

Chapter 8

Interconnecting Networks with TCP/IP

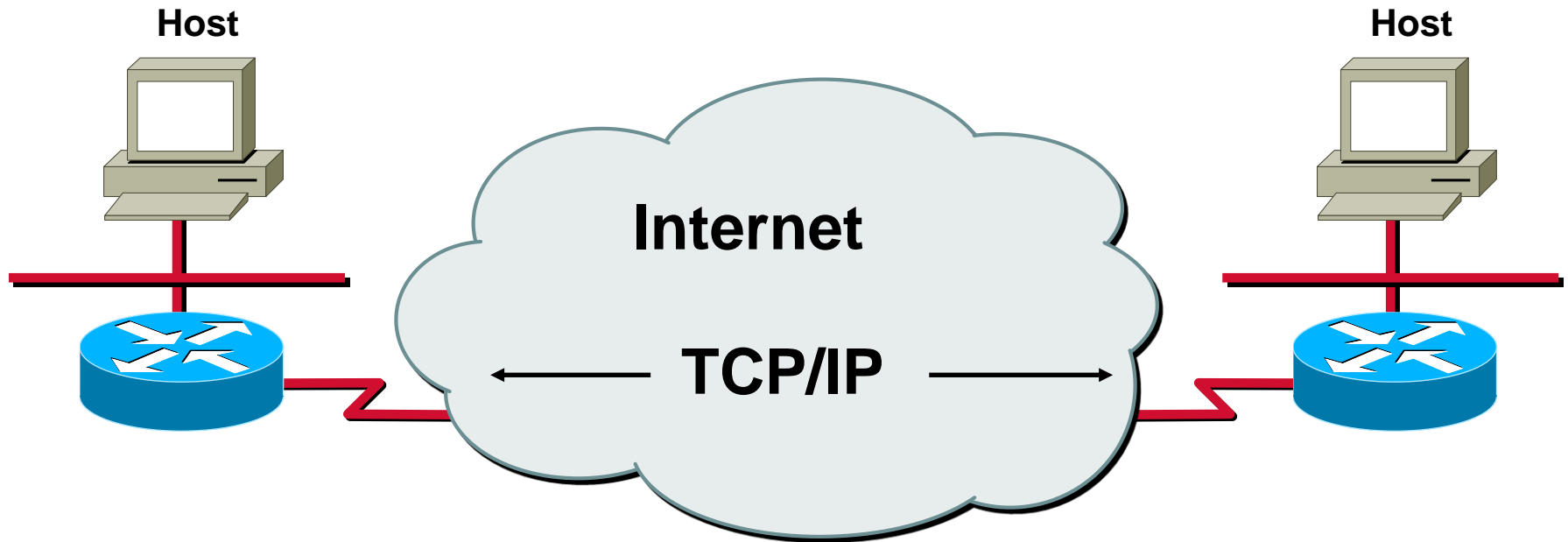


Objectives

Upon completion of this chapter you will be able to perform the following tasks:

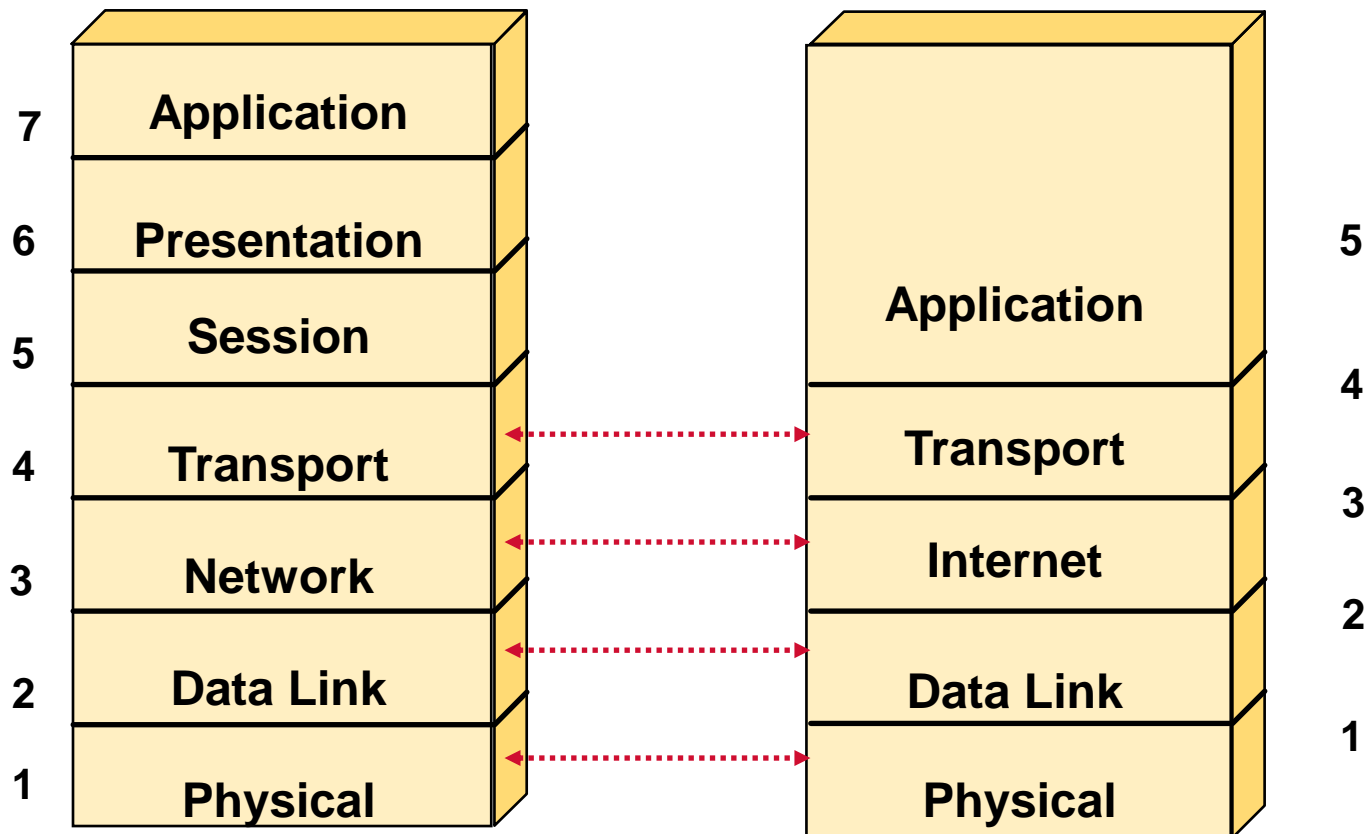
- **Identify the IP protocol stack, its protocol layer functions, and commonly used IP protocols**
- **Identify IP address classes, IP addresses, IP subnet masks, IP network numbers, subnet numbers, and possible host numbers.**
- **Configure IP addresses and subnet masks on a router interface and optionally configure a host table.**
- **Interconnect the VLANs with a layer three device such as a router on a stick.**

