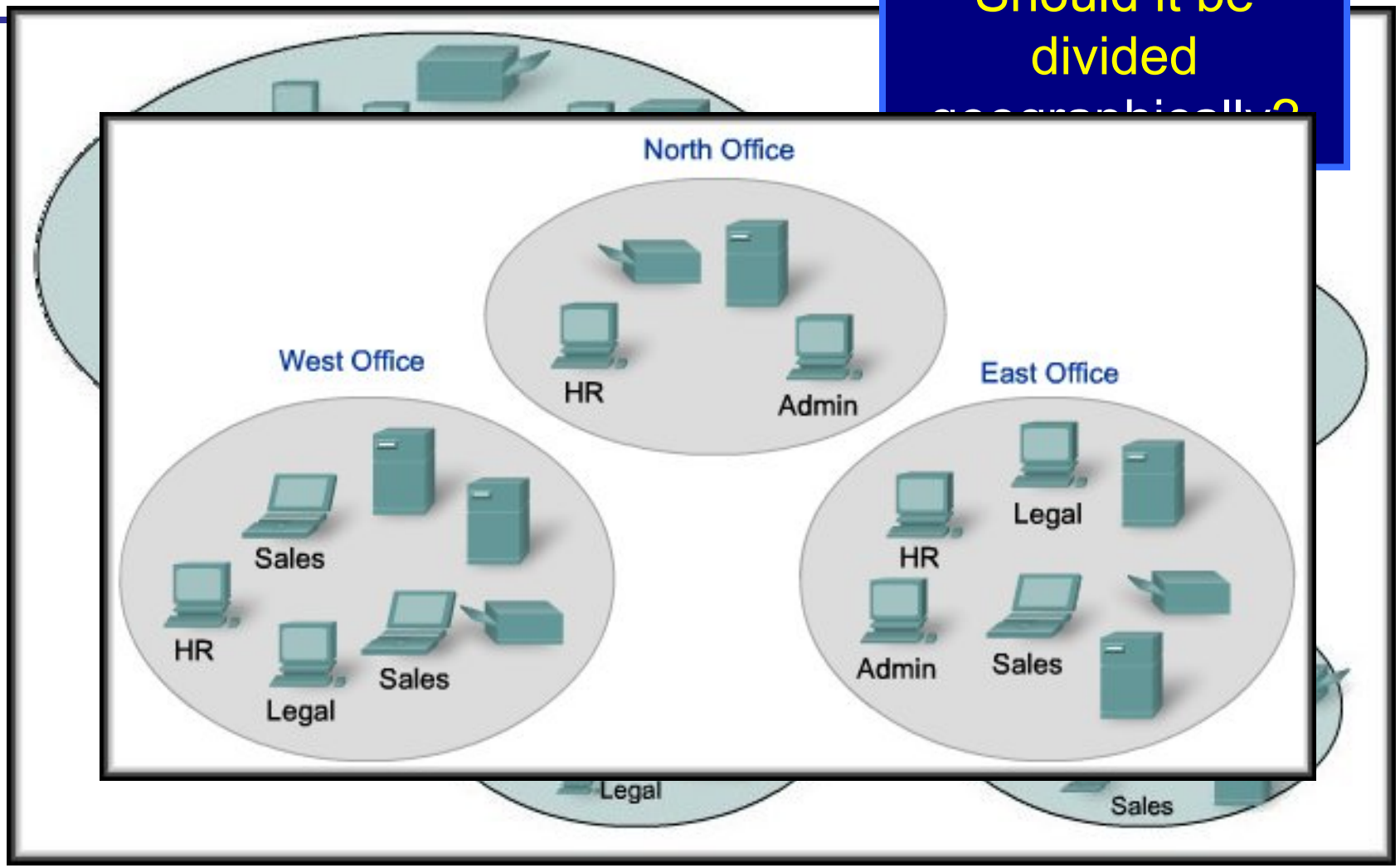
As networks grow, they become too unwieldy to manage as a single entity.

Often, the solution is to divide the large network into several more manageable sub-networks.

The question is…..HOW?

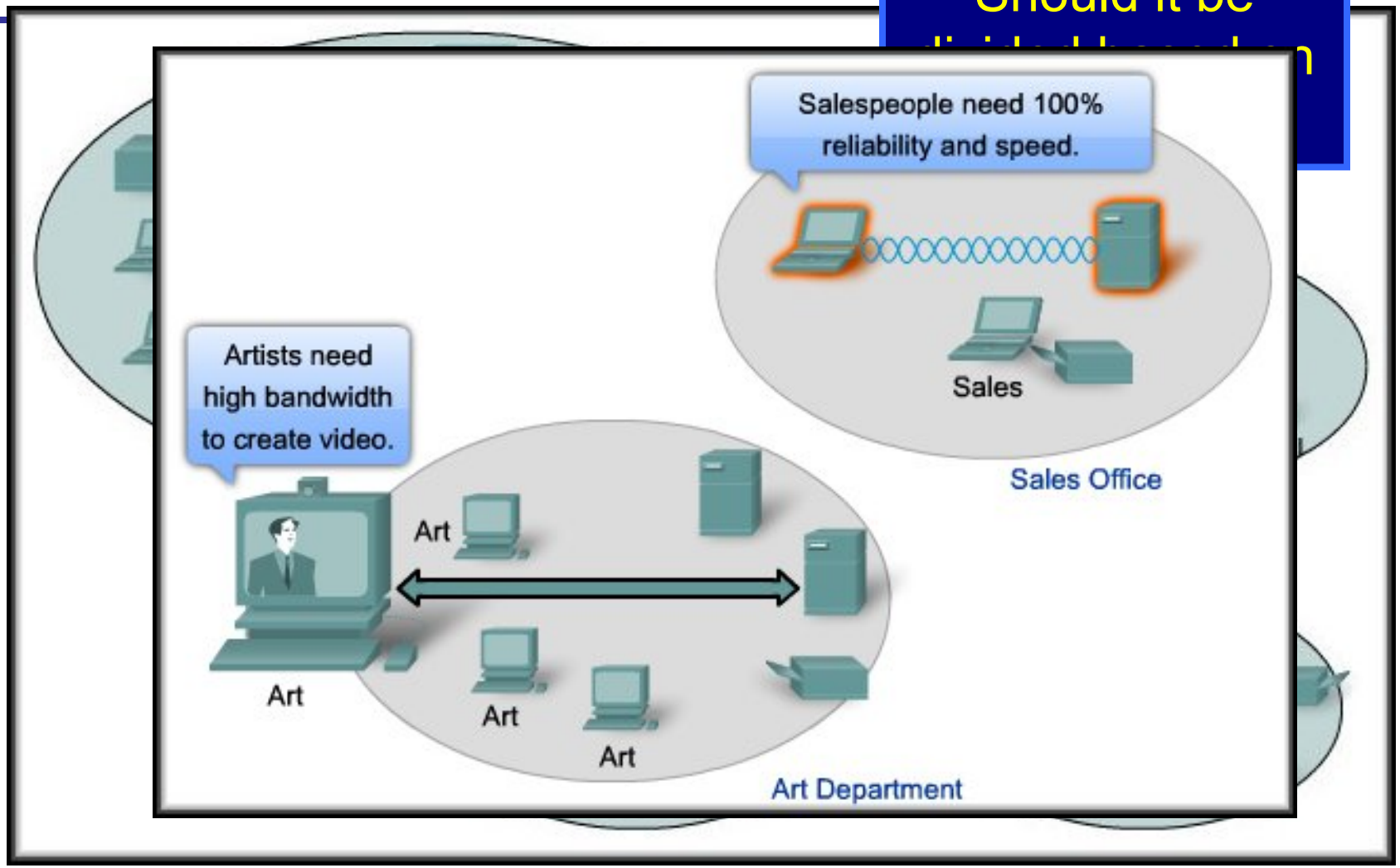
Dividing Hosts into Groups

Should it be divided geographically?



