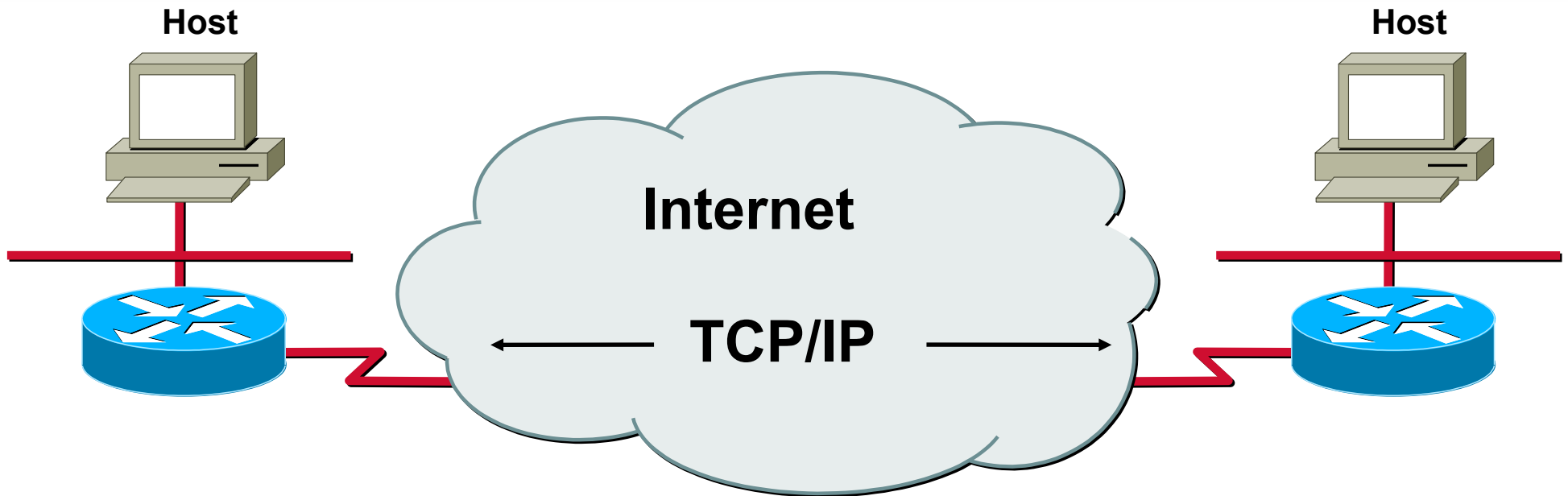
A man in a white shirt and red tie is holding a large red cable that forms a large arch over a colorful landscape. The landscape is divided into yellow, green, and blue sections. The man is standing on a blue section, and the cable is held high above his head, forming a large arch that spans across the yellow and green sections. The background is a textured, light blue surface.

