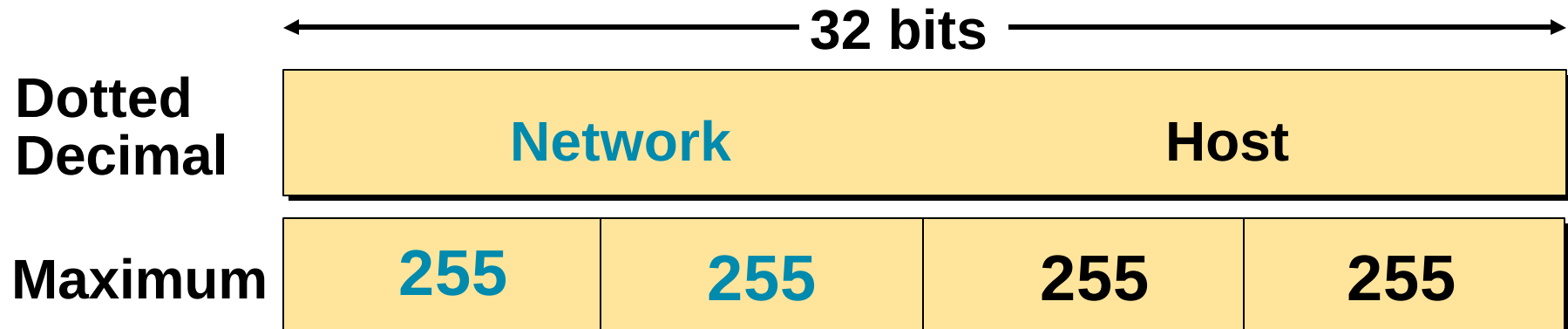


A man in a white shirt and red tie is standing on a green hill, holding a large red cable that loops around a globe. The background is a yellow sky with a blue horizon. The text "IP Addresses" is written in large white letters across the middle of the image.