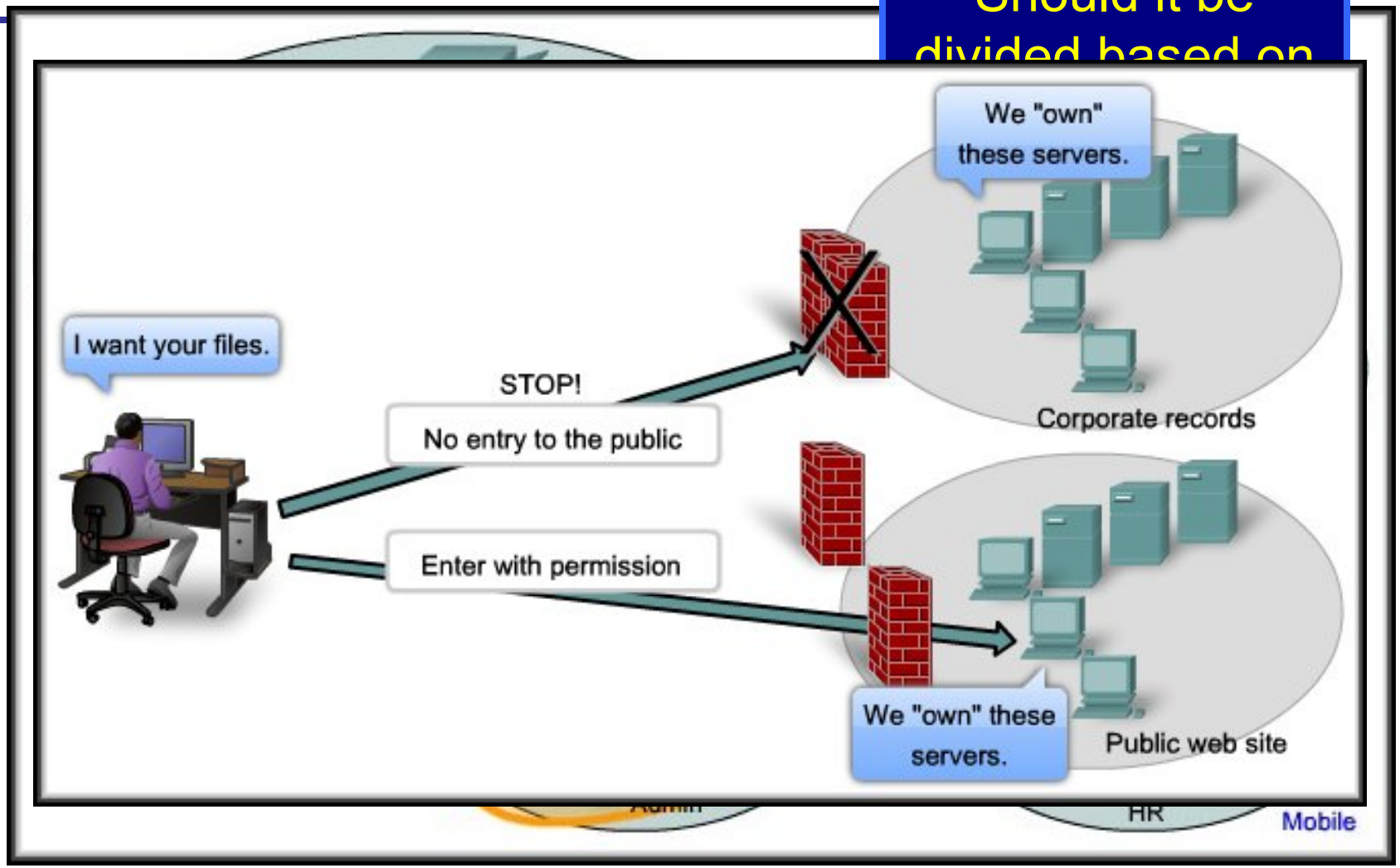
Dividing Hosts into Groups

Should it be

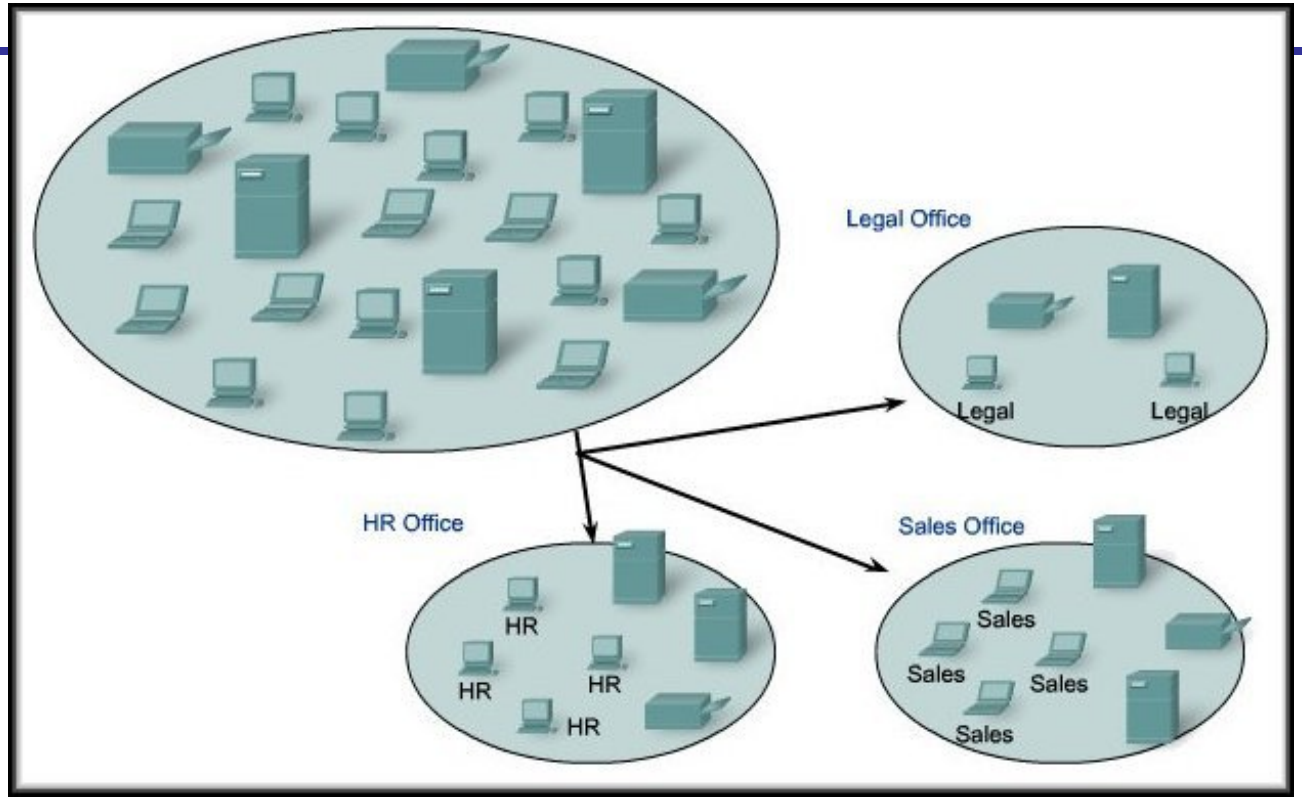


Dividing Hosts into Groups

Should it be divided based on



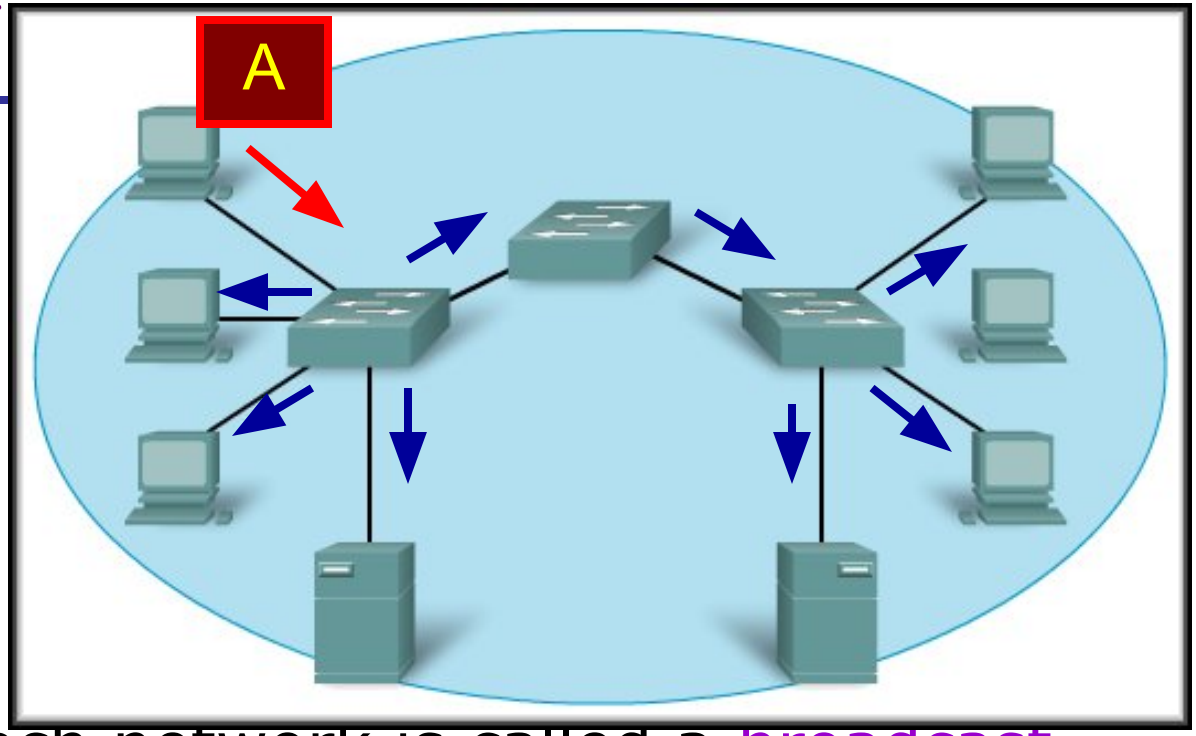
Why Separate Hosts into Networks?



- Performance
- Security
- Address Management

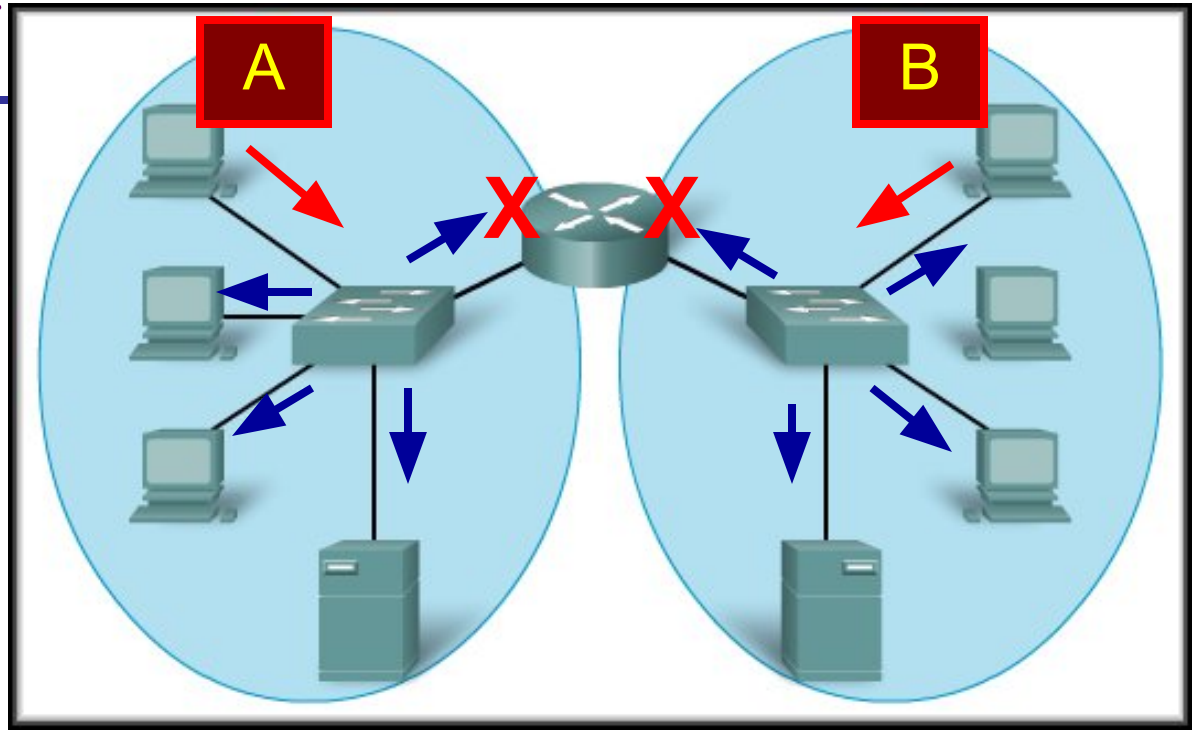
Performance

- Large numbers of hosts on a single network:
  - Actual Data
  - Overhead
- A big part of the overhead is broadcasts.



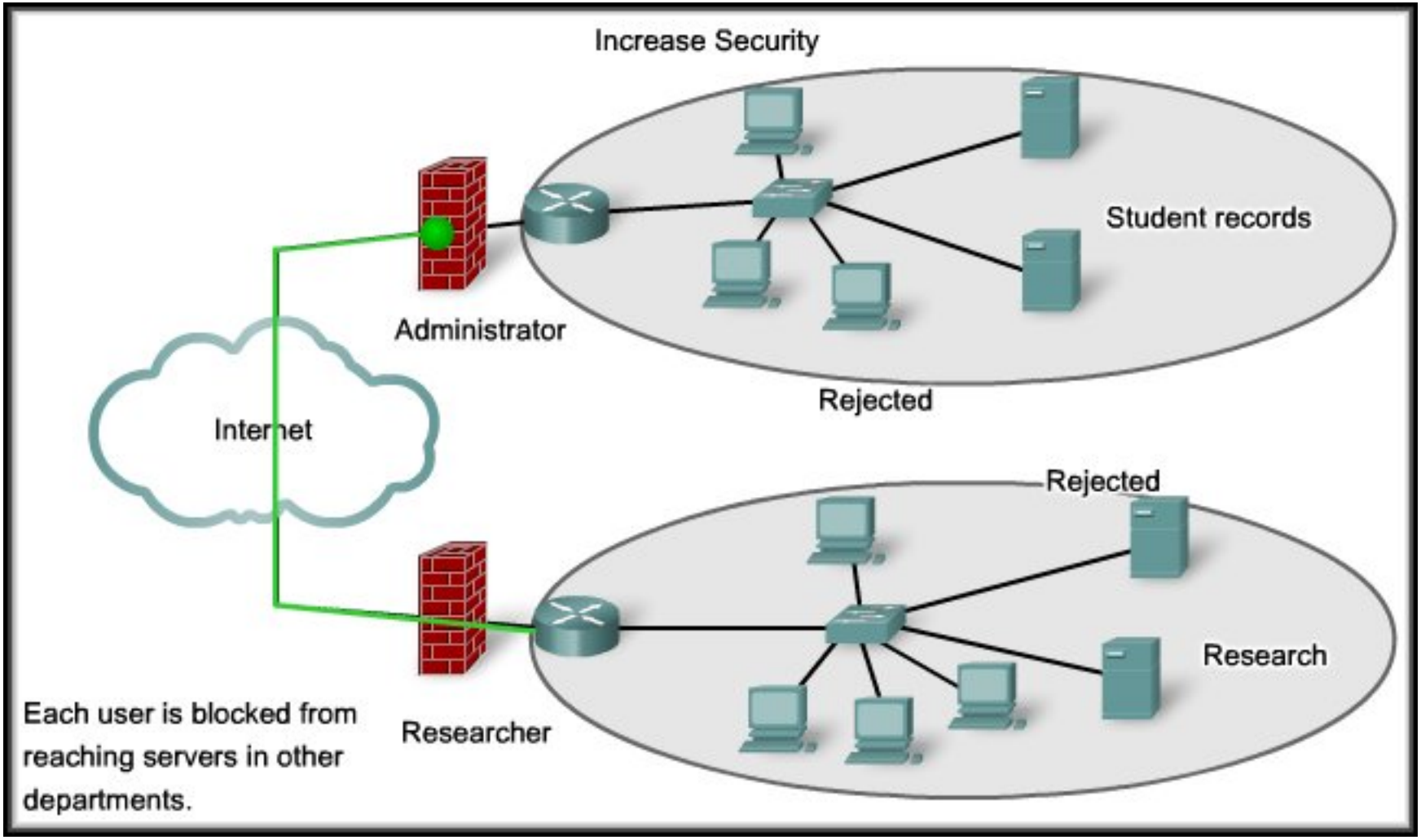
- In this context, each network is called a broadcast domain.
- Switches forward broadcasts to each device connected to a switch port.
- If we can reduce broadcast overhead, it would improve performance on the network.

Performance

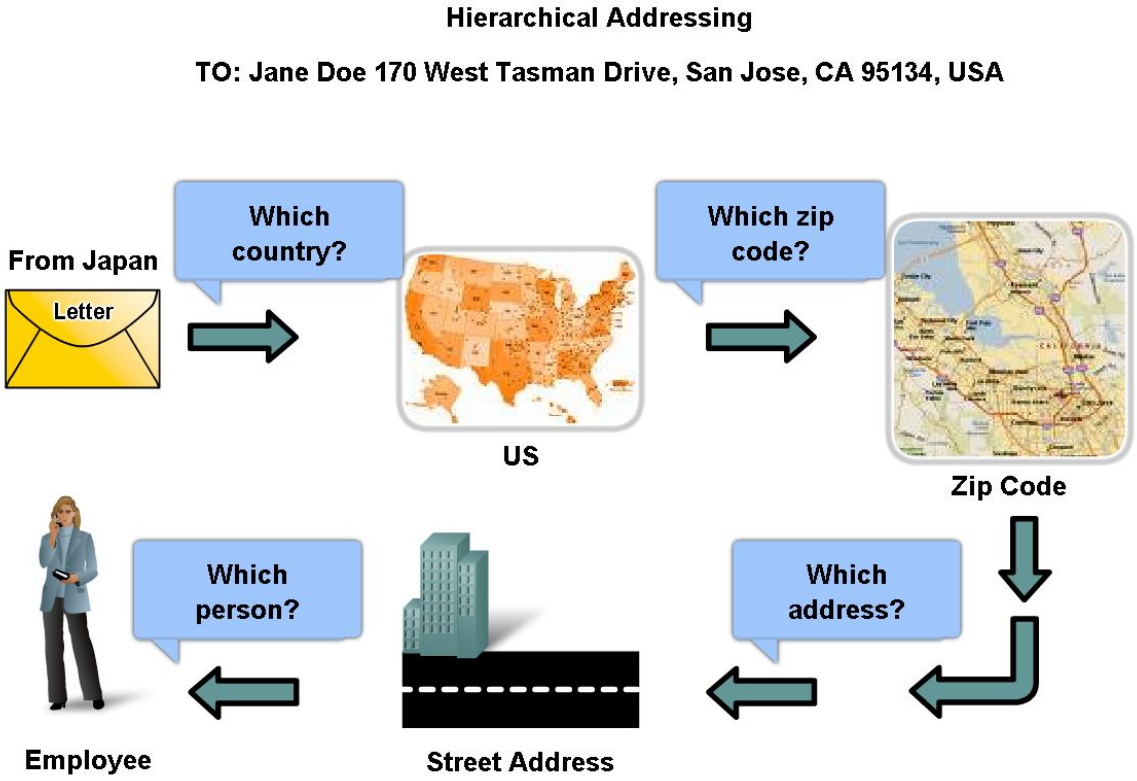


- Routers block broadcasts unless specifically configured to forward them.
- Replacing the switch in the diagram with a router, creates two separate IP sub-networks and two broadcast domains.
- Broadcasts are now contained within each network.