Chapter 8

Interconnecting Networks with TCP/IP

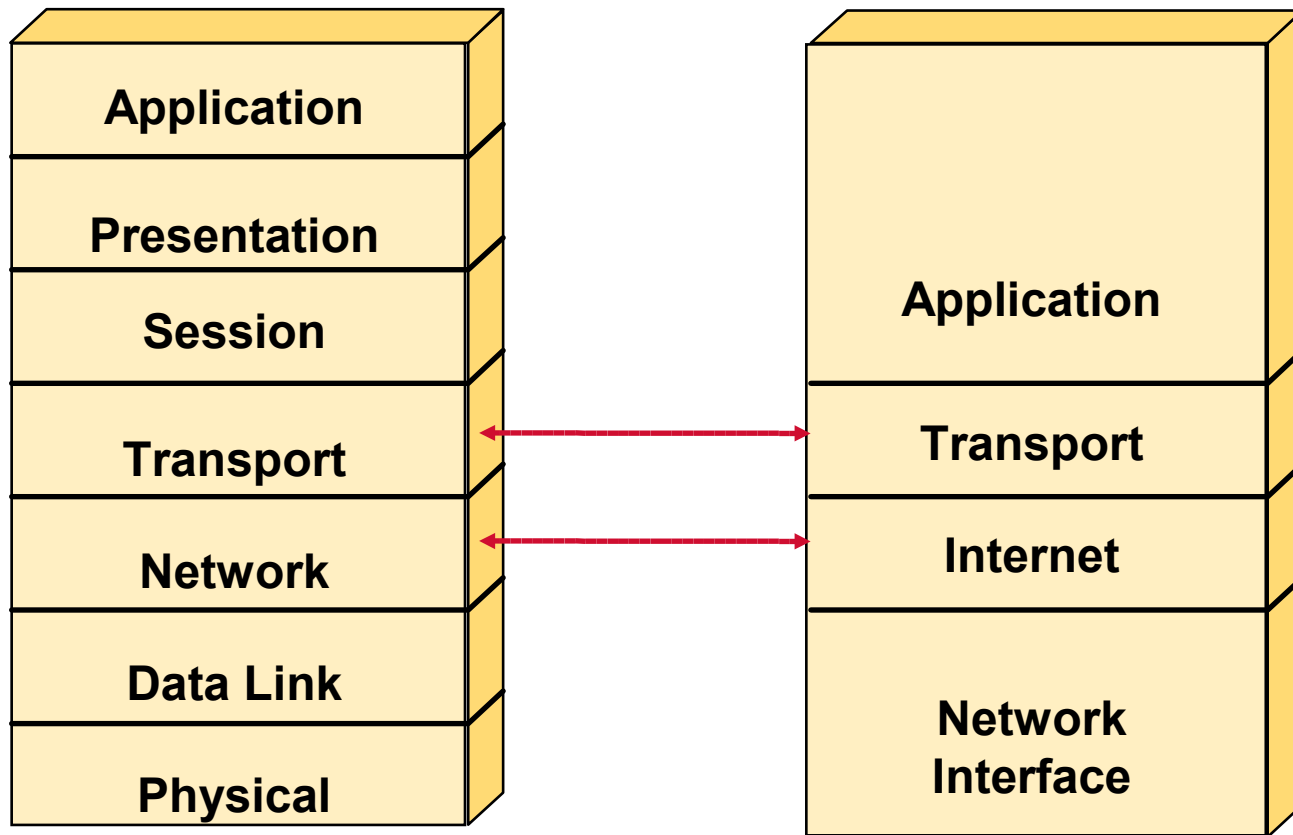


Introduction to TCP/IP

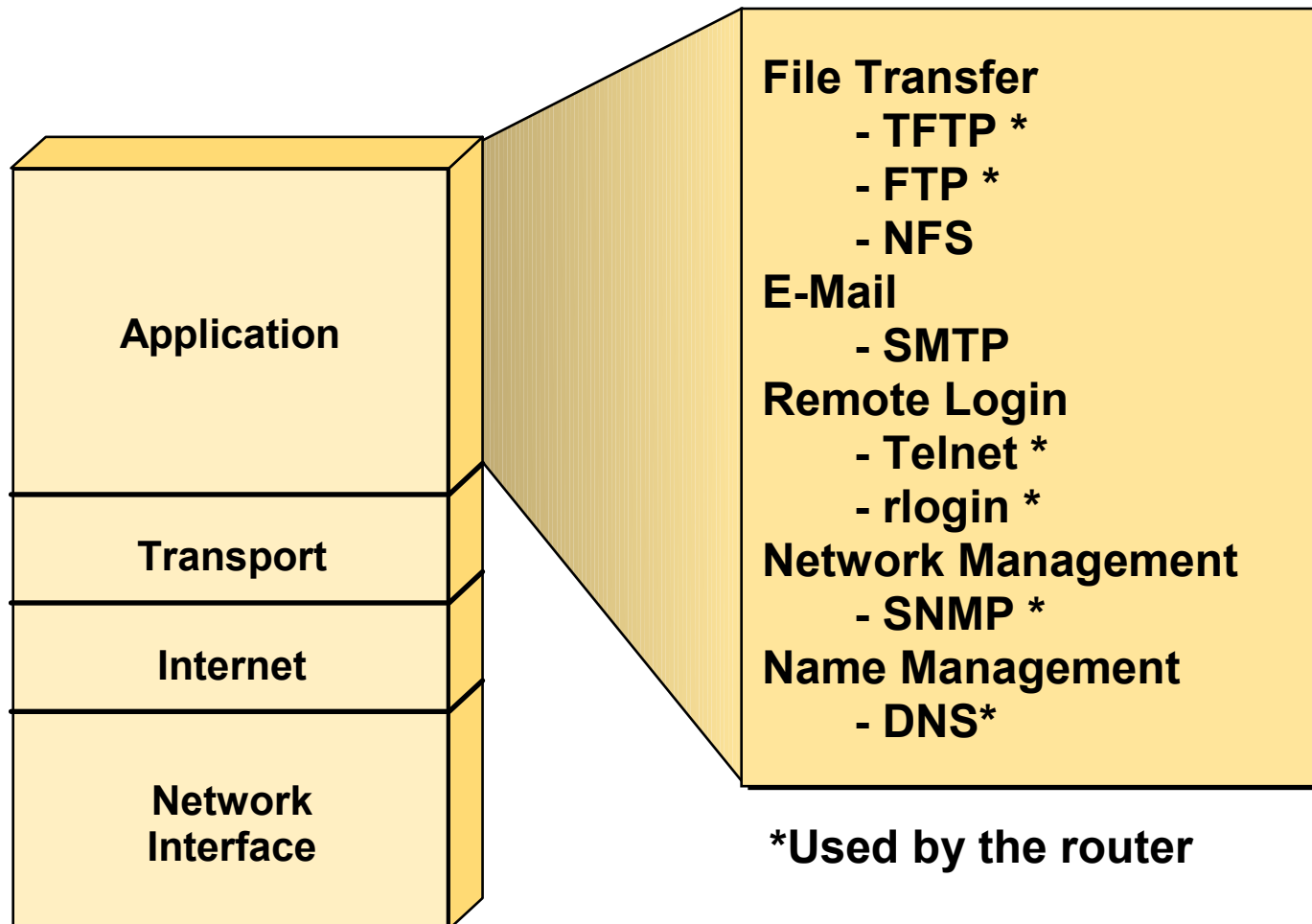


Early protocol suite
Universal

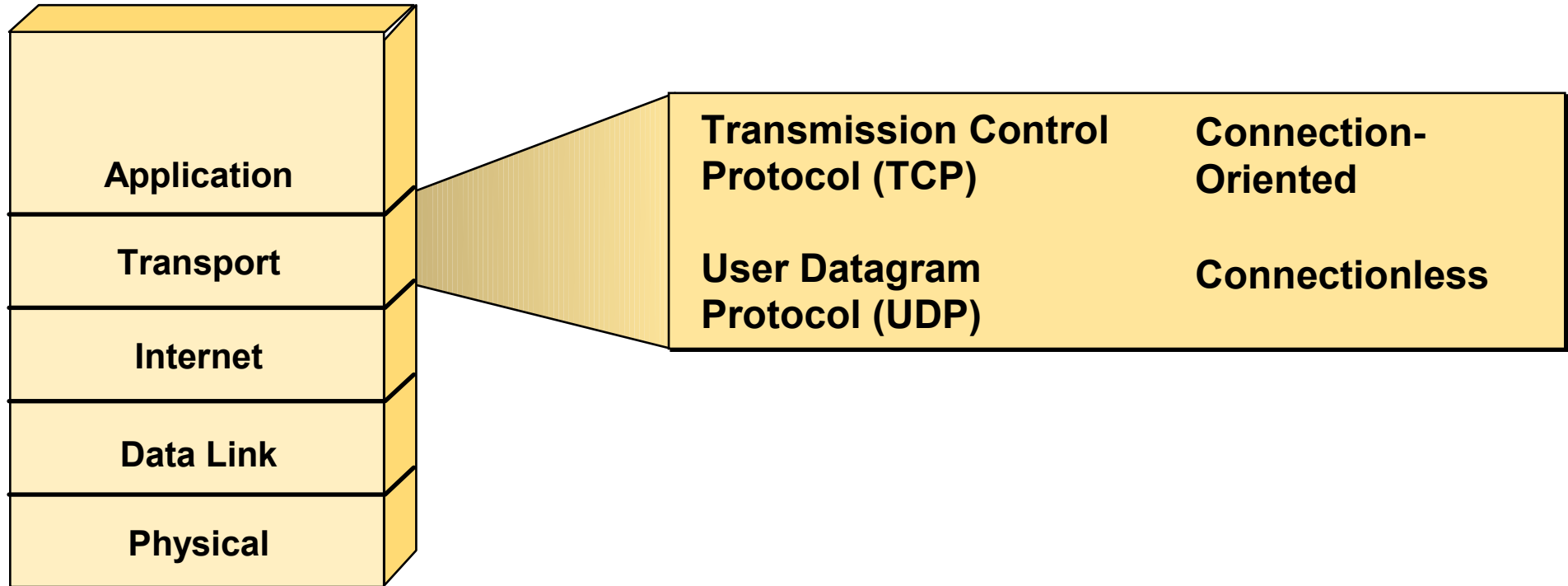
TCP/IP Protocol Stack



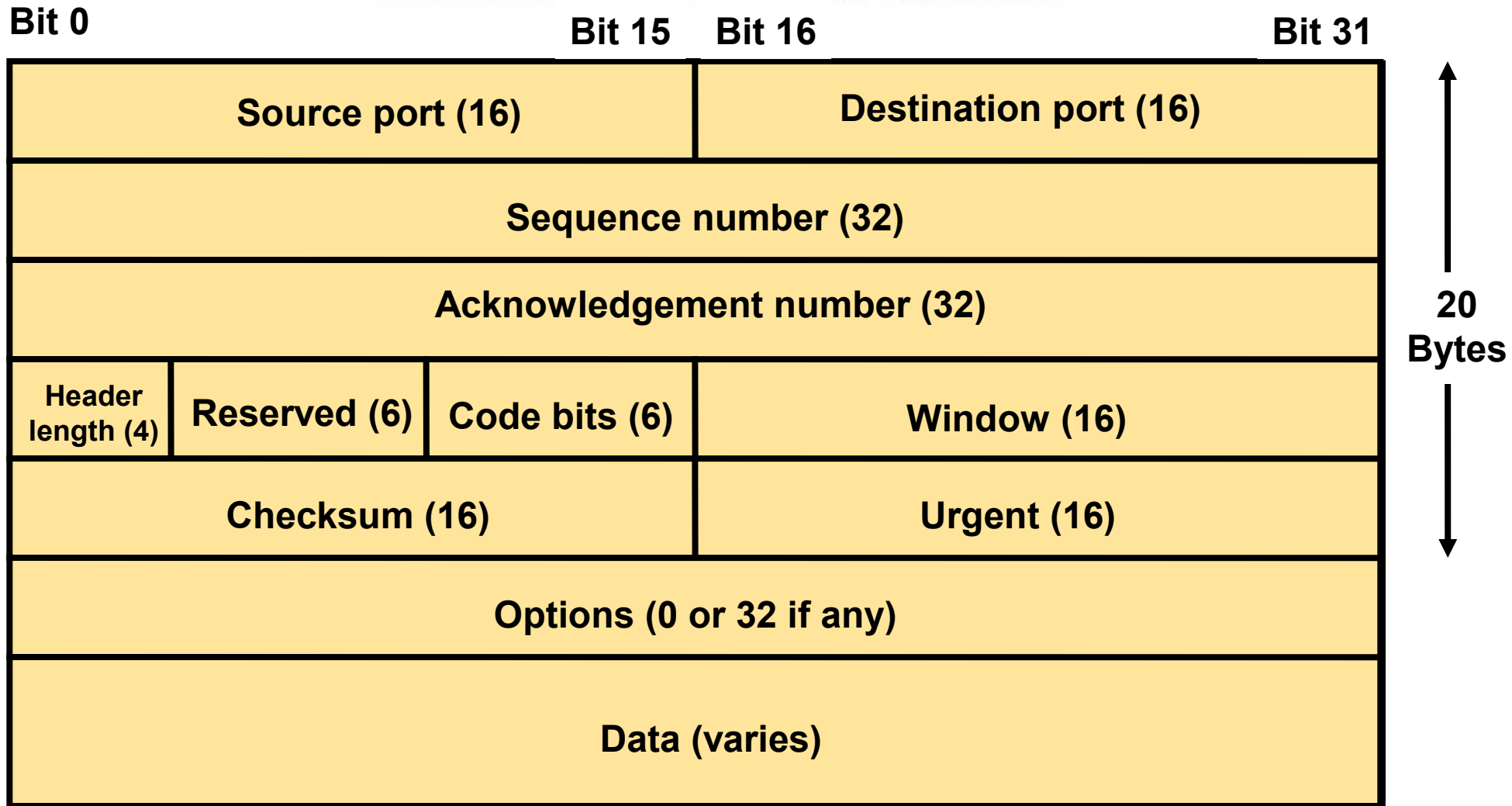
Application Layer Overview



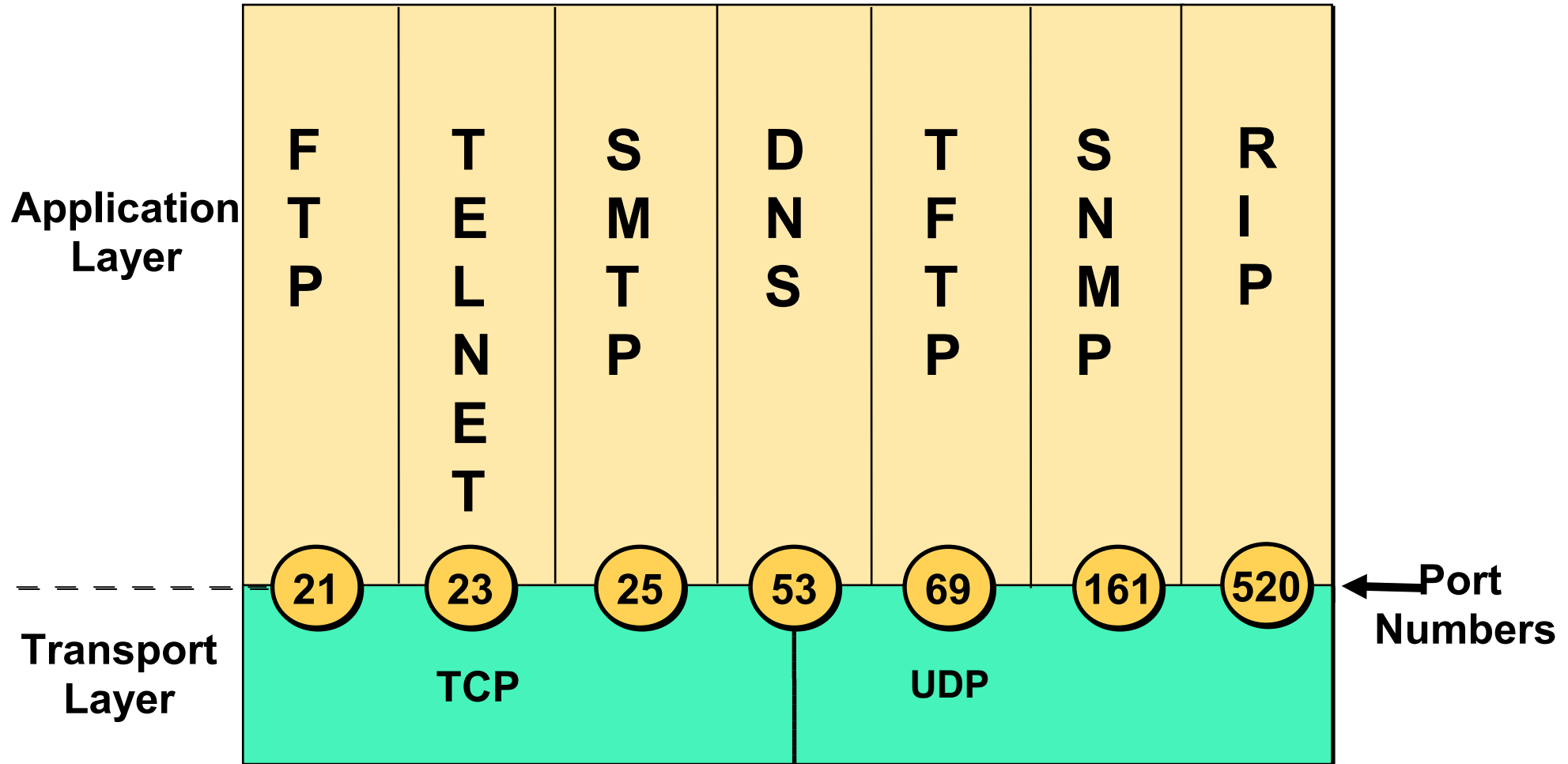
Transport Layer Overview



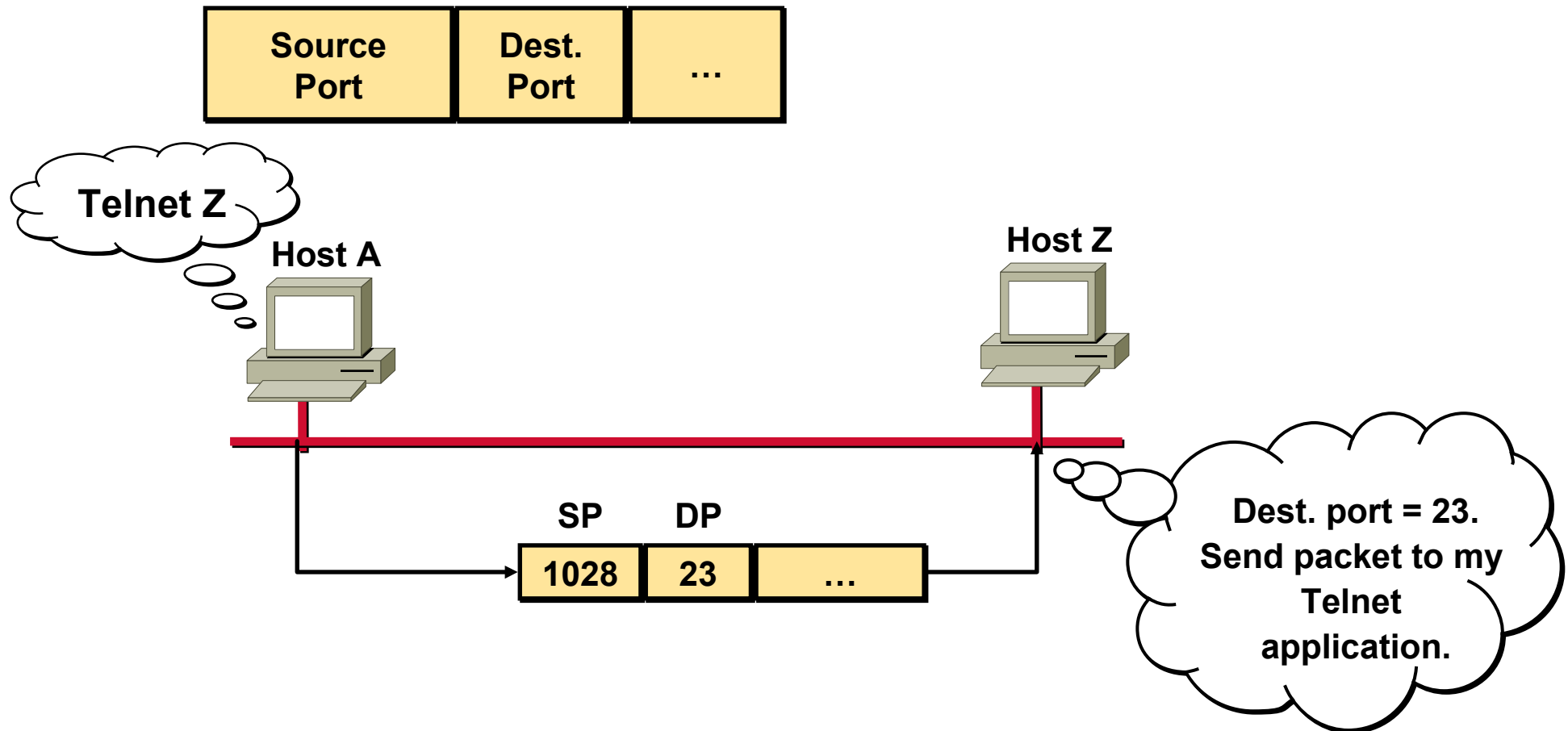
TCP Segment Format



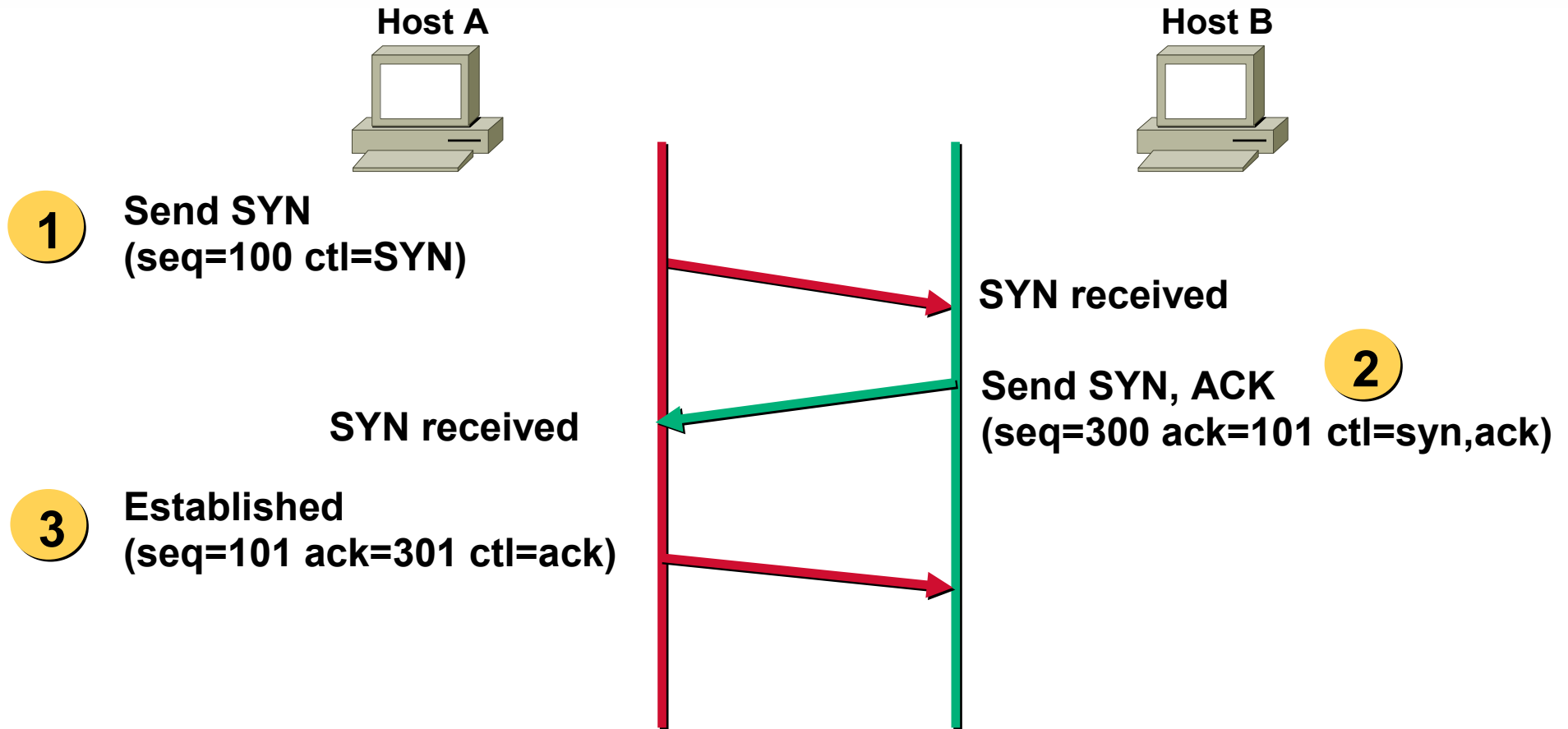
Port Numbers



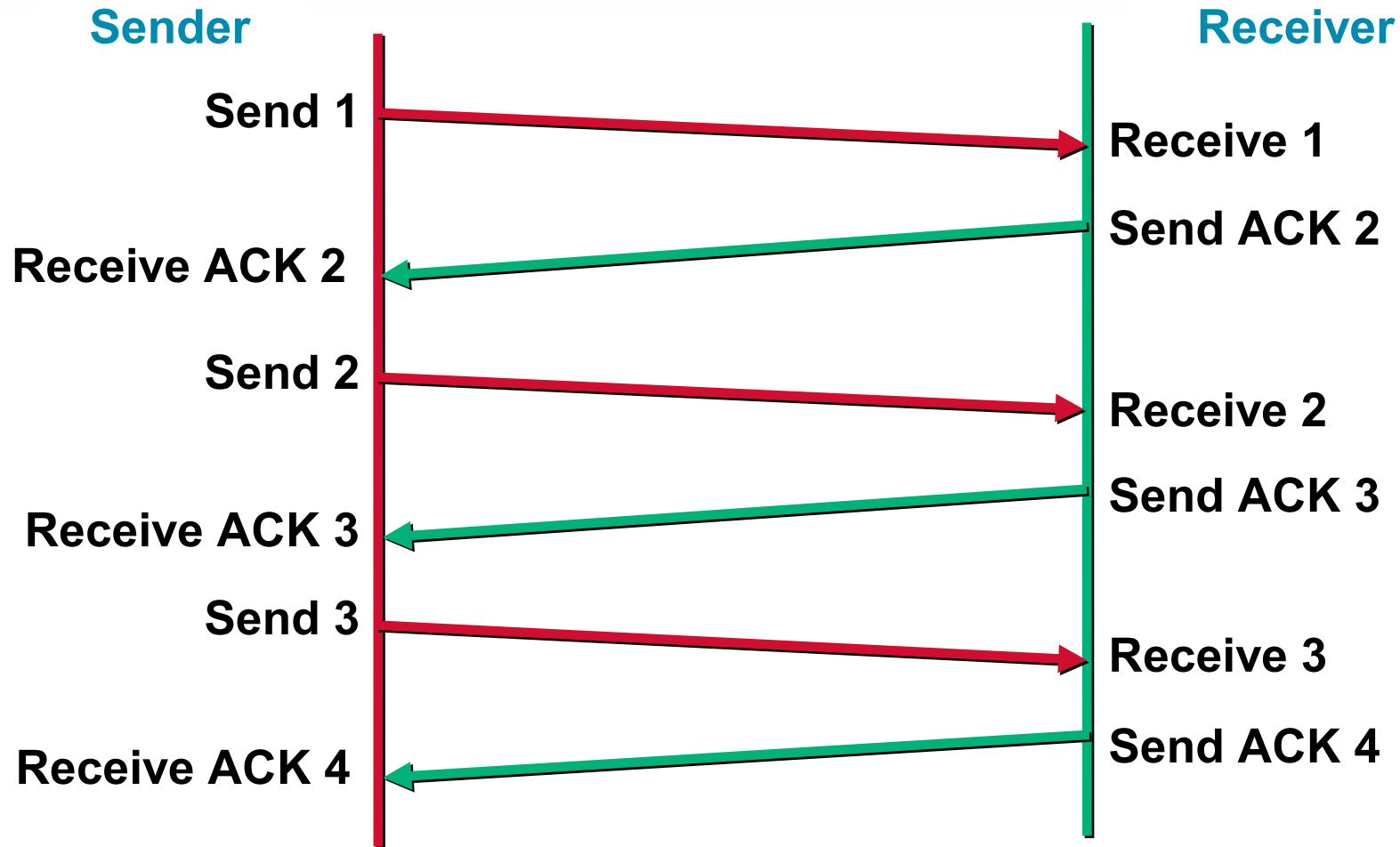
TCP Port Numbers



TCP Three Way Handshake/Open Connection

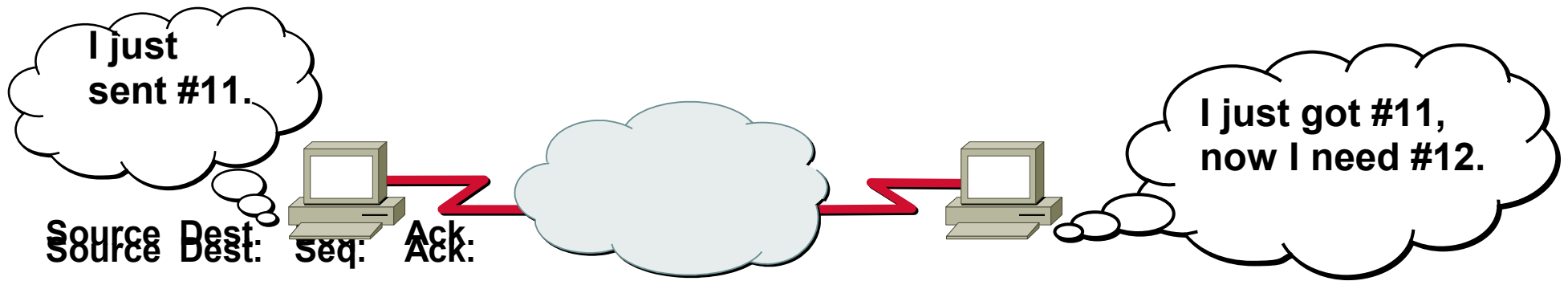