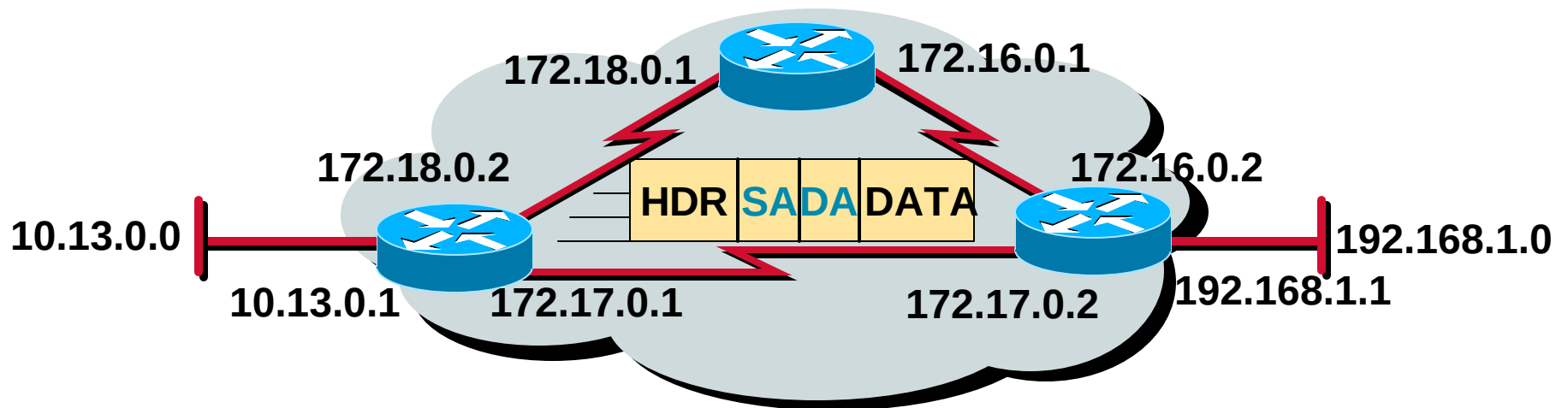
IP Addresses



IP Addressing

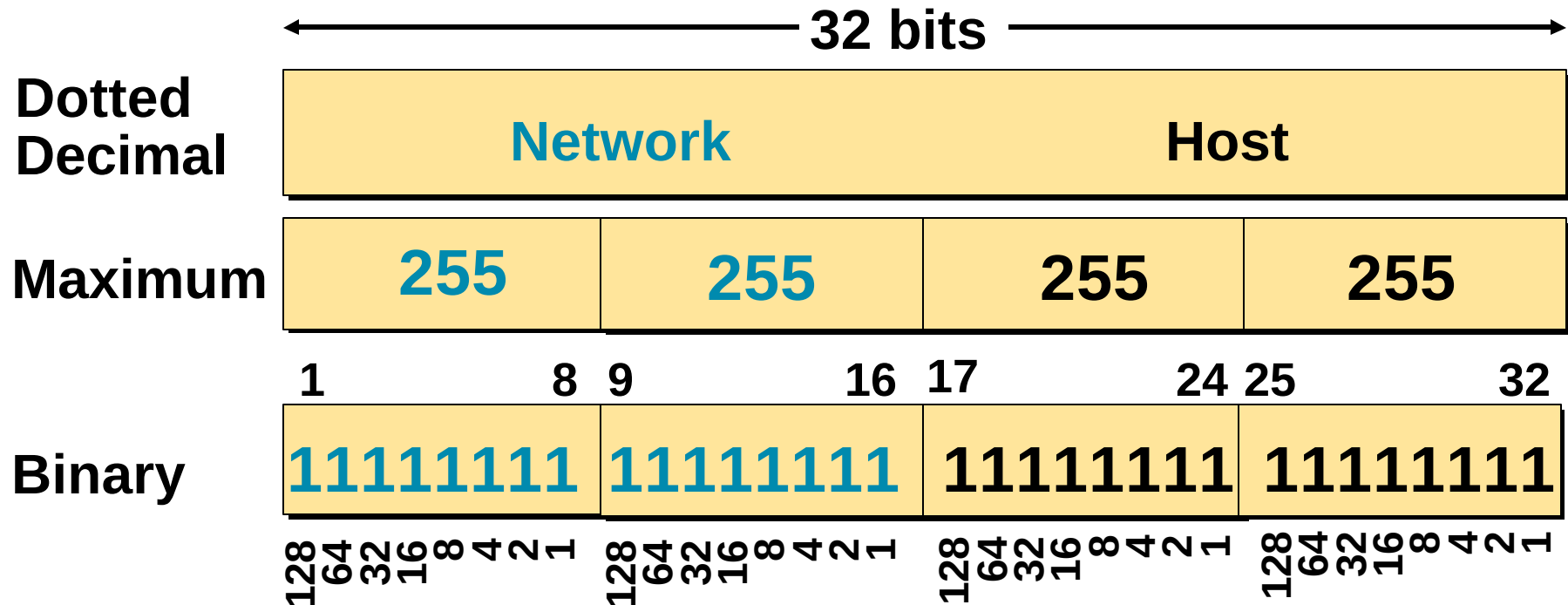


Introduction to IP Addresses



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

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

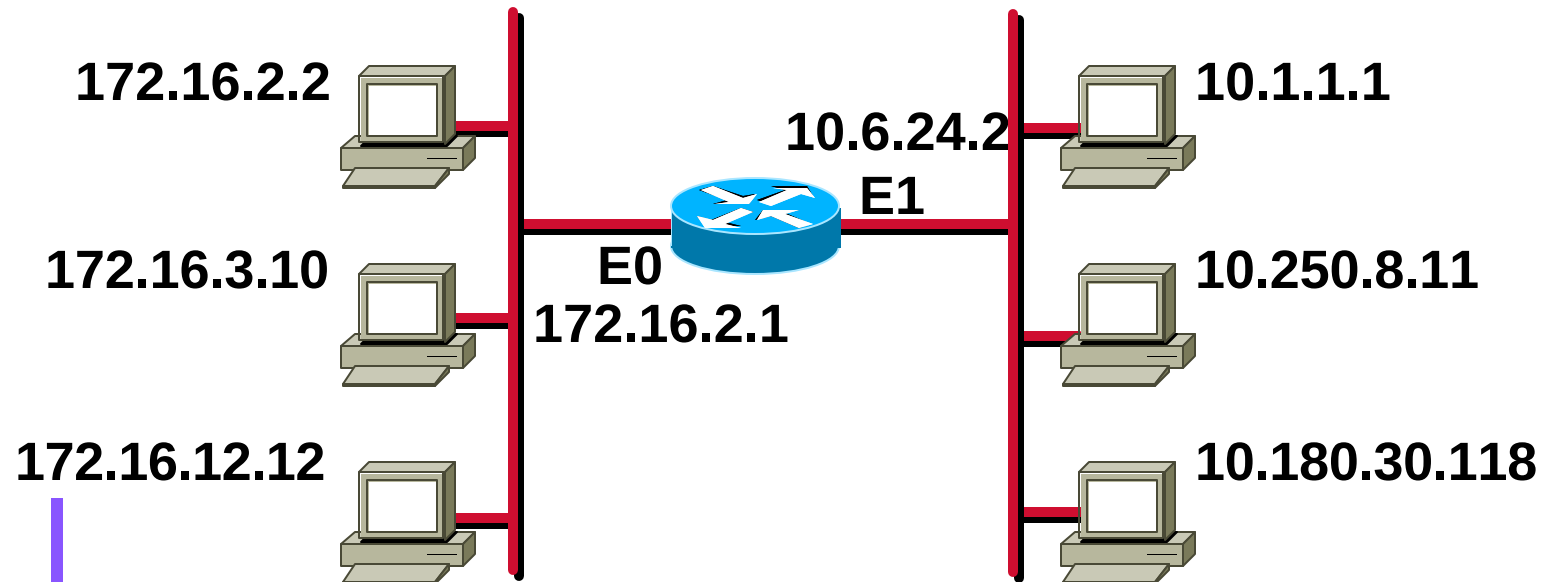
Bits:	1	8 9	16 17	24 25	32
Class A:	0NNNNNNNN	Host	Host	Host	
	Range (1-126)				

Bits:	1	8 9	16 17	24 25	32
Class B:	10NNNNNNN	Network	Host	Host	
	Range (128-191)				

Bits:	1	8 9	16 17	24 25	32
Class C:	110NNNNN	Network	Network	Host	
	Range (192-223)				

Bits:	1	8 9	16 17	24 25	32
Class D:	1110MMMM	Multicast Group	Multicast Group	Multicast Group	
	Range (224-239)				

Host Addresses



172.16.12.12

↓

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**

16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 N

10101100 00010000

00000000 00000000 1
 00000000 00000001 2
 00000000 00000011 3
 ...
 11111111 11111101 65534
 11111111 11111110 65535
 11111111 11111111 65536
 - 2

 65534

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

IP Address Classes Exercise

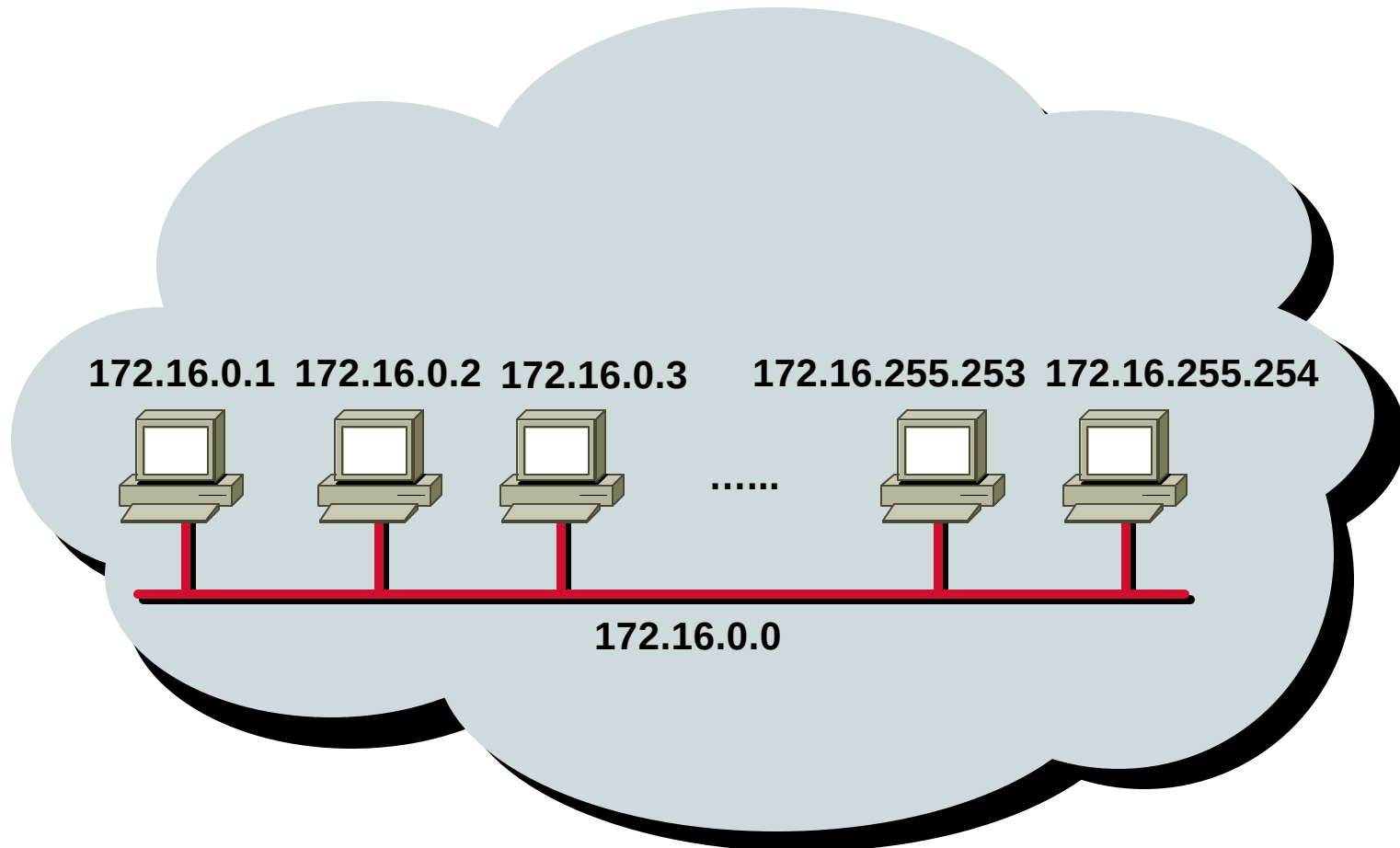
Address	Class	Network	Host
10.2.1.1			
128.63.2.100			
201.222.5.64			
192.6.141.2			
130.113.64.16			
256.241.201.10			