Security

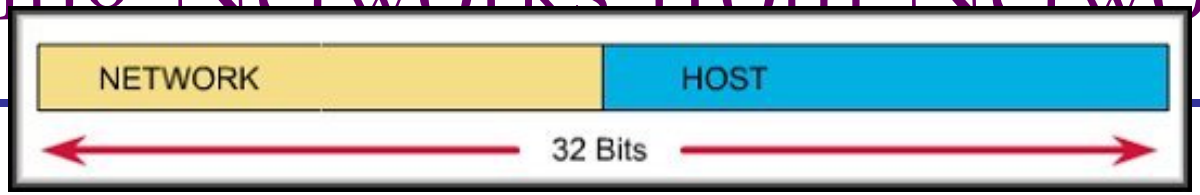

Increase Security
Student records
Administrator
Rejected
Internet
Rejected
Research
Researcher
Each user is blocked from reaching servers in other departments.

Grouping Devices into Networks and Hierarchical Addressing

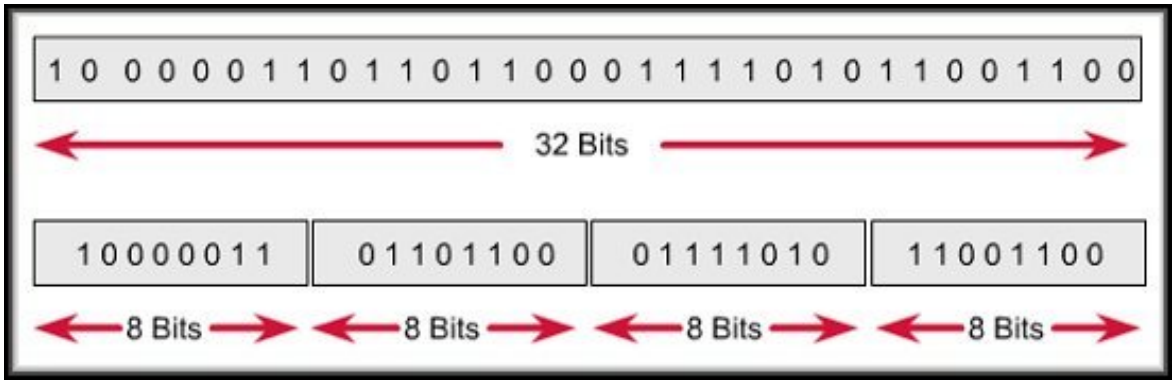


- Employee Name
- Cisco Systems, Inc.
- 170 West Tasman Drive
- San Jose, CA 95134
- USA

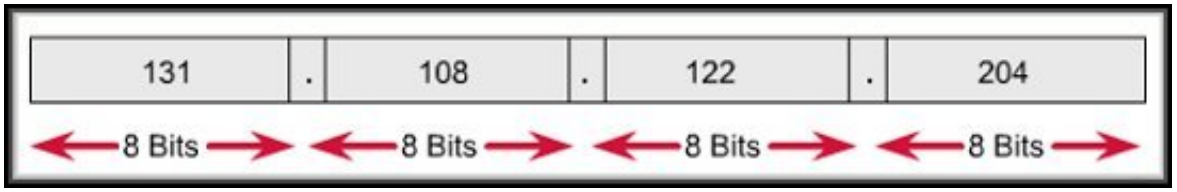
Dividing Networks from Networks



IP Version 4 addresses are 32 bits in length.



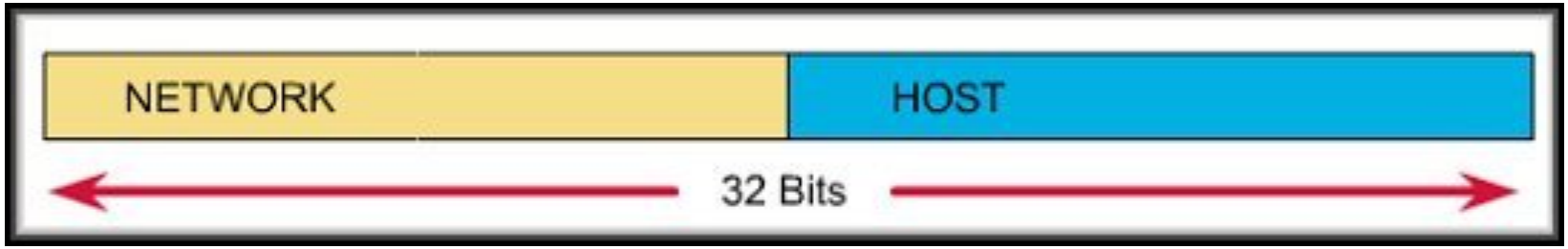
Divided into four separate groups of 8 bits each – 4 Octets.



Convert from binary to decimal Dotted Decimal Notation.

Dividing Networks from Networks

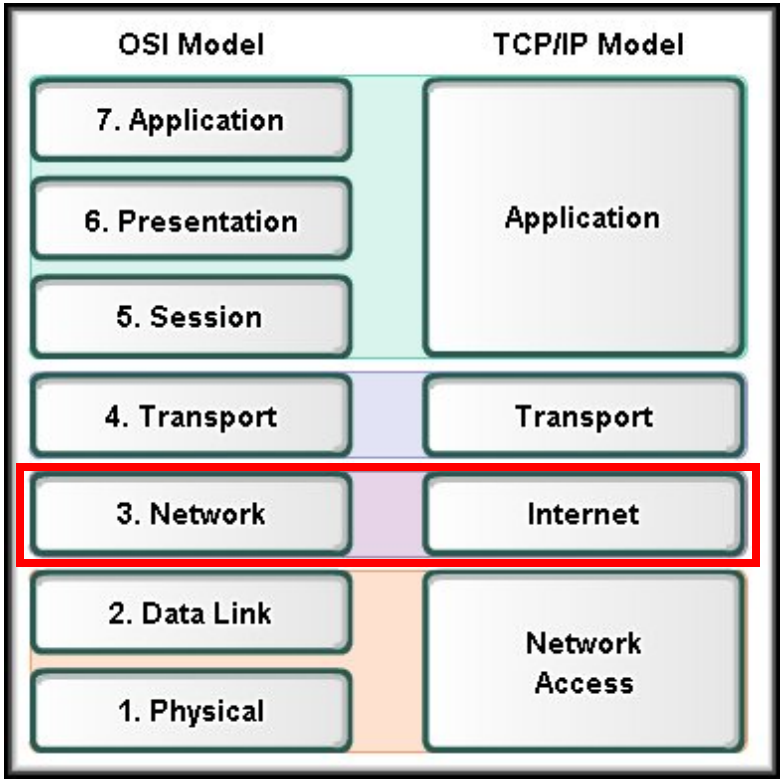
- An IP Version 4 address has two parts:
  - Network number
  - Host number



  - The network portion of the address is the same for all hosts on the network.
  - Each device is identified by a unique host portion.
- This hierarchy means that routers only need to know the network portion – not the address of each individual host.

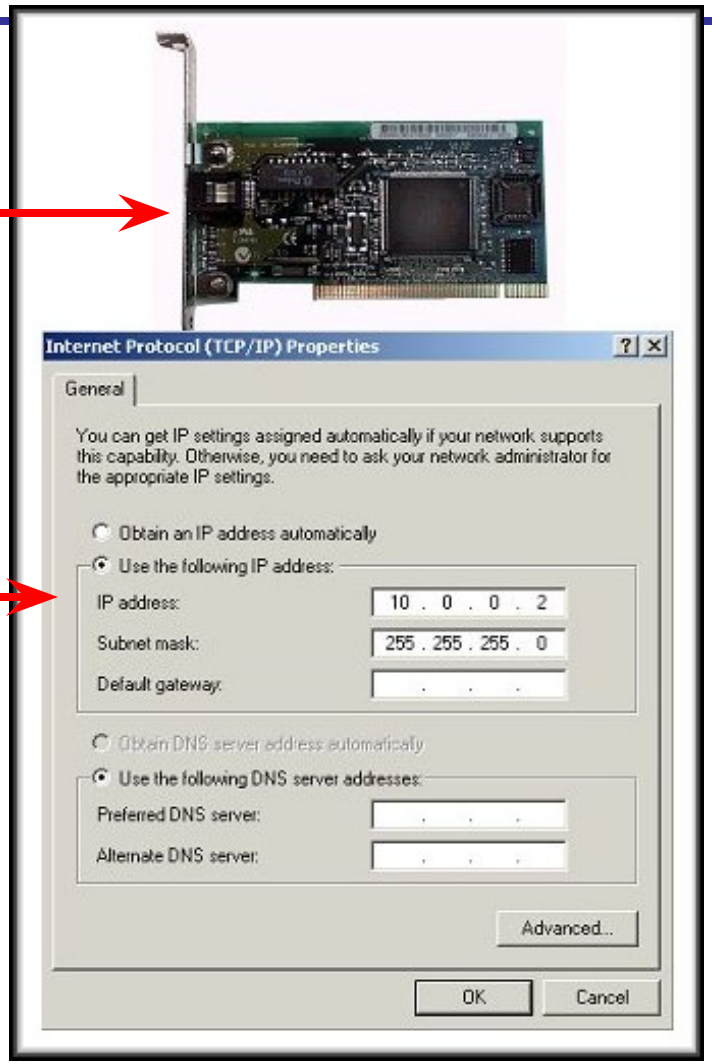
OSI Network Layer

Routing: How Data Packets Are Handled

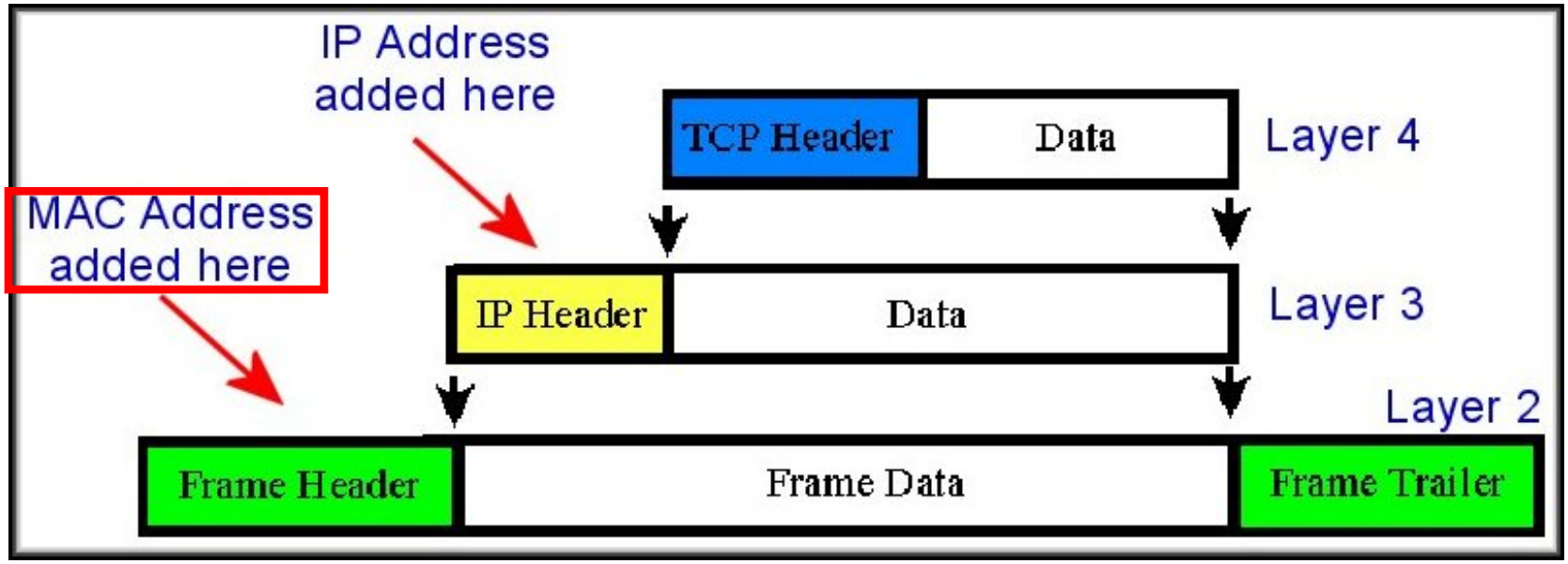


Address Types

- Two address types:
  - **MAC address:**
    - Physical address of the host
    - Burned in to the NIC
    - Layer 2 address
  - **Network Address:**
    - Logical address of the host
    - Assigned by network administrator
    - Layer 3 address