TCP Simple Acknowledgment



TCP Sequence and Acknowledgment Numbers

| | | | | |
|-------------|------------|------------|-------------------|-----|
| Source Port | Dest. Port | Sequence # | Acknowledgement # | ... |
|-------------|------------|------------|-------------------|-----|



Source Dest. seq: Ack:

| | | | |
|------|----|----|---|
| 1028 | 23 | 10 | 1 |
|------|----|----|---|



| | | | |
|------|----|----|---|
| 1028 | 23 | 11 | 2 |
|------|----|----|---|



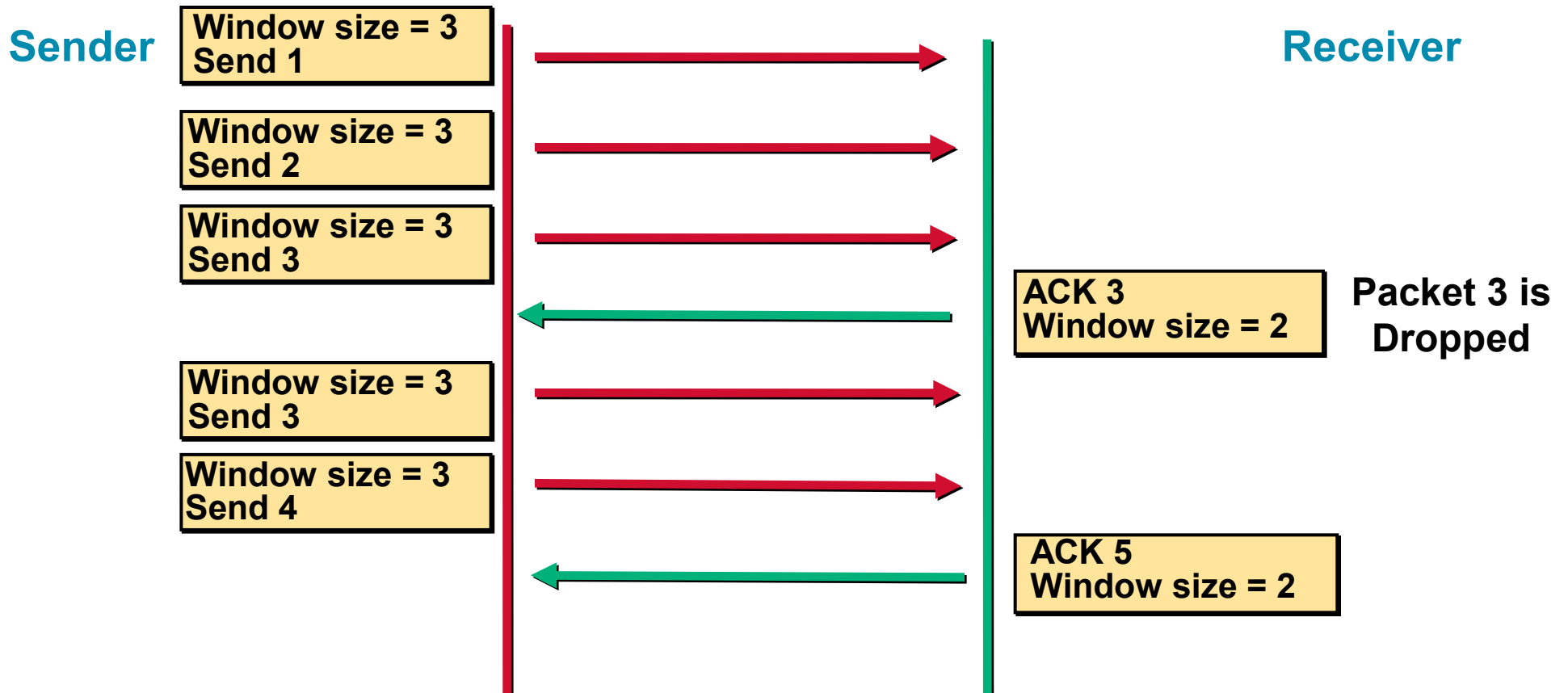
Source Dest. Seq. Ack.

| | | | |
|----|------|---|----|
| 23 | 1028 | 1 | 11 |
|----|------|---|----|

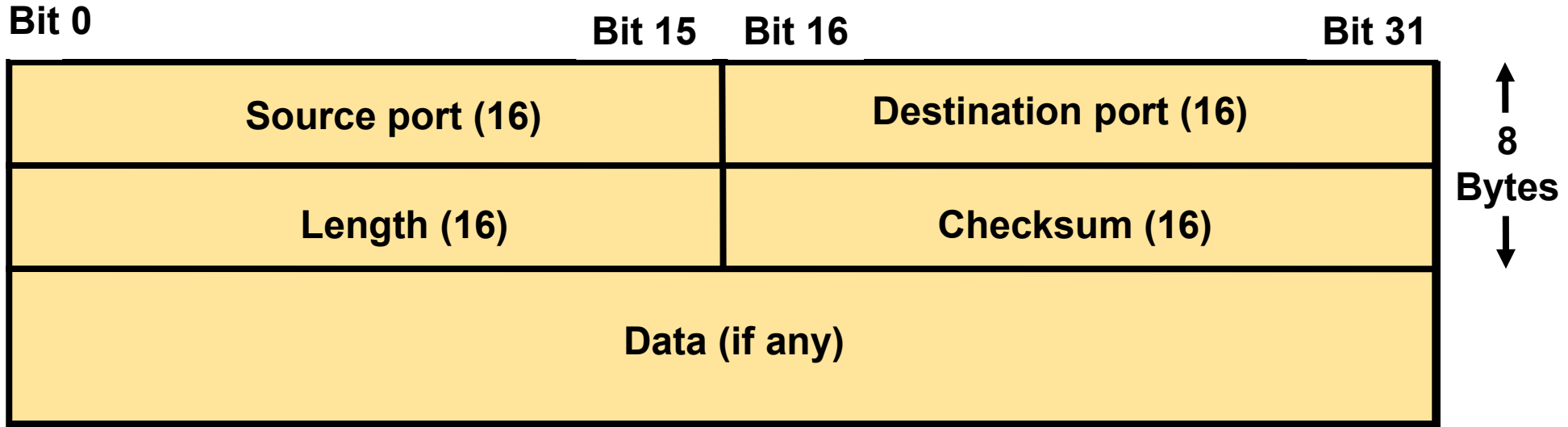
Source Dest. Seq. Ack.