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		

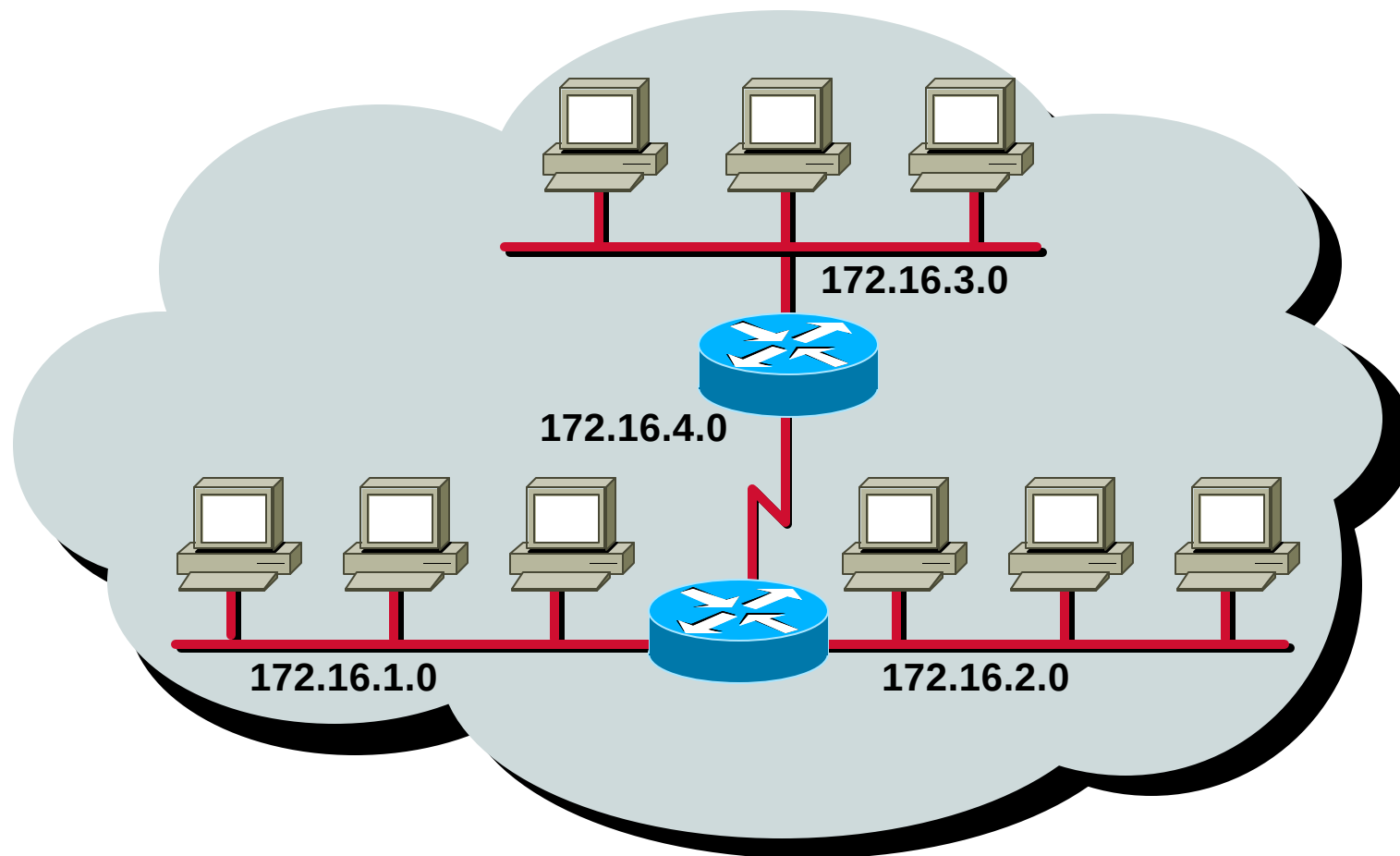
Addressing without Subnets



Network 172.16.0.0

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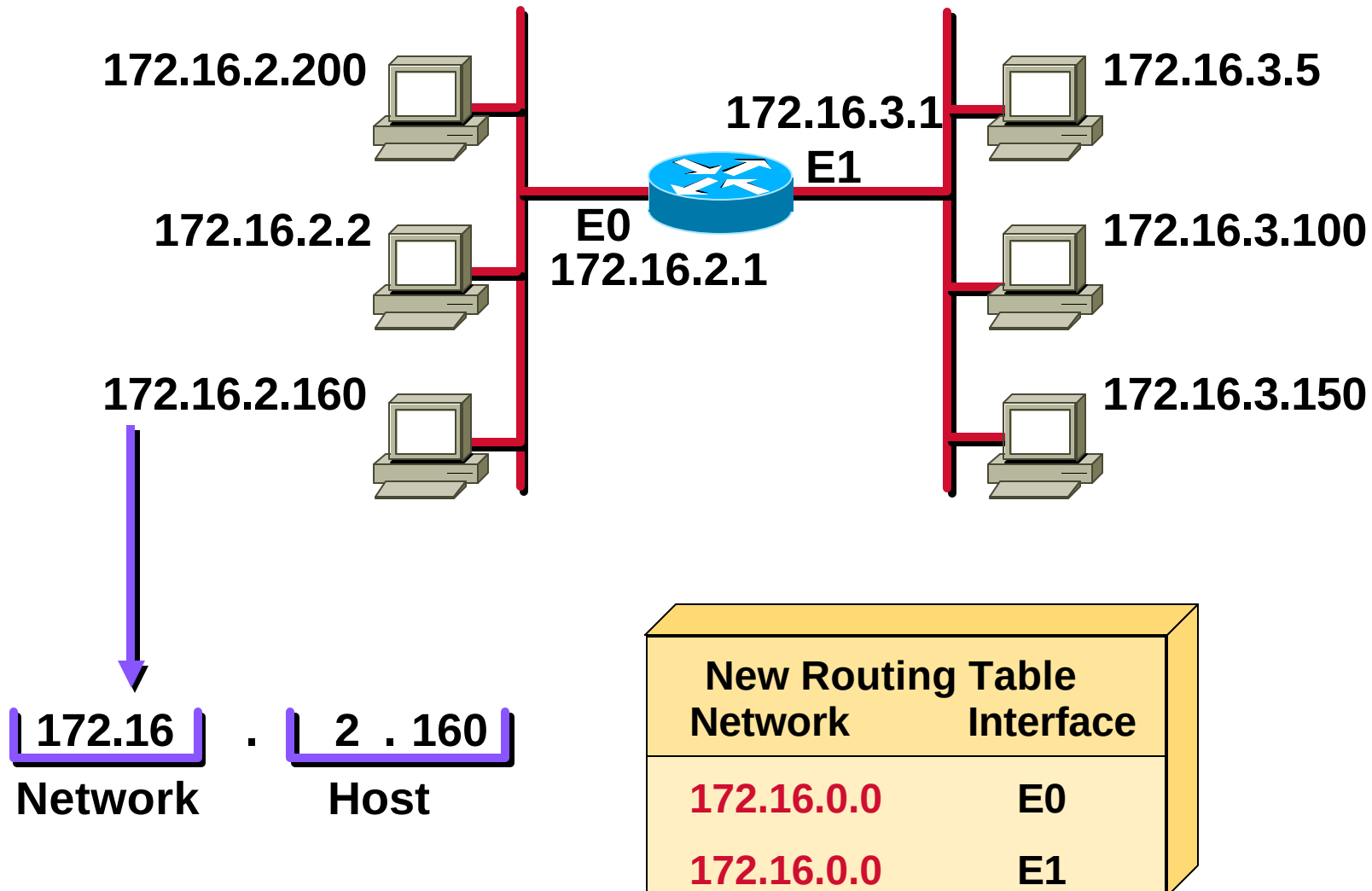
Addressing with Subnets



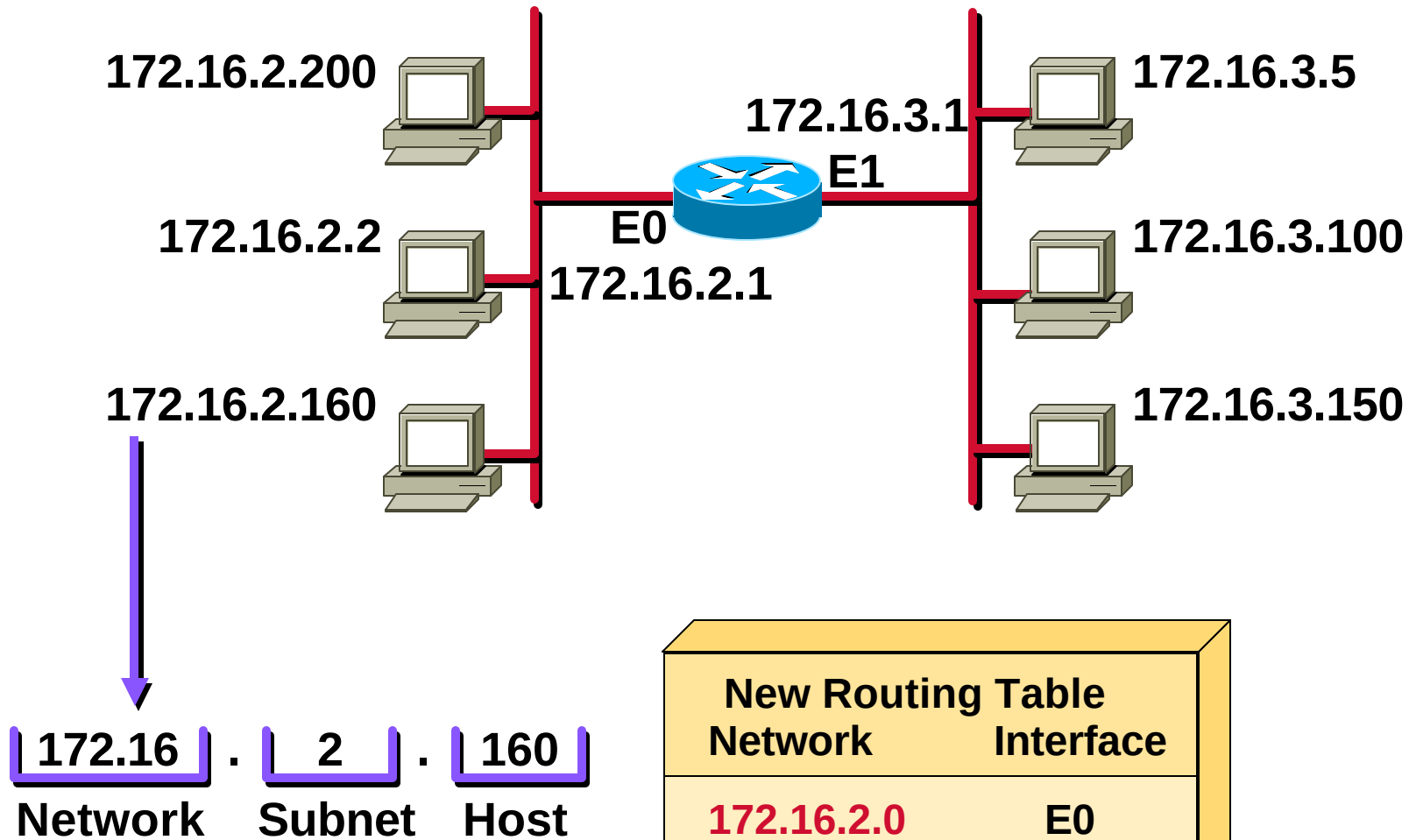
Network 172.16.0.0

Cisco.com

Subnet Addressing



Subnet Addressing



Network	Interface
172.16.2.0	E0
172.16.3.0	E1

Subnet Mask

	Network		Host	
IP Address	172	16	0	0

	Network		Host	
Default Subnet Mask	255 11111111	255 11111111	0 00000000	0 00000000