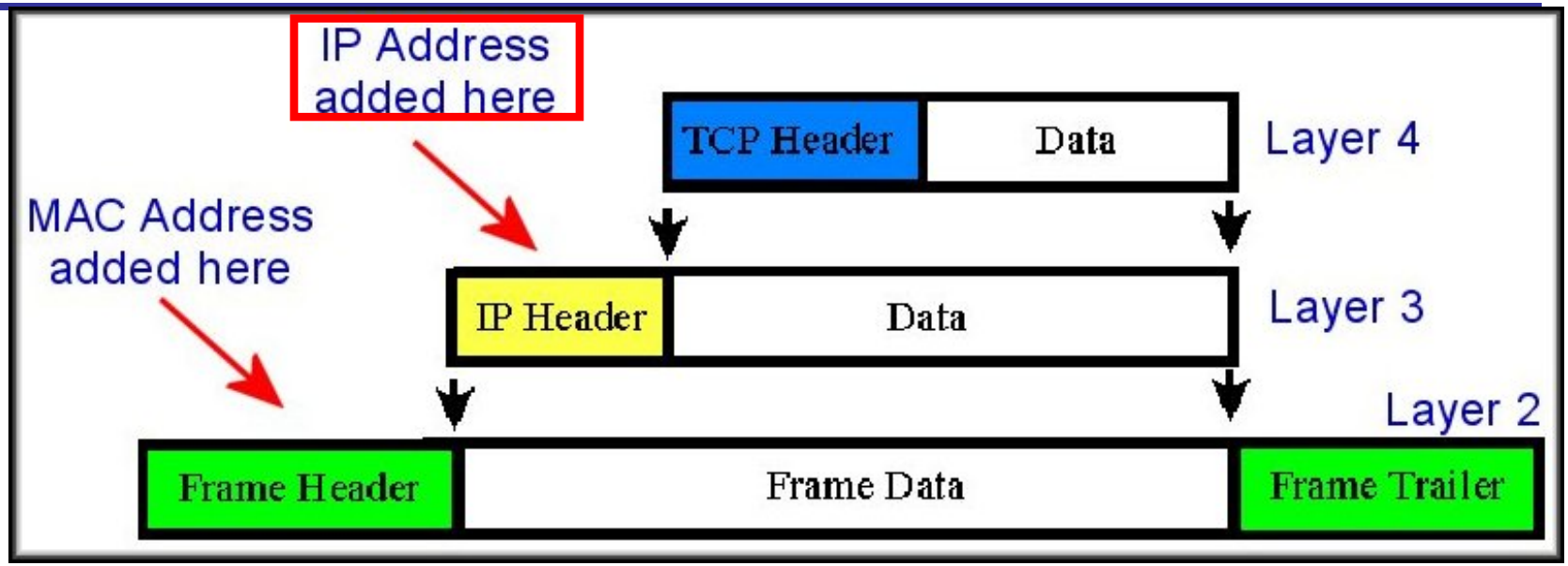


Each Host Has Two Addresses



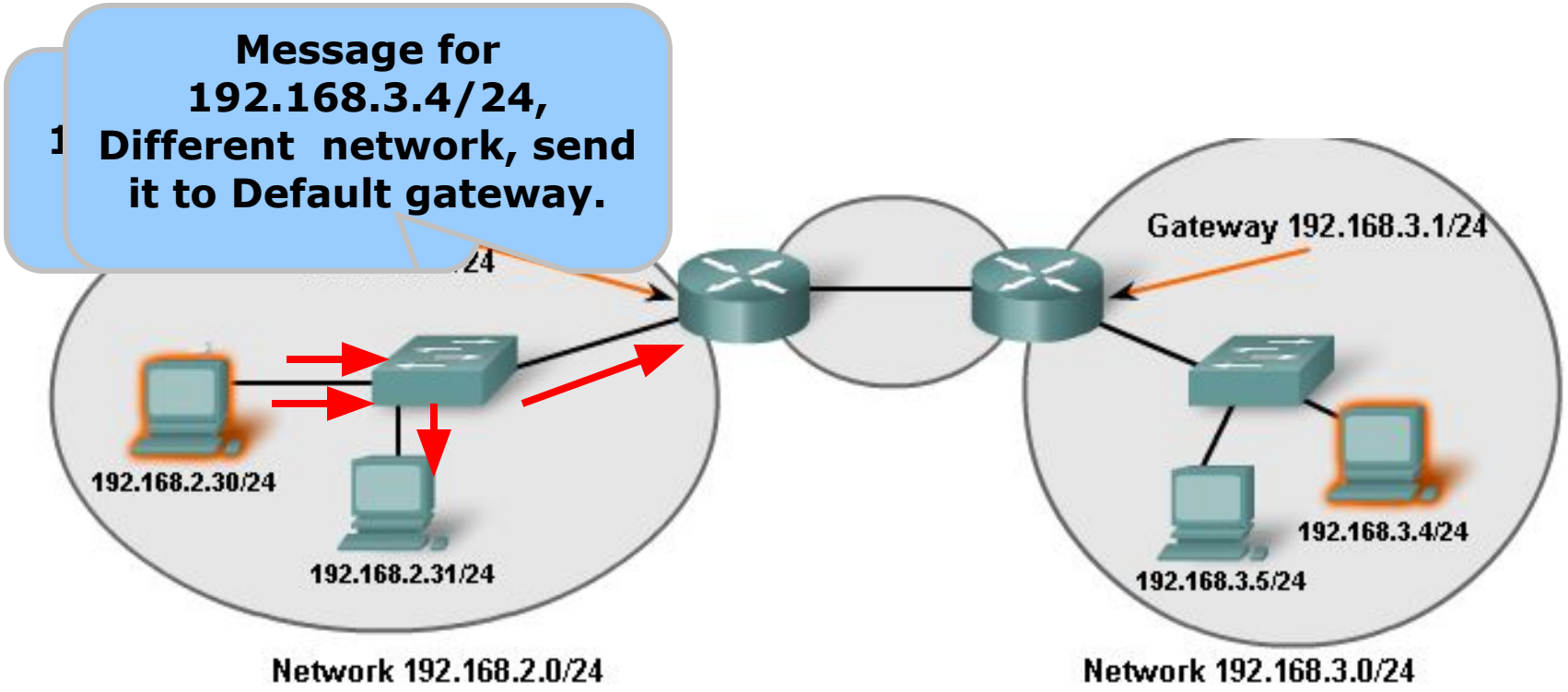
- **Physical (MAC):**
  - The physical address uniquely identifies the host from all other hosts on all other networks at Layer 2.
  - This is the address that is absolutely necessary to get the information into the host. The IP address by itself won't accomplish that.

Each Host Has Two Addresses

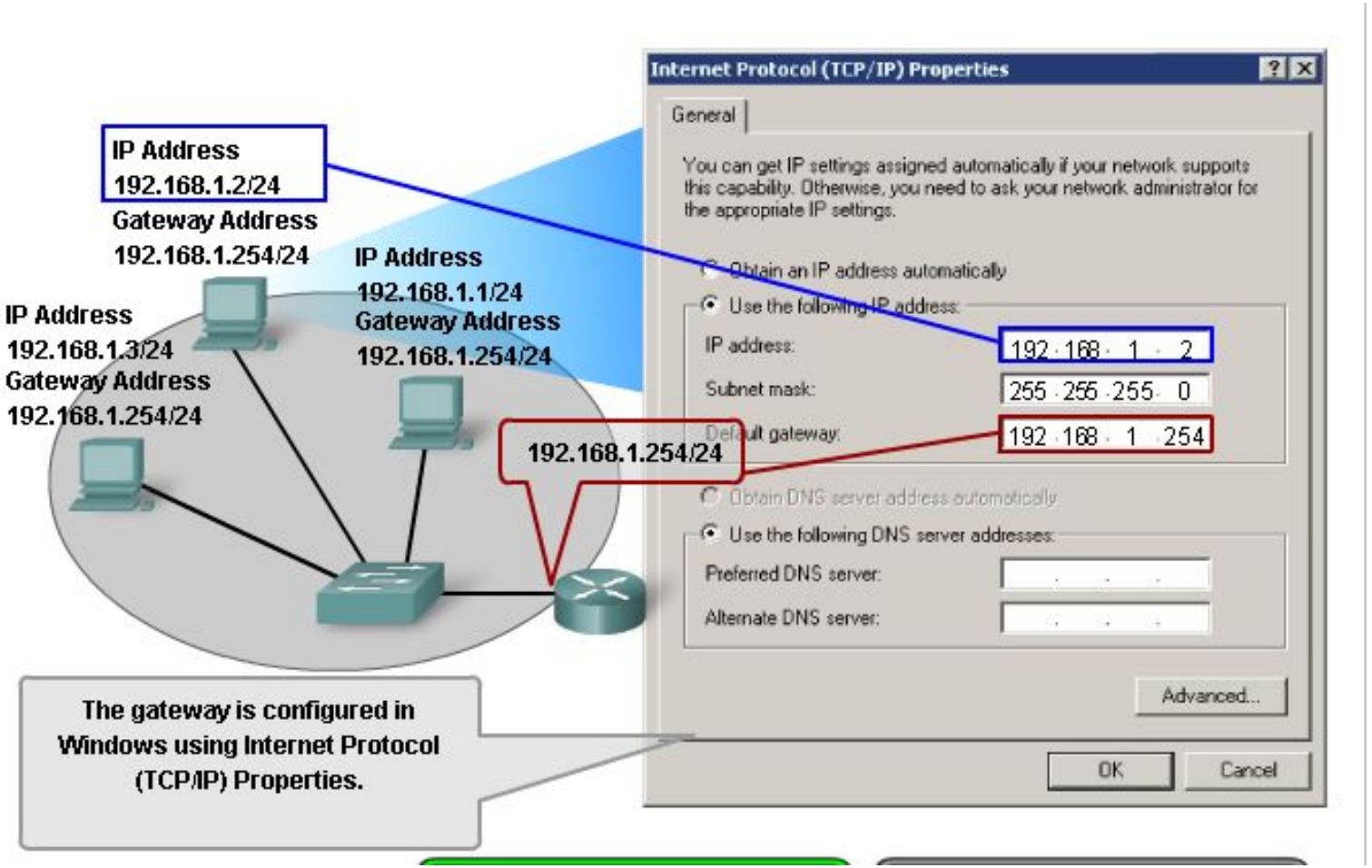


- **Logical (IP):**
  - The logical address uniquely identifies the host and the network to which it belongs at Layer 3.
  - Routers base their decisions on the NETWORK PORTION of the IP address when determining the best path for the packet.

Default Gateway



Default Gateway-The way out of our network



Default gateway

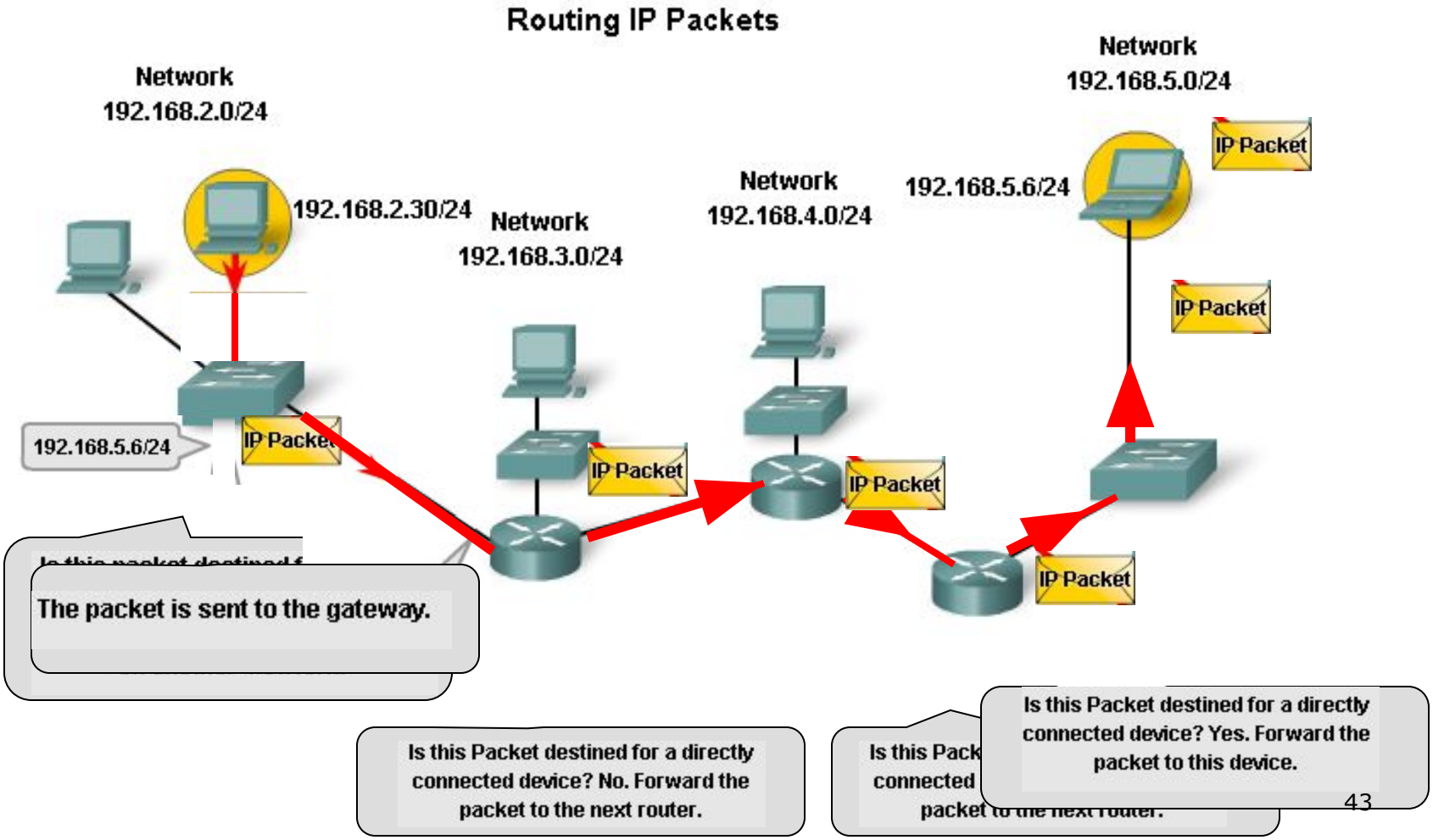
- Each PC is configured with an IP address and a default gateway.
- The default gateway is the IP address of a router port on the same network as the PC.
- It is the router's job to handle messages to other networks.
- Each router port is on a different network and has a different IP address.