| | | | |
|----|------|---|----|
| 23 | 1028 | 2 | 12 |
|----|------|---|----|

TCP Windowing

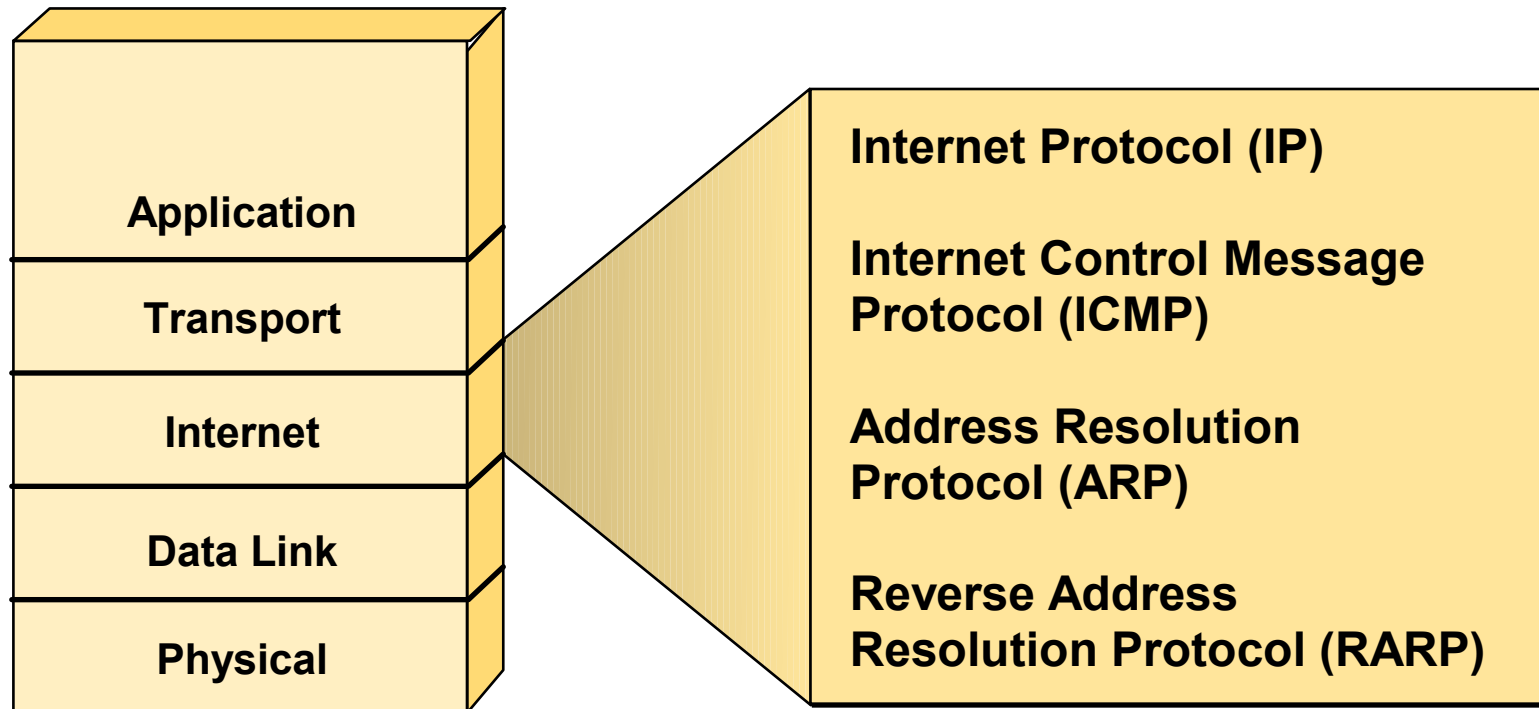


UDP Segment Format



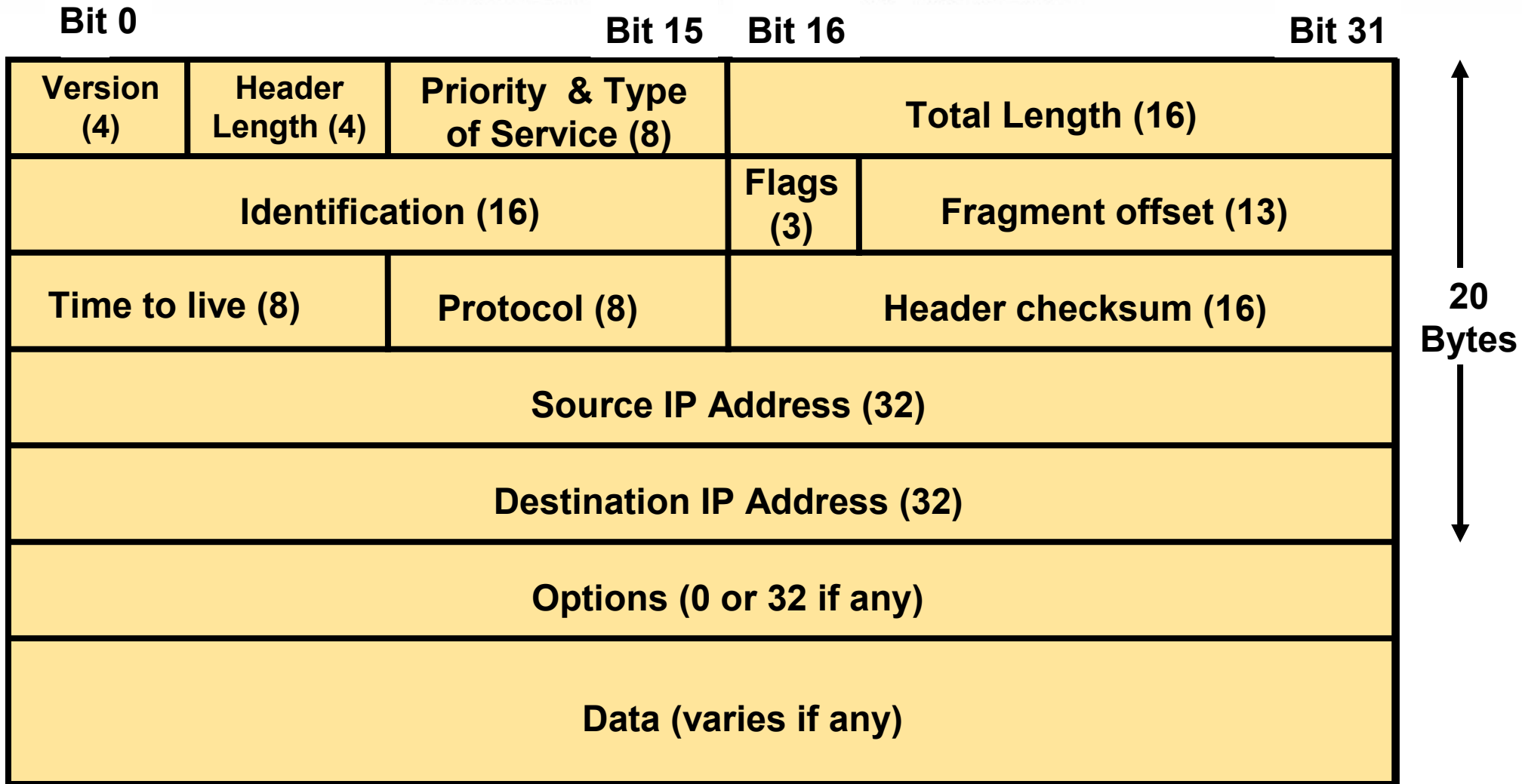
No sequence or acknowledgment fields

Internet Layer Overview

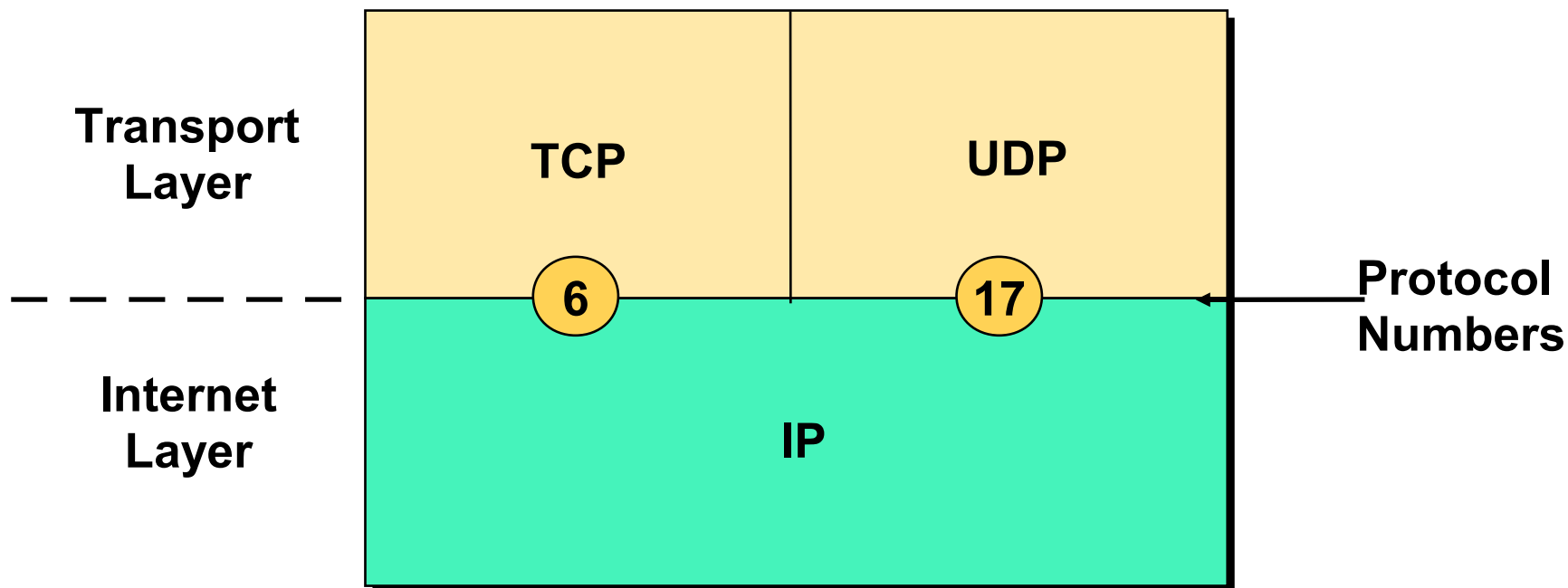


OSI network layer corresponds to the TCP/IP internet layer

IP Datagram

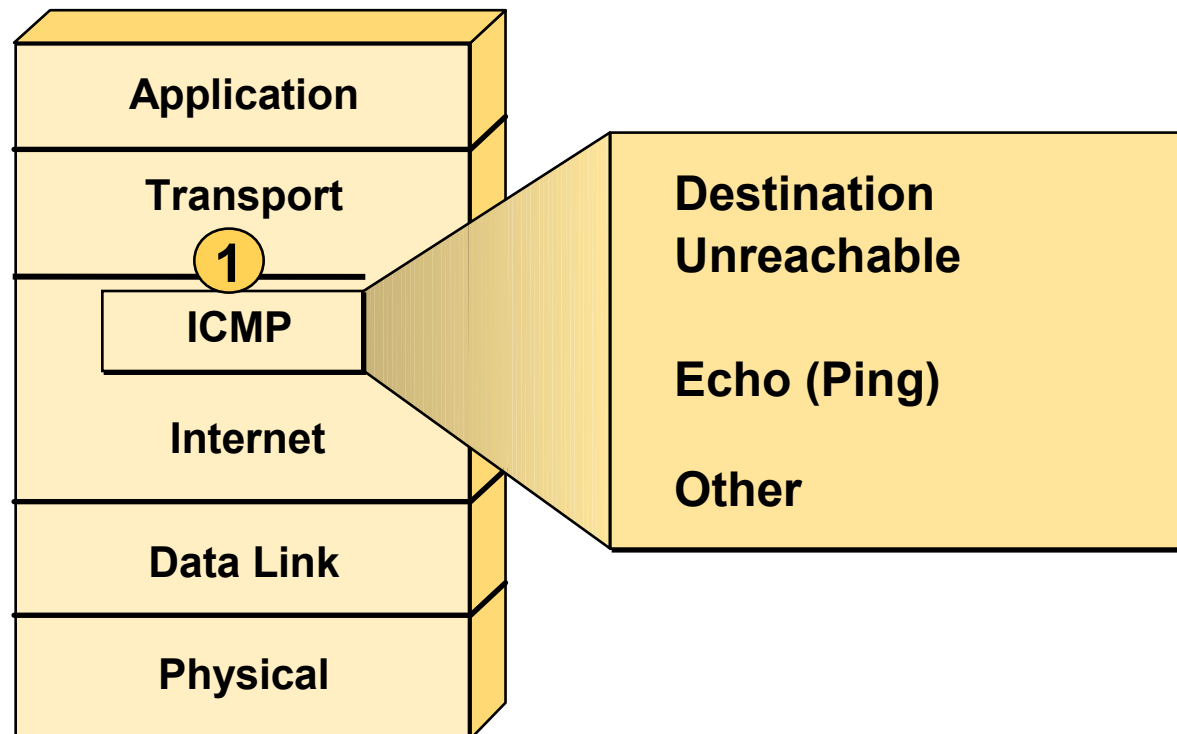


Protocol Field

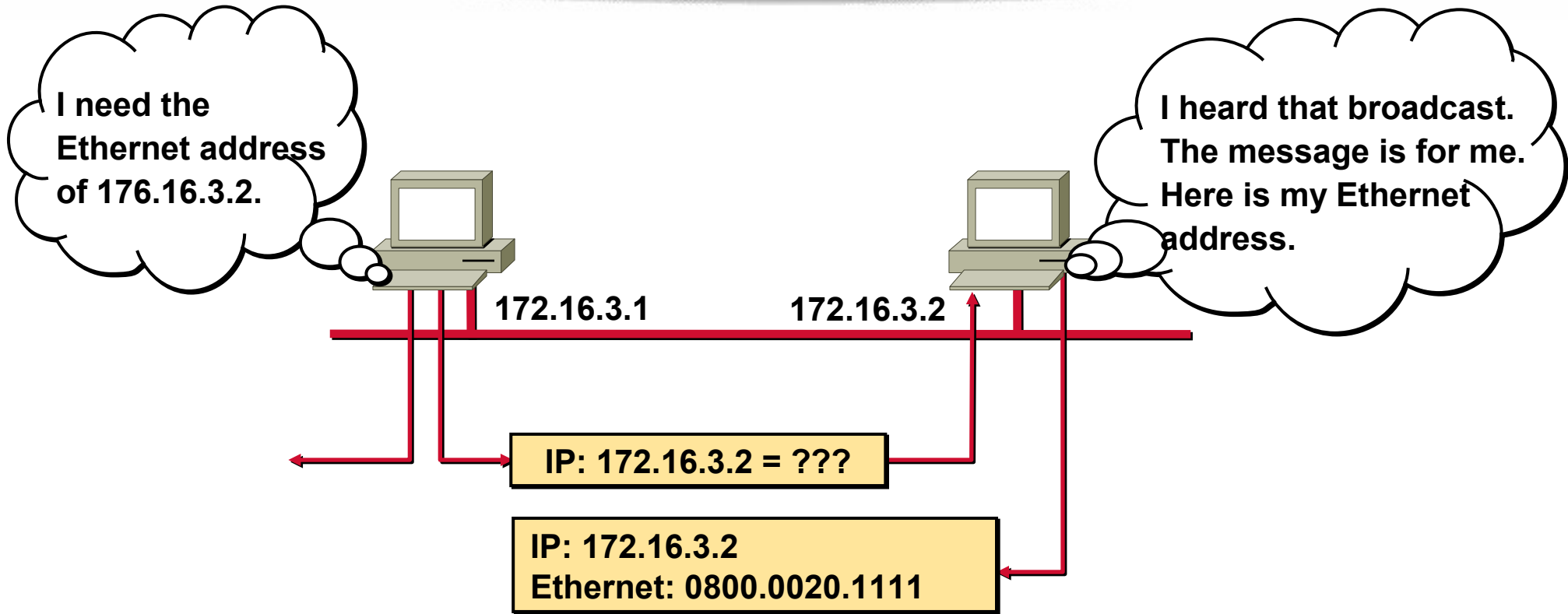


Determines destination upper-layer protocol