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

	Network		Subnet	Host
8-bit Subnet Mask	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

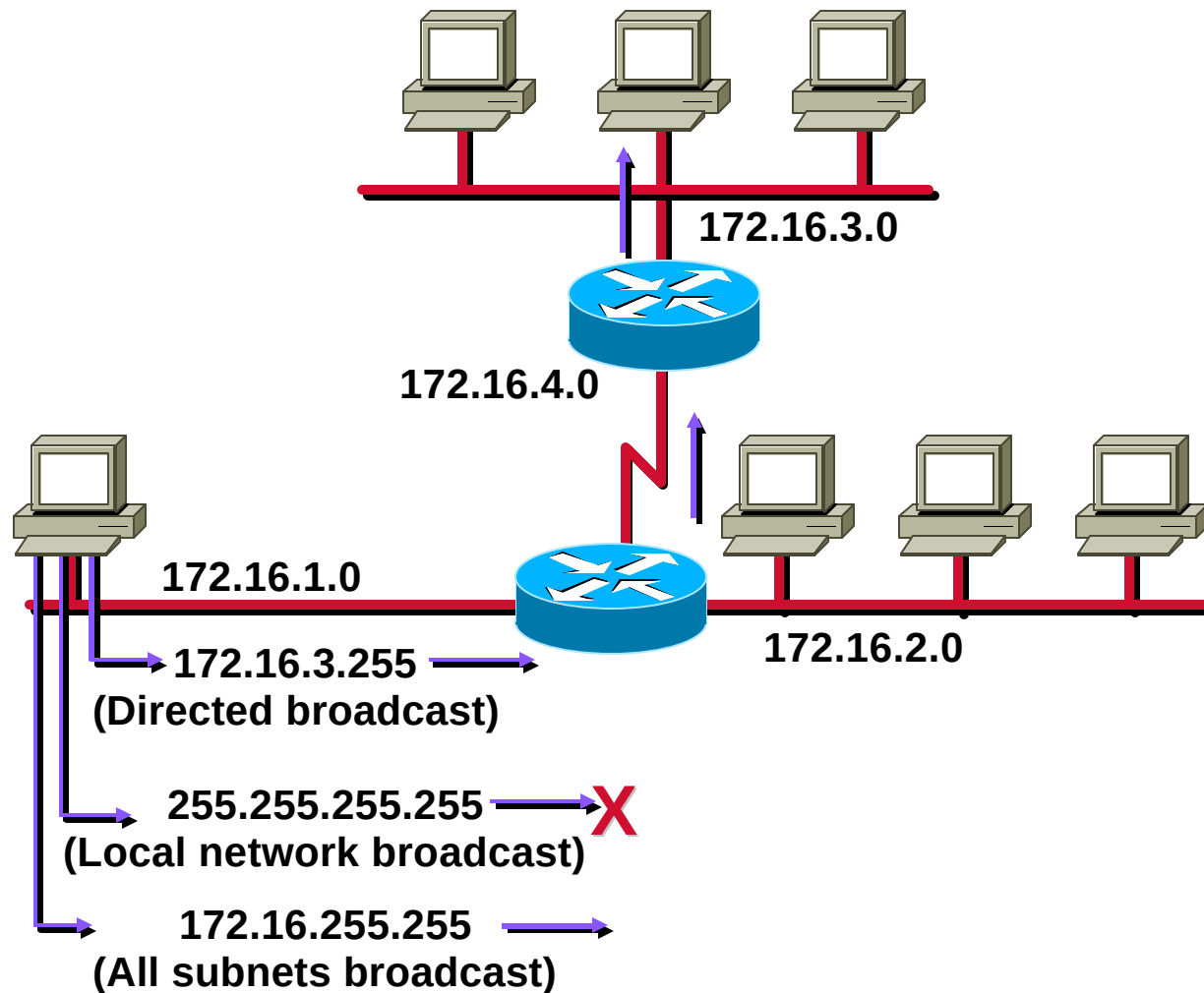
Subnet Mask Exercise

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

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	0000010	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	5	
				10000001	First	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

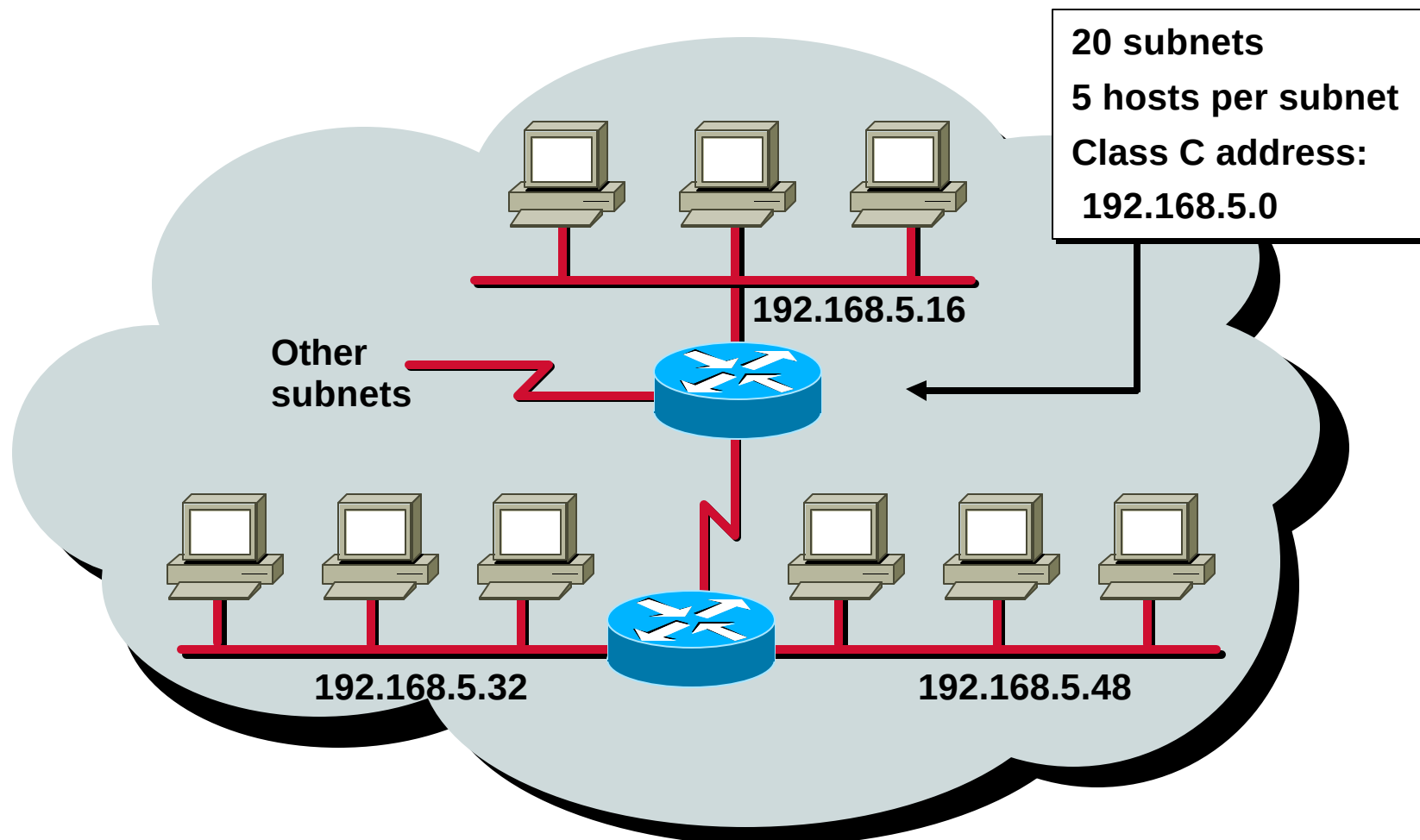
Host Addresses = 172.16.2.1–172.16.2.254