Confirming Gateway Settings

- ipconfig or route commands

```
C:\>ipconfig

Windows IP Configuration

Ethernet adapter Local Area Connection:

        Connection-specific DNS Suffix  . :
① IP Address. . . . . . . . . . . . : 192.168.1.2
② Subnet Mask . . . . . . . . . . . : 255.255.255.0
③ Default Gateway . . . . . . . . . : 192.168.1.254
```

IP Packets-Carrying Data Er



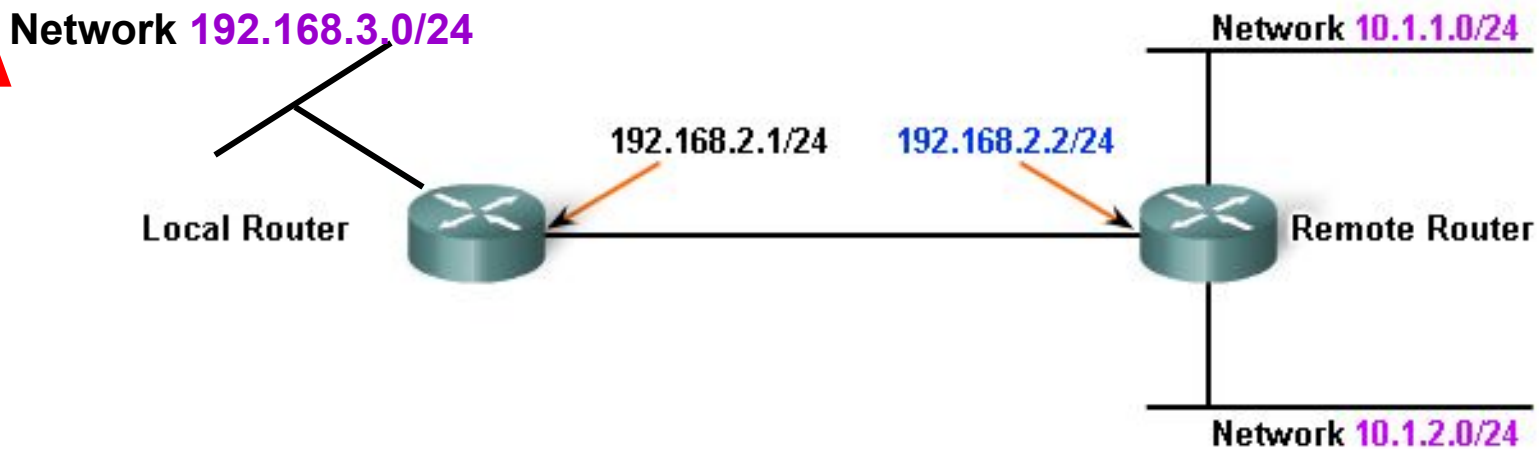
Route/Hops

- No packet can be forwarded without a route.
- Whether the packet is originating in a host or being forwarded by an intermediary device, the device must have a route to identify where to forward the packet.
- A packet may pass through many routers on its journey.
- The trip from one router to the next is called a hop and the next router is called the next hop router.

Routing Table

- Each router has a routing table.
- Stores information about Connected and Remote networks.
- **Connected networks** are directly attached to one of the router interfaces.
- **Remote networks** are networks that are not directly connected to the router.
  - Can be manually configured on the router by the network administrator or learned automatically using dynamic routing protocols.

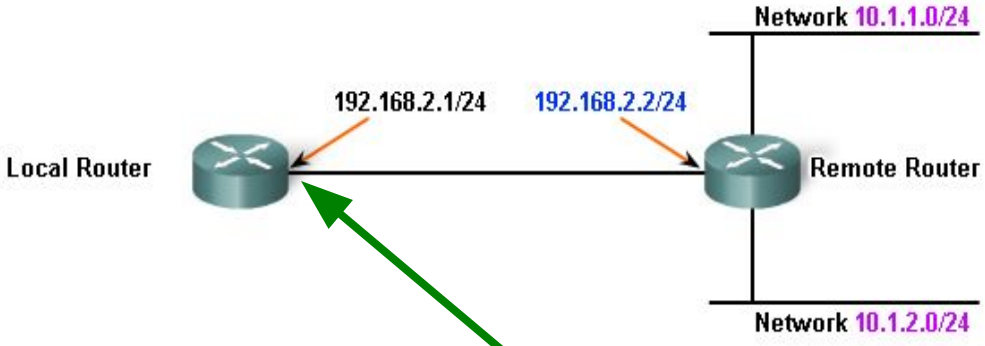
Routing Table




```
    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       192.168.2.0/24 is directly connected, FastEthernet0/0
C 192.168.3.0/24 is directly connected, FastEthernet 0/1
```

Routing Table

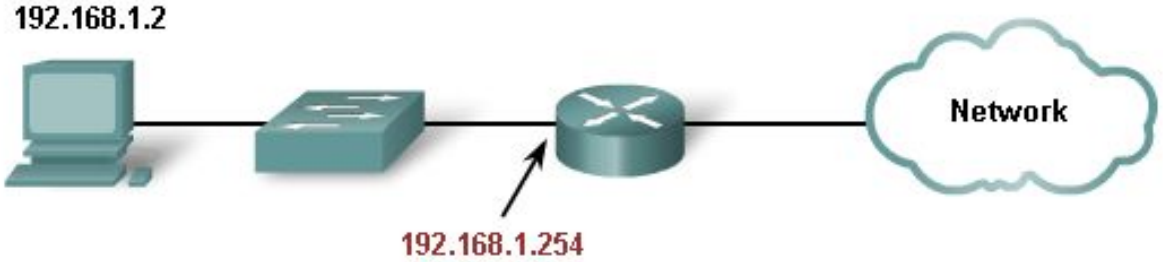
- Routes in a routing table have four main features:
  - **Destination network**
  - **Next-hop**
  - **Metric**
  - **Exit Interface**




```
    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    192.168.2.0/24 is directly connected, FastEthernet0/0
```

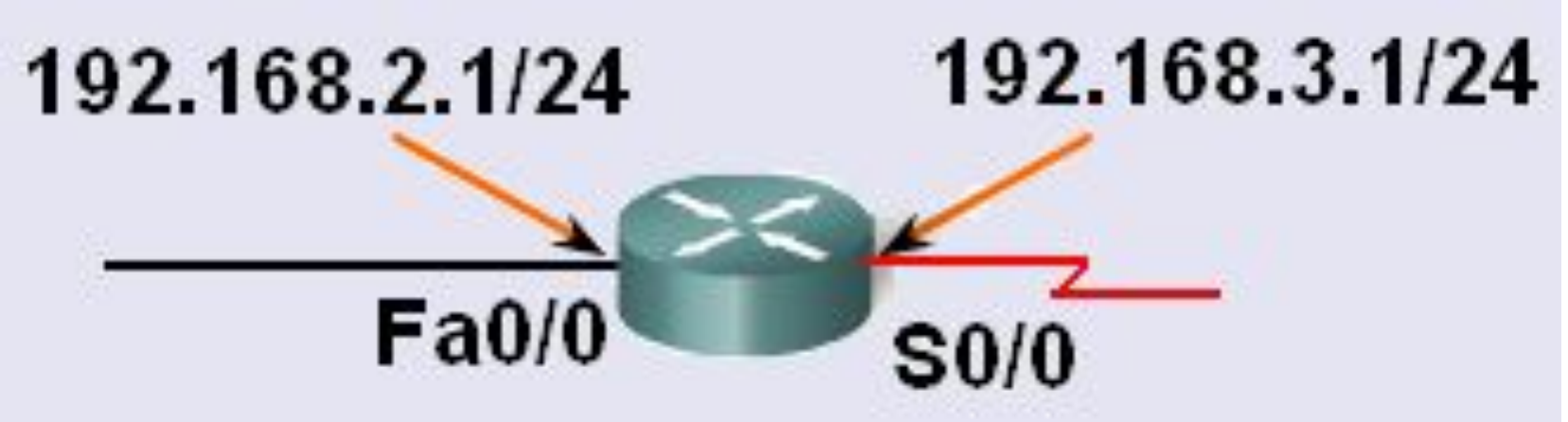
Host Routing Table

- Using netstat -r, route, or route PRINT commands.
- Other Commands
  - route ADD
  - route DELETE
  - route CHANGE




```
Interface List
0x2 ...00 0f fe 26 f7 7b ...  Gigabit Ethernet - Packet Scheduler Miniport
===========================================================================

Active Routes:
Network Destination        Netmask          Gateway       Interface  Metric
          0.0.0.0          0.0.0.0    192.168.1.254    192.168.1.2      20
      192.168.1.0    255.255.255.0        192.168.1.2    192.168.1.2      20
Default Gateway:     192.168.1.254
// output omitted //
===========================================================================
```

Directly connected

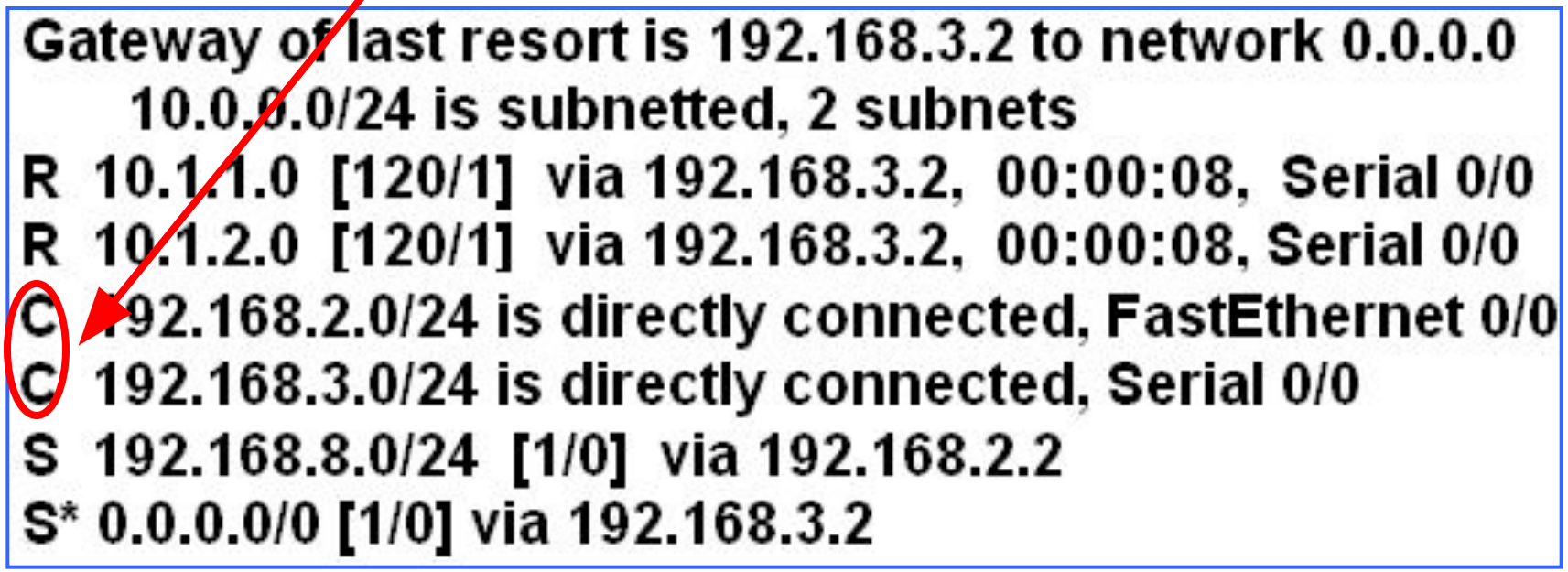


The networks of the router's own interfaces go into the routing table.