Introduction to TCP/IP

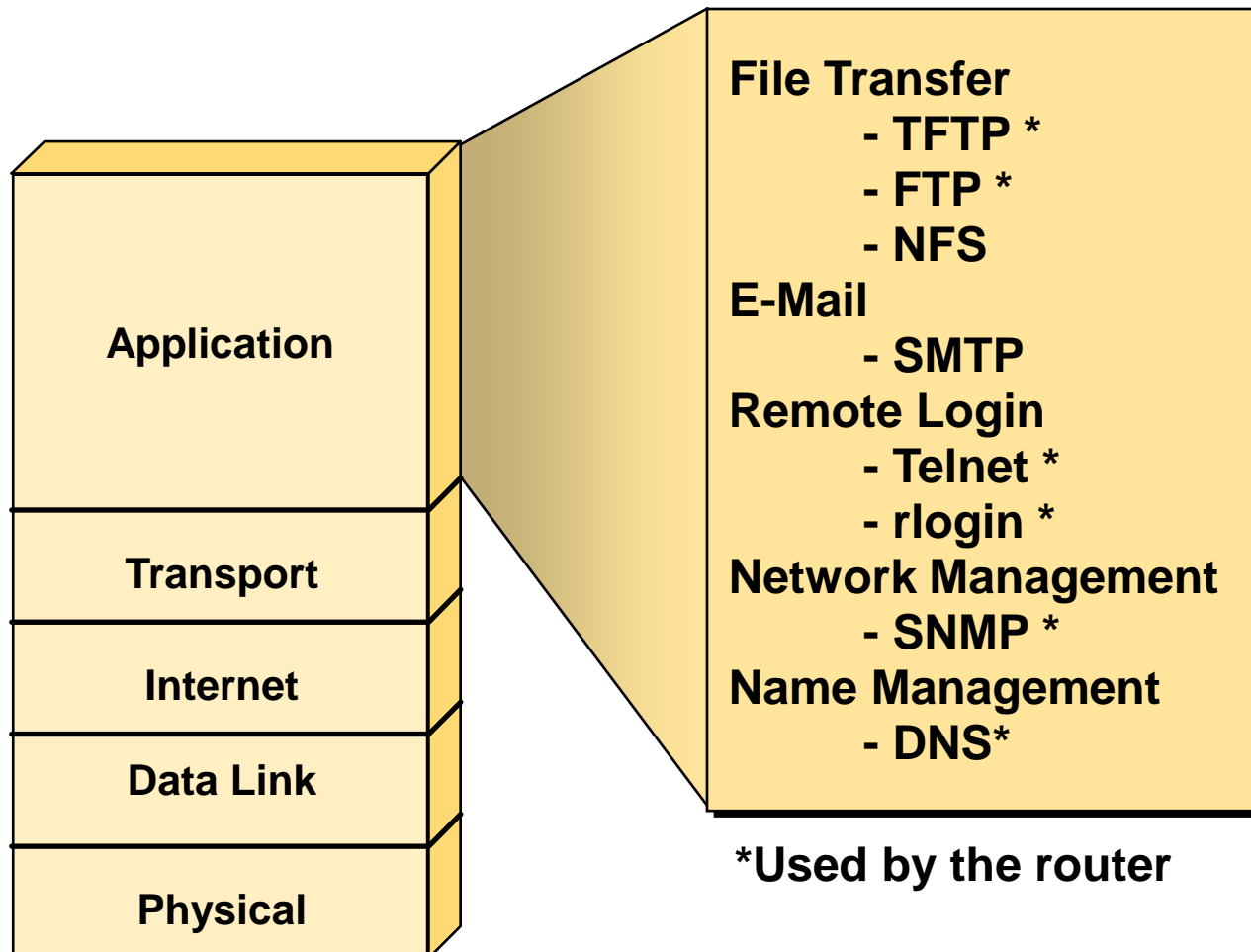


Early protocol suite
Universal

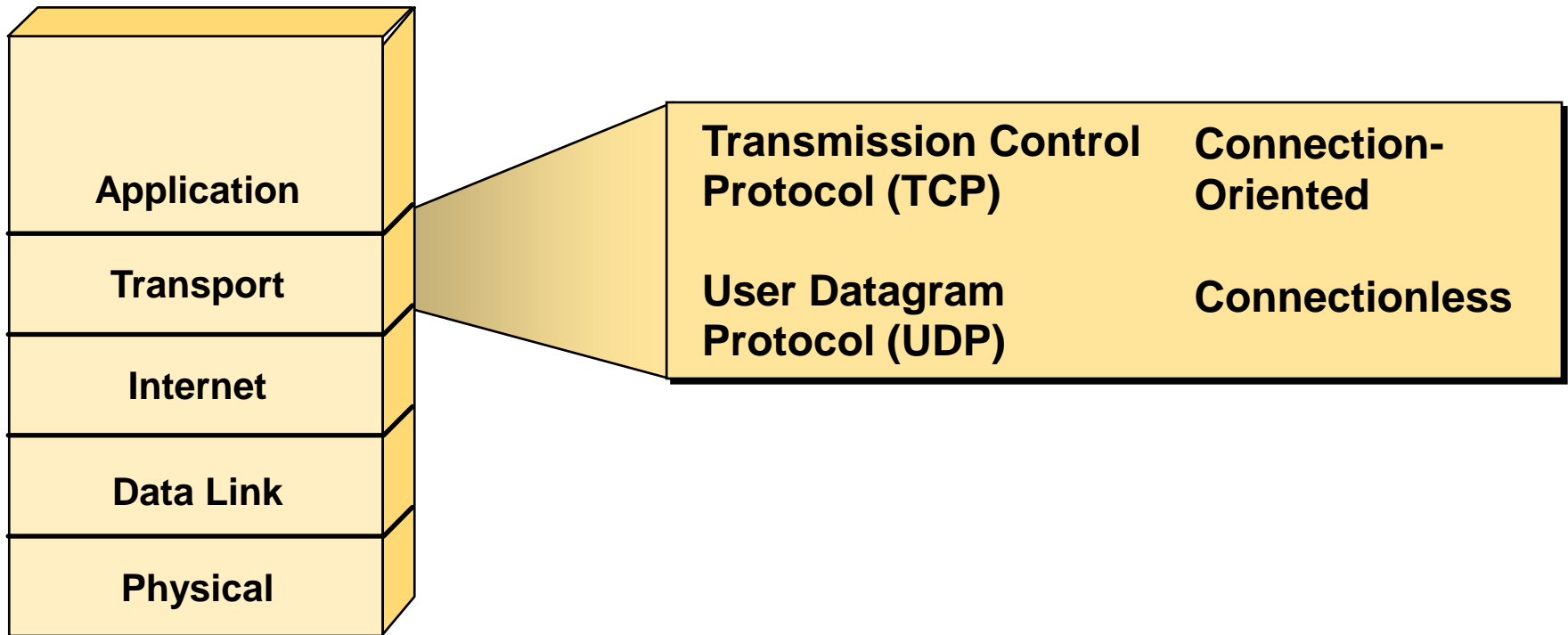
TCP/IP Protocol Stack



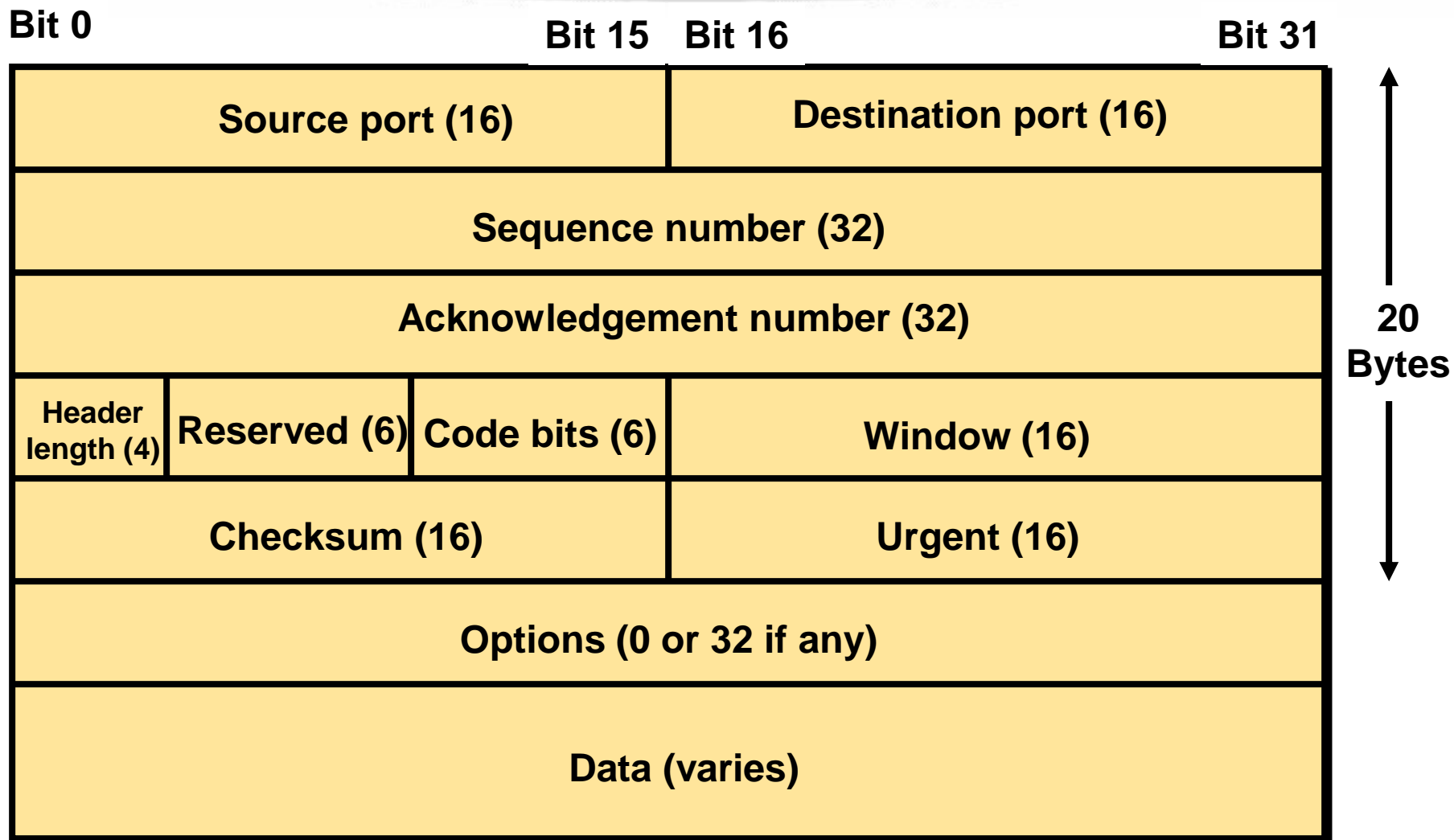
Application Layer Overview



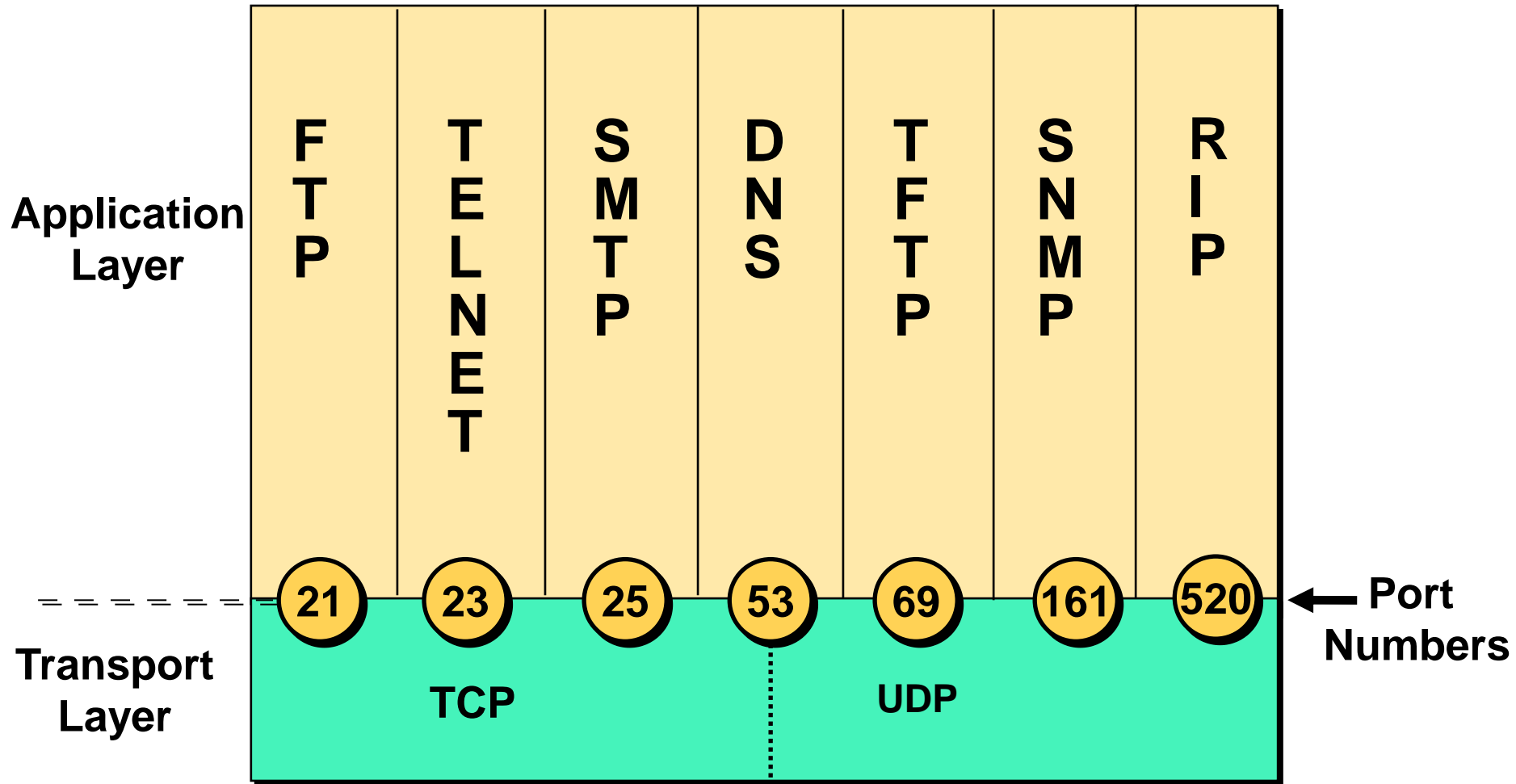
Transport Layer Overview



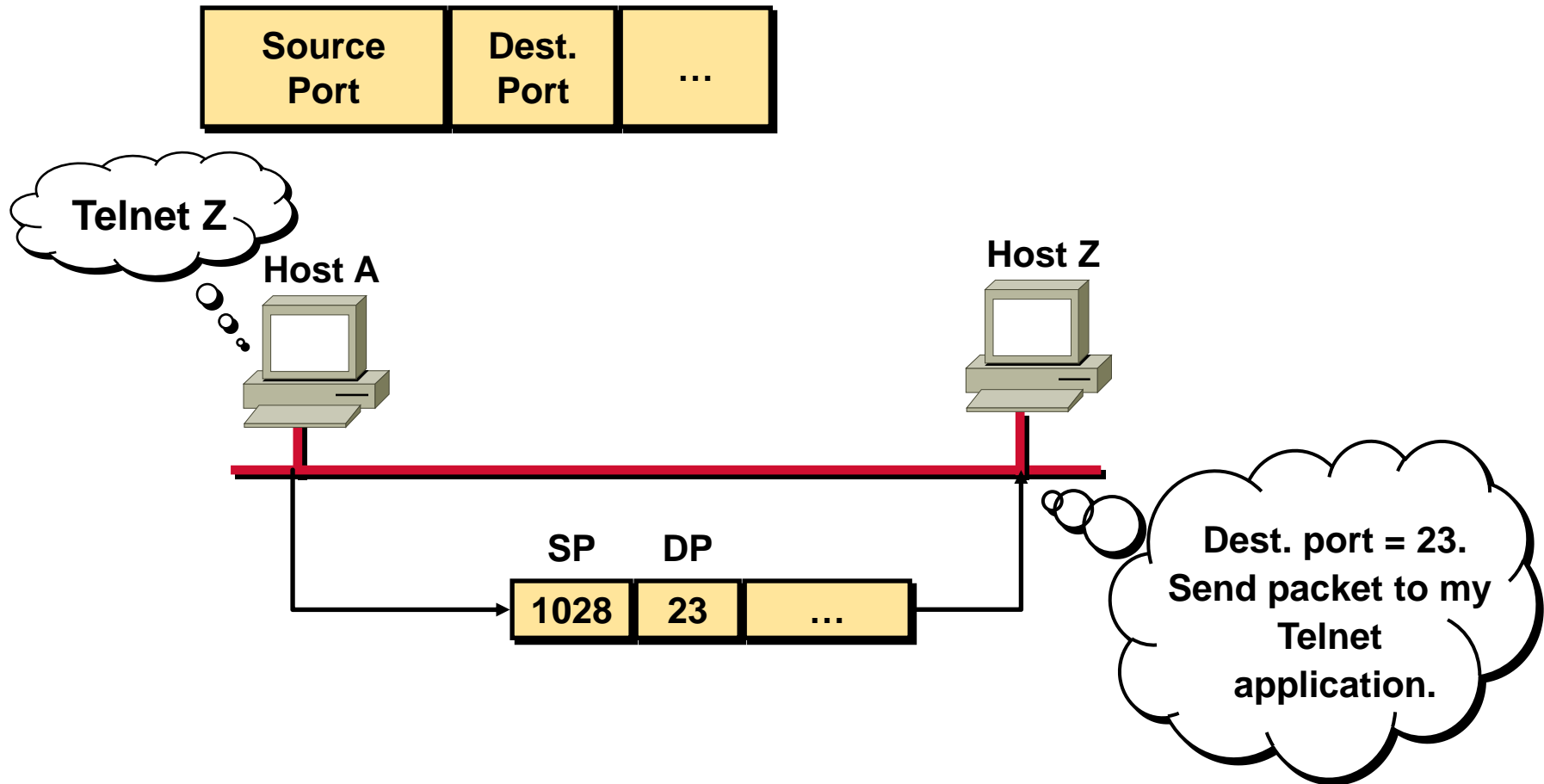
TCP Segment Format



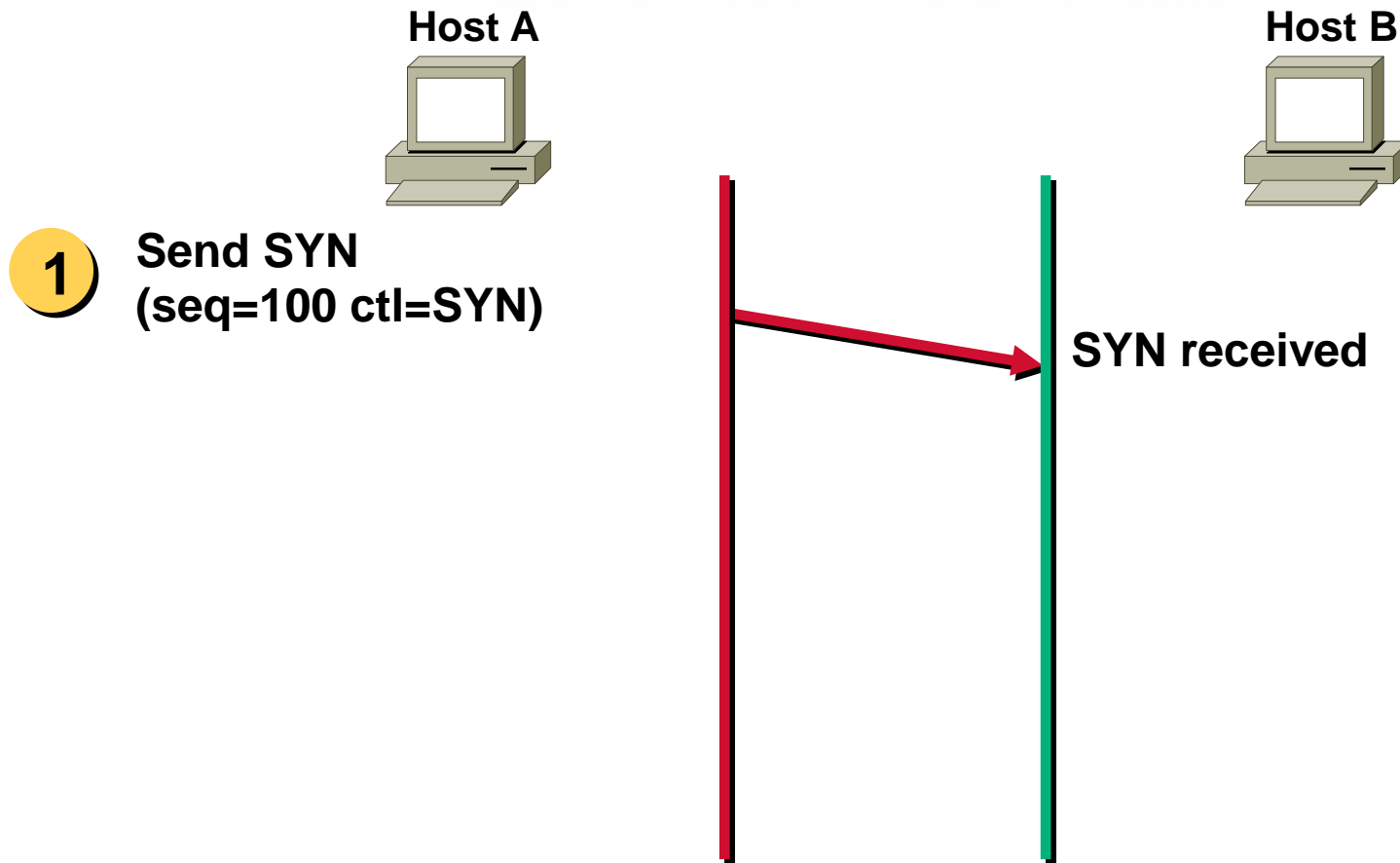
Port Numbers



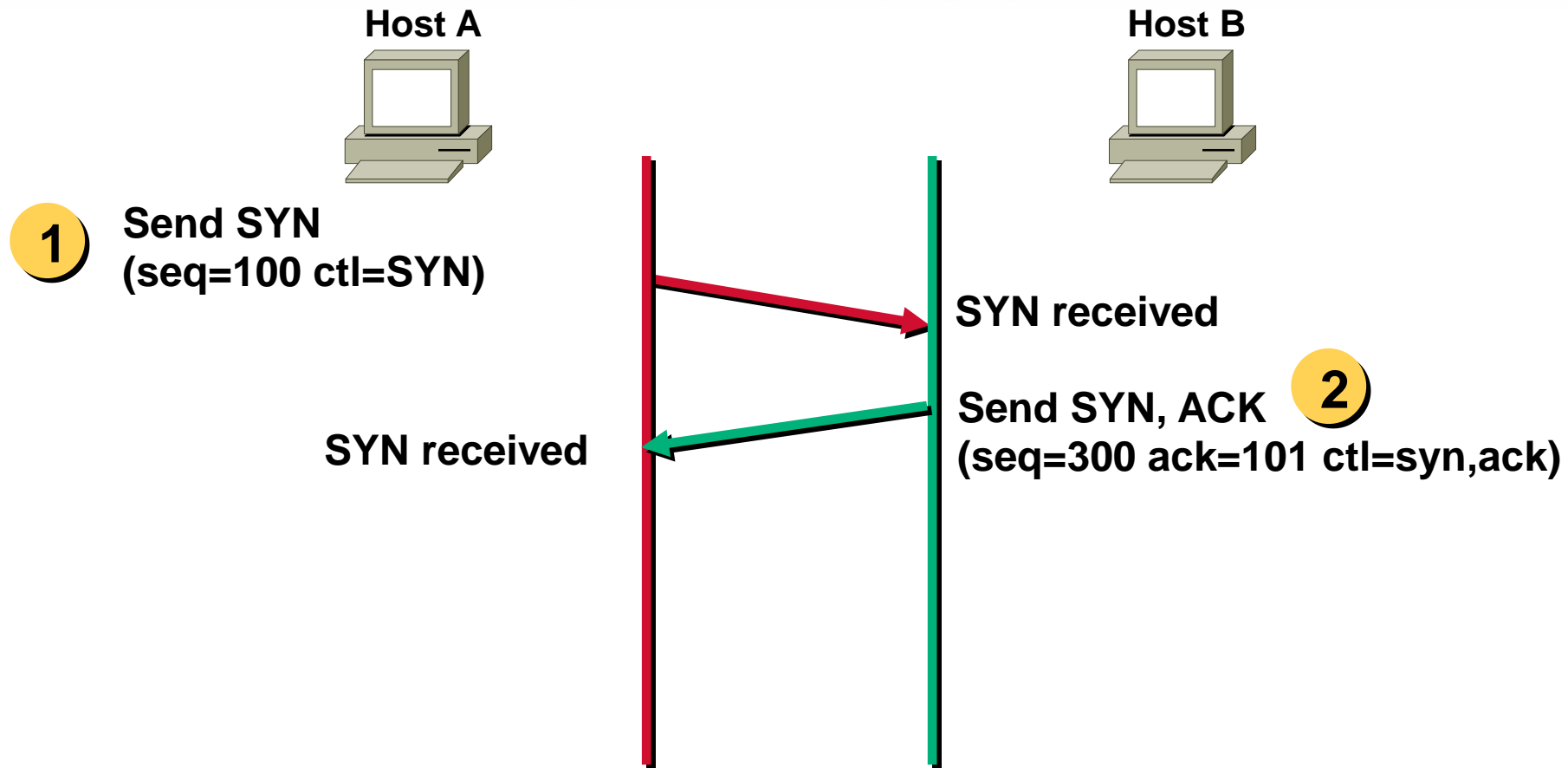
TCP Port Numbers



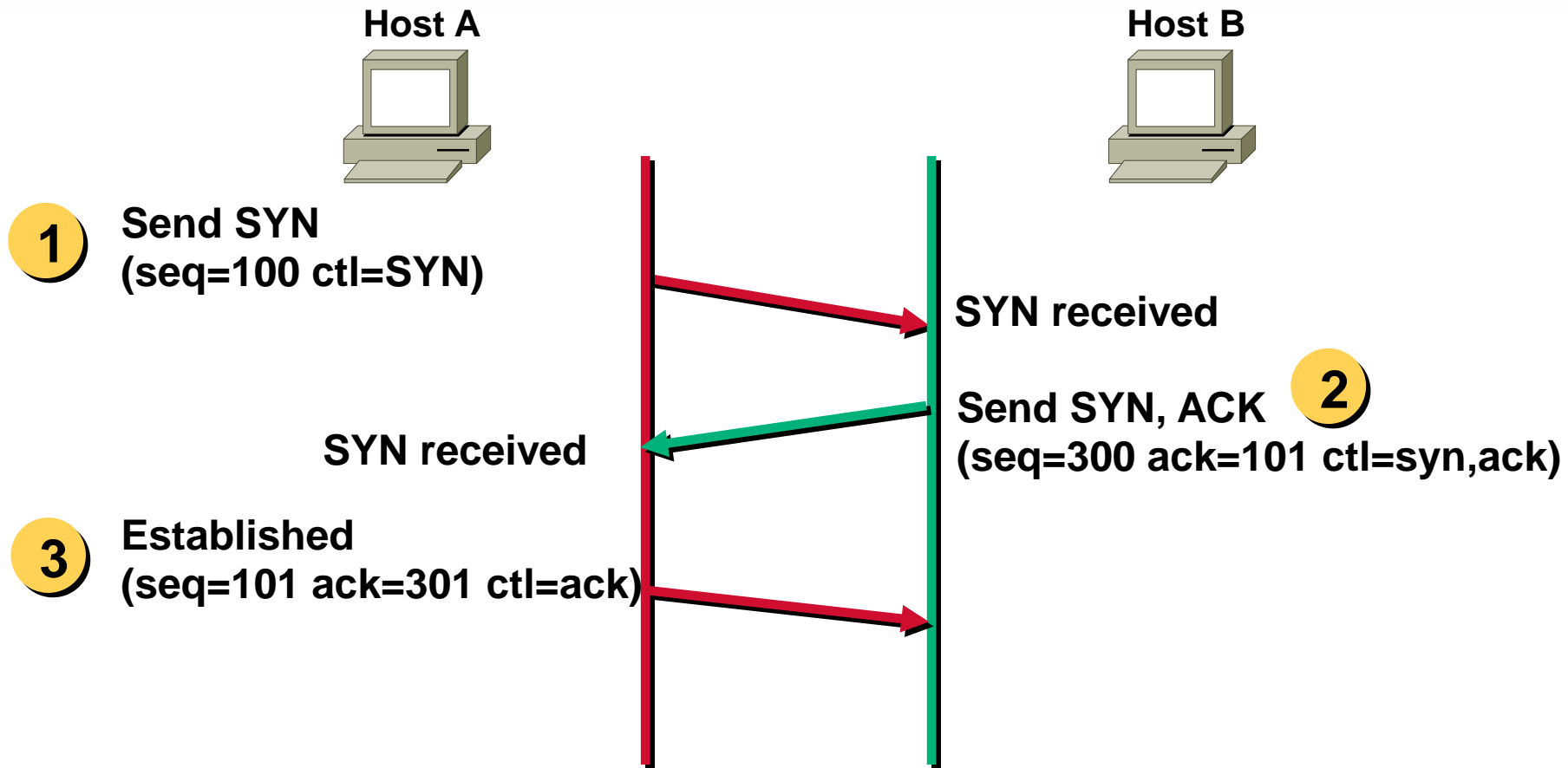
TCP Three Way Handshake/Open Connection



TCP Three Way Handshake/Open Connection



TCP Three Way Handshake/Open Connection



TCP Simple Acknowledgment

Sender

Receiver

Window size = 1

TCP Simple Acknowledgment

Sender

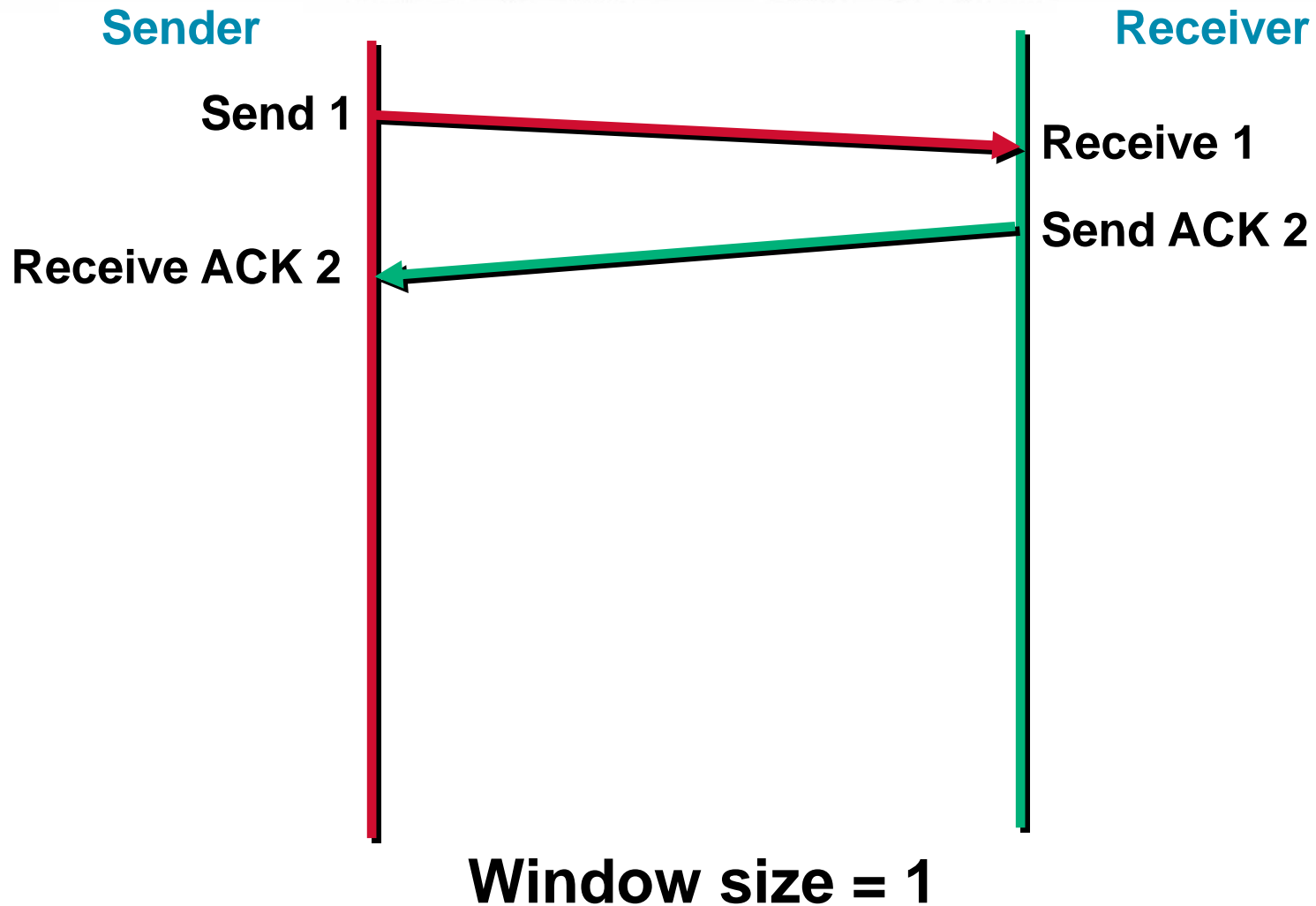
Receiver

Send 1

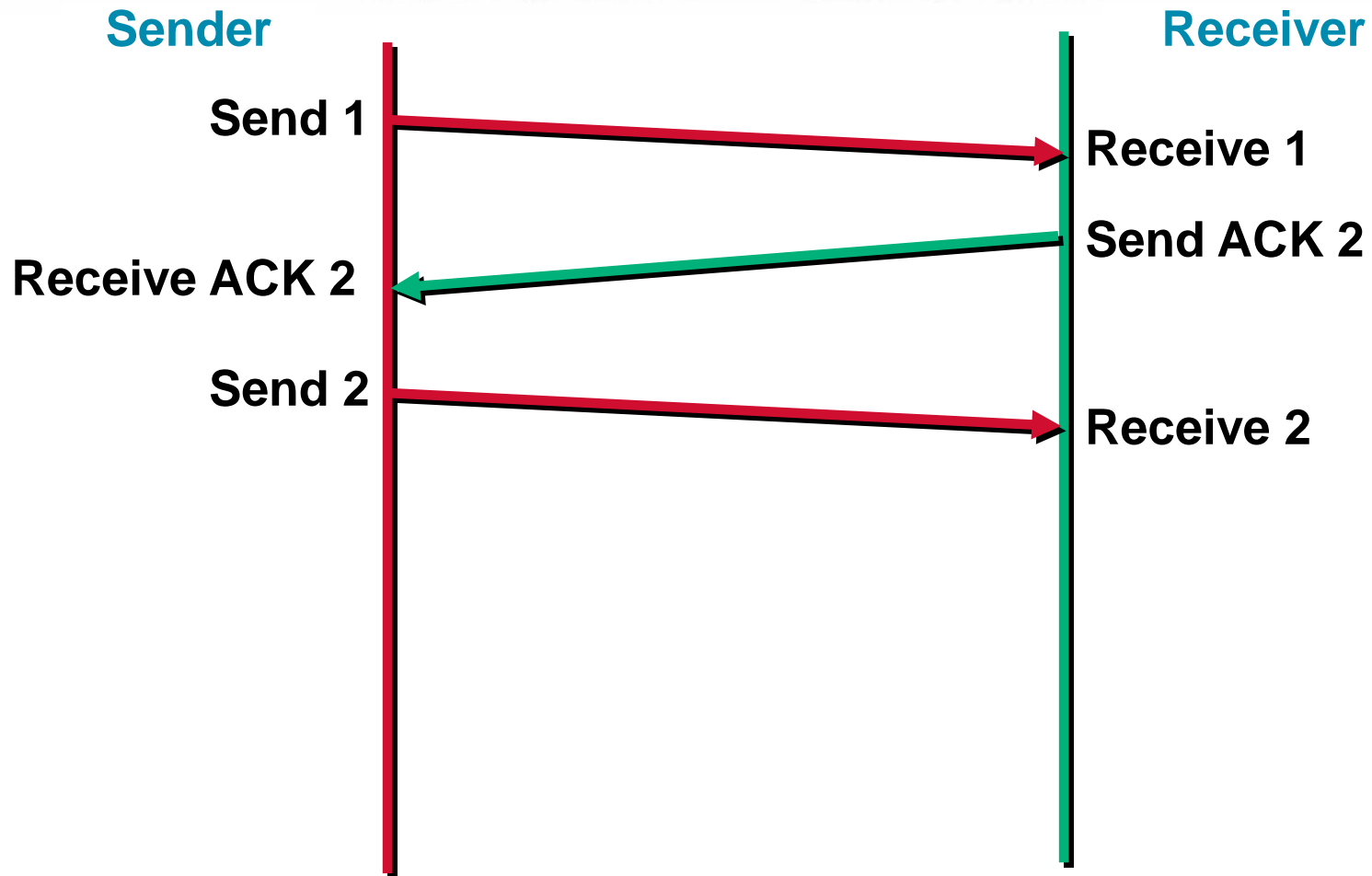
Receive 1

Window size = 1