Broadcast Address = 172.16.2.255

Eight bits of subnetting

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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

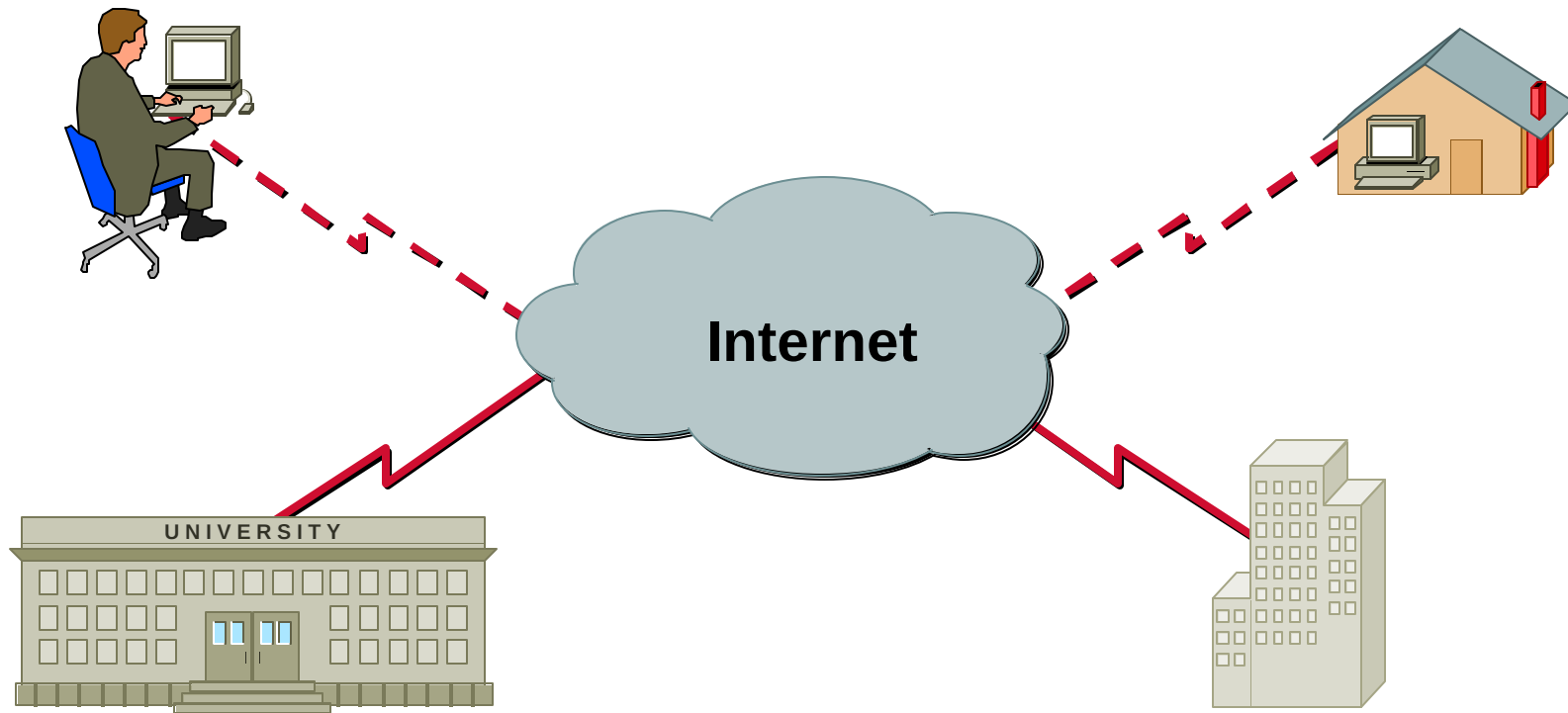
Address	Subnet Mask	Class	Subnet	Broadcast
201.222.10.60	255.255.255.248	C	201.222.10.56	201.222.10.63
15.16.193.6	255.255.248.0	A	15.16.192.0	15.16.199.255
128.16.32.13	255.255.255.252	B	128.16.32.12	128.16.32.15
153.50.6.27	255.255.255.128	B	153.50.6.0	153.50.6.127



Issues with IP Addressing

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Issues with IP Addressing



- IP address exhaustion
- Routing table growth

IP Addressing Solutions

- Subnet masking, RFCs 950, 1812
- Address allocation for private Internets, RFC 1918
- Network Address Translation, RFC 1631
- Hierarchical addressing
- Variable-length subnet masks, RFC 1812
- Route summarization, RFC 1518
- Classless interdomain routing, RFCs 1518, 1519, 2050

Subnetting Overview

- Moving the network boundary to the right creates additional subnetworks at the expense of fewer hosts on each segment
- The new mask will contain additional contiguous 1s indicating by how many bits the network portion has been extended
 - The formula 2^n , where n equals the number of extended bits, indicates the maximum number of subnets created

IP Address Classes

- **IP address and associated mask are represented in 32-bit dotted decimal**
 - **Other formats are commonly used**
- **Decimal value in the first octet determines the class of the address**
 - **001 - 126 = Class A**
 - **128 - 191 = Class B**
 - **192 - 223 = Class C**
 - **224 - 239 = Class D**
 - **240 - 254 = Class E**

Address Class Usage

- **Address classes A, B, and C are available for Internet use**
- **Some Class D multicast addresses are used by routing protocols**
 - **OSPF—224.0.0.5, 224.0.0.6**
 - **RIPv2—224.0.0.9**
 - **EIGRP—224.0.0.10**
- **Other Class D multicast addresses are used by videoconferencing or other applications**



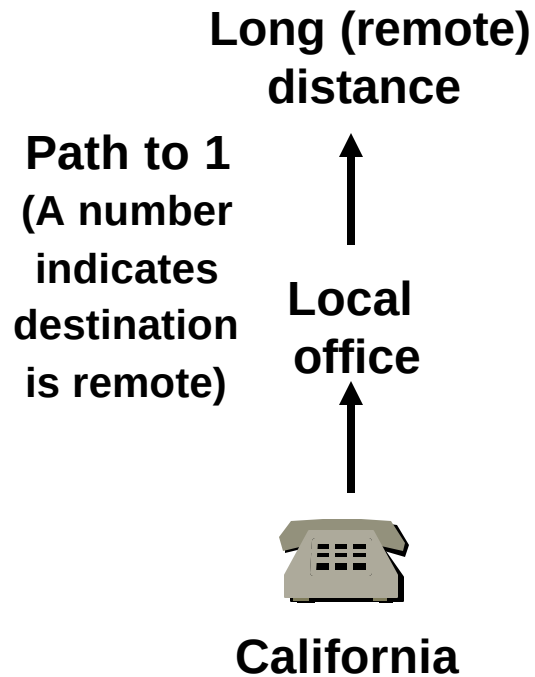
Hierarchical Addressing

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Planning an IP Address Hierarchy