Internet Control Message Protocol



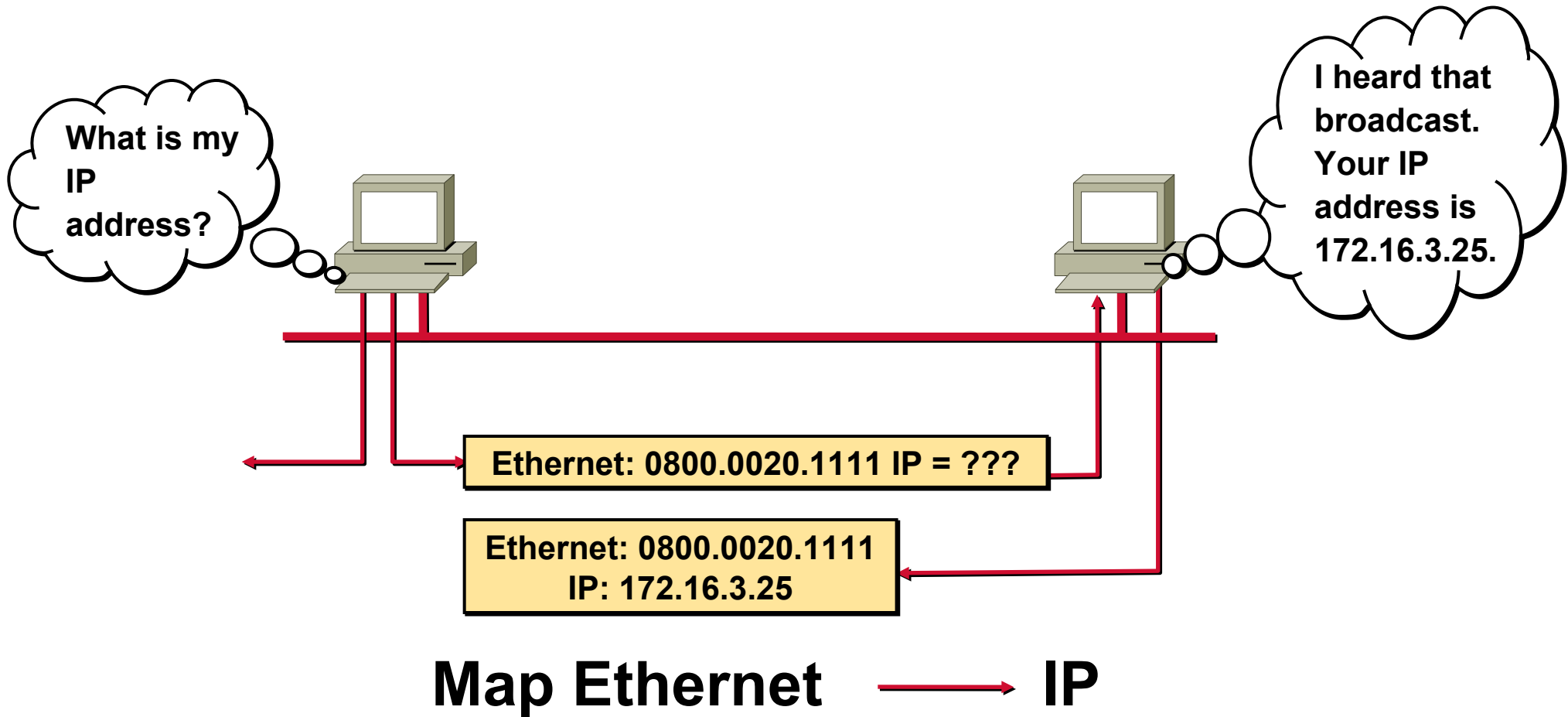
Address Resolution Protocol



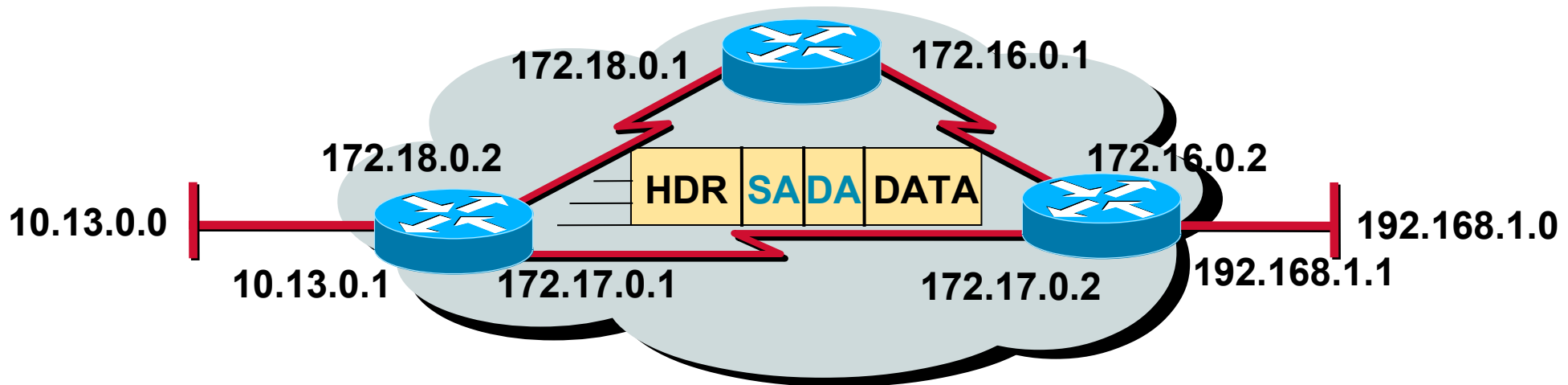
Map IP \longrightarrow Ethernet

Local ARP

Reverse ARP

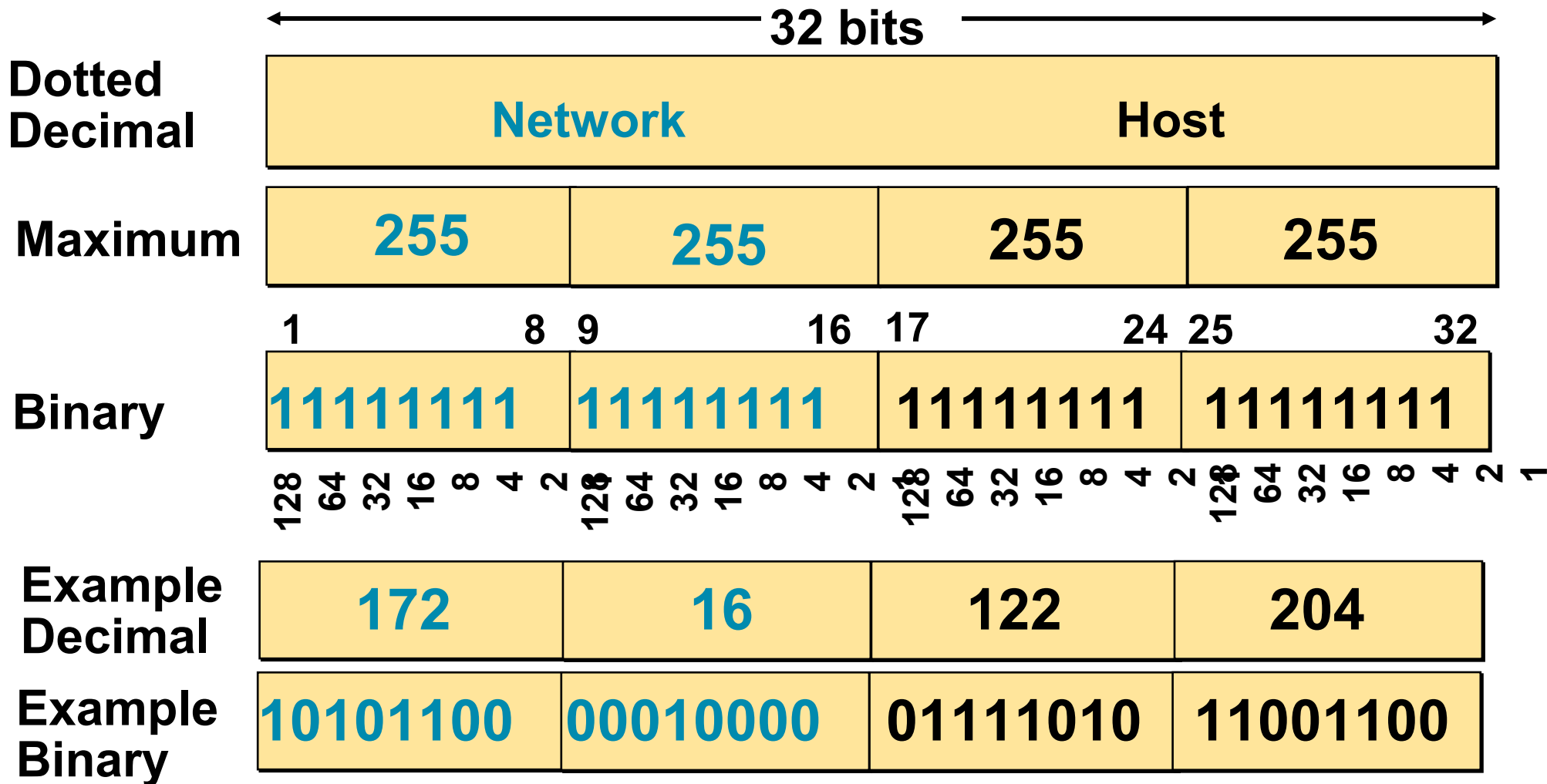


Introduction to TCP/IP Addresses



- Unique addressing allows communication between end stations
- Path choice is based on location

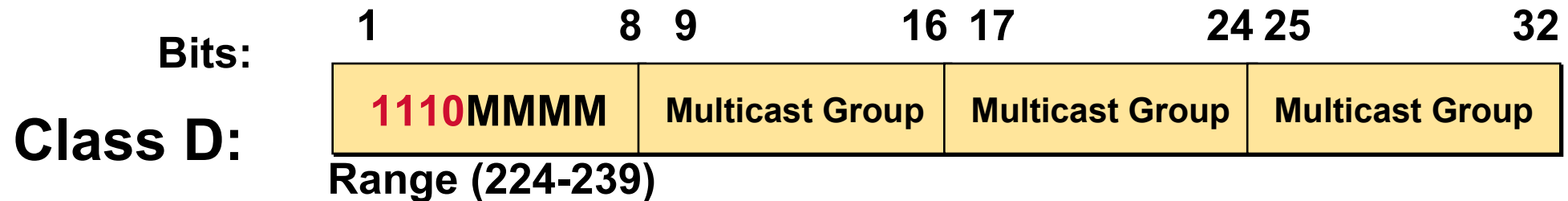
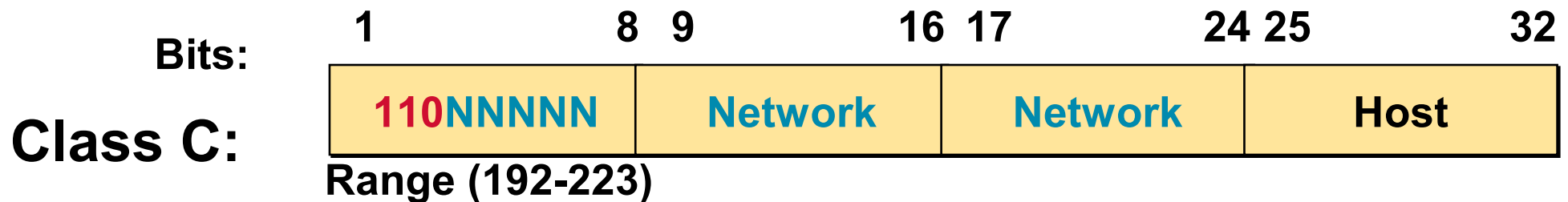
IP Addressing