TCP Simple Acknowledgment

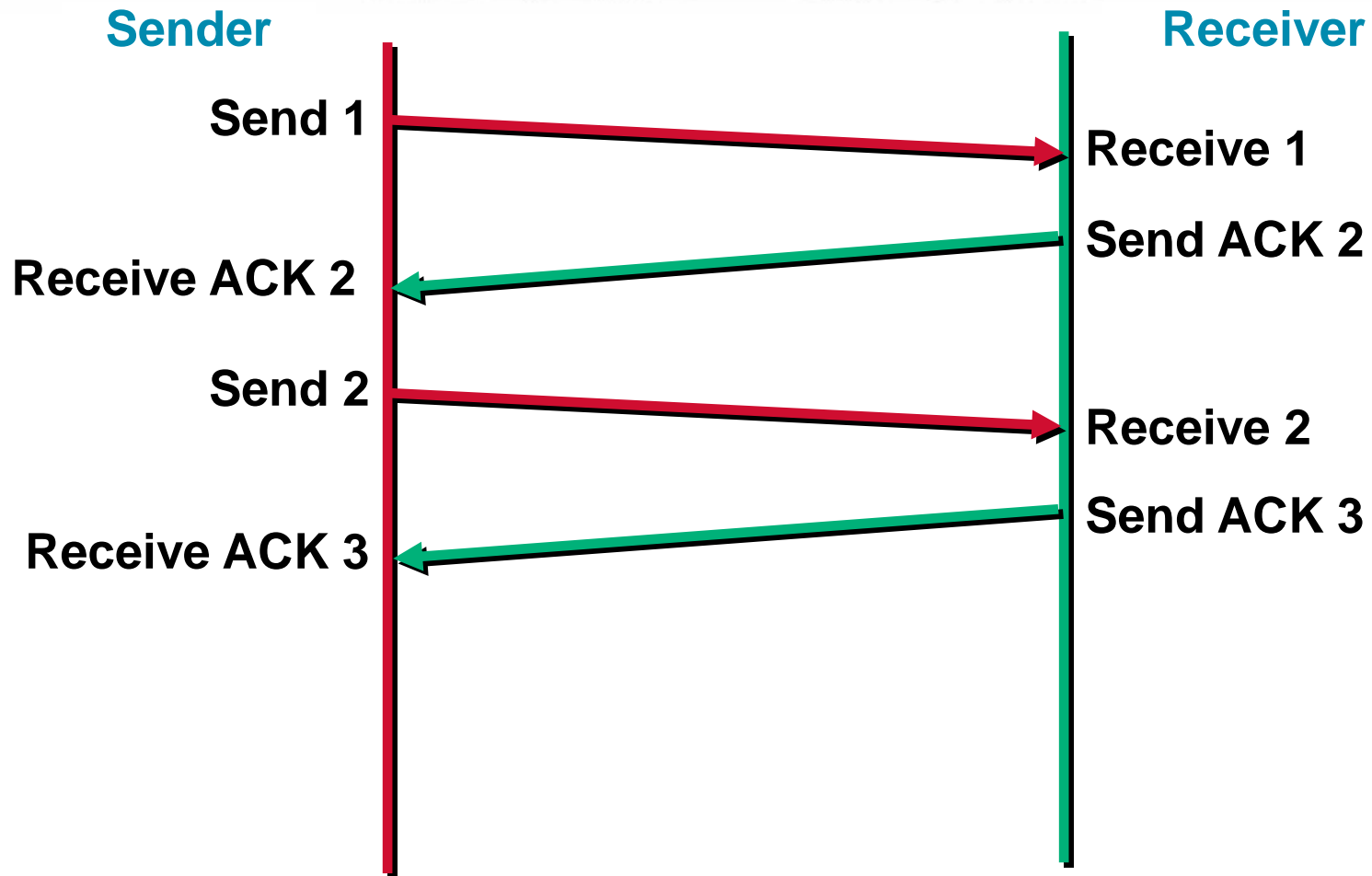


TCP Simple Acknowledgment



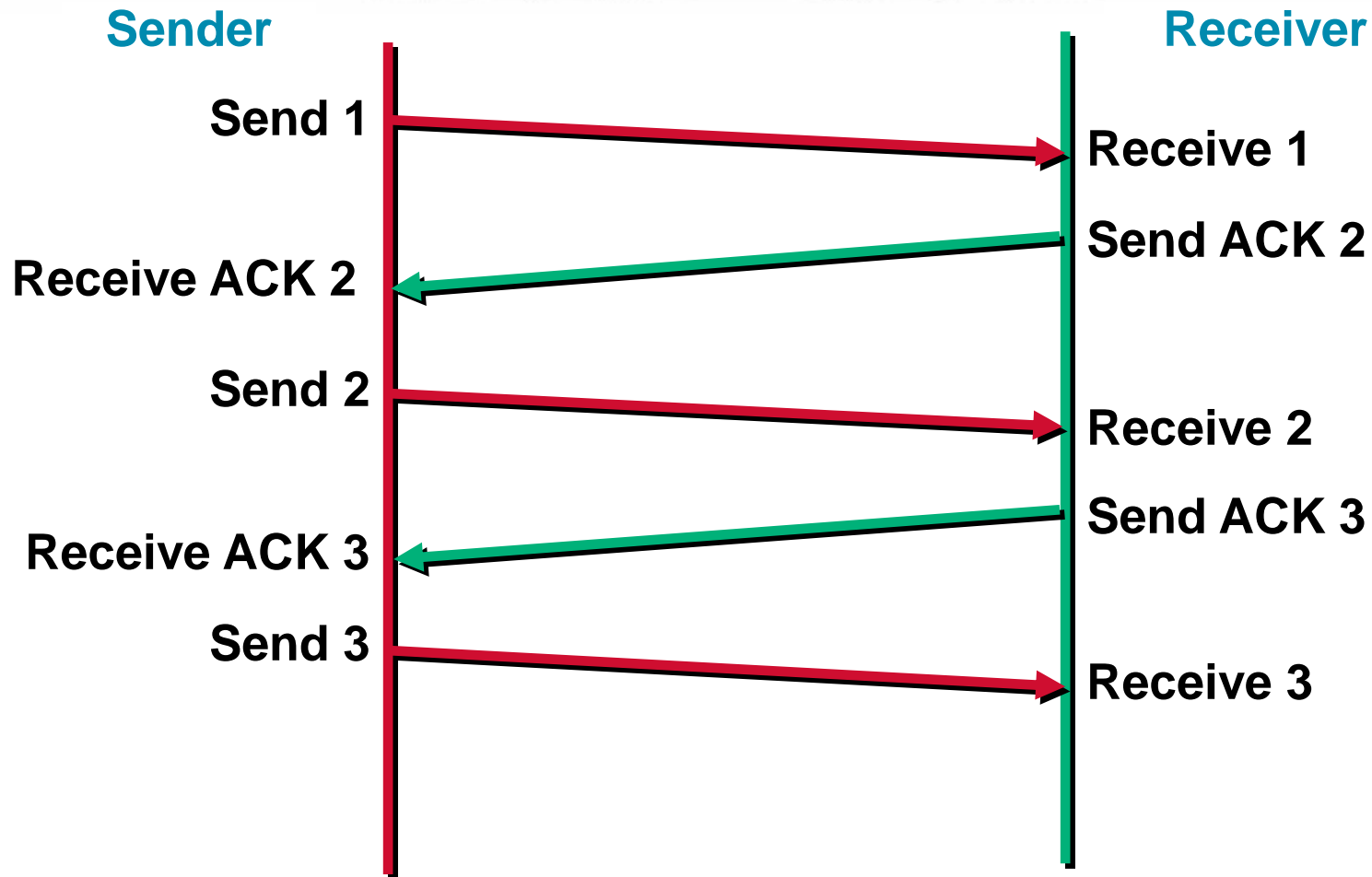
Window size = 1

TCP Simple Acknowledgment



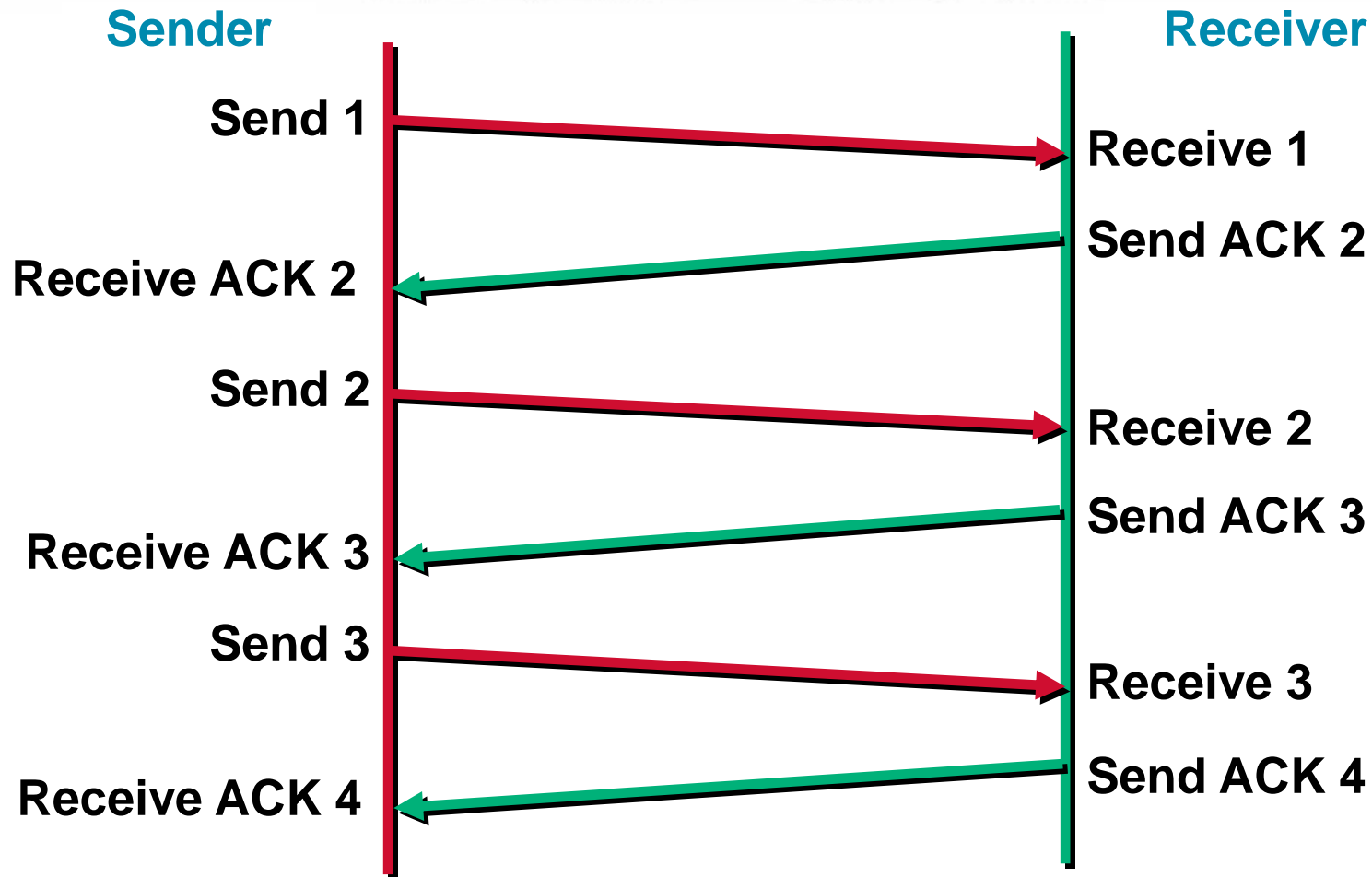
Window size = 1

TCP Simple Acknowledgment



Window size = 1

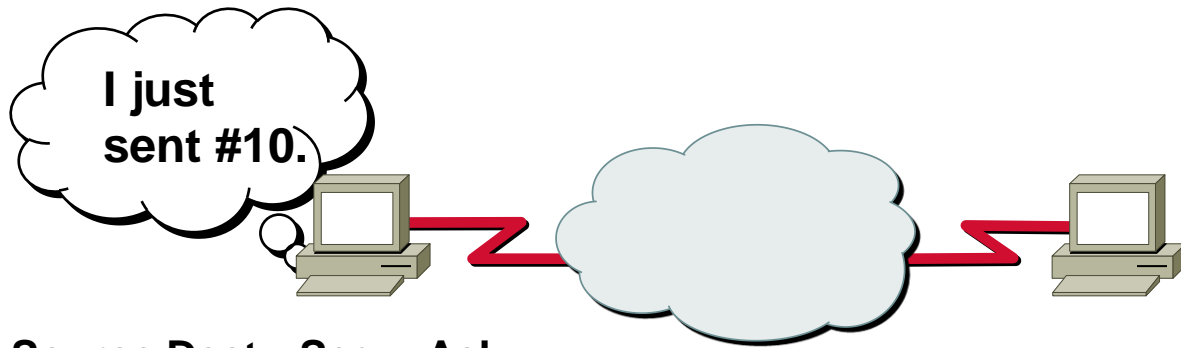
TCP Simple Acknowledgment



Window size = 1

TCP Sequence and Acknowledgment Numbers

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

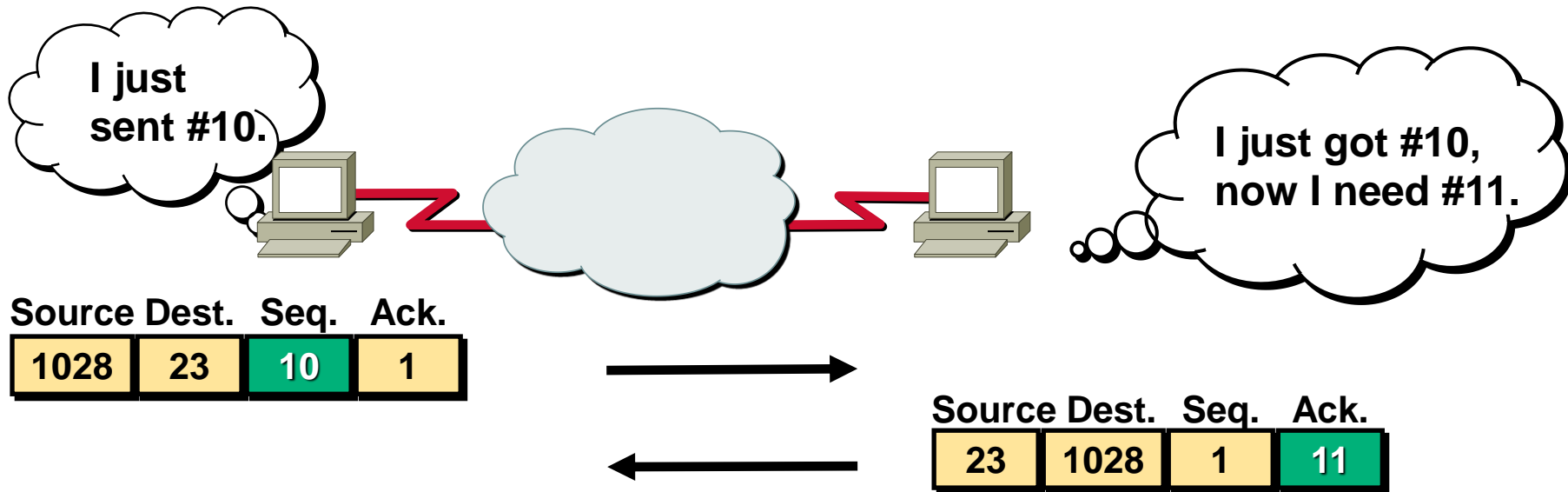


Source	Dest.	Seq.	Ack.
1028	23	10	1



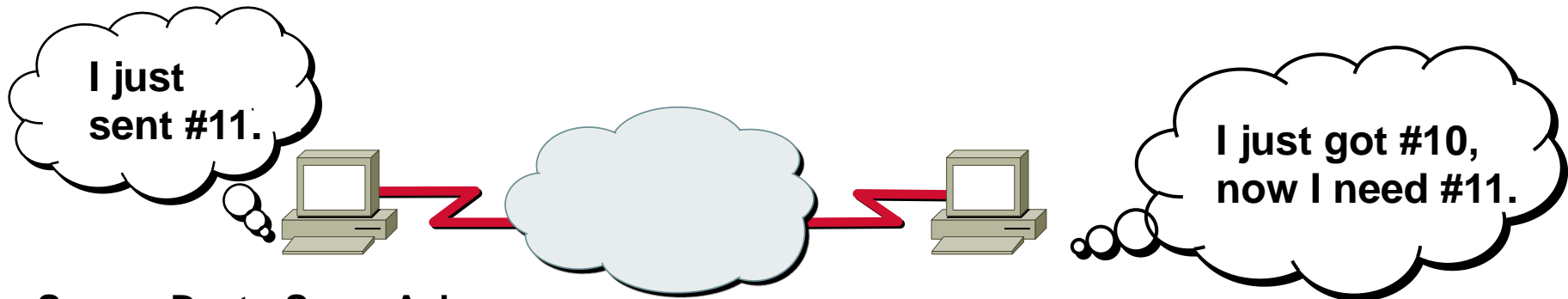
TCP Sequence and Acknowledgment Numbers

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



TCP Sequence and Acknowledgment Numbers

Source Port	Dest. Port	Sequence #	Acknowledgement #	...
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Source	Dest.	Seq.	Ack.
1028	23	10	1