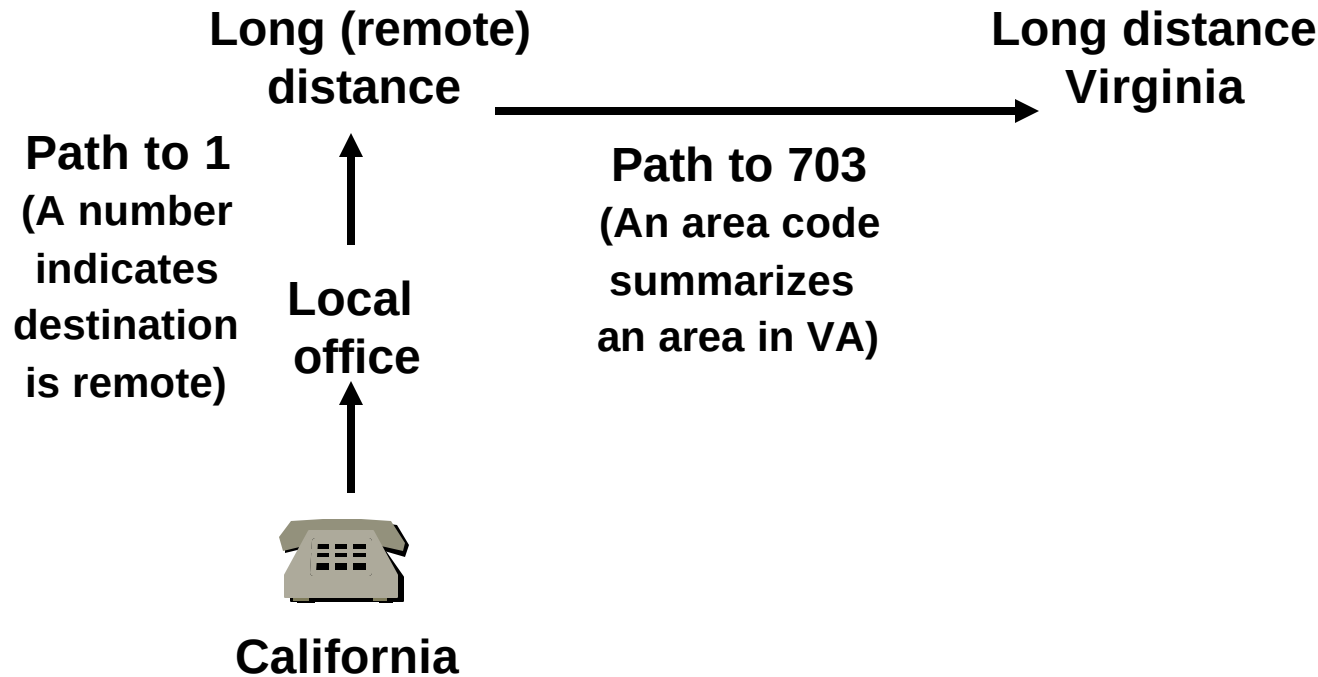
**Does a telephone switch in California know how to reach a specific phone in Virginia?
(1-703-555-1212)**

Planning an IP Address Hierarchy (cont.)



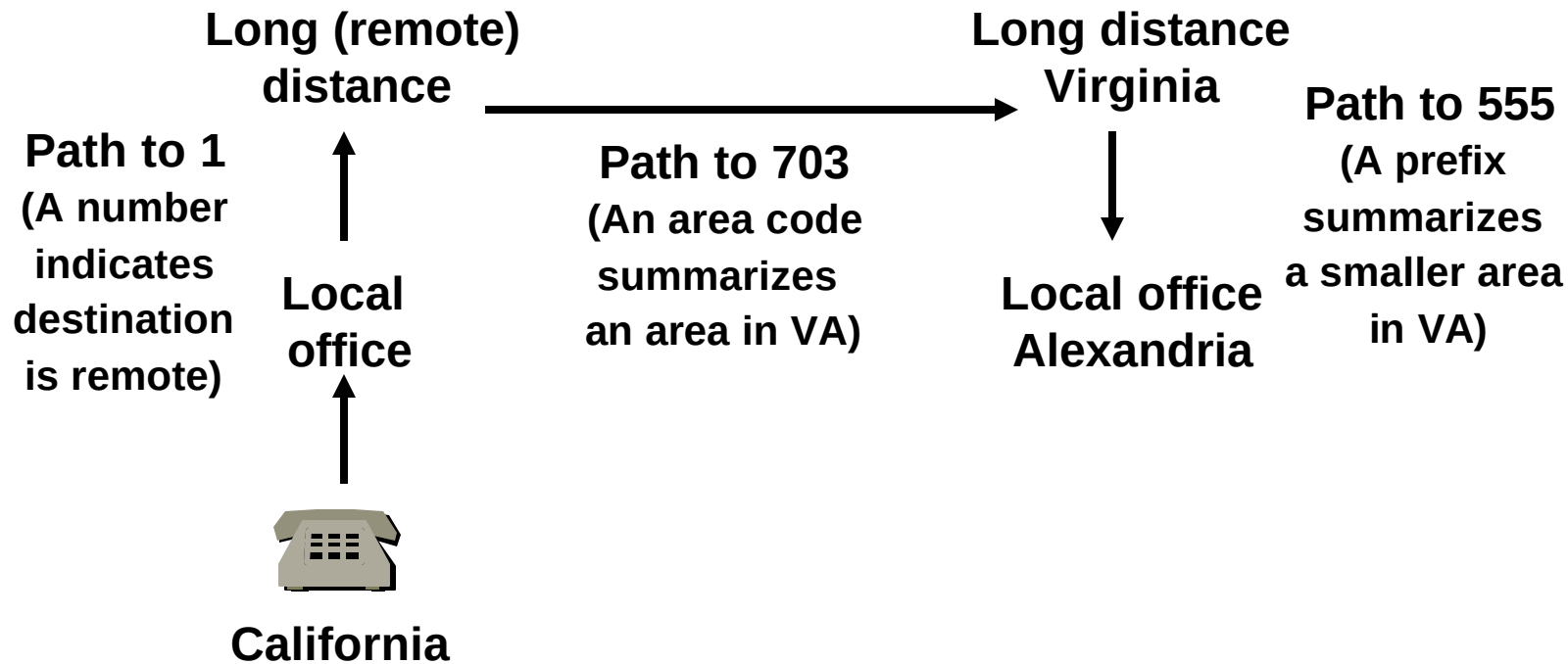
**Does a telephone switch in California know how to reach a specific phone in Virginia?
(1-703-555-1212)**

Planning an IP Address Hierarchy (cont.)



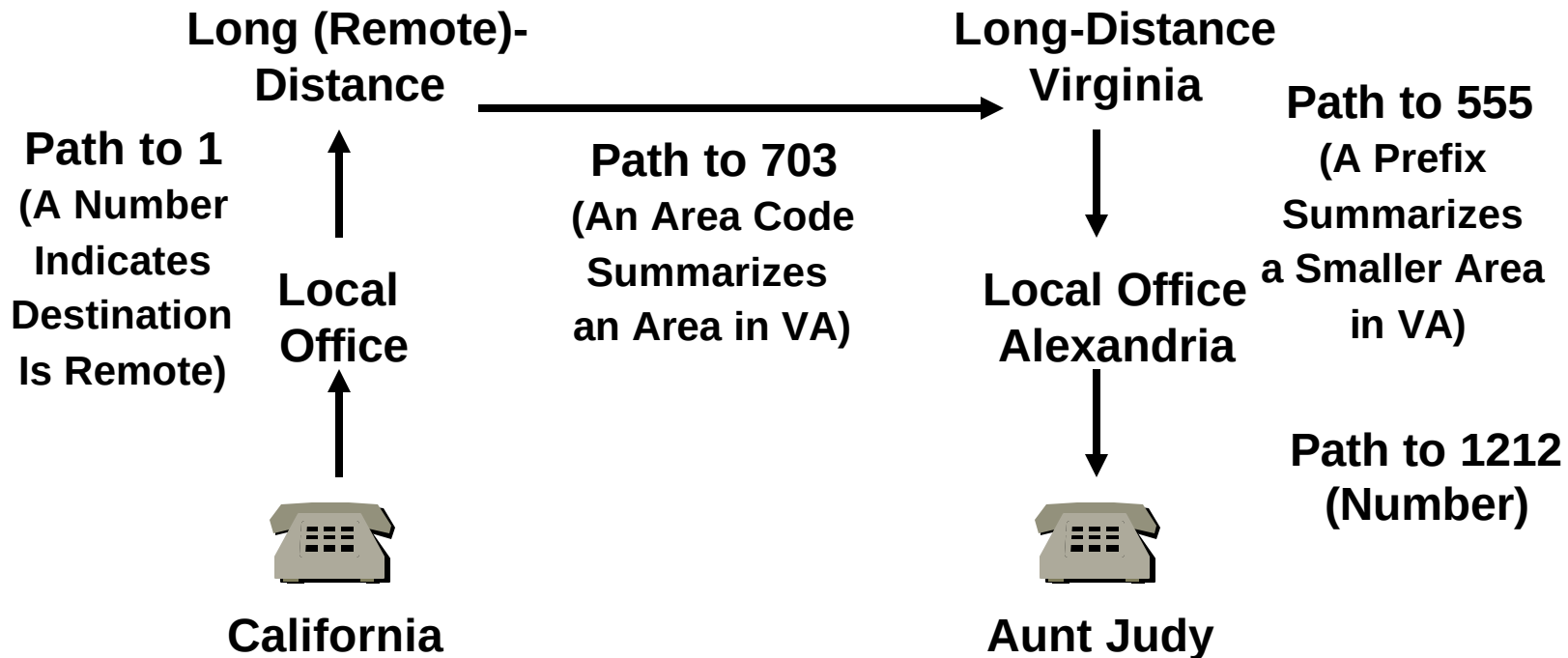
**Does a telephone switch in California know how to reach a specific phone in Virginia?
(1-703-555-1212)**

Planning an IP Address Hierarchy (cont.)