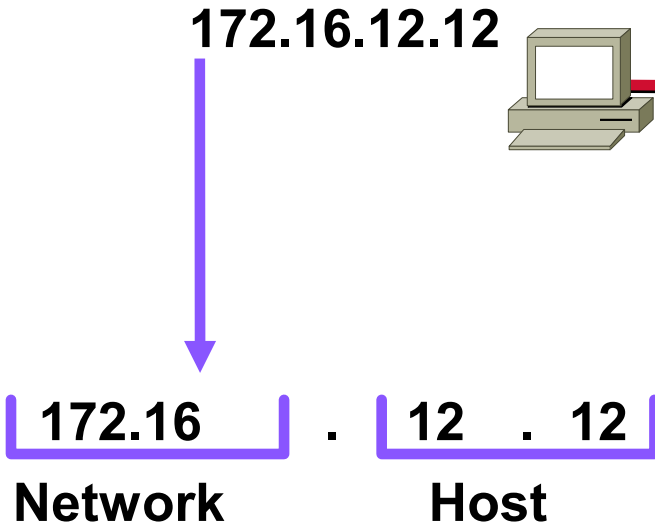
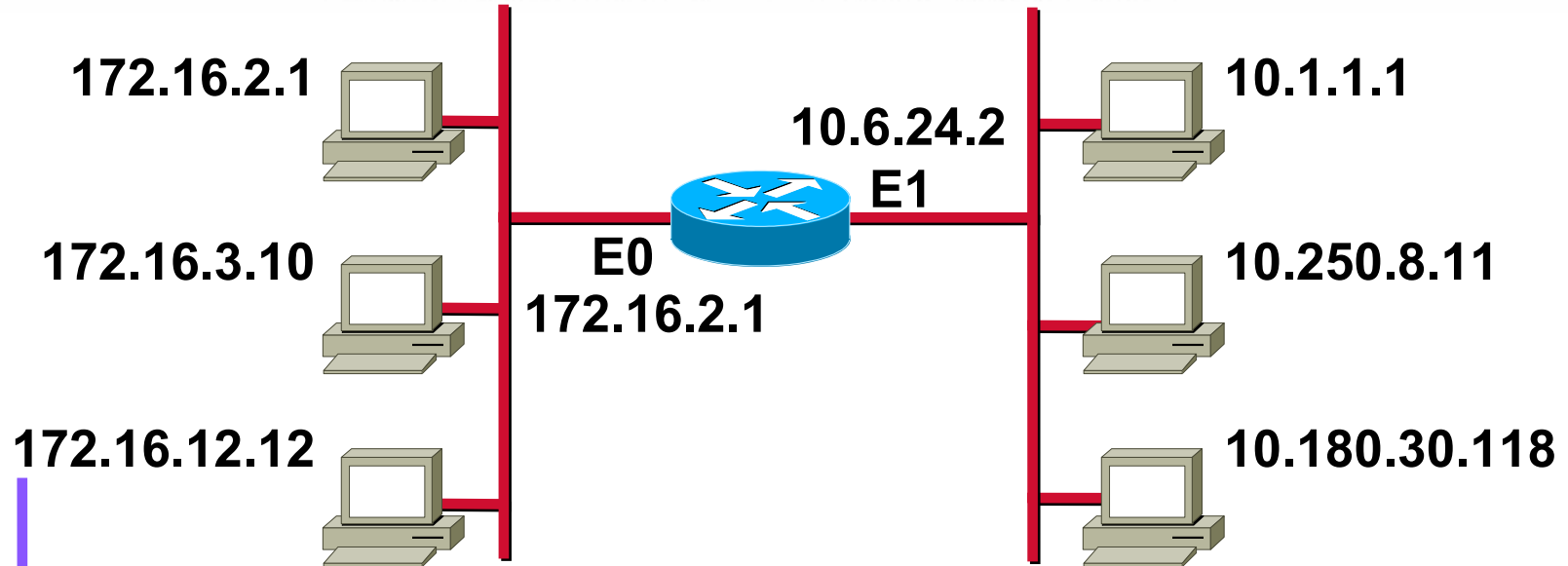
IP Address Classes

| | 8 bits | 8 bits | 8 bits | 8 bits |
|-----------------|------------------|---------|---------|--------|
| Class A: | Network | Host | Host | Host |
| Class B: | Network | Network | Host | Host |
| Class C: | Network | Network | Network | Host |
| Class D: | Multicast | | | |
| Class E: | Research | | | |

IP Address Classes



Host Addresses



| Routing Table | |
|---------------|-----------|
| Network | Interface |
| 172.16.0.0 | E0 |
| 10.0.0.0 | E1 |

Determining Available Host Addresses

Network

Host

| | | | |
|------------|-----------|----------|----------|
| 172 | 16 | 0 | 0 |
|------------|-----------|----------|----------|

10101100 00010000

16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 **N**

| | | |
|----------|----------|--|
| 00000000 | 00000000 | |
| 00000000 | 00000001 | |
| 00000000 | 00000011 | |
| ⋮ | ⋮ | |
| 11111111 | 11111101 | |
| 11111111 | 11111110 | |
| 11111111 | 11111111 | |

1
2
3
⋮
65534
65535

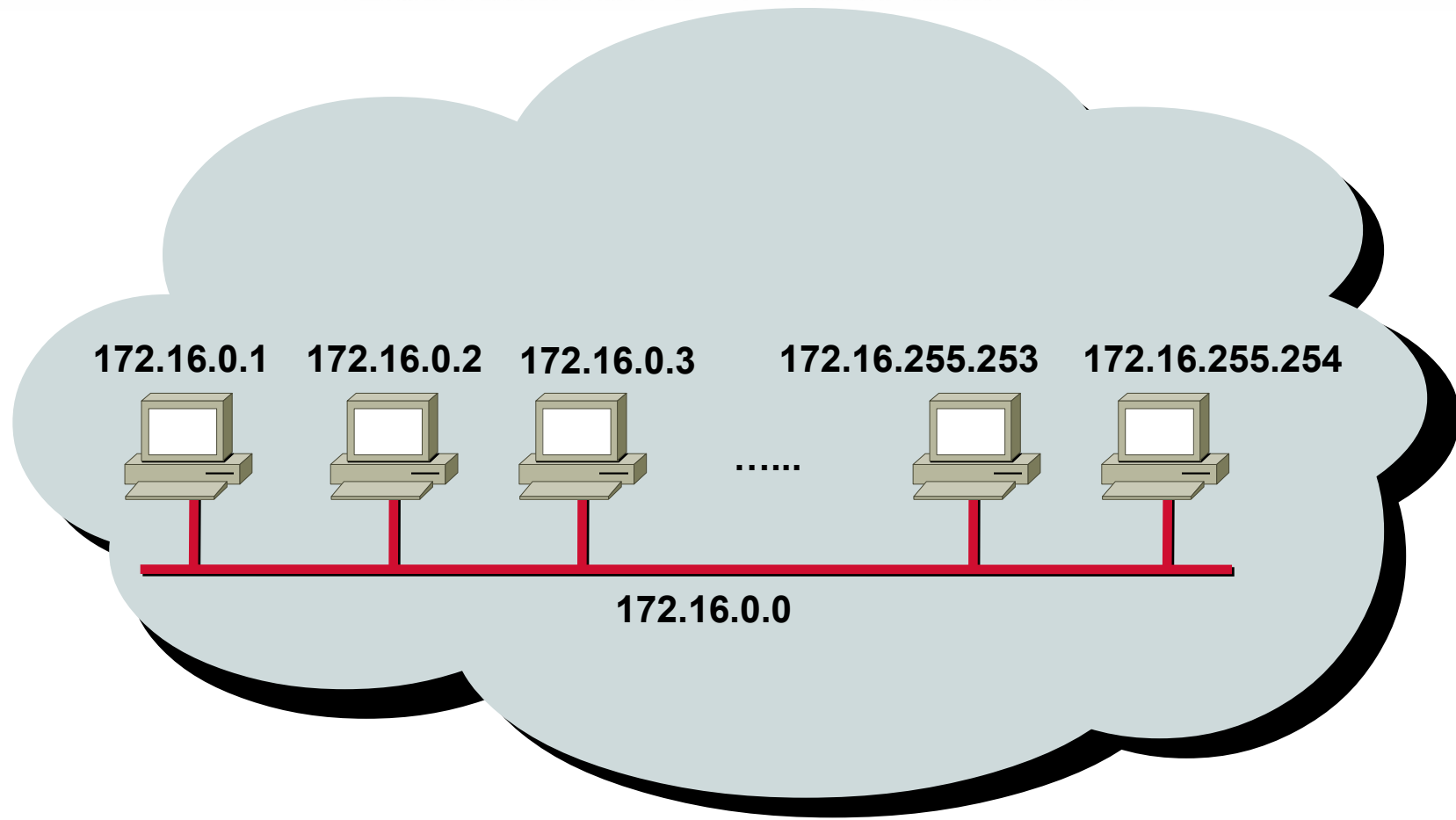
| |
|-------|
| 65536 |
| - 2 |
| 65534 |

| |
|--|
| $2^N - 2 = 2^{16} - 2 = 65534$ |
|--|

IP Address Classes Exercise Answers

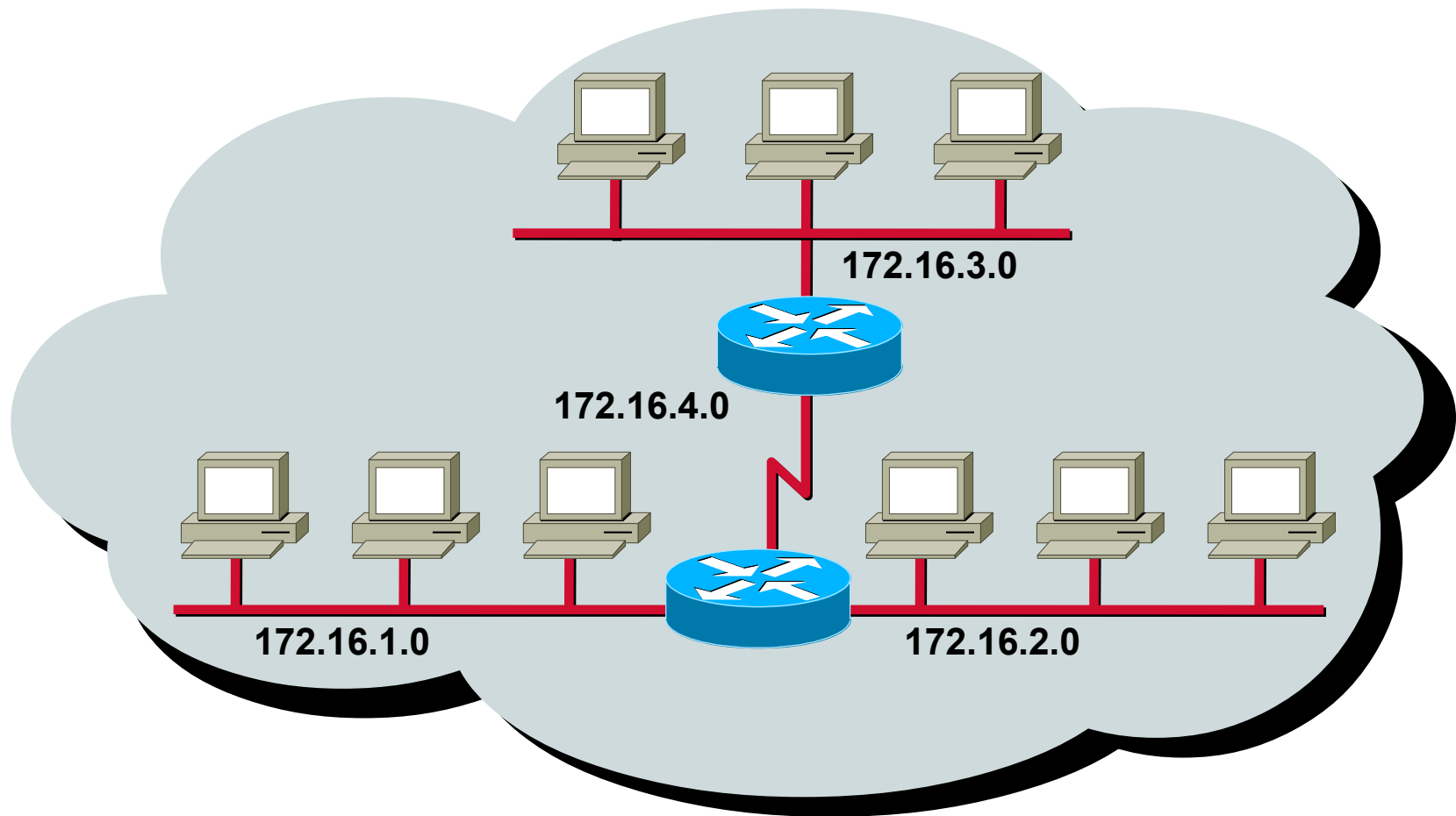
| Address | Class | Network | Host |
|----------------|--------------|-------------|-----------|
| 10.2.1.1 | A | 10.0.0.0 | 0.2.1.1 |
| 128.63.2.100 | B | 128.63.0.0 | 0.0.2.100 |
| 201.222.5.64 | C | 201.222.5.0 | 0.0.0.64 |
| 192.6.141.2 | C | 192.6.141.0 | 0.0.0.2 |
| 130.113.64.16 | B | 130.113.0.0 | 0.0.64.16 |
| 241.256.201.10 | Non-existent | | |