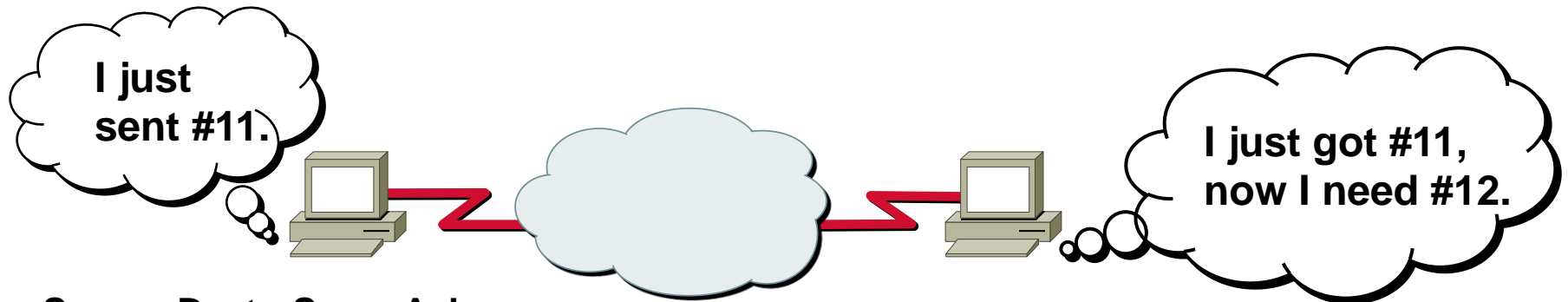
Source	Dest.	Seq.	Ack.
1028	23	11	2



Source	Dest.	Seq.	Ack.
23	1028	1	11

TCP Sequence and Acknowledgment Numbers

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



Source	Dest.	Seq.	Ack.
1028	23	10	100



Source	Dest.	Seq.	Ack.
1028	23	11	101



Source	Dest.	Seq.	Ack.
23	1028	100	11

Source	Dest.	Seq.	Ack.
23	1028	101	12

TCP Windowing

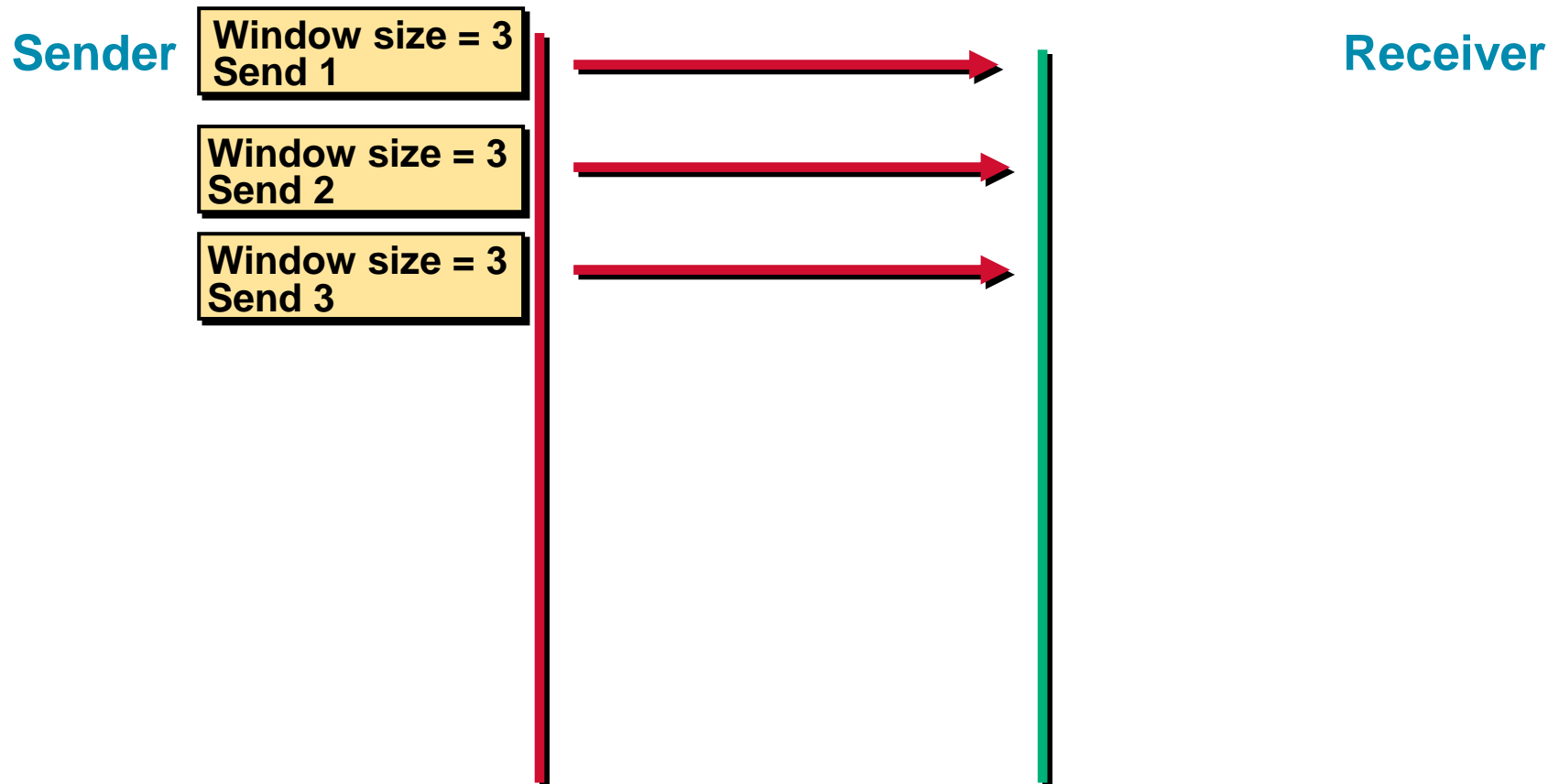
Sender



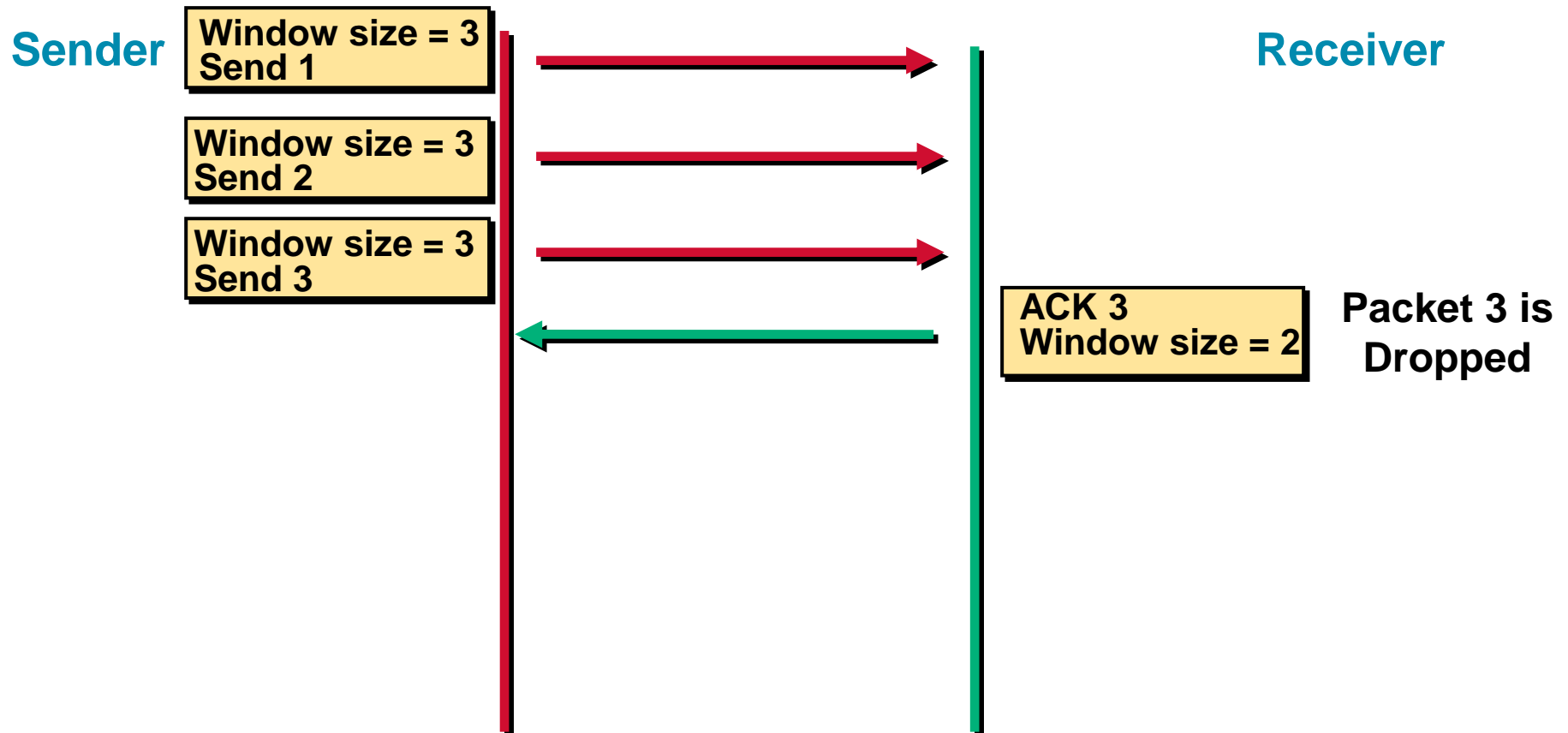
Receiver



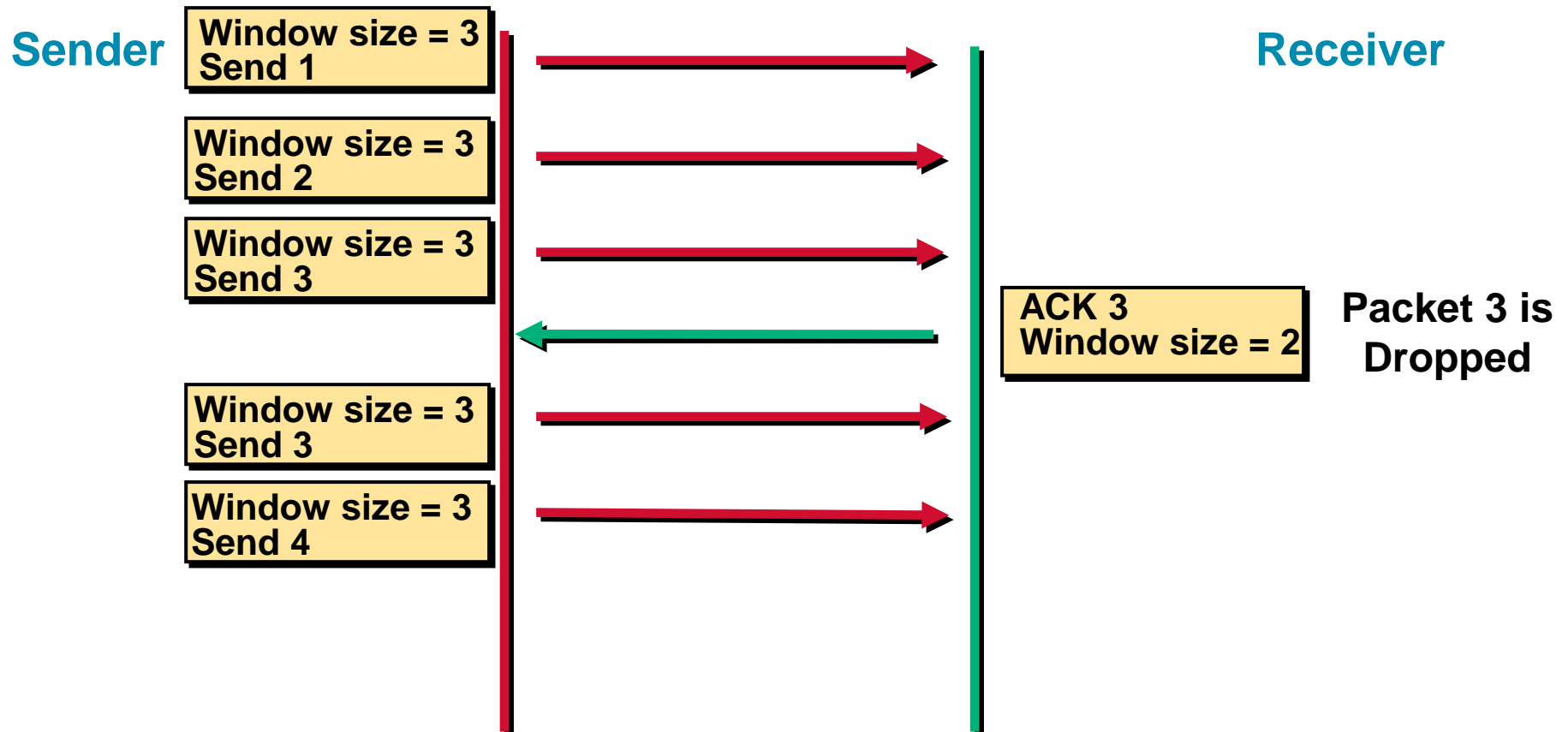
TCP Windowing



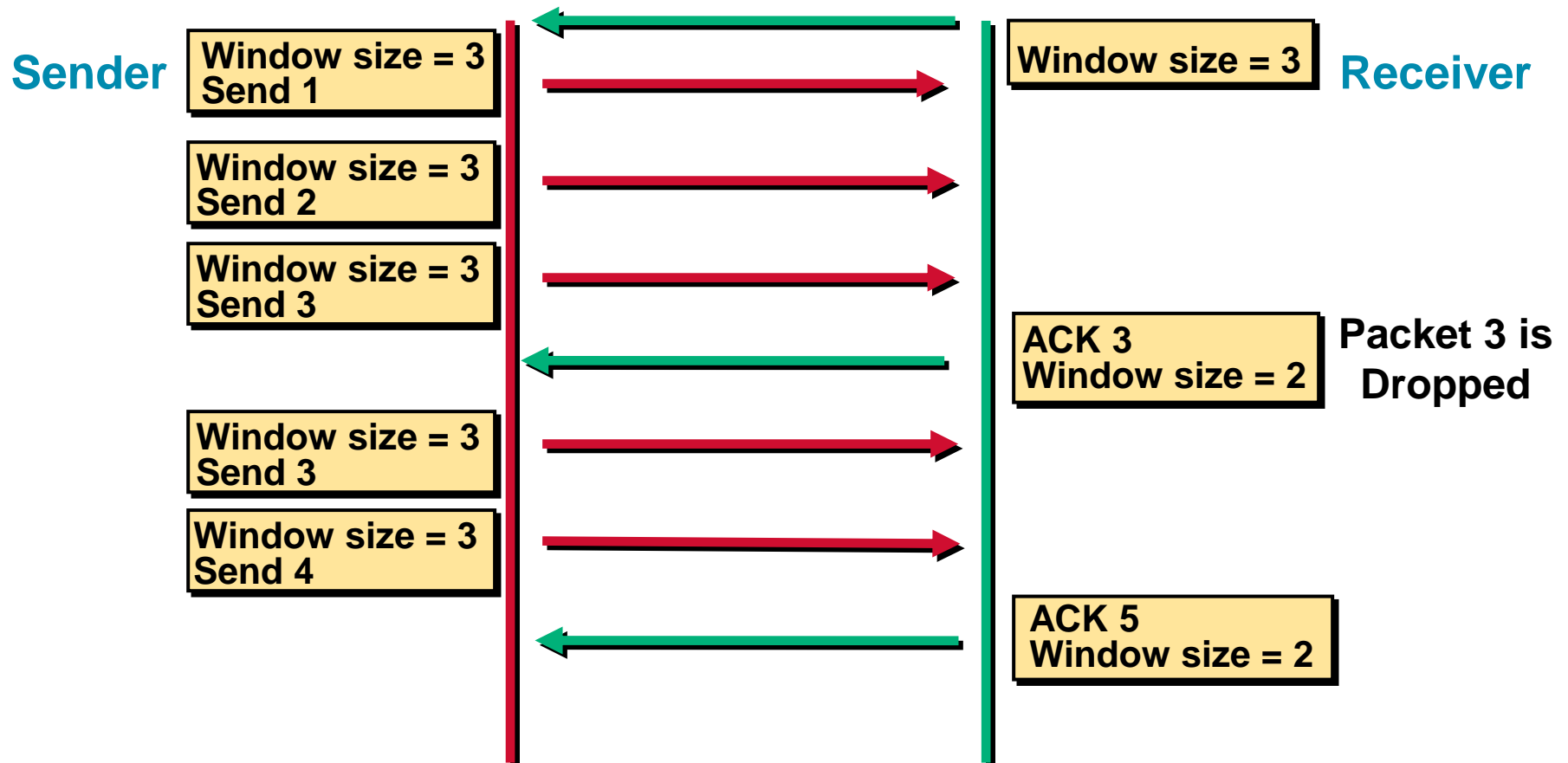
TCP Windowing



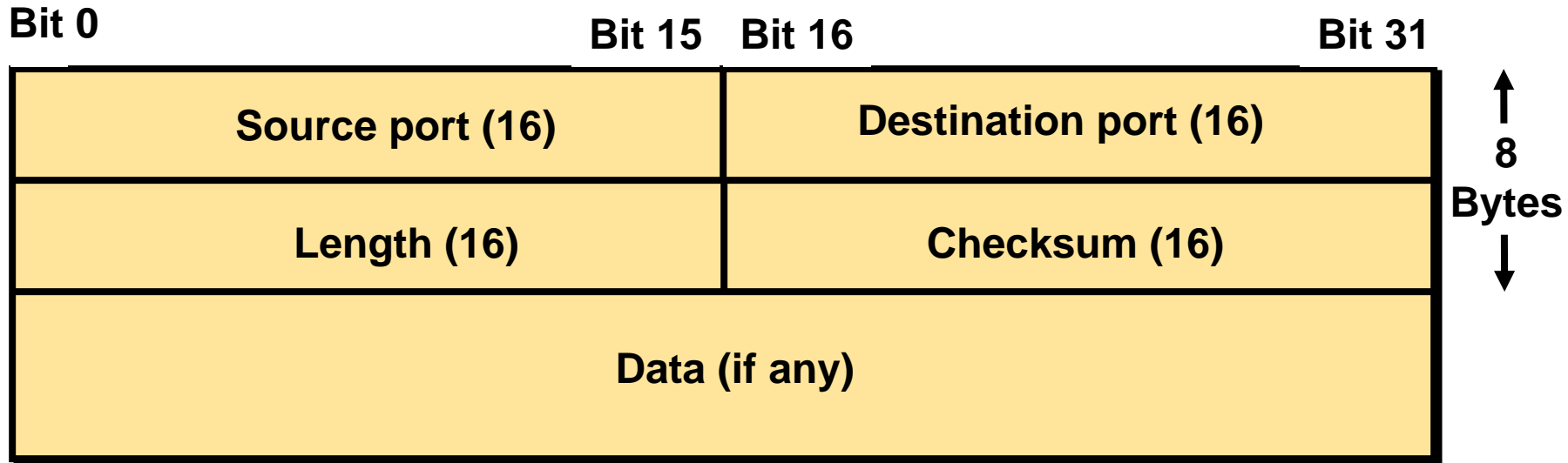
TCP Windowing



TCP Windowing

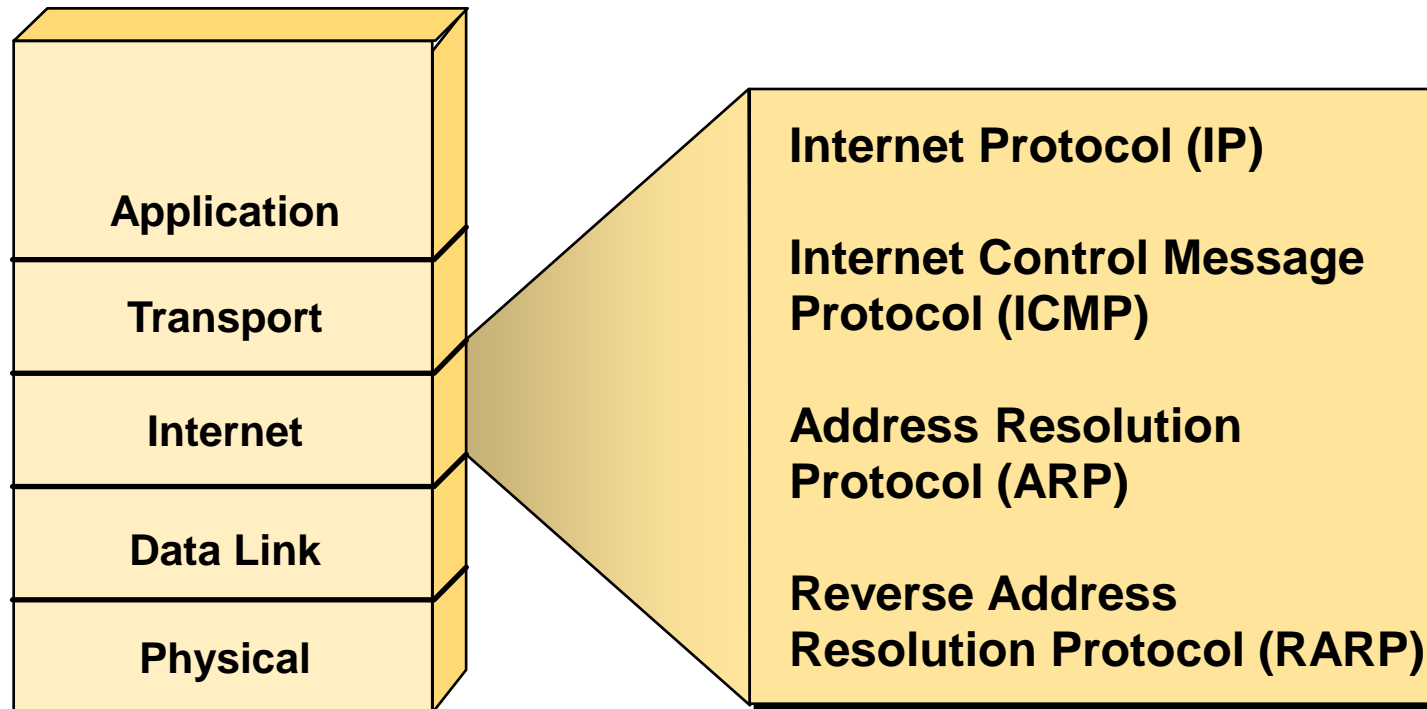


UDP Segment Format



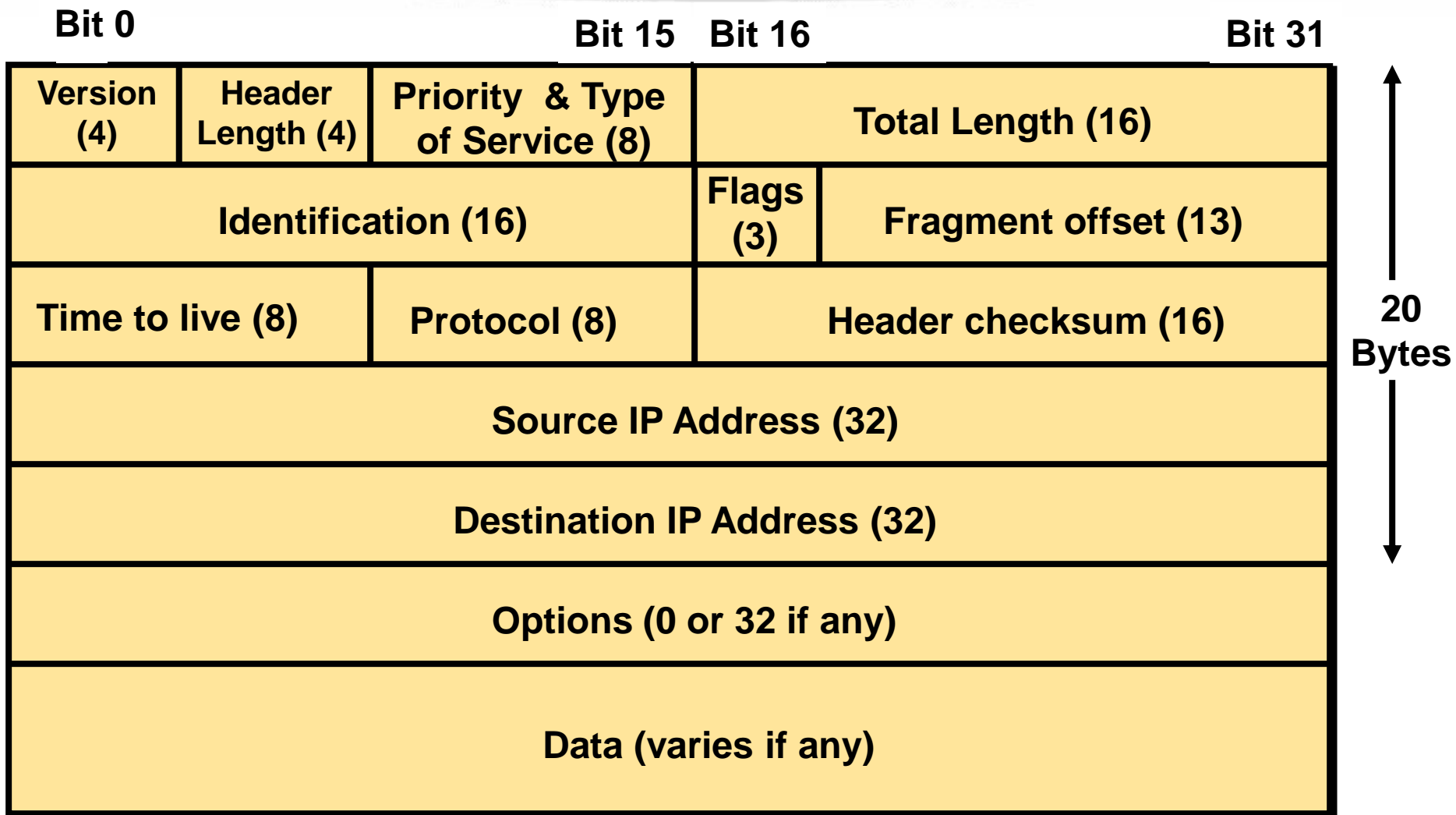
No sequence or acknowledgment fields

Internet Layer Overview

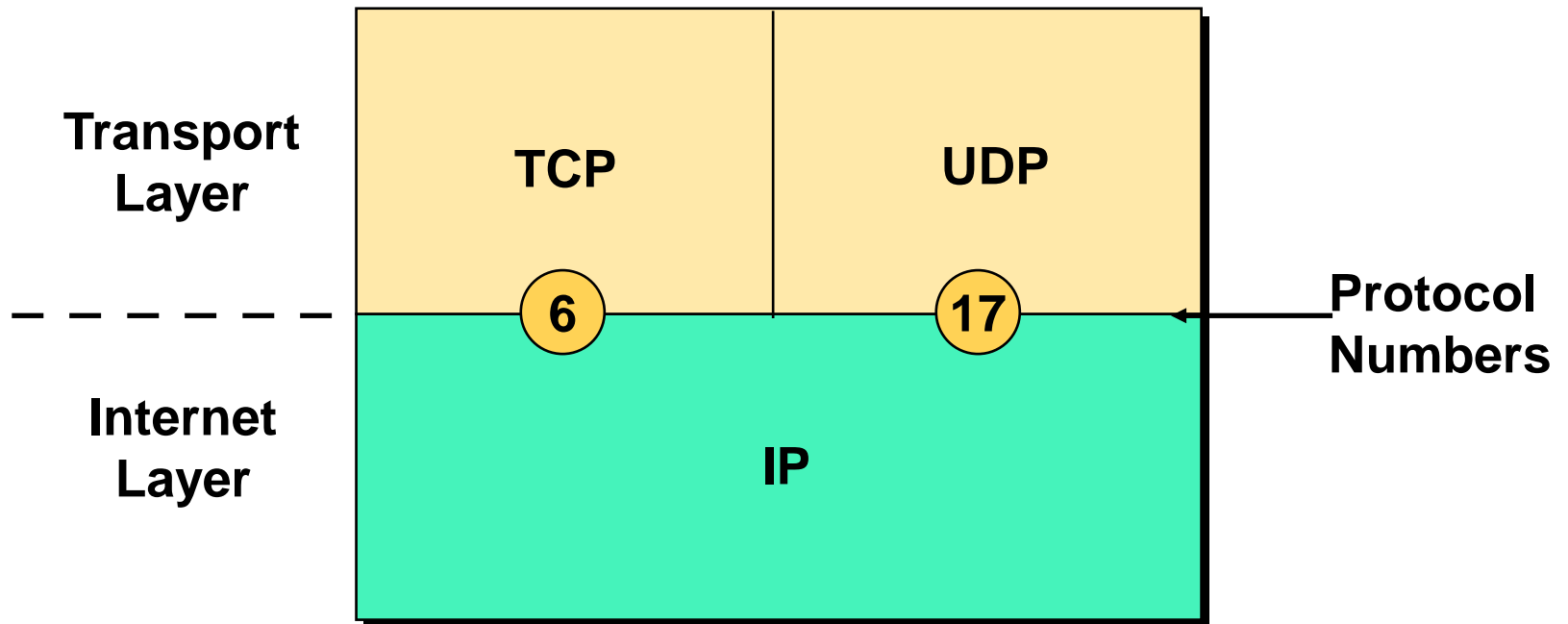


**OSI network layer corresponds to the
TCP/IP internet layer**

IP Datagram

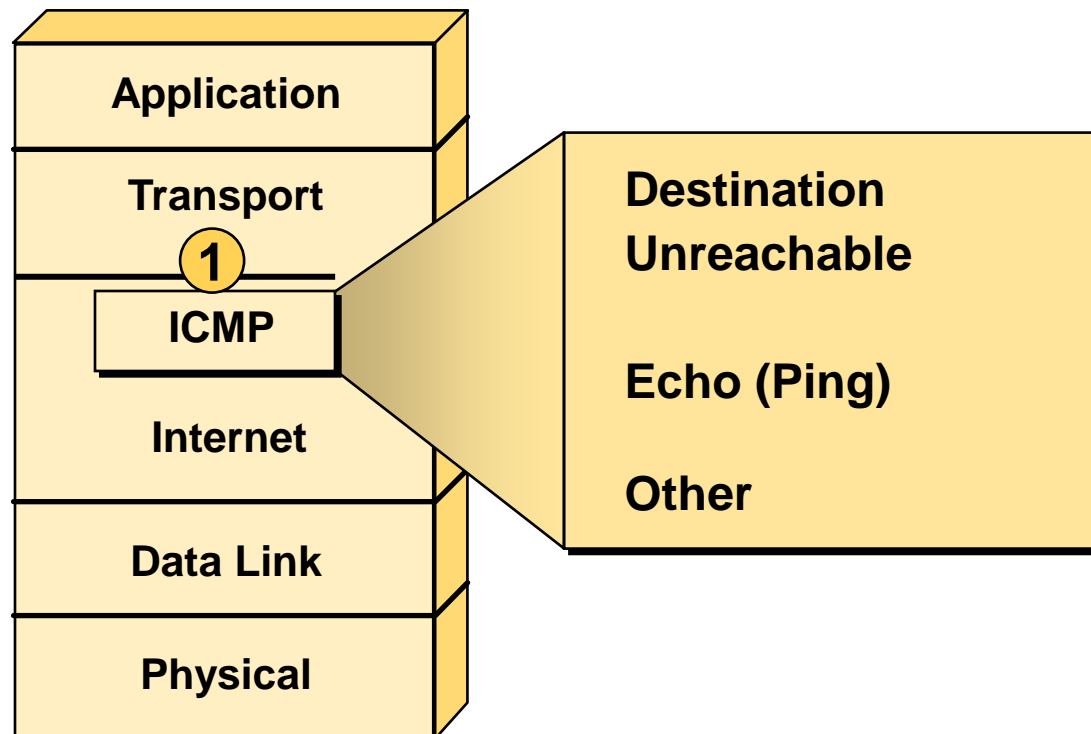


Protocol Field