Does a telephone switch in California know how to reach a specific phone in Virginia? (1-703-555-1212)

Planning an IP Address Hierarchy (cont.)



- Does a telephone switch in California know how to reach a specific phone (1-703-555-1212) in Virginia?

Benefits of Hierarchical Addressing

- **Reduced number of route table entries**
 - Summarize multiple addresses into route summaries
- **Efficient allocation of addresses**
 - Contiguous address assignment allows you to use all possible addresses

A man in a white shirt and tie is holding a large, curved, glowing blue object that resembles a giant computer mouse or a stylized letter 'C'. The background is a textured blue surface. The overall image has a blue monochromatic theme.

Variable-Length Subnet Masks

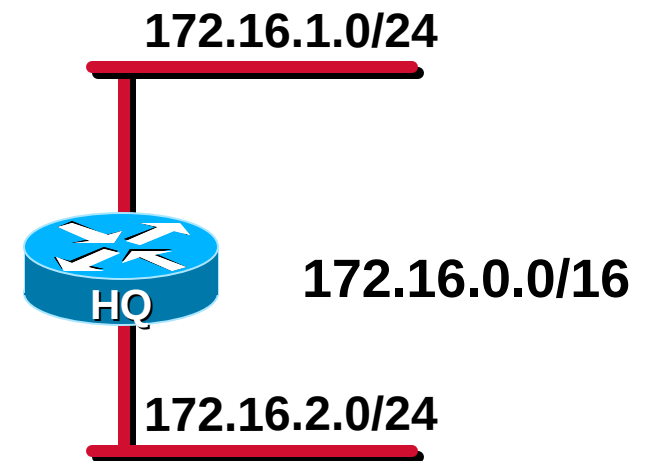
Cisco.com

What Is a Variable-Length Subnet Mask?

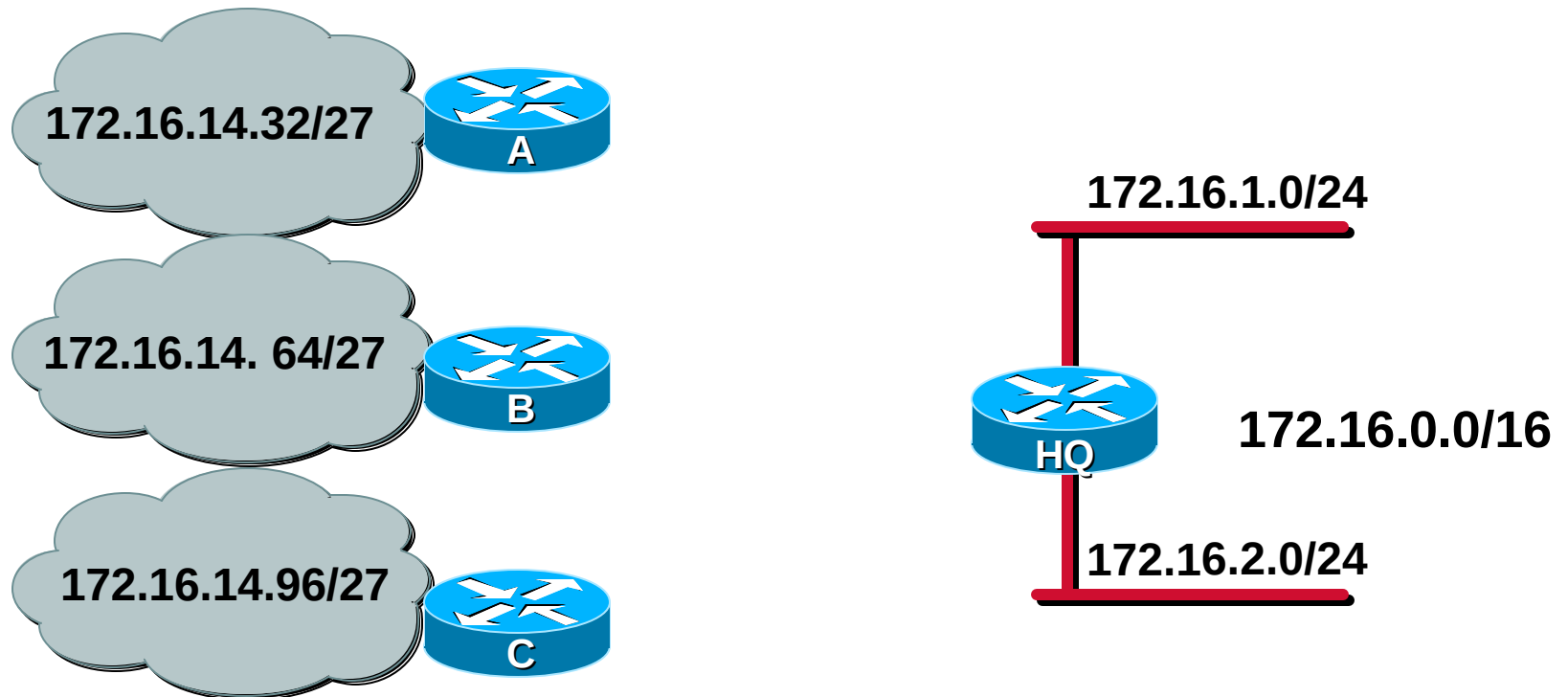


172.16.0.0/16

What Is a Variable-Length Subnet Mask? (cont.)

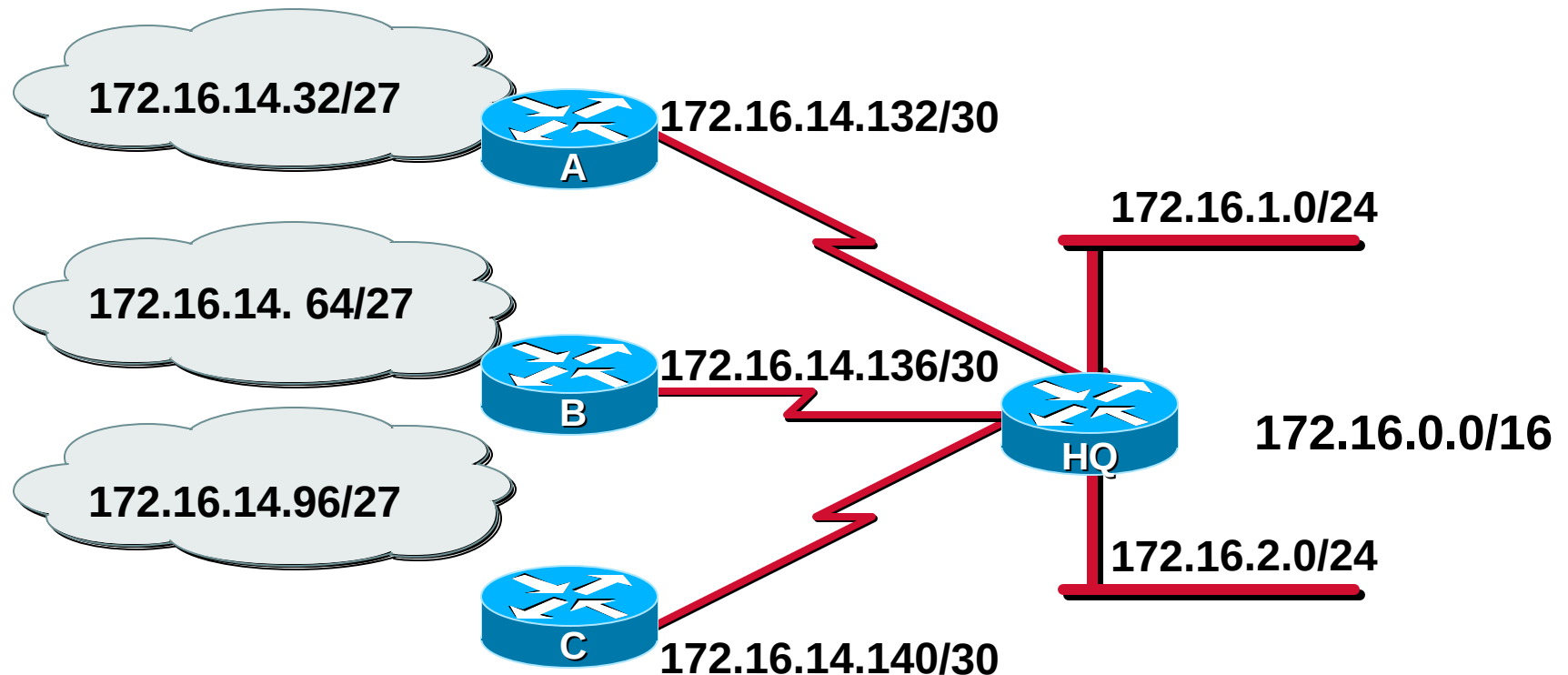


What Is a Variable-Length Subnet Mask? (cont.)