Addressing without Subnets



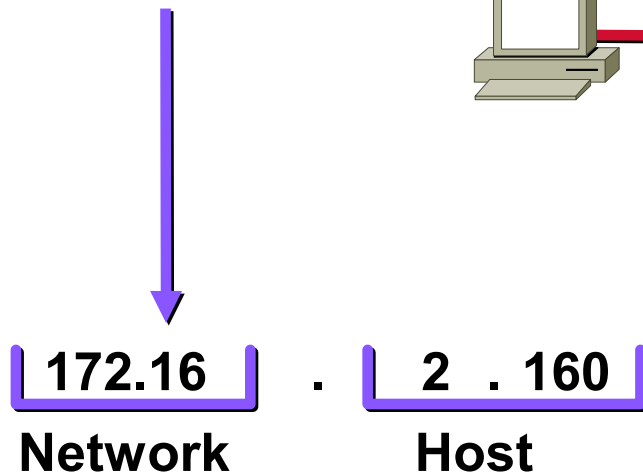
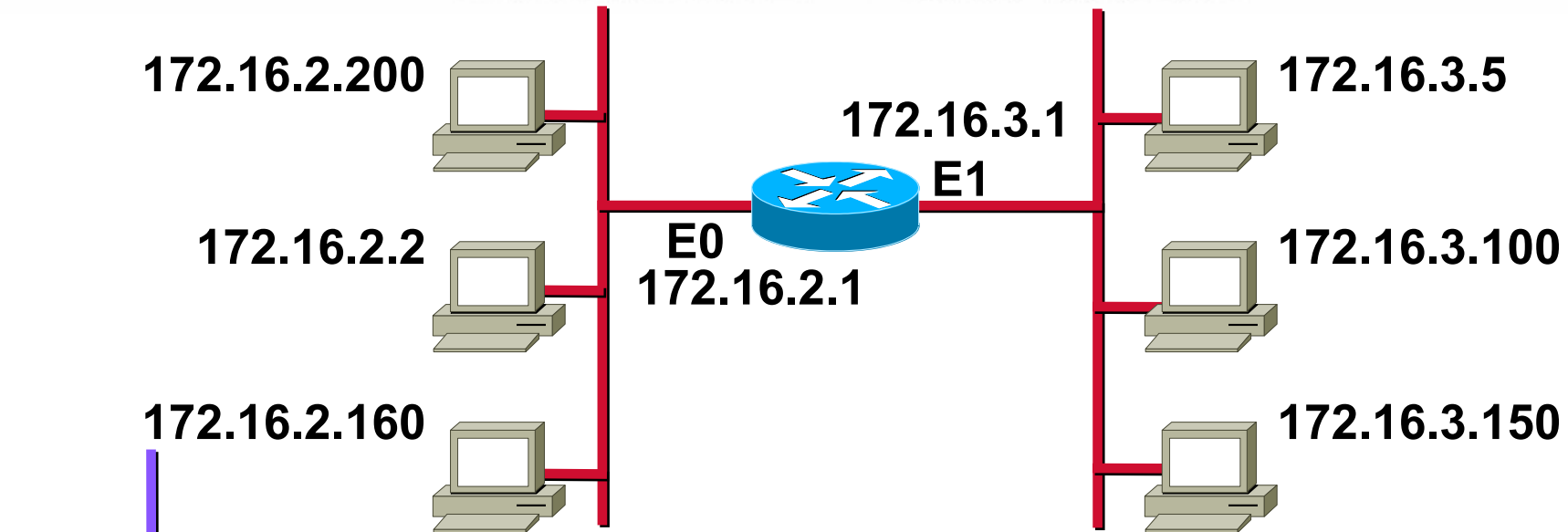
Network 172.16.0.0

Addressing with Subnets



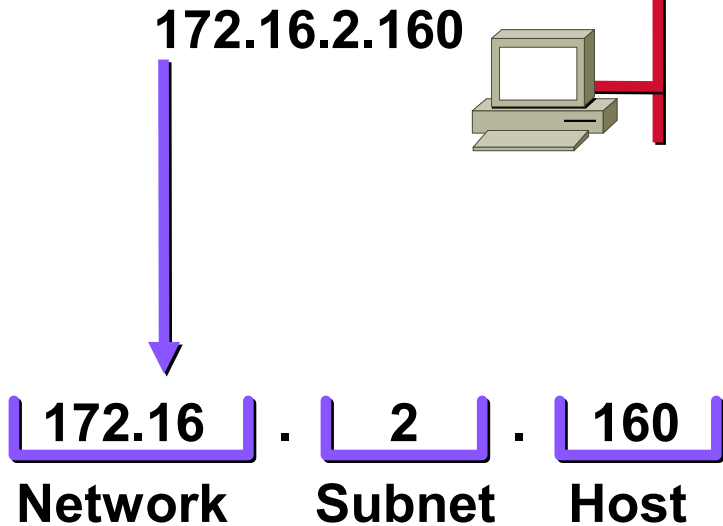
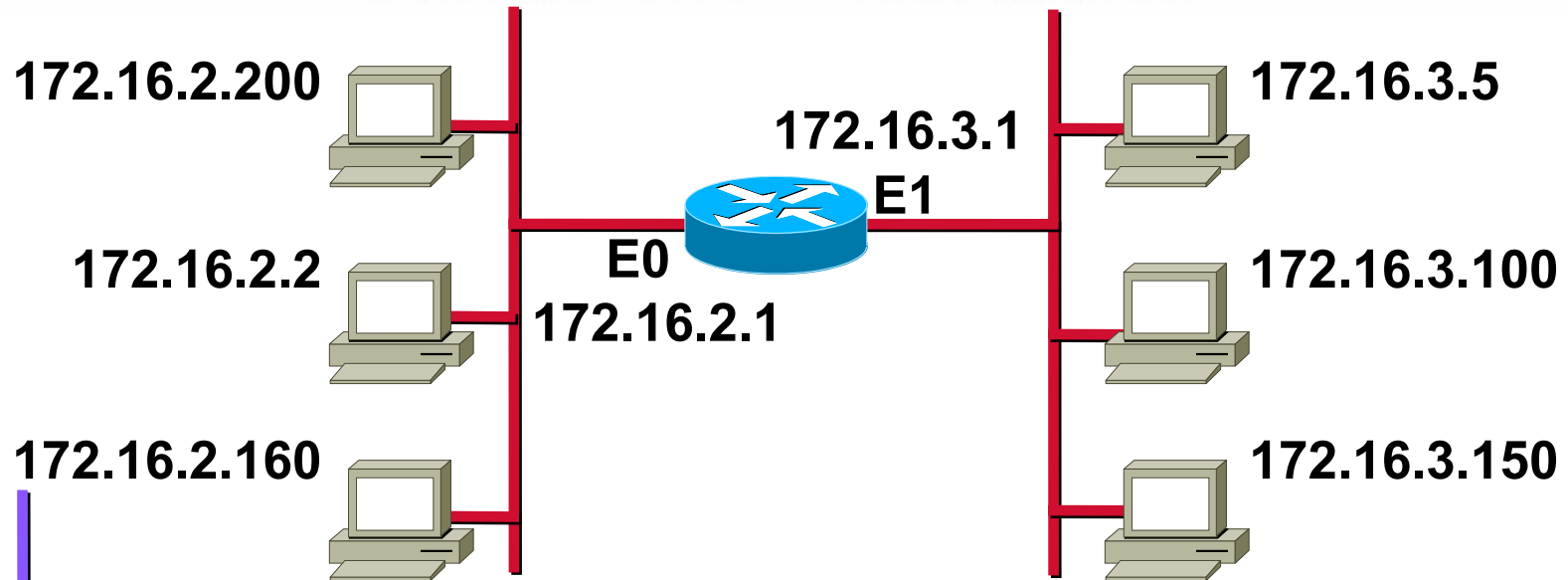
Network 172.16.0.0

Subnet Addressing



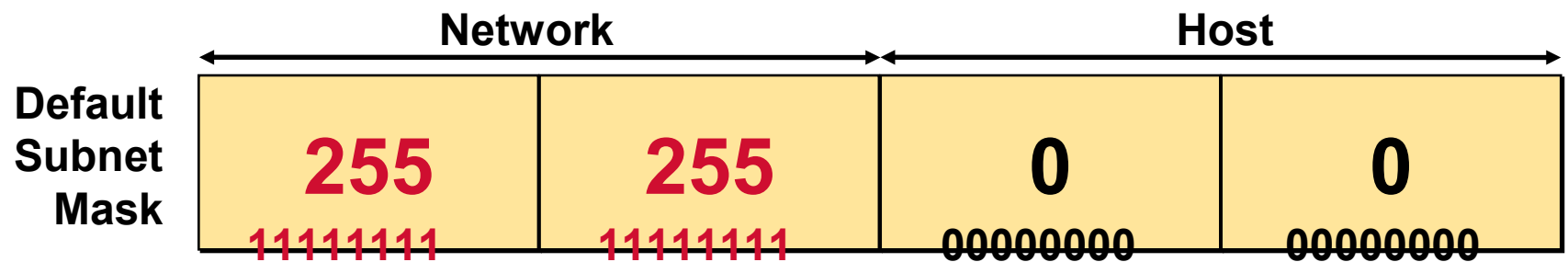
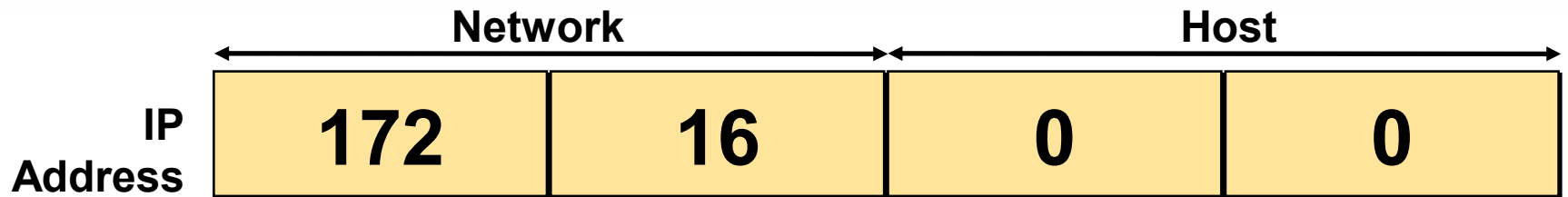
| New Routing Table | |
|-------------------|-----------|
| Network | Interface |
| 172.16.0.0 | E0 |
| 172.16.0.0 | E1 |

Subnet Addressing

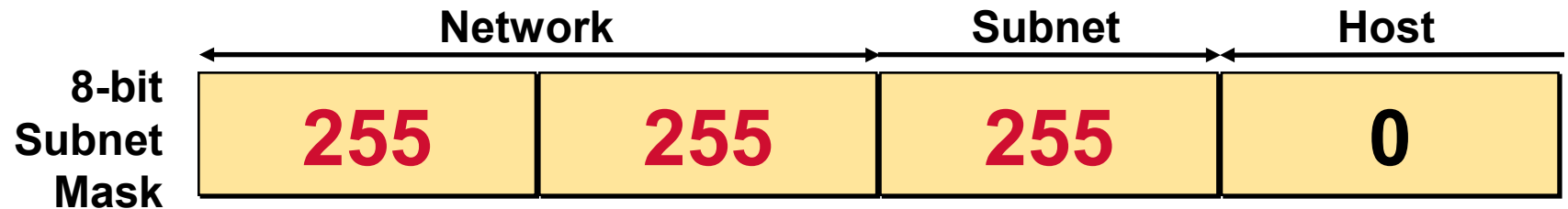


| New Routing Table | |
|-------------------|-----------|
| Network | Interface |
| 172.16.2.0 | E0 |
| 172.16.3.0 | E1 |

Subnet Mask



Also written as **"/16"** where 16 represents the number of 1s in the mask.



Also written as **"/24"** where 24 represents the number of 1s in the mask.