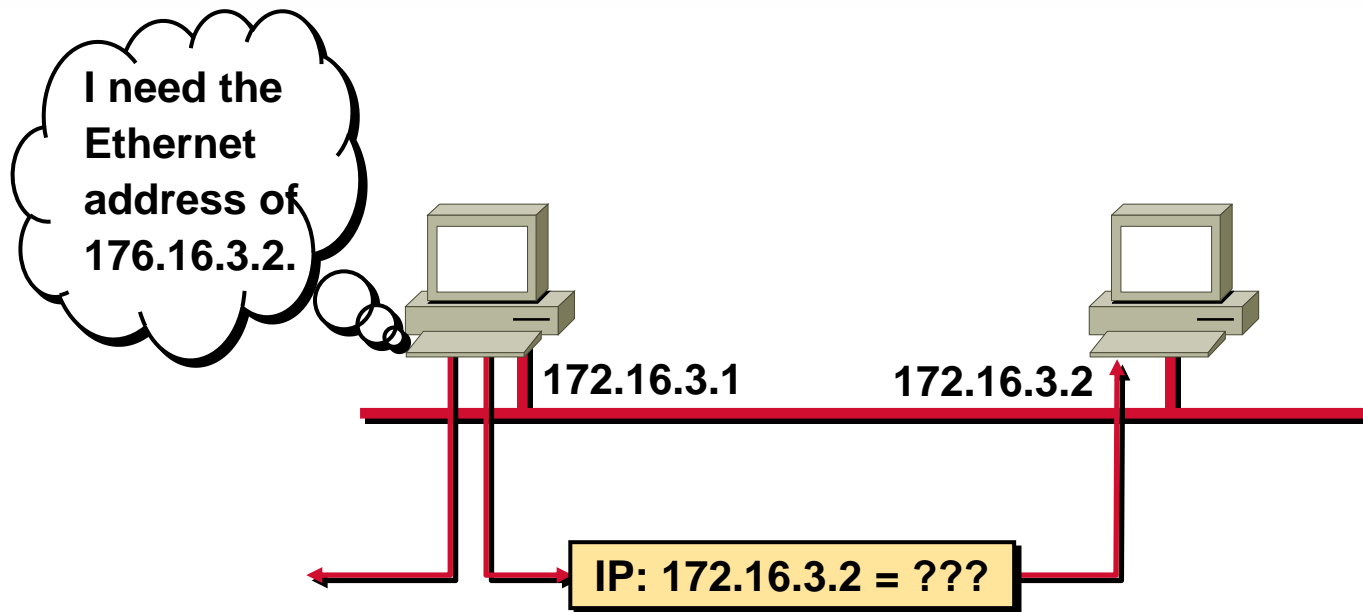


Determines destination upper-layer protocol

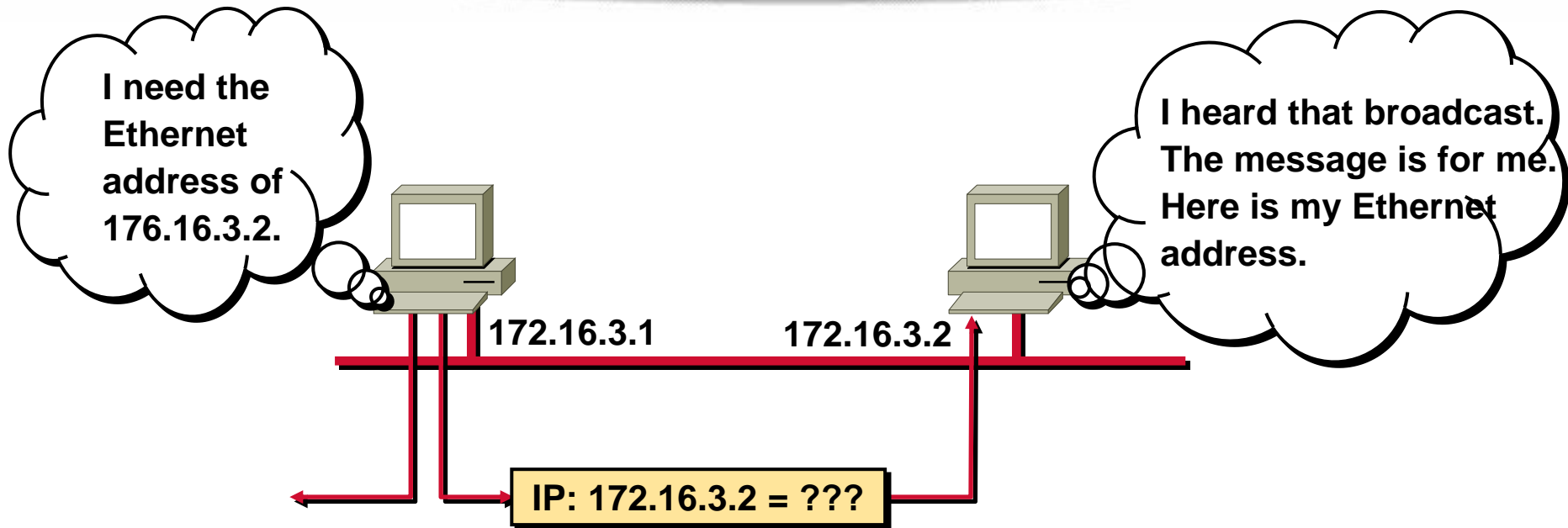
Internet Control Message Protocol



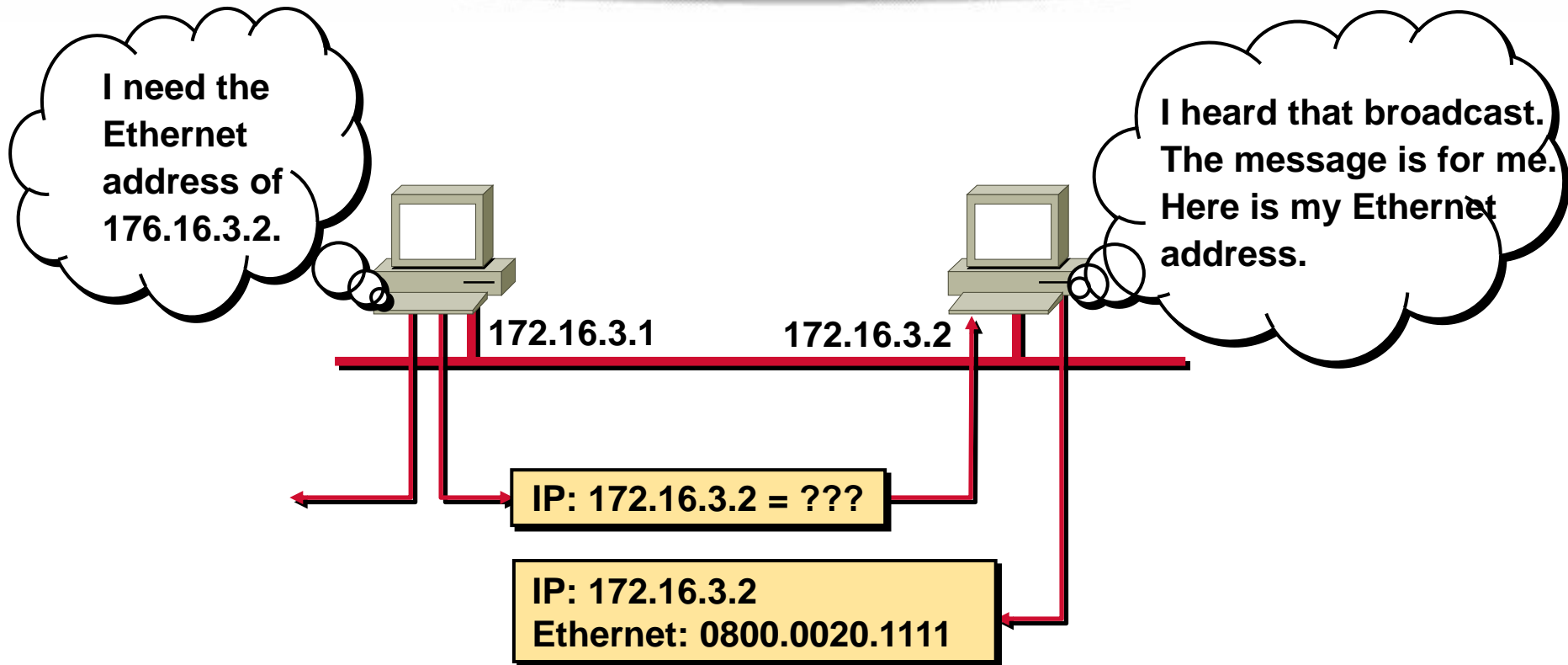
Address Resolution Protocol



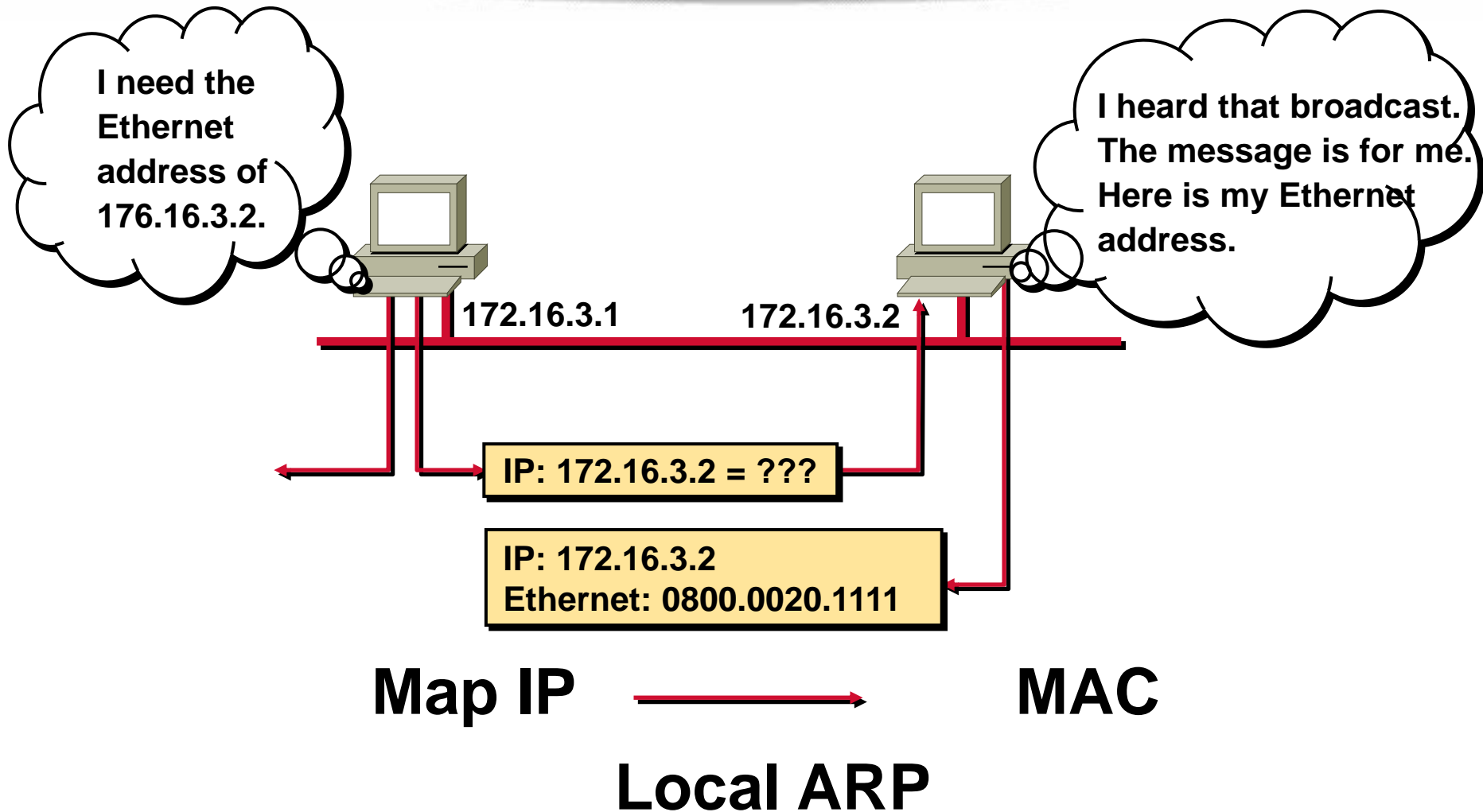
Address Resolution Protocol



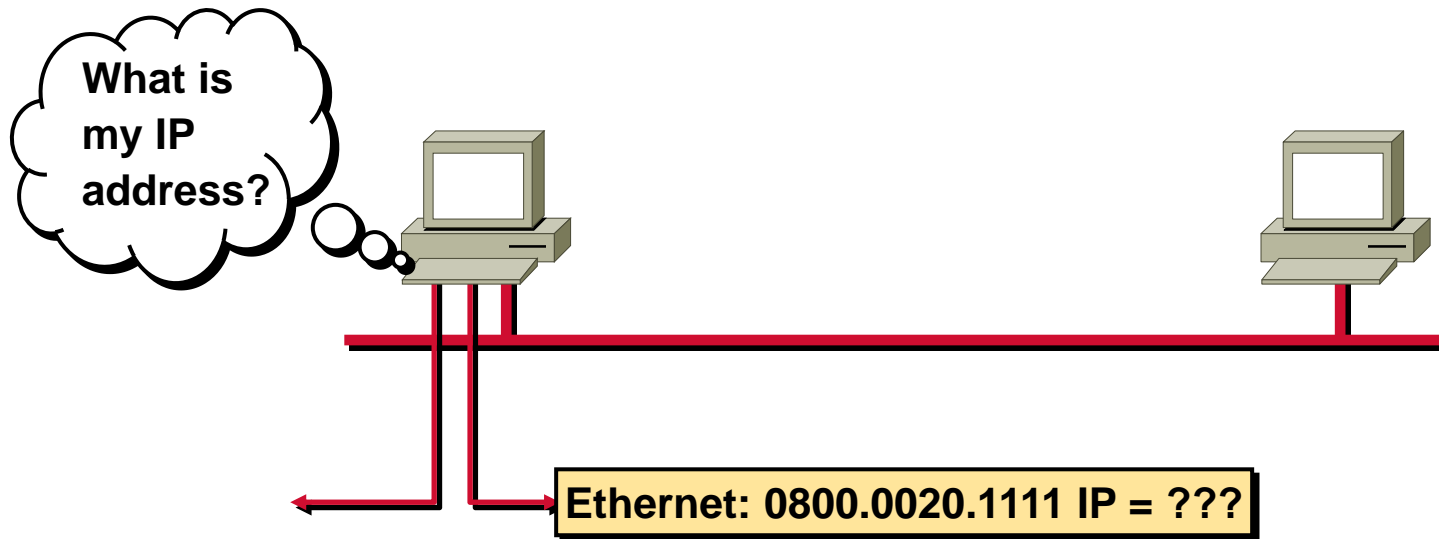
Address Resolution Protocol



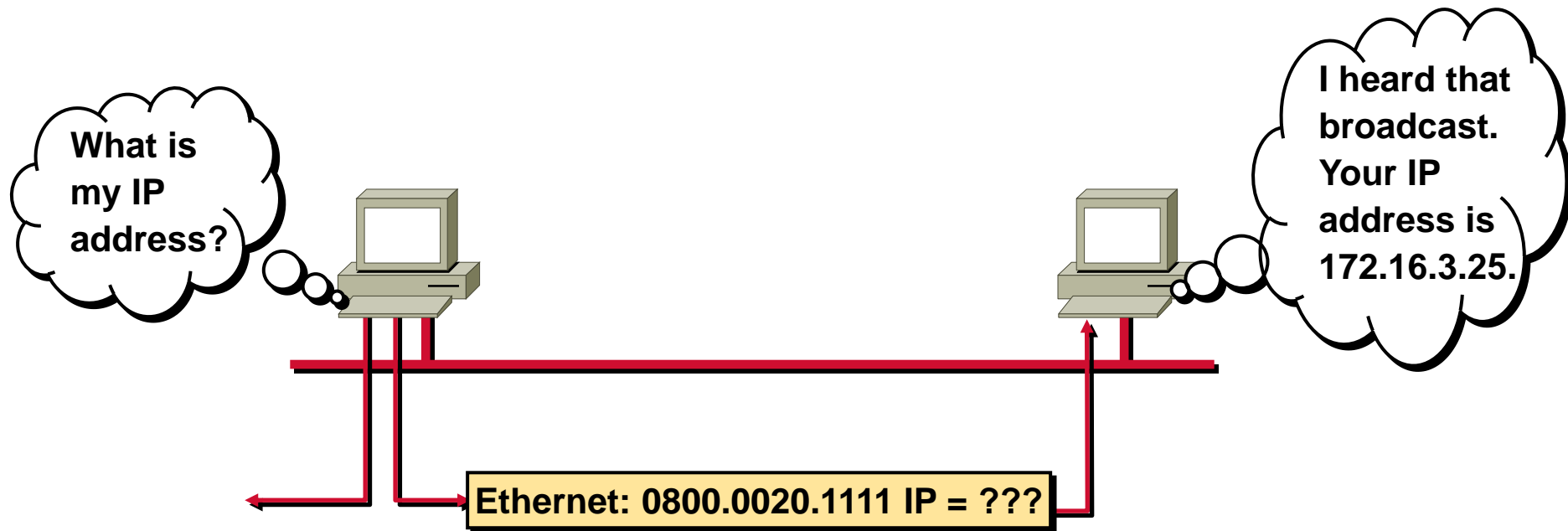
Address Resolution Protocol



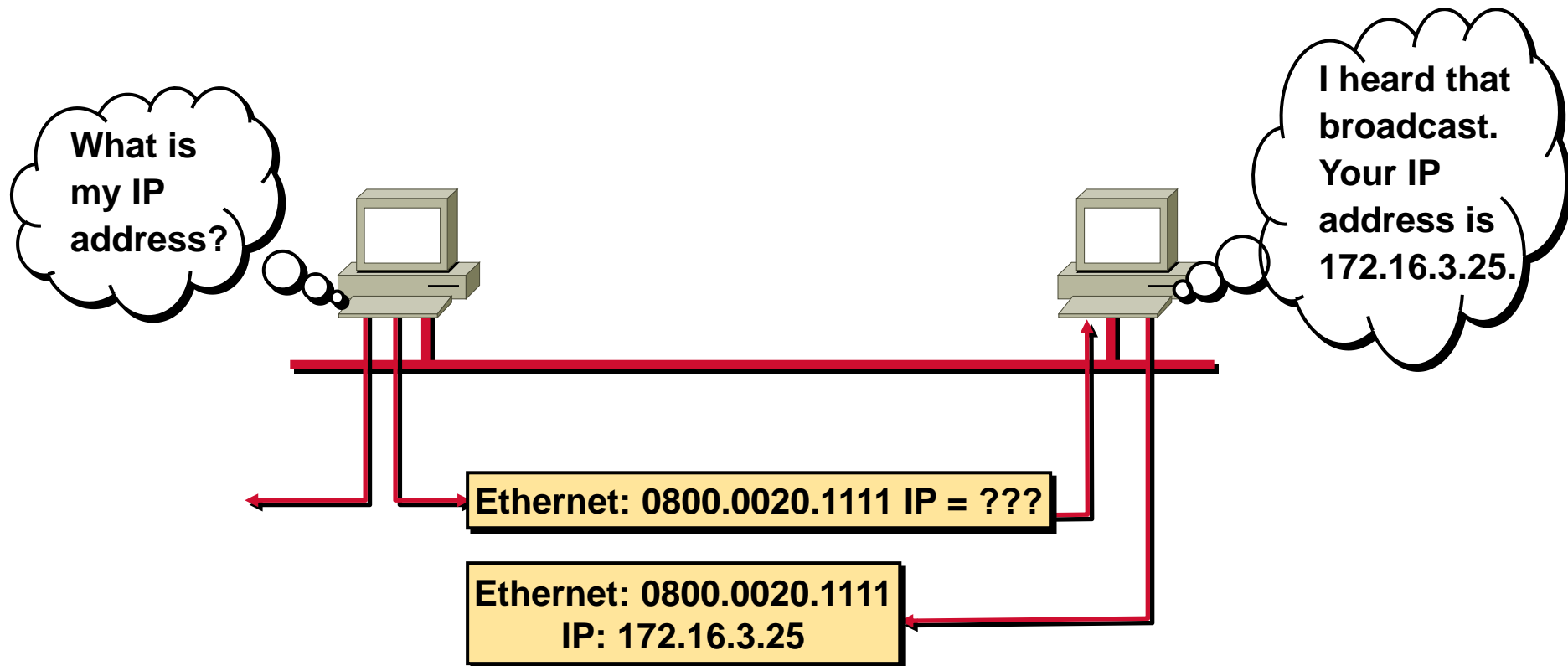
Reverse ARP



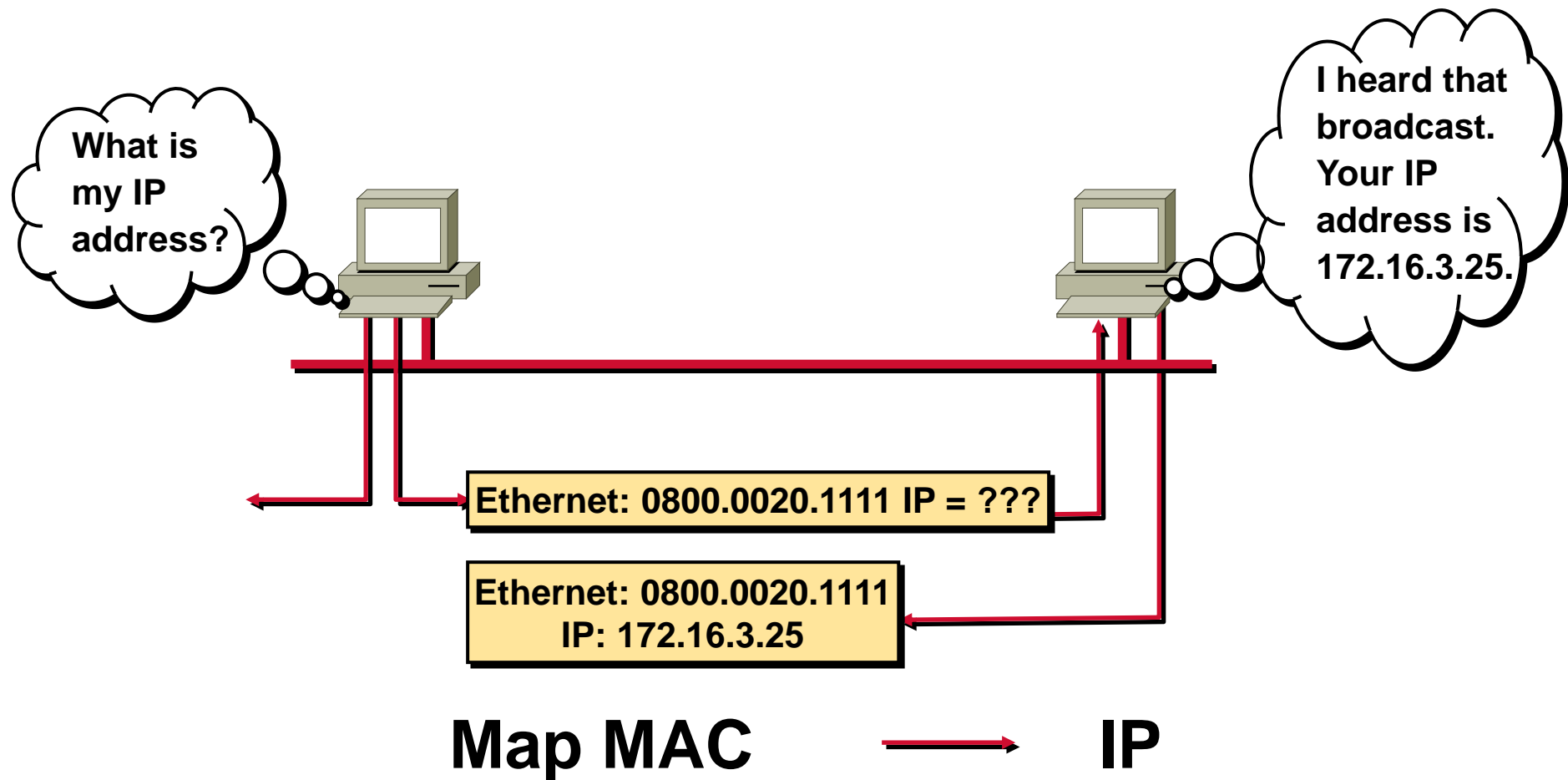
Reverse ARP



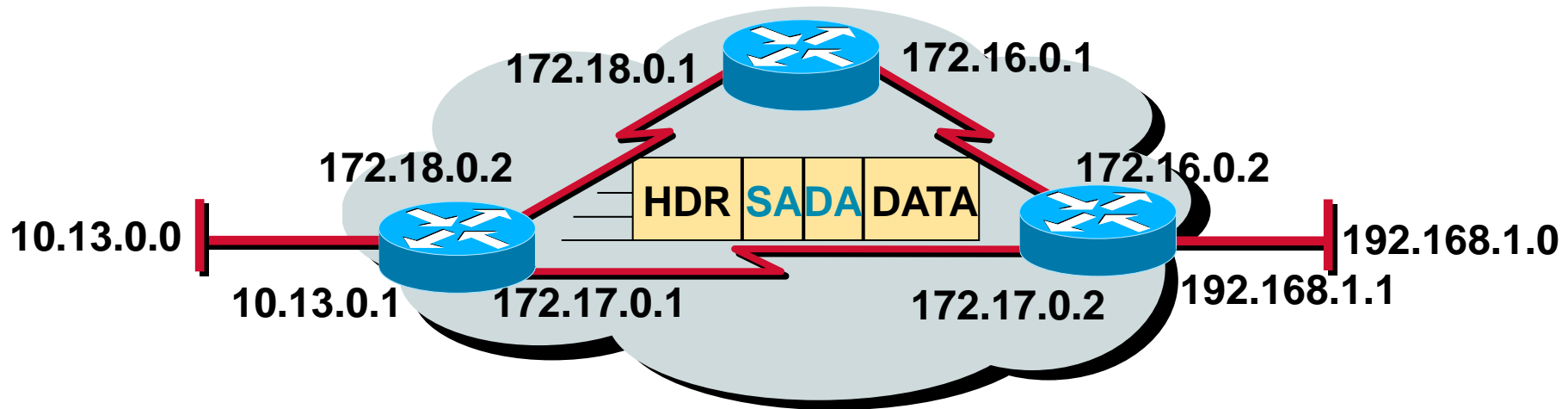
Reverse ARP



Reverse ARP

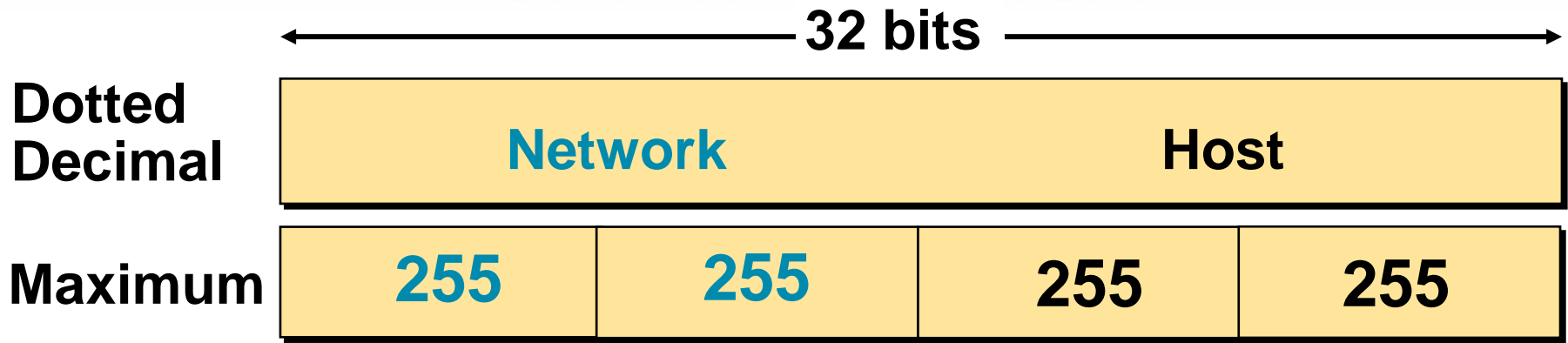


Introduction to TCP/IP Addresses

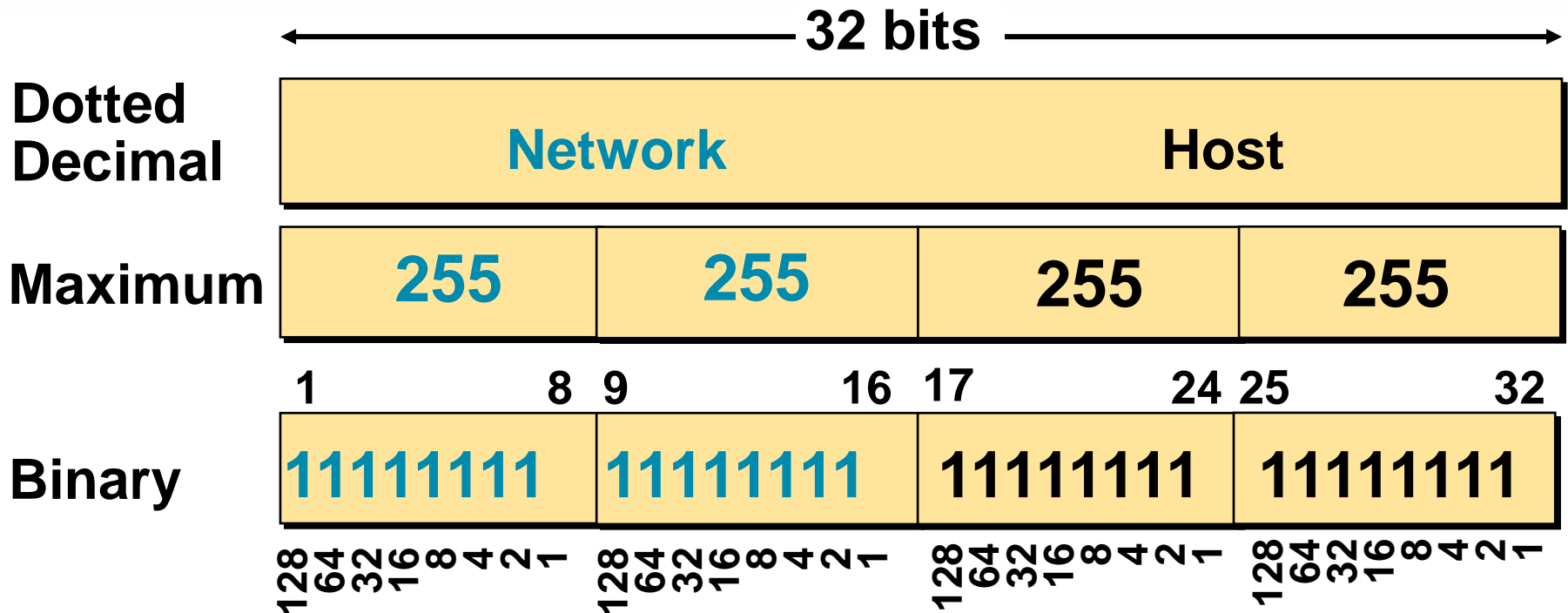


- Unique addressing allows communication between end stations
- Path choice is based on destination address

IP Addressing



IP Addressing



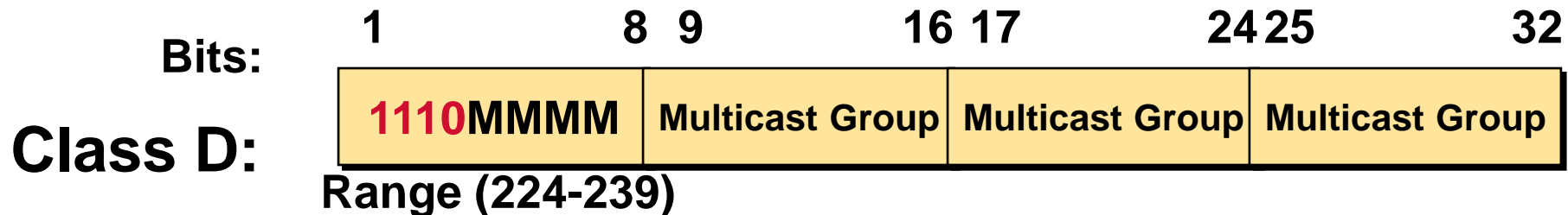
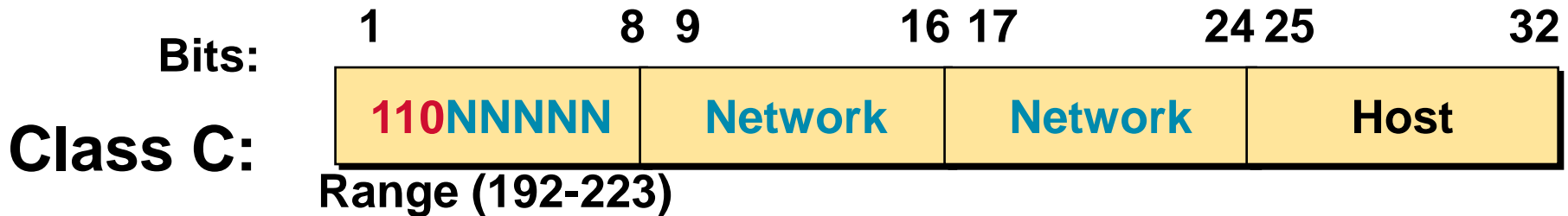
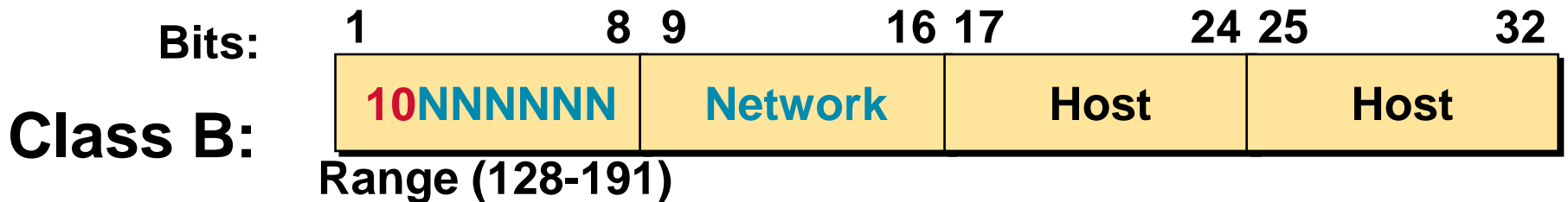