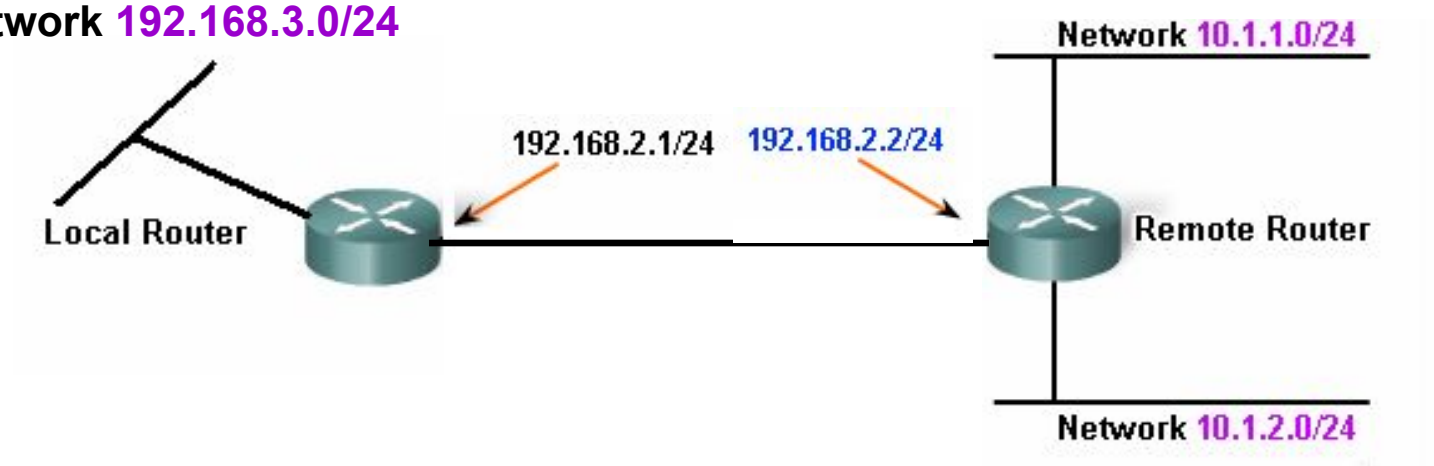
```
C  192.168.2.0/24 is directly connected, FastEthernet 0/0
C  192.168.3.0/24 is directly connected, Serial 0/0
```

Routing table entries

Directly connected shown by **C**



Directly Connected Routes



Routing Table of Local Router :

Routing Table of Remote Router :

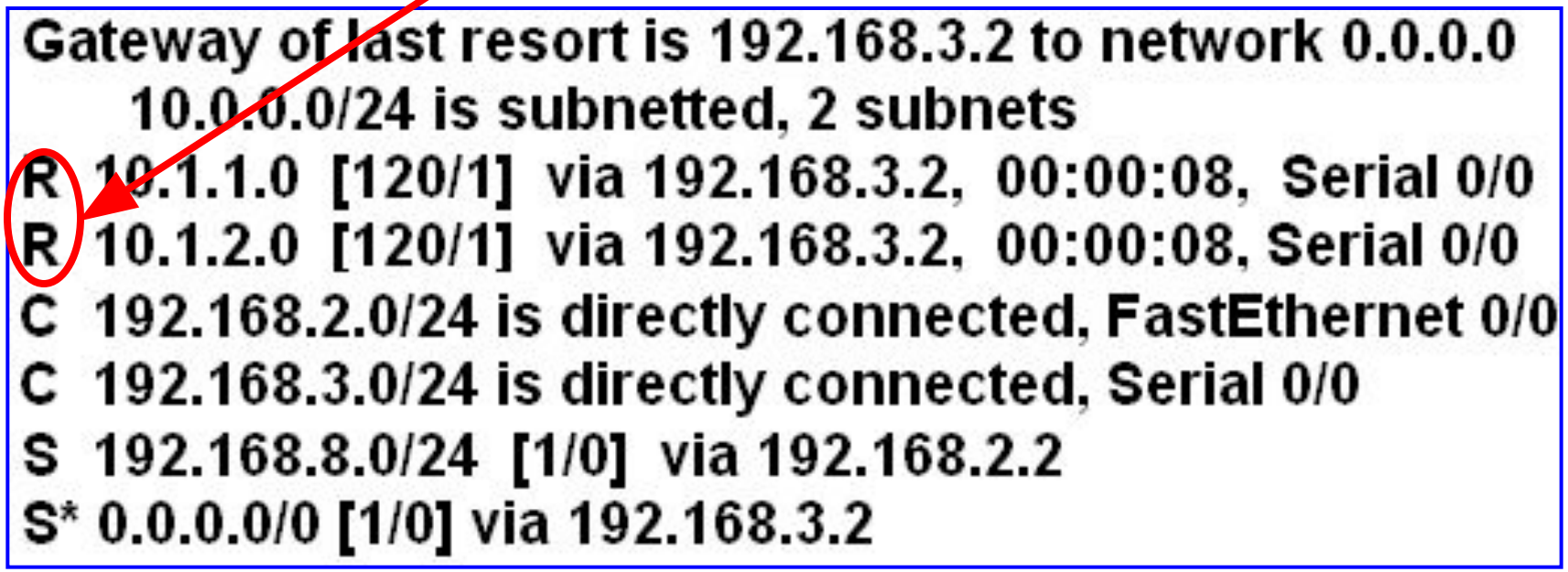
```
Gateway of last resort is not set.

C 192.168.2.0/24 is directly connected, FastEthernet 0/1
C 10.1.2.0/24 is directly connected, FastEthernet 0/1
```

Other networks

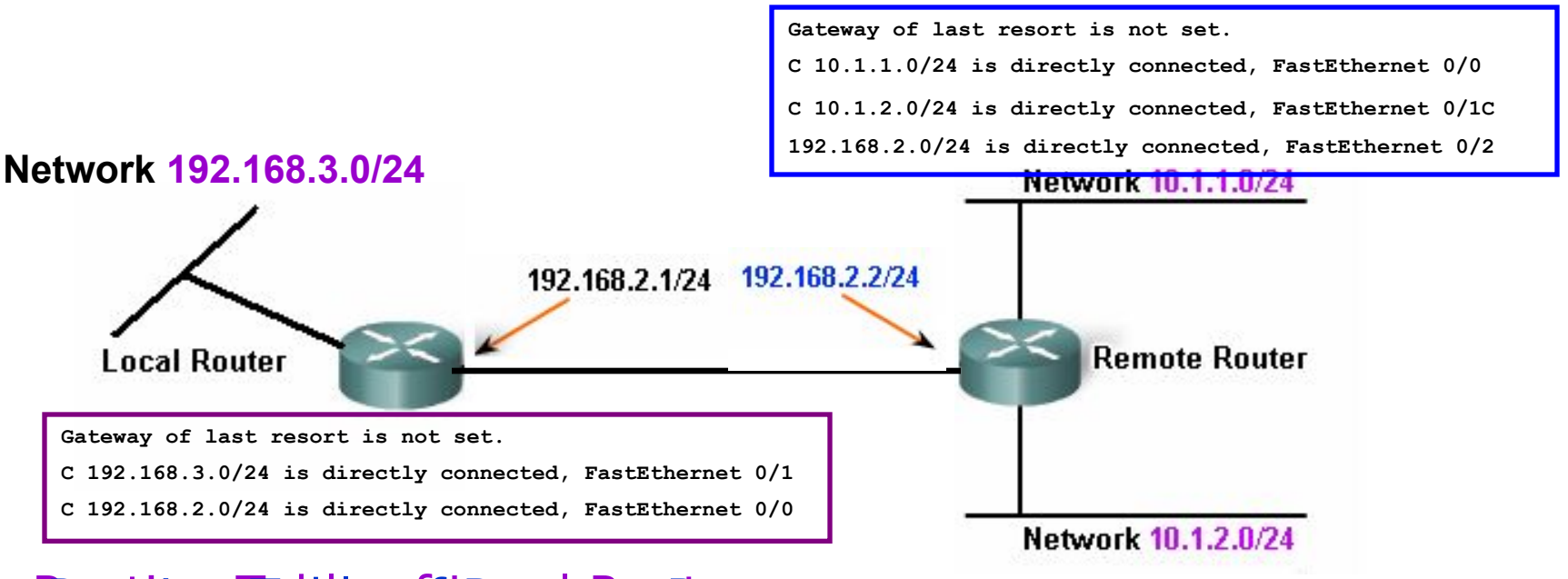
- Routes to other networks can be configured by an administrator (static routes)
- Or they can be learned from another router using a routing protocol (dynamic routes)
- A router can have a default route. Packets for unknown networks go on this route instead of being dropped.

Routing Table Entries: Dynamic Routes

Learned from another router using RIP routing protocol, shown by **R**



Dynamic Routes



Routing Table of Local Router :

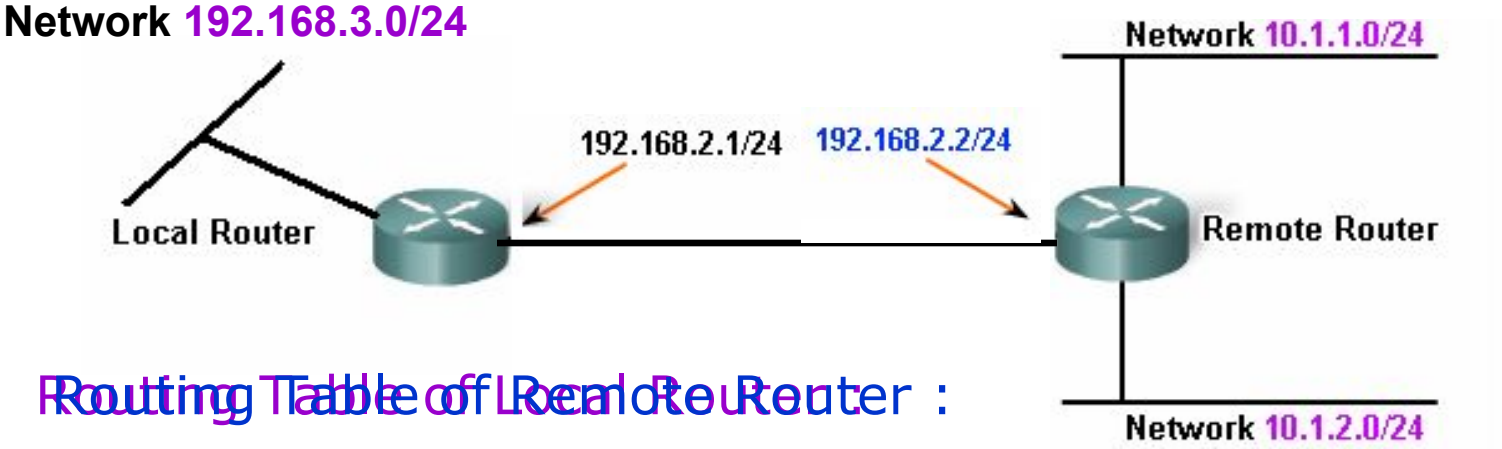
Routing Table of Remote Router :

```
Gateway of last resort is not set.
C 192.168.3.0/24 is directly connected, FastEthernet 0/1
C 192.168.2.0/24 is directly connected, FastEthernet 0/0
```


```
Gateway of last resort is not set.
C 10.1.1.0/24 is directly connected, FastEthernet 0/0
C 10.1.2.0/24 is directly connected, FastEthernet 0/1
```


```
C 192.168.2.0/24 is directly connected, FastEthernet 0/2
```

Dynamic Routes

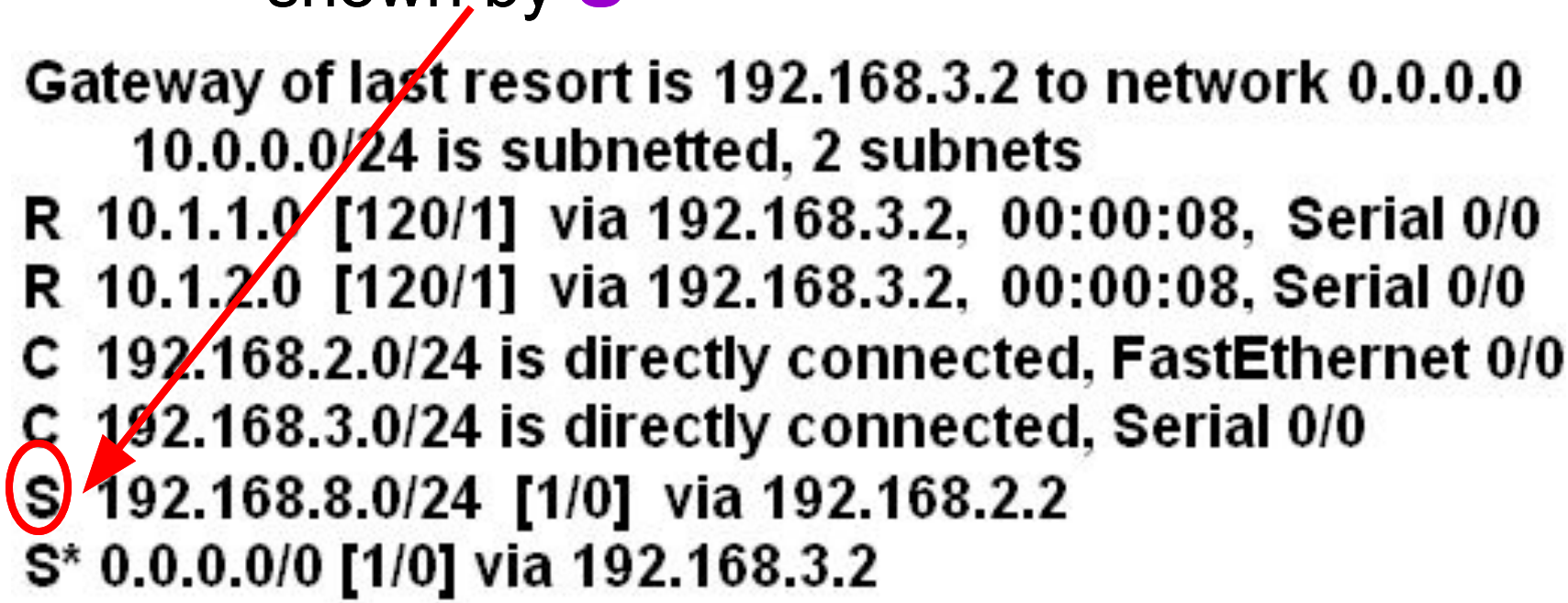


Routing Table of Local Router :