Decimal Equivalents of Bit Patterns

| 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | |
|-----|----|----|----|---|---|---|---|-------|
| ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | = 128 |
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | = 192 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | = 224 |
| 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | = 240 |
| 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | = 248 |
| 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | = 252 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | = 254 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | = 255 |

Subnet Mask without Subnets

| | Network | | Host | |
|-----------------------|----------|----------|----------|----------|
| 172.16.2.160 | 10101100 | 00010000 | 00000010 | 10100000 |
| 255.255.0.0 | 11111111 | 11111111 | 00000000 | 00000000 |
| | 10101100 | 00010000 | 00000000 | 00000000 |
| Network Number | 172 | 16 | 0 | 0 |

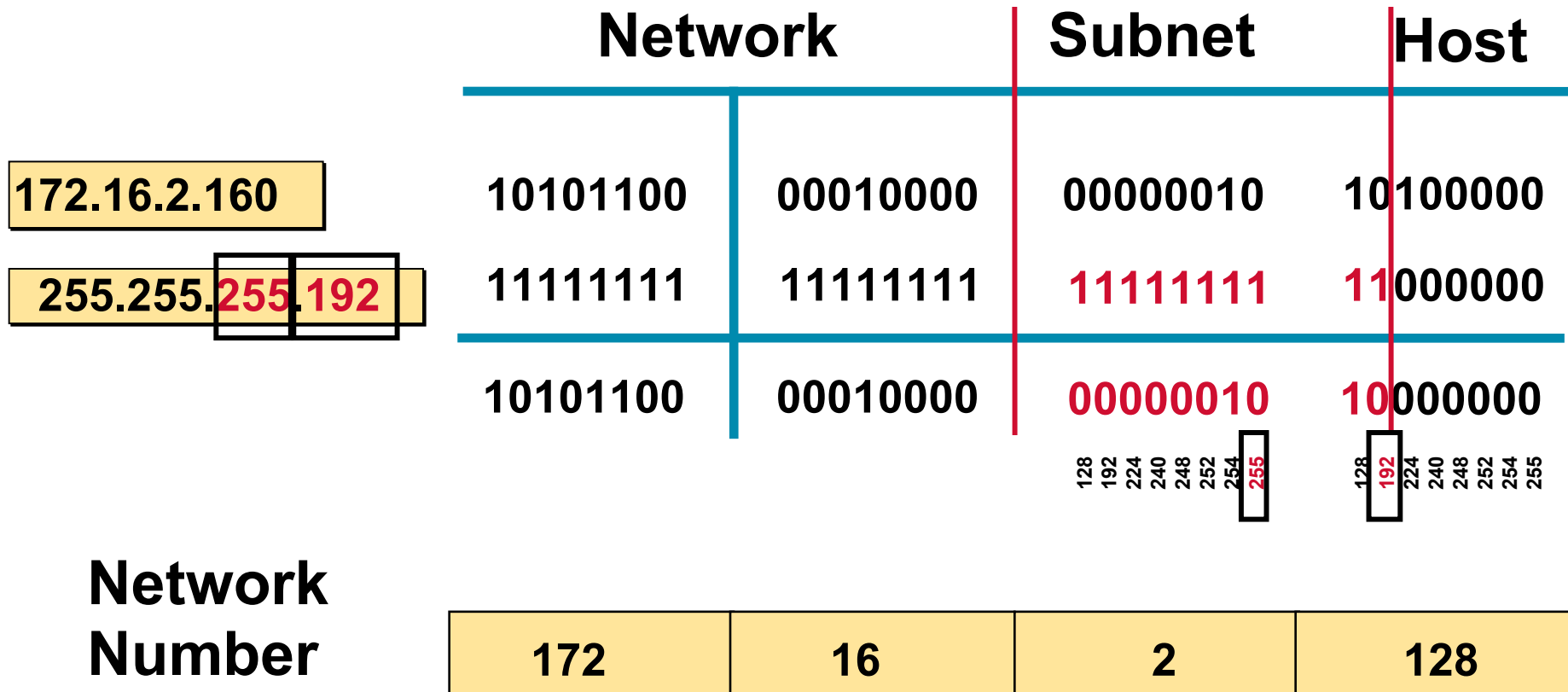
Subnets not in use—the default

Subnet Mask with Subnets

| | Network | | Subnet | | Host |
|-----------------------|----------|----------|--|--|----------|
| 172.16.2.160 | 10101100 | 00010000 | 00000010 | | 10100000 |
| 255.255.255.0 | 11111111 | 11111111 | 11111111 | | 00000000 |
| | 10101100 | 00010000 | 00000010 | | 00000000 |
| | | | 128 192 224 240 248 252 254 255 | | |
| Network Number | 172 | 16 | 2 | | 0 |

Network number extended by eight bits

Subnet Mask with Subnets (cont.)

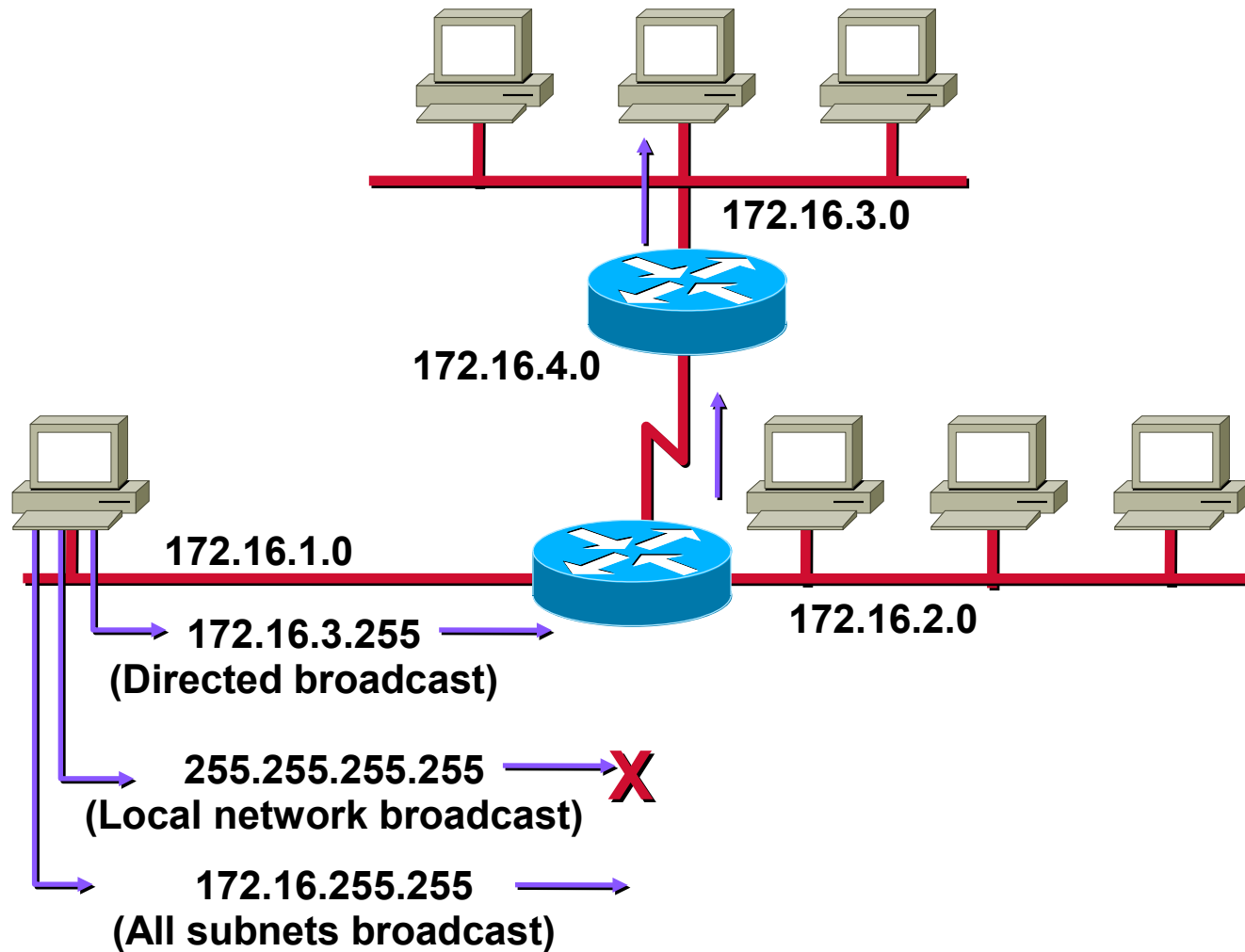


Network number extended by ten bits

Subnet Mask Exercise Answers

| Address | Subnet Mask | Class | Subnet |
|-------------|---------------|-------|------------|
| 172.16.2.10 | 255.255.255.0 | B | 172.16.2.0 |
| 10.6.24.20 | 255.255.240.0 | A | 10.6.16.0 |
| 10.30.36.12 | 255.255.255.0 | A | 10.30.36.0 |

Broadcast Addresses



Addressing Summary Example

| | | | |
|-----|----|---|-----|
| 172 | 16 | 2 | 160 |
|-----|----|---|-----|

3

| | | | | | | |
|-----------------|----------|----------|----------|-----------|-----------|---|
| 172.16.2.160 | 10101100 | 00010000 | 00000010 | 10 100000 | Host | 1 |
| 255.255.255.192 | 11111111 | 11111111 | 11111111 | 11 000000 | Mask | 2 |
| 172.16.2.128 | 10101100 | 00010000 | 00000010 | 10 000000 | Subnet | 4 |
| 172.16.2.191 | 10101100 | 00010000 | 00000010 | 10 111111 | Broadcast | 5 |
| 172.16.2.129 | 10101100 | 00010000 | 00000010 | 10 000001 | First | 6 |
| 172.16.2.190 | 10101100 | 00010000 | 00000010 | 10 111110 | Last | 7 |

Class B Subnet Example

IP Host Address: 172.16.2.121

Subnet Mask: 255.255.255.0

| | Network | Network | Subnet | Host |
|----------------|----------|----------|----------|----------|
| 172.16.2.121: | 10101100 | 00010000 | 00000010 | 01111001 |
| 255.255.255.0: | 11111111 | 11111111 | 11111111 | 00000000 |
| Subnet: | 10101100 | 00010000 | 00000010 | 00000000 |
| Broadcast: | 10101100 | 00010000 | 00000010 | 11111111 |

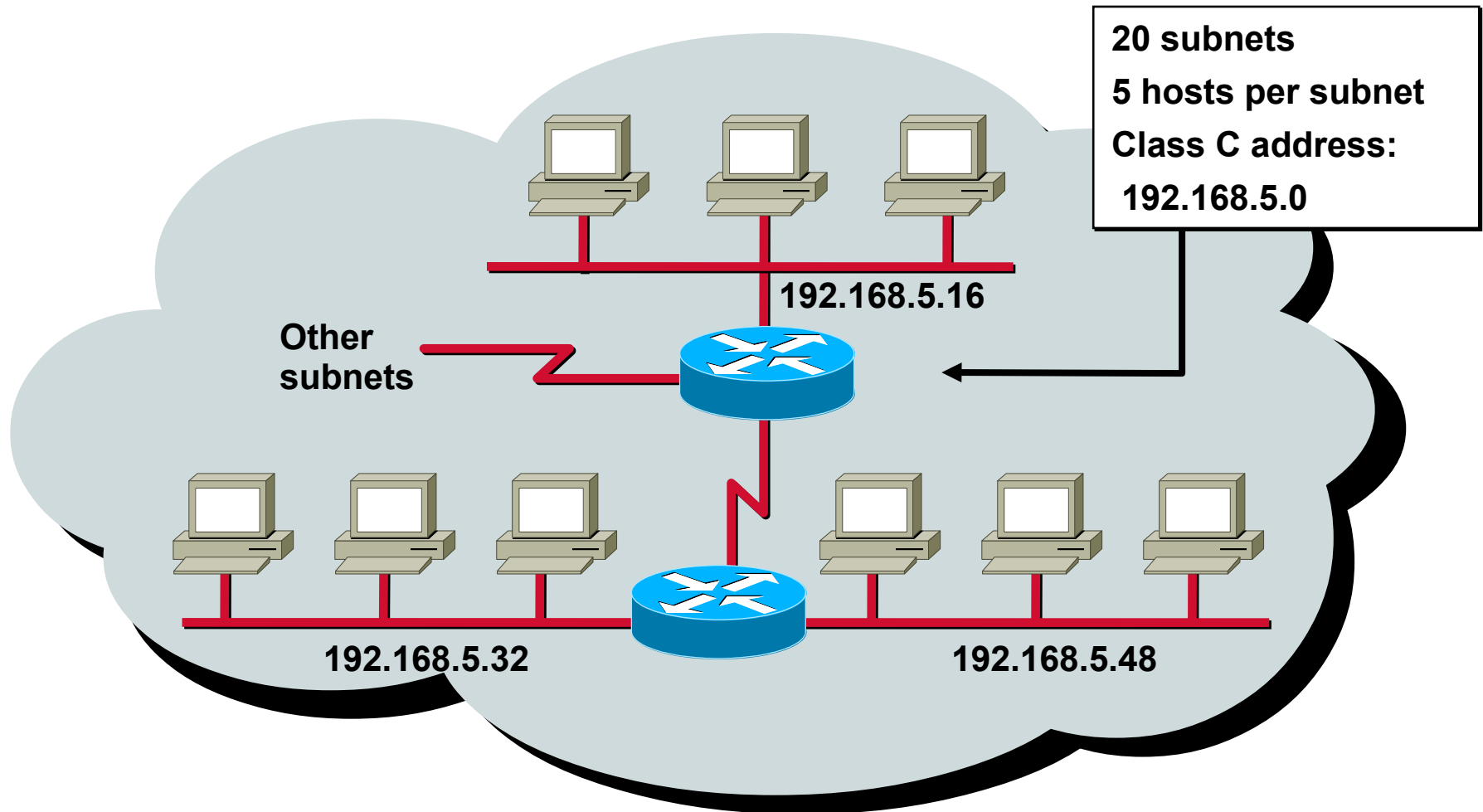
Subnet Address = 172.16.2.0

Host Addresses = 172.16.2.1–172.16.2.254

Broadcast Address = 172.16.2.255

Eight bits of subnetting

Subnet Planning



Class C Subnet Planning Example

IP Host Address: 192.168.5.121

Subnet Mask: 255.255.255.248

| | Network | Network | Network | Subnet | Host |
|------------------|----------|----------|----------|----------|------|
| 192.168.5.121: | 11000000 | 10101000 | 00000101 | 01111001 | |
| 255.255.255.248: | 11111111 | 11111111 | 11111111 | 11111000 | |
| Subnet: | 11000000 | 10101000 | 00000101 | 01111000 | |
| Broadcast: | 11000000 | 10101000 | 00000101 | 01111111 | |

Subnet Address = 192.168.5.120

Host Addresses = 192.168.5.121–192.168.5.126

Broadcast Address = 192.168.5.127

Five Bits of Subnetting

Broadcast Addresses Exercise Answers

| Address | Subnet Mask | Class | Subnet | Broadcast |
|---------------|-----------------|-------|---------------|---------------|
| 201.222.10.60 | 255.255.255.248 | C | 201.222.10.56 | 201.222.10.63 |
| 15.16.193.6 | 255.255.248.0 | A | 15.16.192.0 | 15.16.199.255 |
| 128.16.32.13 | 255.255.255.252 | B | 128.16.32.12 | 128.16.32.15 |
| 153.50.6.27 | 255.255.255.128 | B | 153.50.6.0 | 153.50.6.127 |