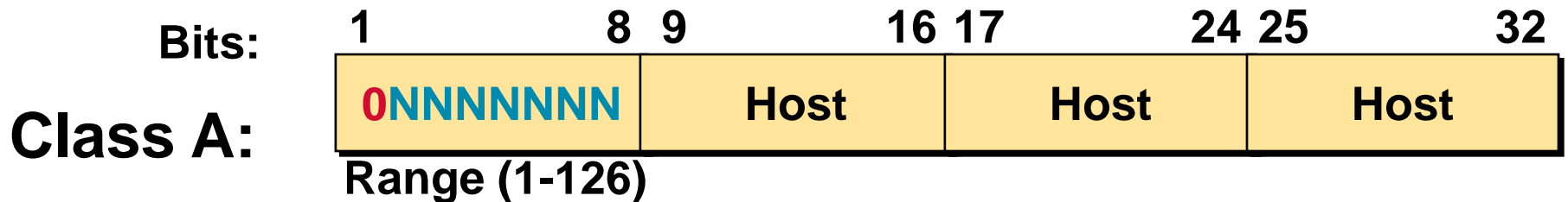
IP Addressing

	← 32 bits →															
Dotted Decimal	Network								Host							
Maximum	255				255				255				255			
	1		8		9		16		17		24		25		32	
Binary	11111111				11111111				11111111				11111111			
	128	64	32	16	8	4	2	1	128	64	32	16	8	4	2	1
Example Decimal	172				16				122				204			
Example Binary	10101100				00010000				01111010				11001100			

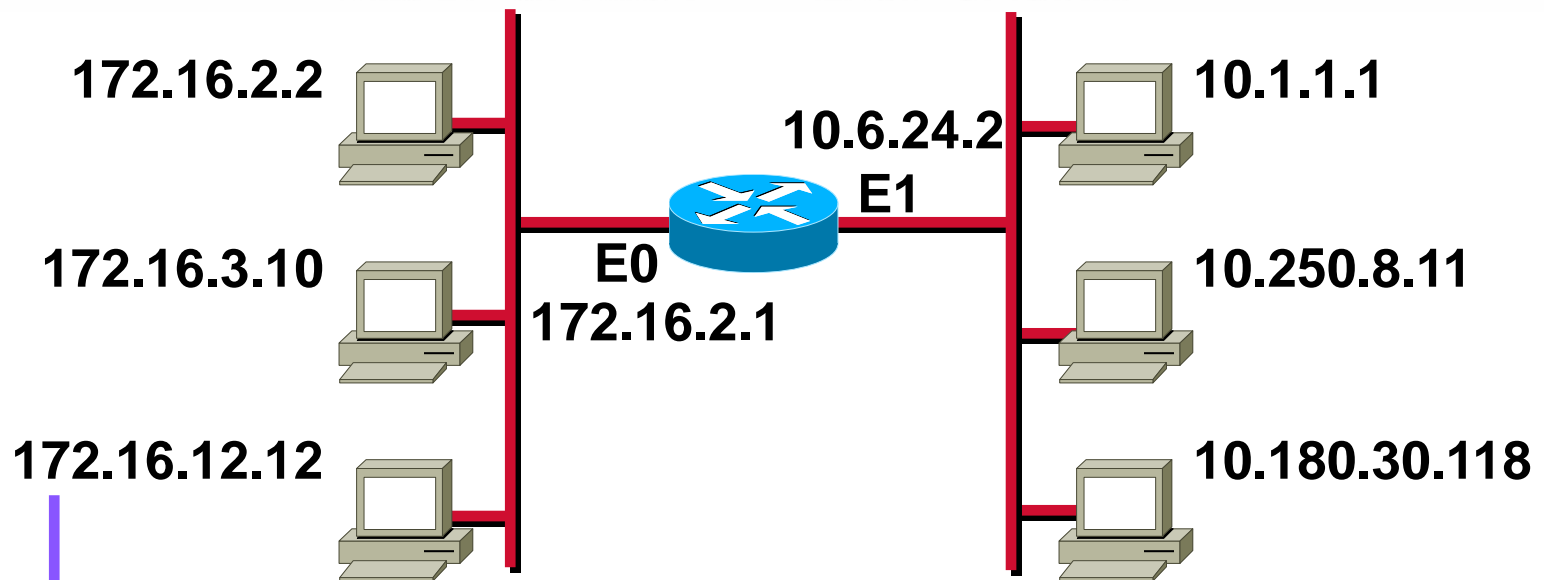
IP Address Classes

	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



172.16 . 12 . 12
Network Host

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 1 N

00000000 00000000
00000000 00000001
00000000 00000011

⋮
11111111 11111101
11111111 11111110
11111111 11111111

1
2
3

⋮
65534
65535

65536
- 2

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

$$\frac{65536}{2} = 32768$$

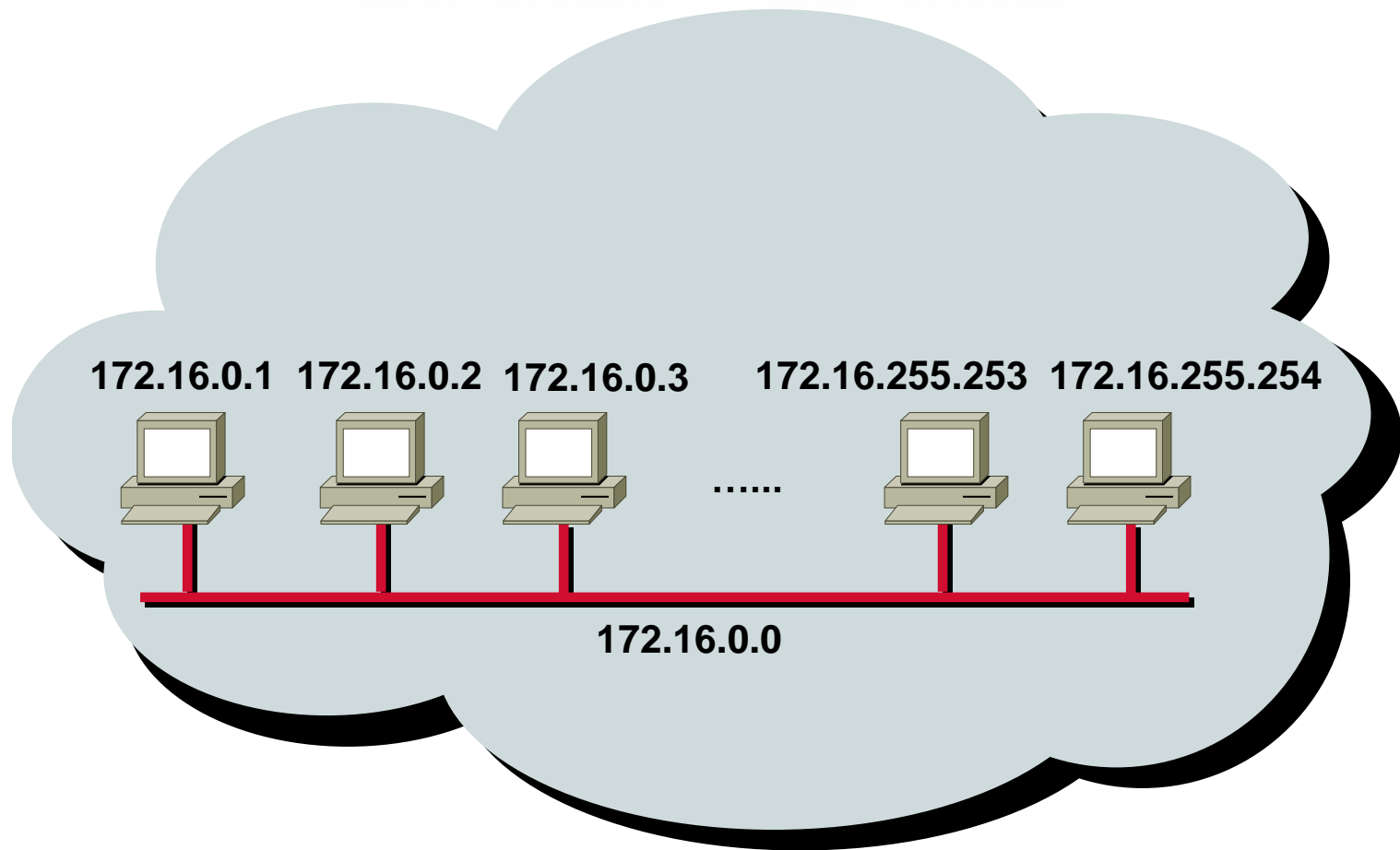
IP Address Classes Exercise

Address	Class	Network	Host
10.2.1.1			
128.63.2.100			
201.222.5.64			
192.6.141.2			
130.113.64.16			
256.241.201.10			