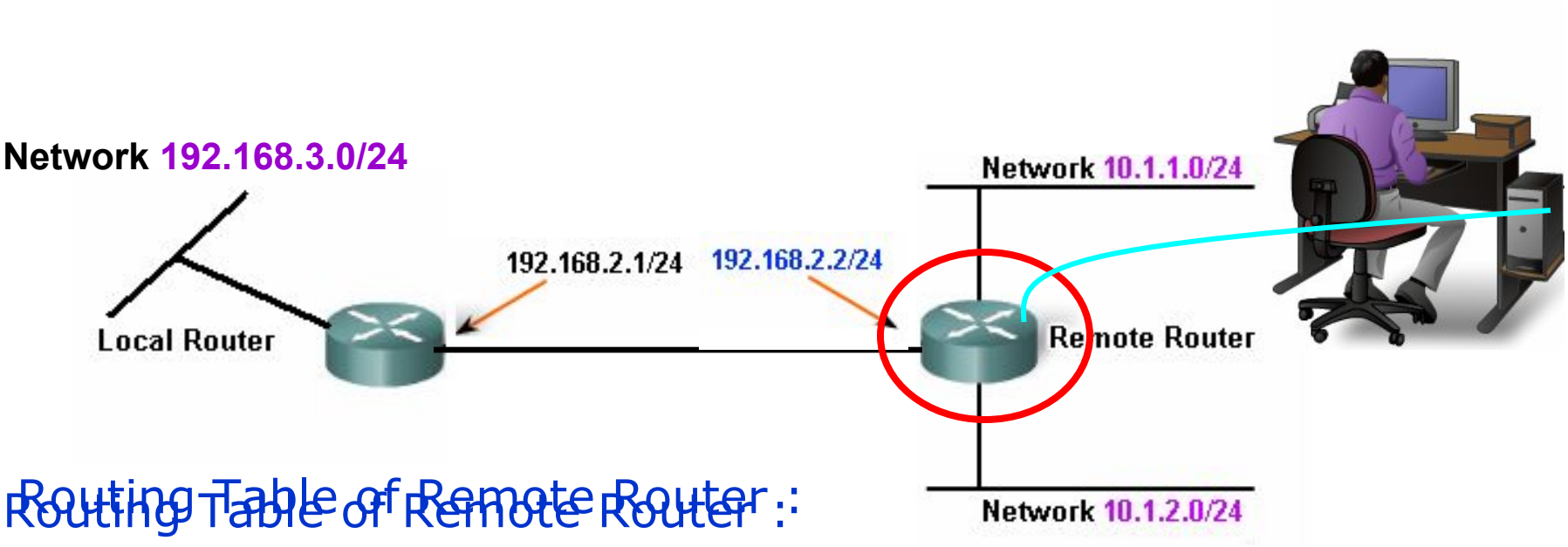
```
Gateway of last resort is not set:
10.0.0.0/24 is subnetted, 2 subnets
R 192.168.3.0[120/1] via 192.168.2.1,00:00:20, FastEthernet 0/0
C 10.1.1.0/24 is directly connected, FastEthernet 0/0
C 10.1.2.0/24 is directly connected, FastEthernet 0/1
C 192.168.2.0/24 is directly connected, FastEthernet 0/0
```

Routing table entries: Static Routes

Static, configured by administrator, shown by **S**



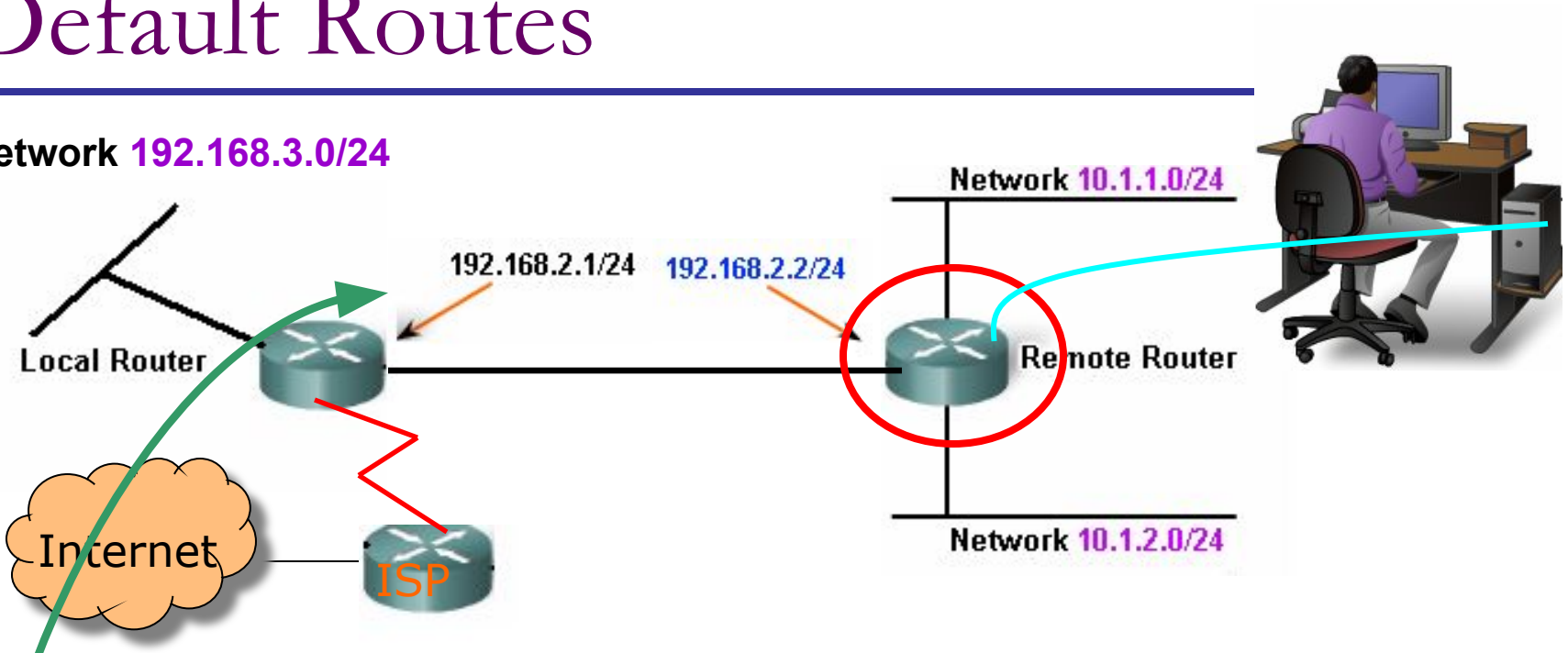
Static Routes



Routing Table of Remote Router :

```
Gateway of last resort is not set.

R 192.168.1.0/24 [120/1] via 192.168.2.1, 00:00:20, FastEthernet 0/0
C 10.1.2.0/24 is directly connected, FastEthernet 0/1
C 192.168.2.0/24 is directly connected, FastEthernet 0/2
S 192.168.3.0/24 is directly connected, FastEthernet 0/2
```

Default Routes

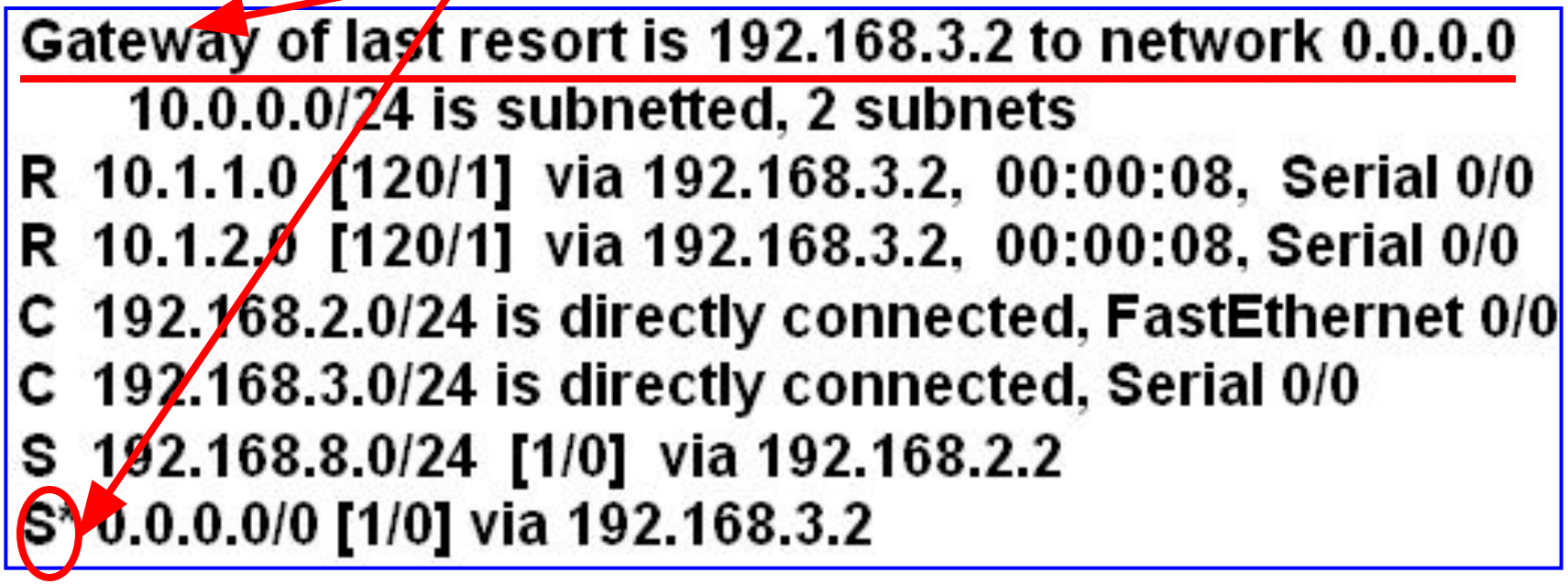


Routing Table of Remote Router :

```
Gateway of last resort is 192.168.2.1 to network 0.0.0.0
R 192.168.3.0[120/1] via 192.168.2.1,00:00:20, FastEthernet 0/0
C 10.1.1.0/24 is directly connected, FastEthernet 0/0
C 10.1.2.0/24 is directly connected, FastEthernet 0/1
C 192.168.2.0/24 is directly connected, FastEthernet 0/2
S* 0.0.0.0/0 [1/0] via 192.168.2.1
```

Routing Table Entries: Default Routes

Default, configured by administrator, shown by **S***



Routing protocols

- Routers learn routes from each other and put them in their routing tables.
- A routing protocol is the set of rules they use to swap information.
- These routes are dynamic routes