IP Address Classes Exercise Answers

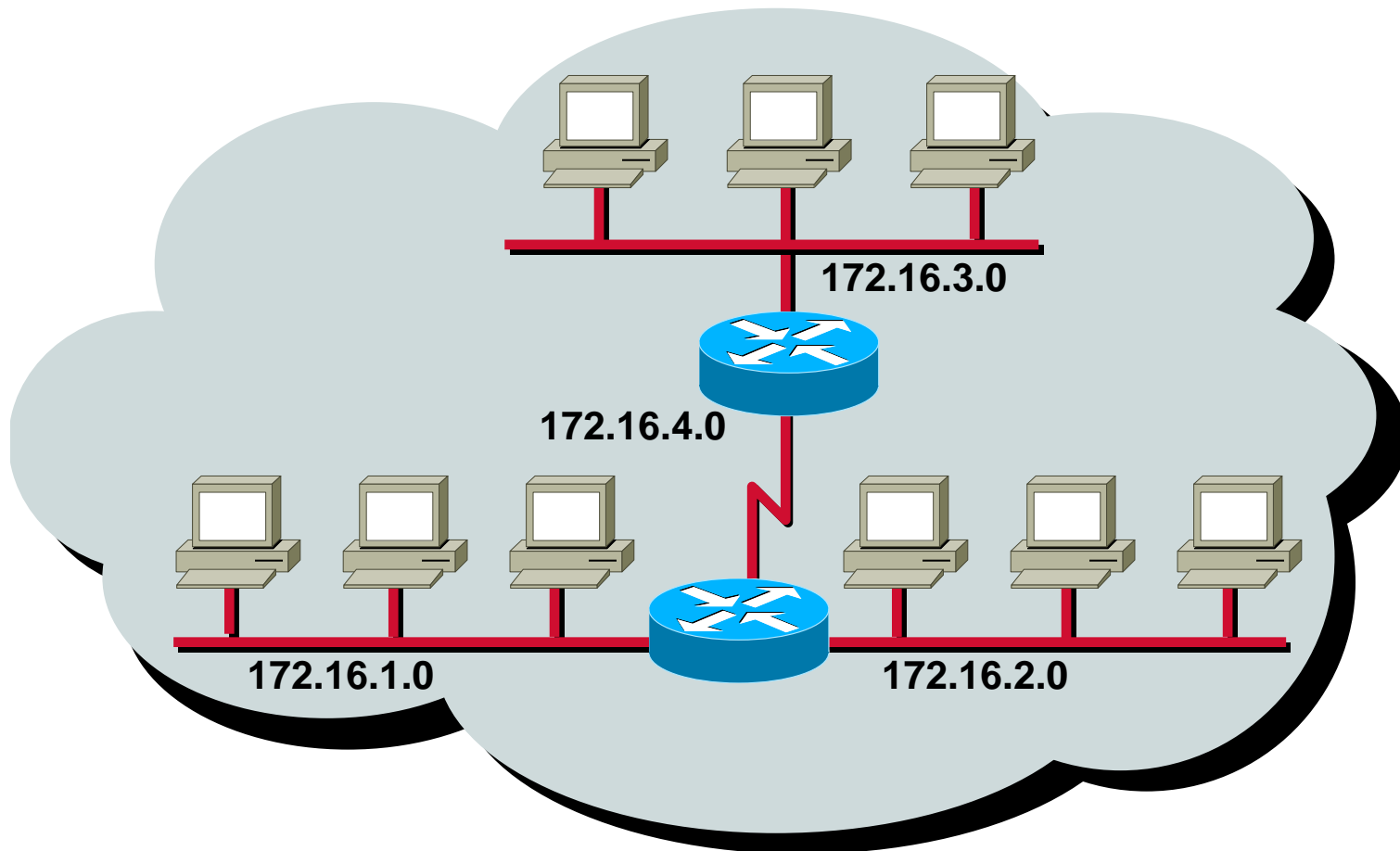
Address	Class	Network	Host
10.2.1.1	A	10.0.0.0	0.2.1.1
128.63.2.100	B	128.63.0.0	0.0.2.100
201.222.5.64	C	201.222.5.0	0.0.0.64
192.6.141.2	C	192.6.141.0	0.0.0.2
130.113.64.16	B	130.113.0.0	0.0.64.16
256.241.201.10	Nonexistent		

Addressing without Subnets



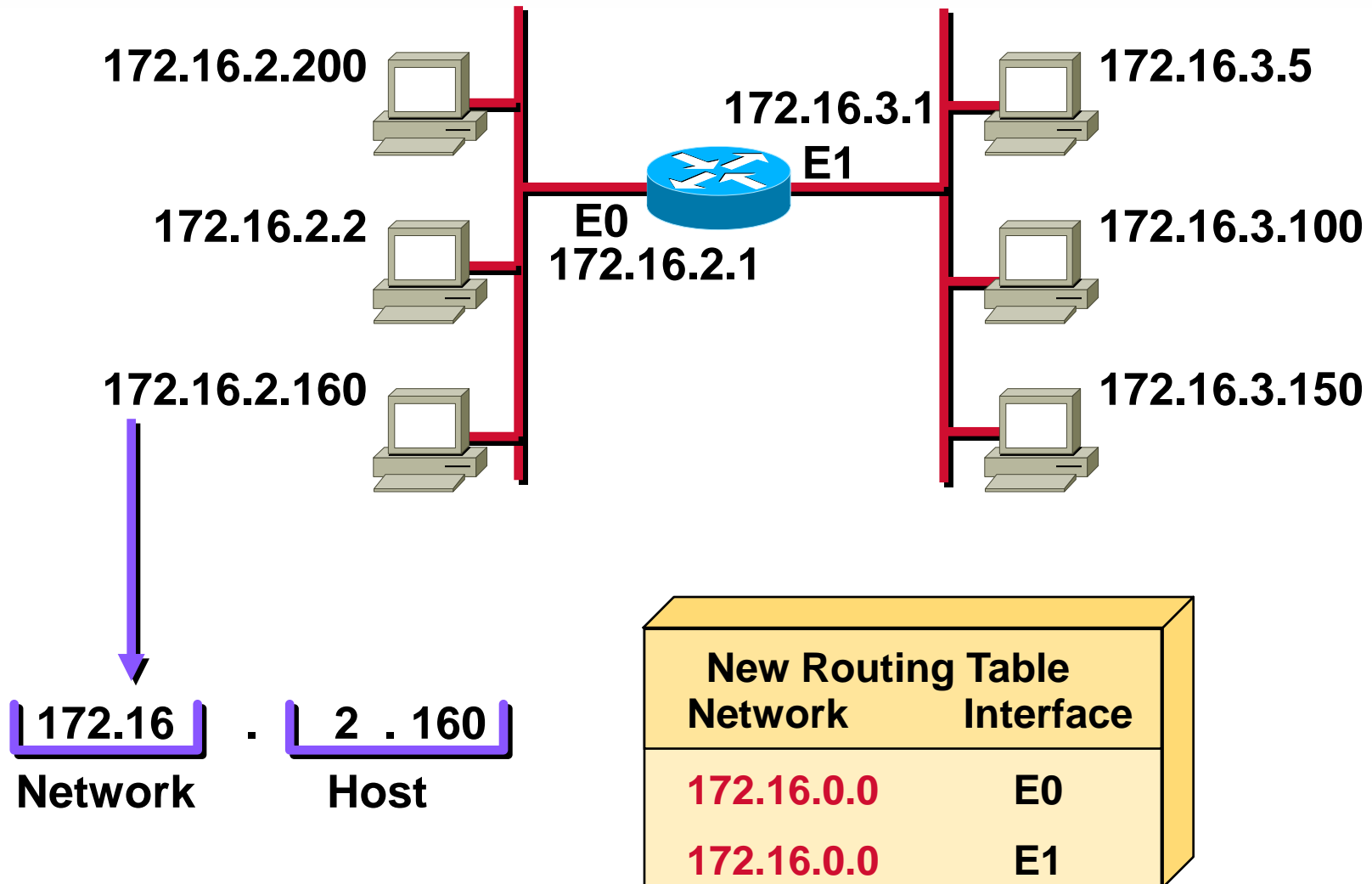
Network 172.16.0.0

Addressing with Subnets

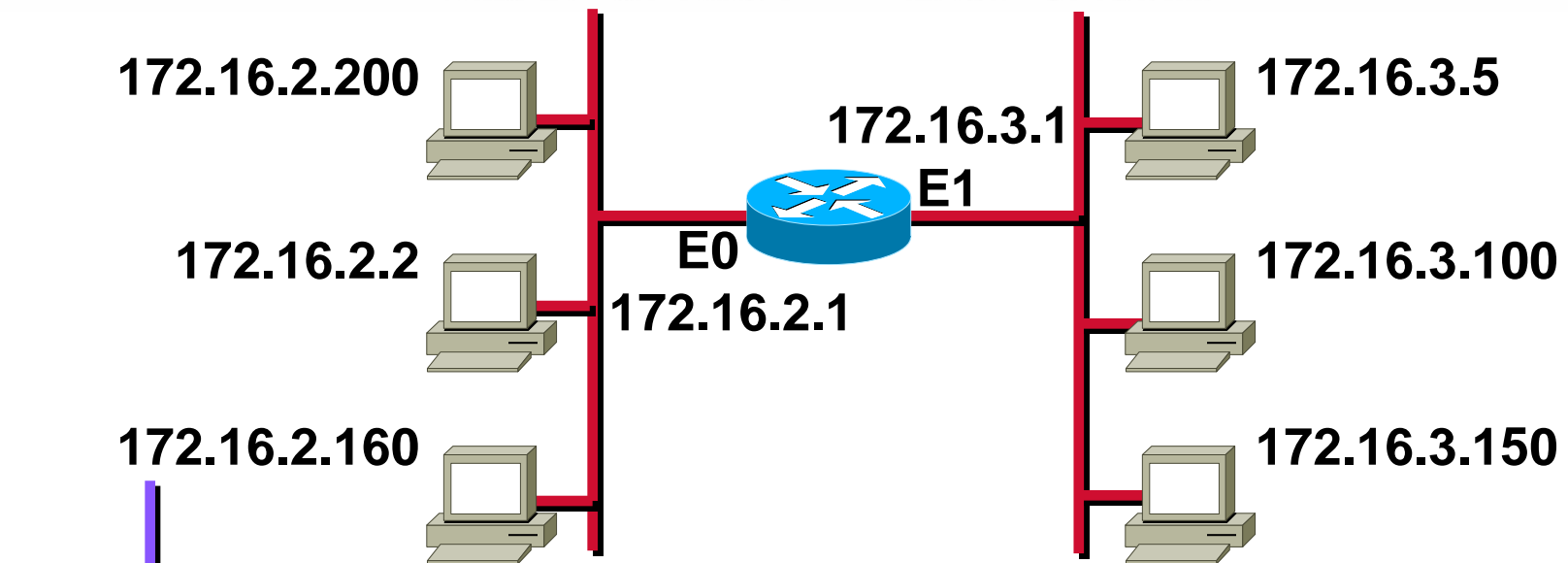


Network 172.16.0.0

Subnet Addressing



Subnet Addressing



172.16 . 2 . 160
Network Subnet Host

Network	Interface
172.16.2.0	E0
172.16.3.0	E1

Subnet Mask

IP
Address

Network		Host	
172	16	0	0

Default
Subnet
Mask

Network		Host	
255 11111111	255 11111111	0 00000000	0 00000000

Also written as “/16” where 16 represents the number of 1s in the mask.

8-bit
Subnet
Mask

Network		Subnet	Host
255	255	255	0

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	
↓	↓	↓	↓	↓	↓	↓	↓	
0	0	0	0	0	0	0	0	= 0
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		Subnet	Host
172.16.2.160	10101100	00010000	00000010	10100000
255.255.255.192	11111111	11111111	11111111	11000000
	10101100	00010000	00000010	10000000
			128 192 224 240 248 252 254 255	128 192 224 240 248 252 254 255
Network Number	172	16	2	128

Network number extended by ten bits

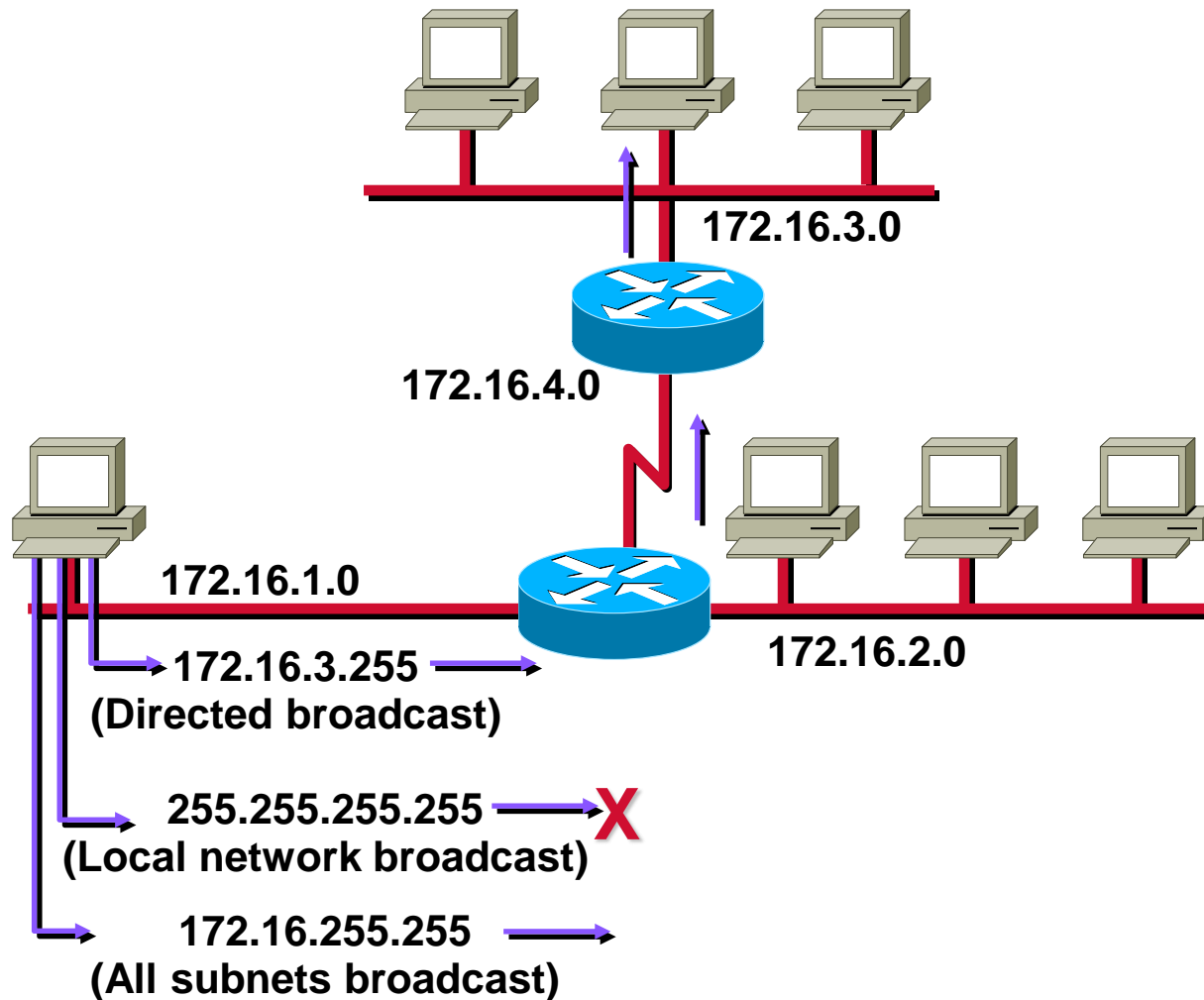
Subnet Mask Exercise

Address	Subnet Mask	Class	Subnet
172.16.2.10	255.255.255.0		
10.6.24.20	255.255.240.0		
10.30.36.12	255.255.255.0		

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
-----	----	---	-----

172.16.2.160

10101100 00010000 00000010 10100000 Host **1**

255.255.255.192

Mask

Subnet

Broadcast

First

Last

Addressing Summary Example

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

172.16.2.160	10101100	00010000	00000010	10100000	Host	1
255.255.255.192	11111111	11111111	11111111	11000000	Mask	2
					Subnet	
					Broadcast	
					First	
					Last	

Addressing Summary Example

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

				3	
172.16.2.160	10101100	00010000	00000010	10100000	Host 1
255.255.255.192	11111111	11111111	11111111	11000000	Mask 2
					Subnet
					Broadcast
					First
					Last

Addressing Summary Example

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

				3	
172.16.2.160	10101100	00010000	00000010	10100000	Host 1
255.255.255.192	11111111	11111111	11111111	11000000	Mask 2
				10000000	Subnet 4
					Broadcast
					First
					Last

Addressing Summary Example

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

				3	
172.16.2.160	10101100	00010000	00000010	10100000	Host 1
255.255.255.192	11111111	11111111	11111111	11000000	Mask 2
				10000000	Subnet 4
				10111111	Broadcast
				5	First
					Last

Addressing Summary Example

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

				3	
172.16.2.160	10101100	00010000	00000010	10100000	Host 1
255.255.255.192	11111111	11111111	11111111	11000000	Mask 2
				10000000	Subnet 4
				10111111	Broadcast
				5	
				10000001	First 6
					Last

Addressing Summary Example

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

						3	
172.16.2.160	10101100	00010000	00000010	10100000	Host	1	
255.255.255.192	11111111	11111111	11111111	11000000	Mask	2	
				10000000	Subnet	4	
				10111111	Broadcast		
				10000001	First	5	6
				10111110	Last		7

Addressing Summary Example

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

						3	
172.16.2.160	10101100	00010000	00000010	10100000	Host	1	
255.255.255.192	11111111	11111111	11111111	11000000	Mask	2	
8							
	10101100	00010000	00000010	10000000	Subnet	4	
	10101100	00010000	00000010	10111111	Broadcast		
					5		
	10101100	00010000	00000010	10000001	First	6	
	10101100	00010000	00000010	10111110	Last	7	

Addressing Summary Example

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

						3	
172.16.2.160	10101100	00010000	00000010	10100000	Host	1	
255.255.255.192	11111111	11111111	11111111	11000000	Mask	2	
9	8						
172.16.2.128	10101100	00010000	00000010	10000000	Subnet	4	
172.16.2.191	10101100	00010000	00000010	10111111	Broadcast		
						5	
172.16.2.129	10101100	00010000	00000010	10000001	First	6	
172.16.2.190	10101100	00010000	00000010	10111110	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