Static routes Dynamic routes

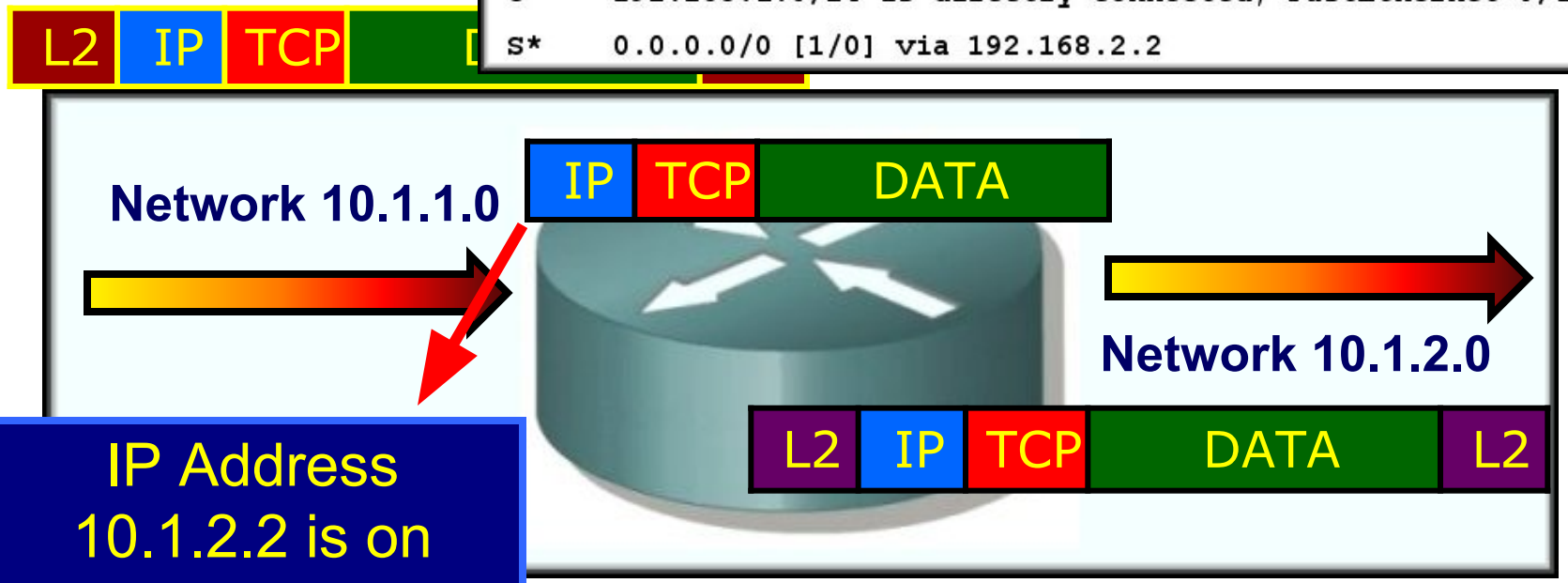
- Entered by administrator
- Time consuming, different for each router
- Must be updated if routes change
- Little processing
- No bandwidth used
- Gives nothing away

- Learned from other routers
- Start the protocol then it runs by itself
- Automatically updates when routes change
- More processing
- Uses bandwidth
- Gives away information

Packet Forwarding: Route Found

Data for Host
10.1.2.2 / 24

```
Gateway of last resort is 192.168.2.2 to network 0.0.0.0
    10.0.0.0/24 is subnetted, 2 subnets
R       10.1.1.0 [120/1] via 192.168.1.3, 00:00:08, FastEthernet 0/0
R       10.1.2.0 [120/1] via 192.168.2.2, 00:00:08, FastEthernet 0/1
C       192.168.1.0/24 is directly connected, FastEthernet 0/0
C       192.168.2.0/24 is directly connected, FastEthernet 0/1
S*      0.0.0.0/0 [1/0] via 192.168.2.2
```

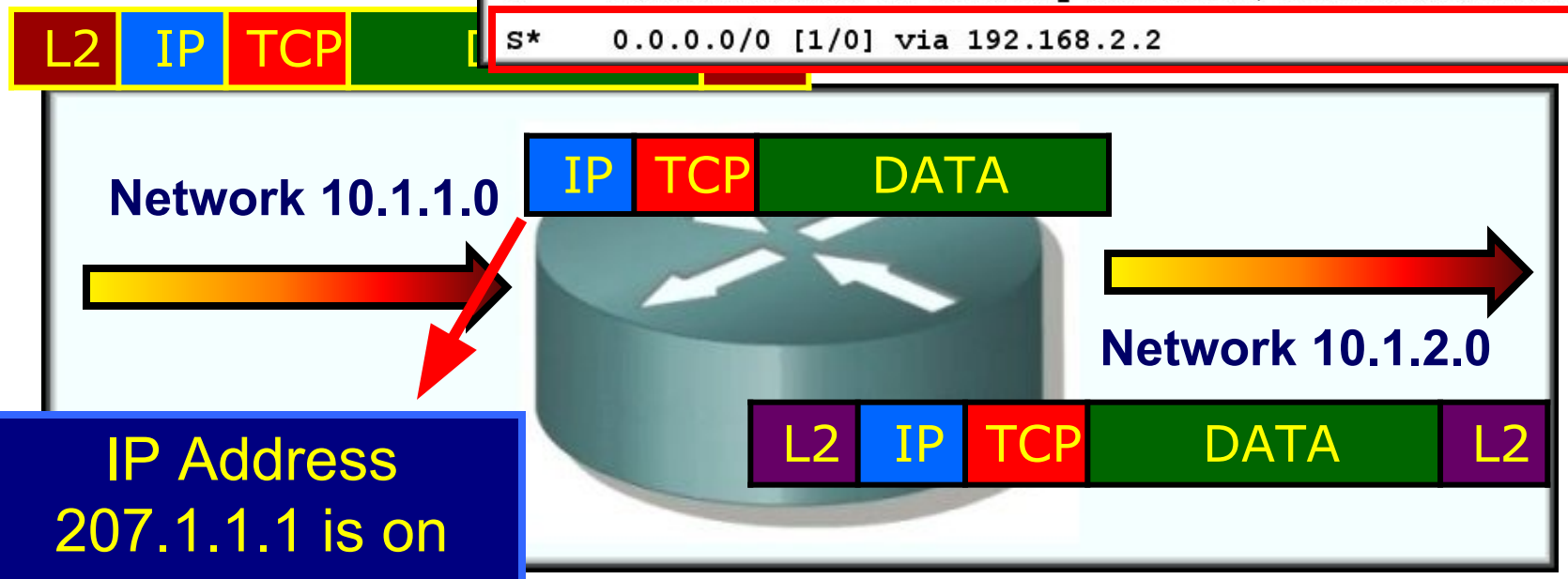


IP Address
10.1.2.2 is on
network 10.1.2.0

Packet Forwarding: Default Route

Data for Host 207.1.1.1 / 24

```
Gateway of last resort is 192.168.2.2 to network 0.0.0.0
   10.0.0.0/24 is subnetted, 2 subnets
R     10.1.1.0 [120/1] via 192.168.1.3, 00:00:08, FastEthernet 0/0
R     10.1.2.0 [120/1] via 192.168.2.2, 00:00:08, FastEthernet 0/1
C     192.168.1.0/24 is directly connected, FastEthernet 0/0
C     192.168.2.0/24 is directly connected, FastEthernet 0/1
S*    0.0.0.0/0 [1/0] via 192.168.2.2
```



IP Address 207.1.1.1 is on network 207.1.1.0

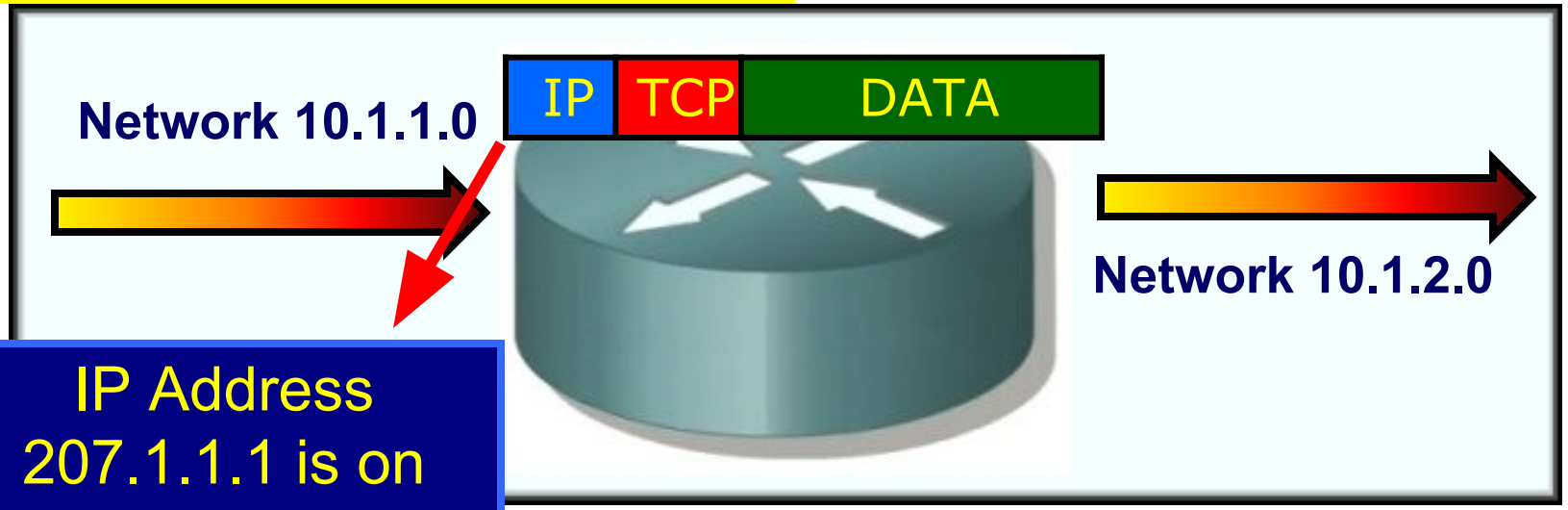
Packet Forwarding: Route Not Found

Data for Host 207.1.1.1 / 24

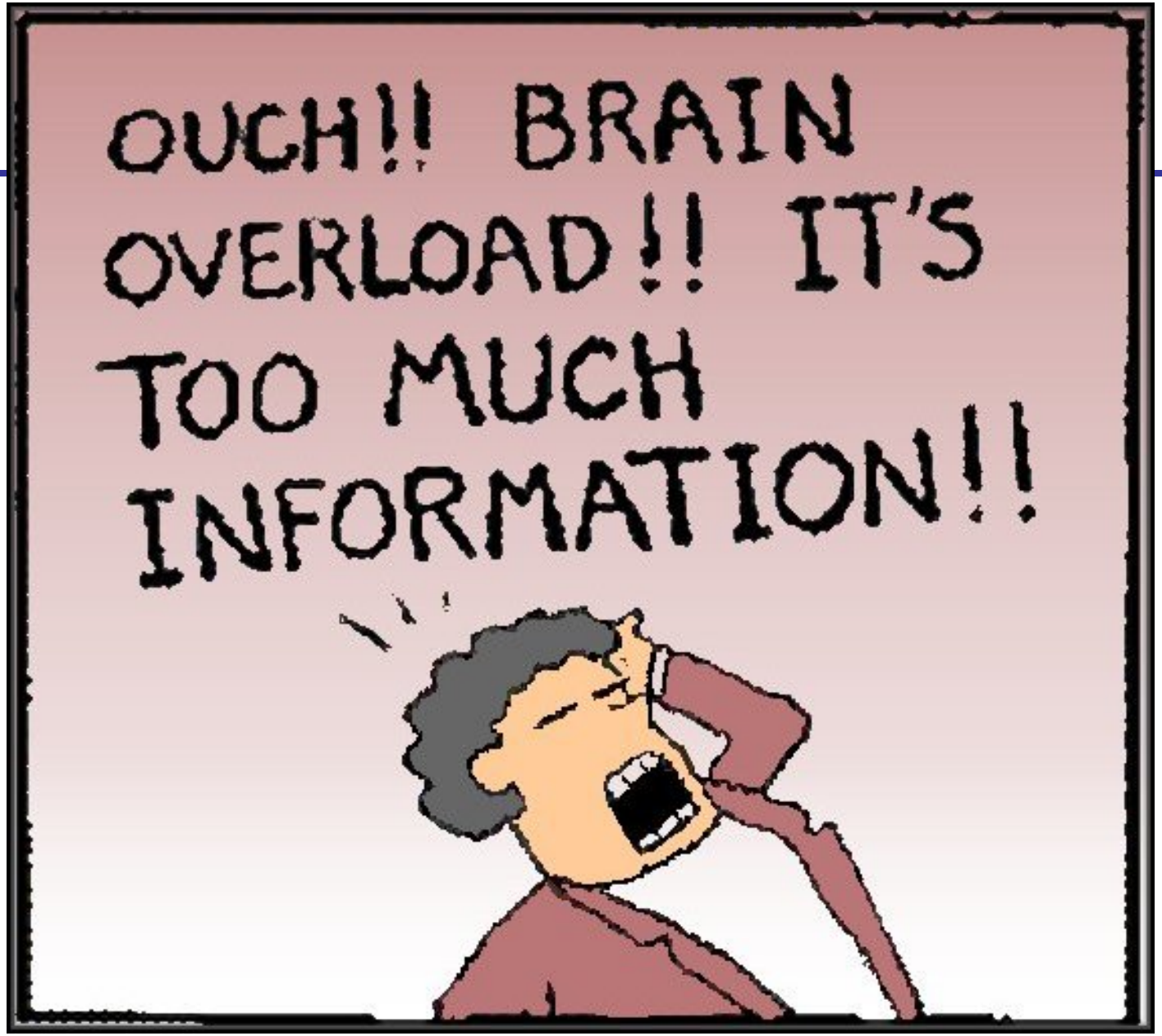
```
Gateway of last resort is not set
   10.0.0.0/24 is subnetted, 3 subnets
R     10.1.1.0 [120/1] via 192.168.1.3, 00:00:08, FastEthernet 0/0
R     10.1.2.0 [120/1] via 192.168.2.2, 00:00:08, FastEthernet 0/1
C     192.168.1.0/24 is directly connected, FastEthernet 0/0
C     192.168.2.0/24 is directly connected, FastEthernet 0/1
```

?

L2 | IP | TCP | D



IP Address 207.1.1.1 is on network 207.1.1.0


OUCH!! BRAIN OVERLOAD!! IT'S TOO MUCH INFORMATION!!