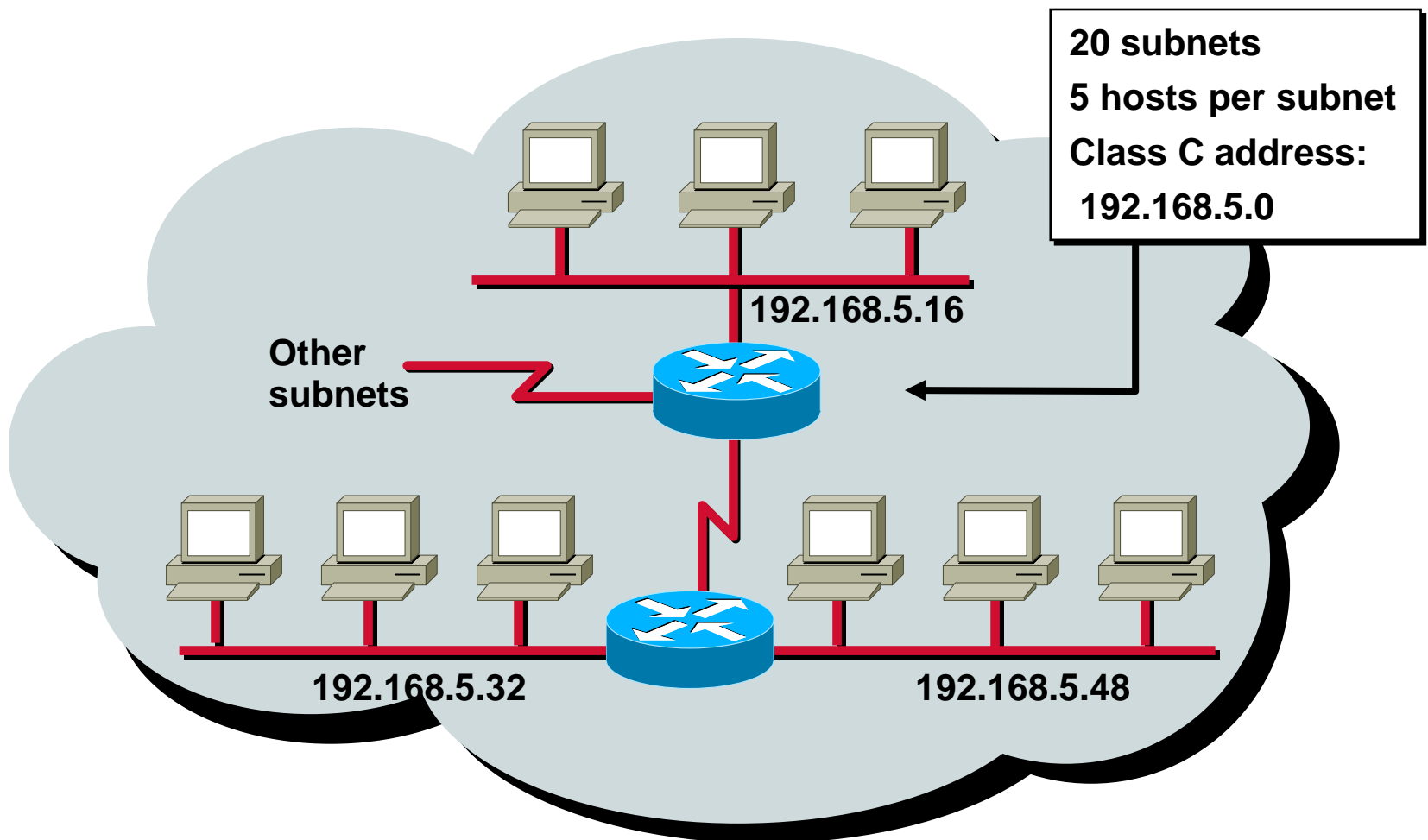
Subnet Address = 172.16.2.0

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

Address	Subnet Mask	Class	Subnet	Broadcast
201.222.10.60	255.255.255.248			
15.16.193.6	255.255.248.0			
128.16.32.13	255.255.255.252			
153.50.6.27	255.255.255.128			

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

Switch IP Address Configuration

```
Switch(config)#ip address ip-address subnet-mask
```

- Assigns an address and subnet mask
- Starts IP processing on a switch

```
Switch(config)#ip default-gateway ip-address
```

- Specifies a default gateway

Router IP Address Configuration

```
Router(config-if)#ip address ip-address subnet-mask
```

- Assigns an address and subnet mask
- Starts IP processing on a router interface

Router IP Address Configuration

```
Router#term ip netmask-format {bitcount|  
decimal | hexadecimal}
```

- **Sets display format of network mask for current session**

```
Router(config-line)#ip netmask-format  
{bitcount | decimal | hexadecimal}
```

- **Sets format of network mask for a specific line**

Router IP Host Names

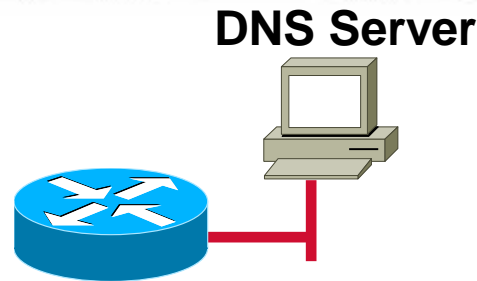
```
Router(config)#ip host name [tcp-port-number]  
address [address]
```

- **Defines static host name to IP address mapping**

```
ip host Norine 172.16.3.1 192.168.3.1  
ip host Roger 172.16.4.3
```

- **Hosts/interfaces selectable by name or IP address**

Router Name Server Configuration



```
Router(config)#ip name-server server-address1  
[ [server-address2] ... [server-address6] ]
```

- Specifies one or more hosts that supply host name to logical address resolution

Router Name System

```
Router(config)#ip domain-lookup
Router(config)#end
Router#pat
Translating "pat"...domain server (255.255.255.255)
% Unknown command or computer name, or unable to find computer address
Router#config t
Router(config)#no ip domain-lookup
Router(config)#end
Router#pat
Translating "pat"
% Unknown command or computer name, or unable to find computer address
Router#
```

- **DNS enabled by default**

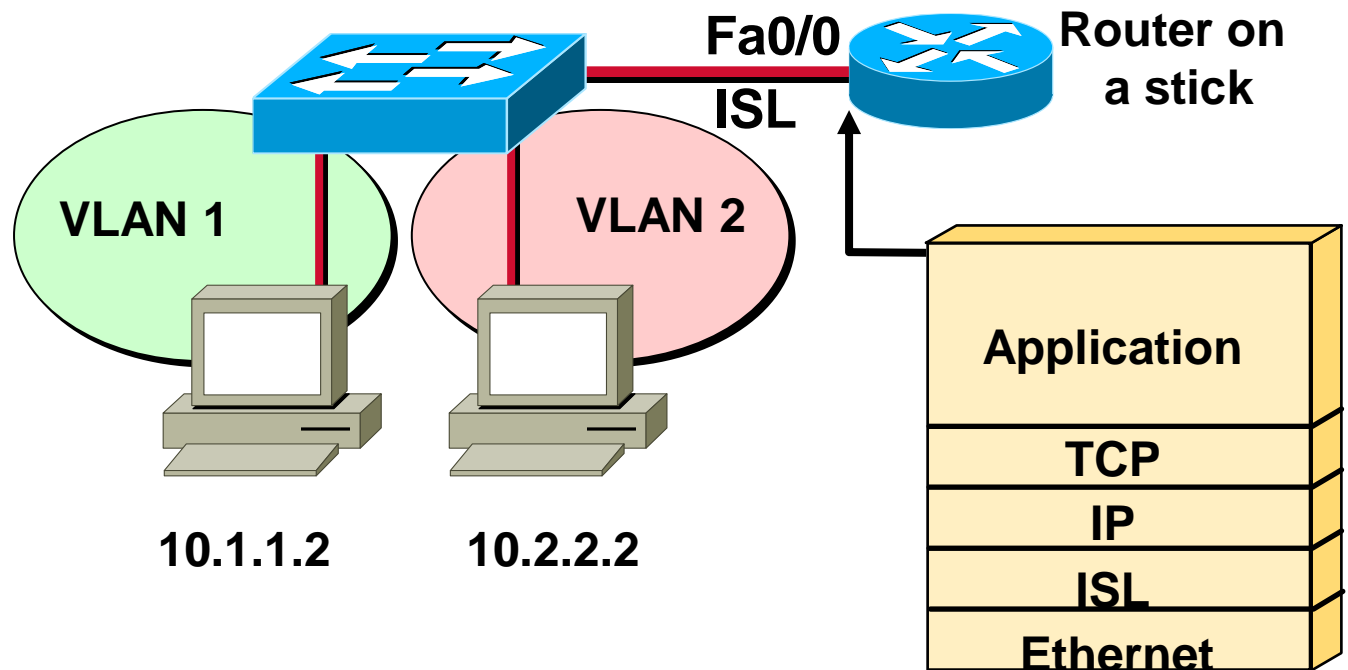
Router Display Host Names

```
Router#show hosts
Default domain is not set
Name/address lookup uses domain service
Name servers are 255.255.255.255
```

Host	Flags	Age	Type	Address(es)
Norine	(perm, OK)	0	IP	172.16.100.100
Roger	(perm, OK)	0	IP	172.16.100.101
Frank	(perm, OK)	0	IP	172.16.200.200
Bob	(perm, OK)	0	IP	172.16.200.201

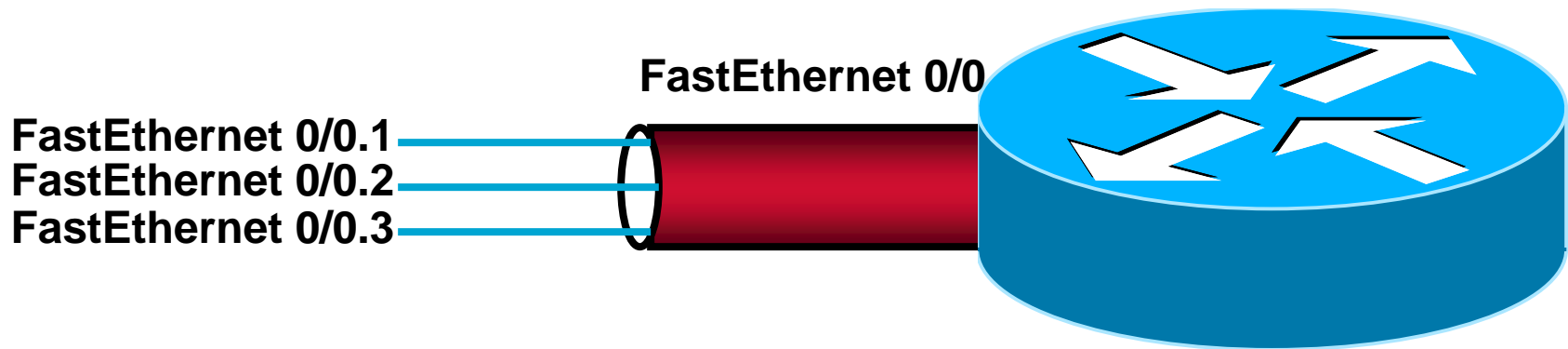
- Shows the host table

VLAN to VLAN Overview



Network layer devices combine multiple broadcast domains

Dividing a Physical Interface into Subinterfaces



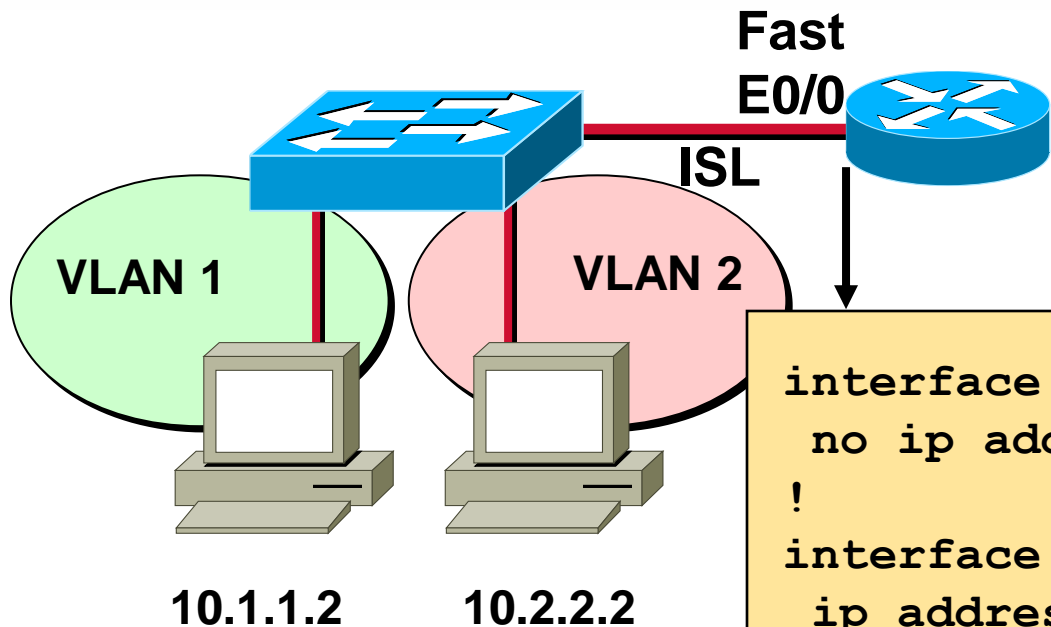
Physical interfaces can be divided into multiple subinterfaces

ISL Encapsulation

```
Router(config-subif)#encapsulation isl vlan identifier
```

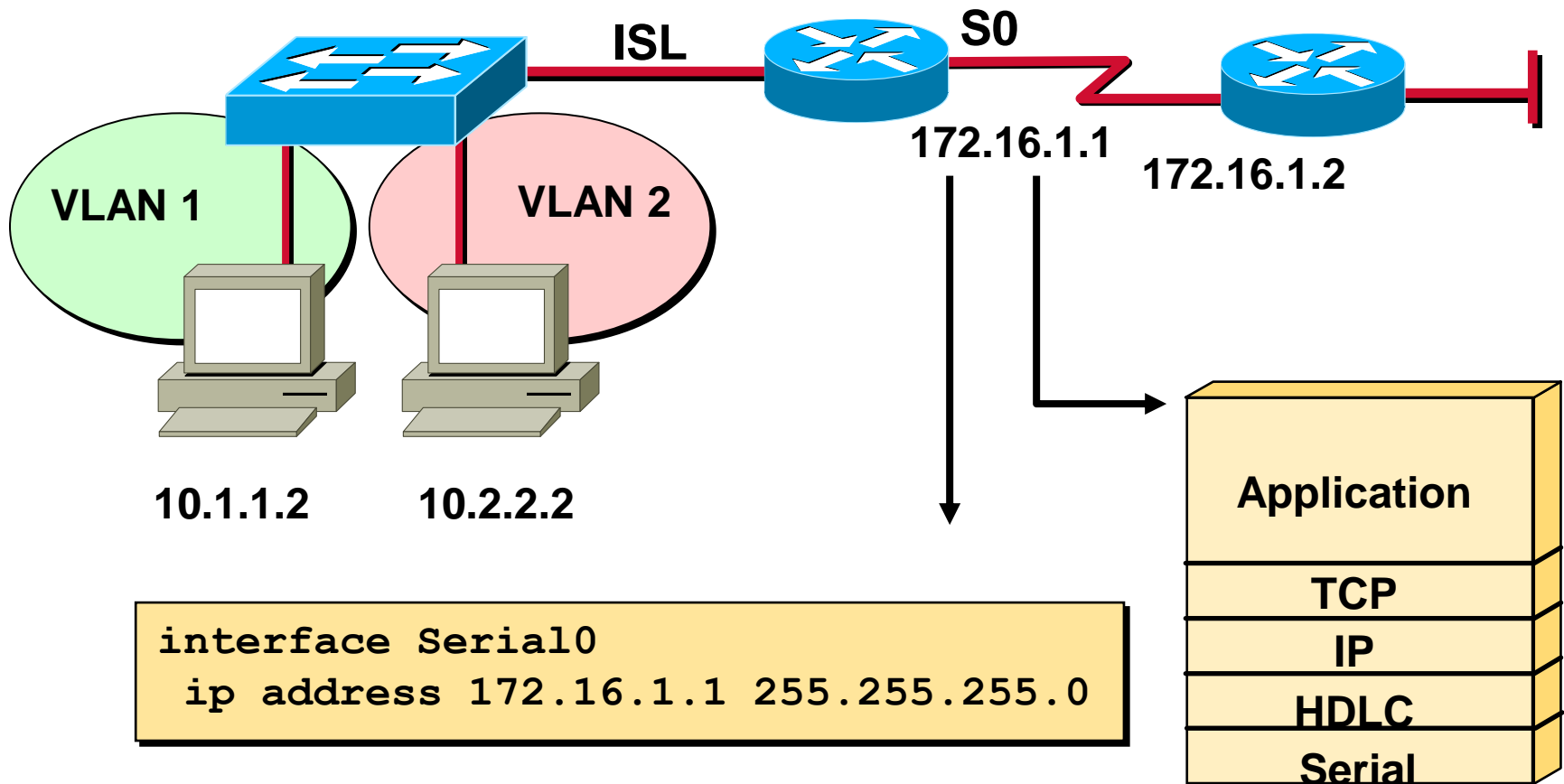
- **Enables ISL on a subinterface**

Routing Between VLANs



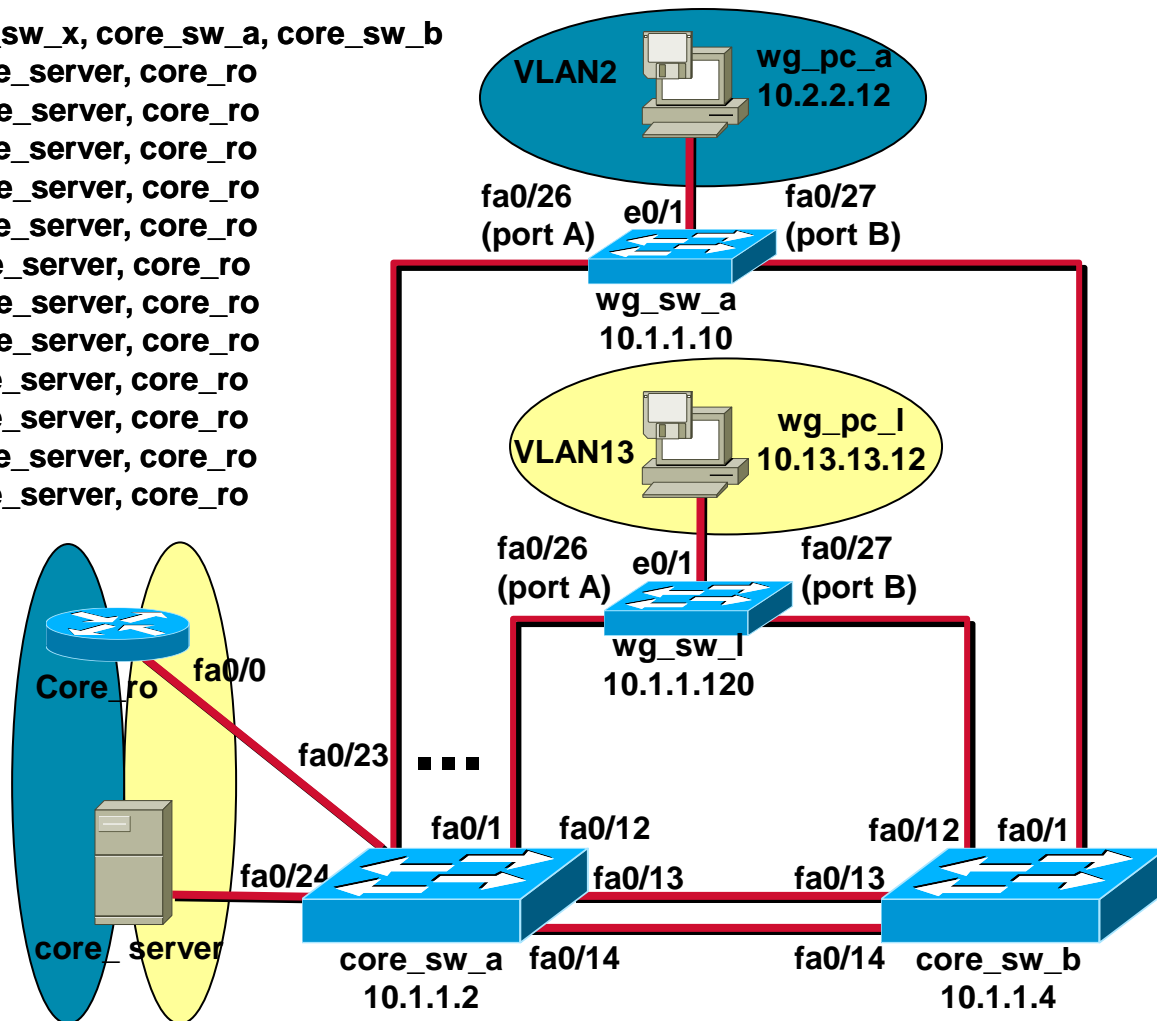
```
interface fastethernet 0/0
  no ip address
!
interface fastethernet 0/0.1
  ip address 10.1.1.1 255.255.255.0
  encapsulation isl 1
interface fastethernet 0/0.2
  ip address 10.2.2.1 255.255.255.0
  encapsulation isl 2
```

Routing Between WANs



Visual Objective

SUBNET	VLAN	POD
10.1.1.0	1	wg_ro_x, wg_sw_x, core_sw_a, core_sw_b
10.2.2.0	2	wg_pc_a, core_server, core_ro
10.3.3.0	3	wg_pc_b, core_server, core_ro
10.4.4.0	4	wg_pc_c, core_server, core_ro
10.5.5.0	5	wg_pc_d, core_server, core_ro
10.6.6.0	6	wg_pc_e, core_server, core_ro
10.7.7.0	7	wg_pc_f, core_server, core_ro
10.8.8.0	8	wg_pc_g, core_server, core_ro
10.9.9.0	9	wg_pc_h, core_server, core_ro
10.10.10.0	10	wg_pc_i, core_server, core_ro
10.11.11.0	11	wg_pc_j, core_server, core_ro
10.12.12.0	12	wg_pc_k, core_server, core_ro
10.13.13.0	13	wg_pc_l, core_server, core_ro



Summary

After completing this chapter, you should be able to perform the following tasks:

- **Identify the TCP/IP protocol stack and the functions of each layer**
- **Separate an IP address into its subcomponents: the network, subnet, and host portions**
- **Configure IP addresses on Cisco router and switch interfaces**
- **Interconnect VLANs using a layer three device such as a “router on a stick”**

Review Questions

- 1. What is the difference between the TCP and UDP transport layer protocols?**
- 2. Given a host with IP address, 192.168.20.1/24, how many other hosts can you have in that network?**
- 3. What is required to interconnect separate VLANs?**