- Subnet 172.16.14.0/24 is divided into smaller subnets:
 - Subnet with one mask at first (/27)

What Is a Variable-Length Subnet Mask? (cont.)



- Subnet 172.16.14.0/24 is divided into smaller subnets:
 - Subnet with one mask at first (/27)
 - Then further subnet one of the unused /27 subnets into multiple /30 subnets

Calculating VLSMs

Subnetted Address: 172.16.32.0/20

In Binary 10101100. 00010000.00100000.00000000

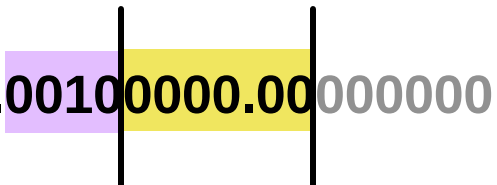
Calculating VLSMs (cont.)

Subnetted Address: 172.16.32.0/20

In Binary 10101100. 00010000.00100000.00000000

VLSM Address: 172.16.32.0/26

In Binary 10101100. 00010000.00100000.00000000



Calculating VLSMs (cont.)

Subnetted Address: 172.16.32.0/20

In Binary 10101100. 00010000.00100000.00000000

VLSM Address: 172.16.32.0/26

In Binary 10101100. 00010000.00100000.00000000

1st subnet: 10101100 . 00010000 .0010 0000.00 000000=172.16.32.0/26

Network

Subnet

VLSM
subnet

Host

Calculating VLSMs (cont.)

Subnetted Address: 172.16.32.0/20

In Binary 10101100. 00010000.00100000.00000000

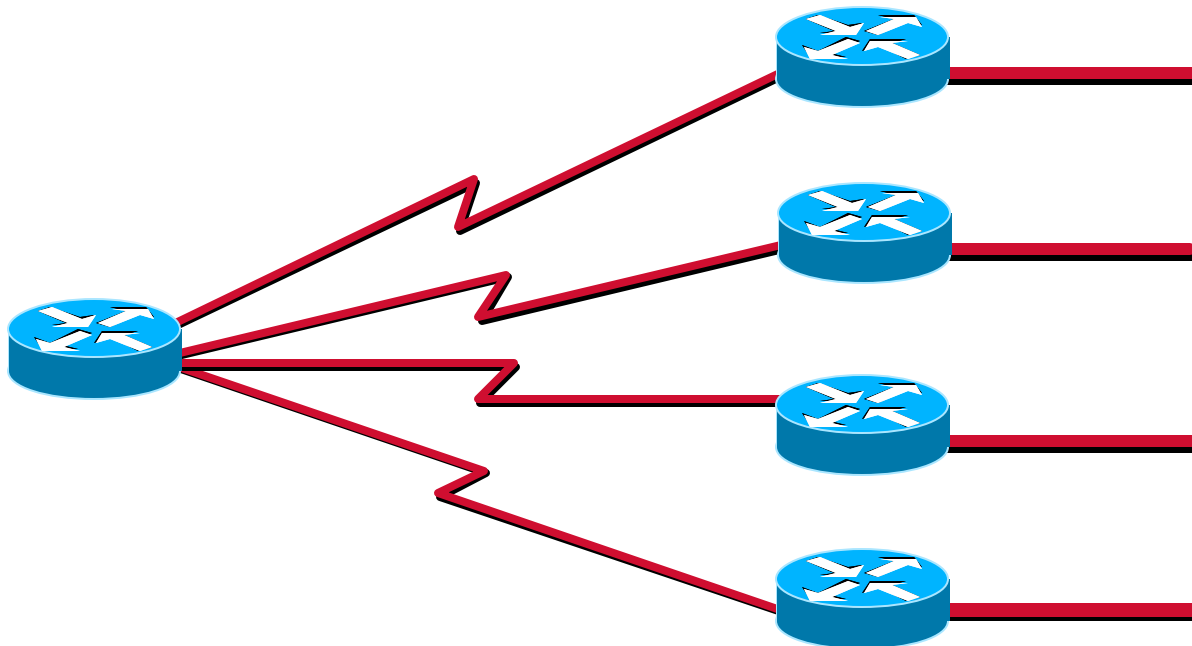
VLSM Address: 172.16.32.0/26

In Binary 10101100. 00010000.00100000.00000000

1st subnet:	10101100 . 00010000	.0010	0000.00	000000=172.16.32.0/26
2nd subnet:	172 . 16	.0010	0000.01	000000=172.16.32.64/26
3rd subnet:	172 . 16	.0010	0000.10	000000=172.16.32.128/26
4th subnet:	172 . 16	.0010	0000.11	000000=172.16.32.192/26
5th subnet:	172 . 16	.0010	0001.00	000000=172.16.33.0/26
	Network	Subnet	VLSM Subnet	Host

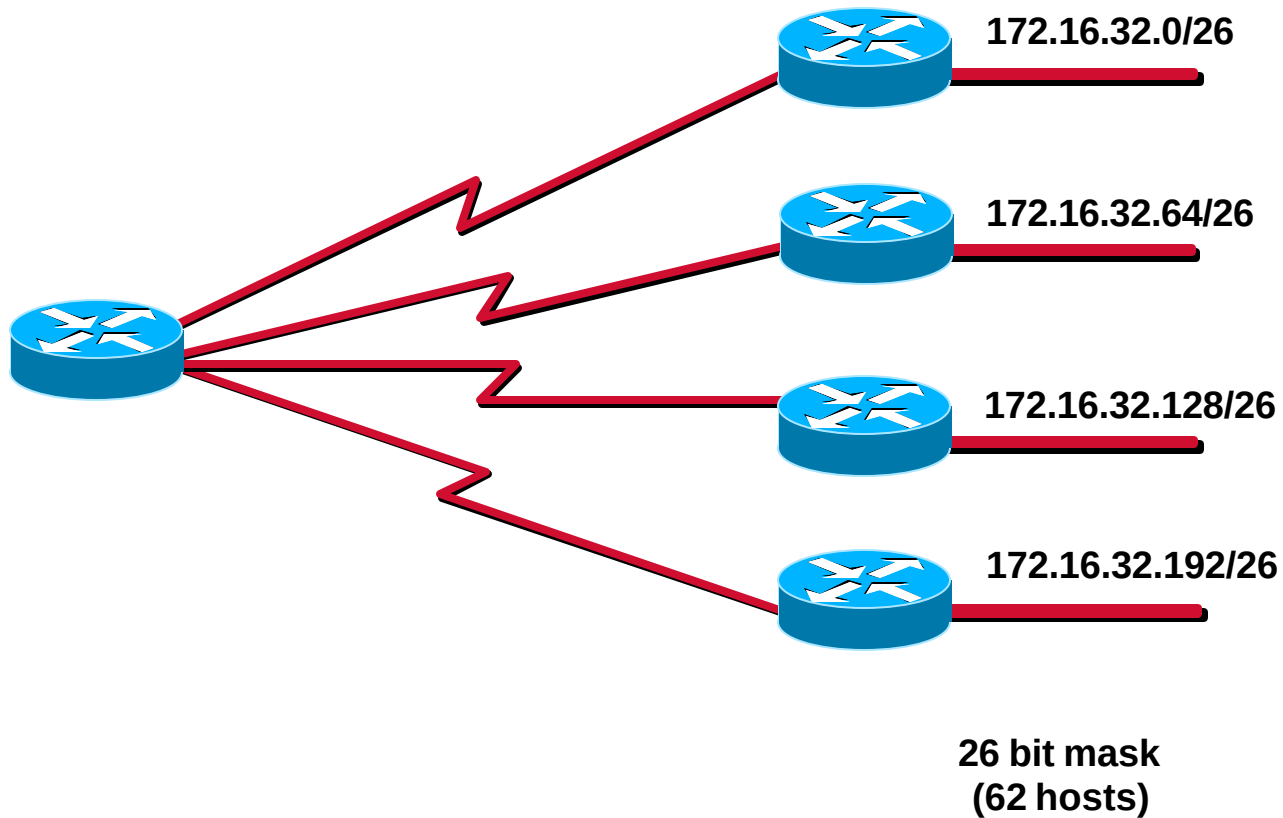
A Working VLSM Example

Derived from the 172.16.32.0/20 Subnet

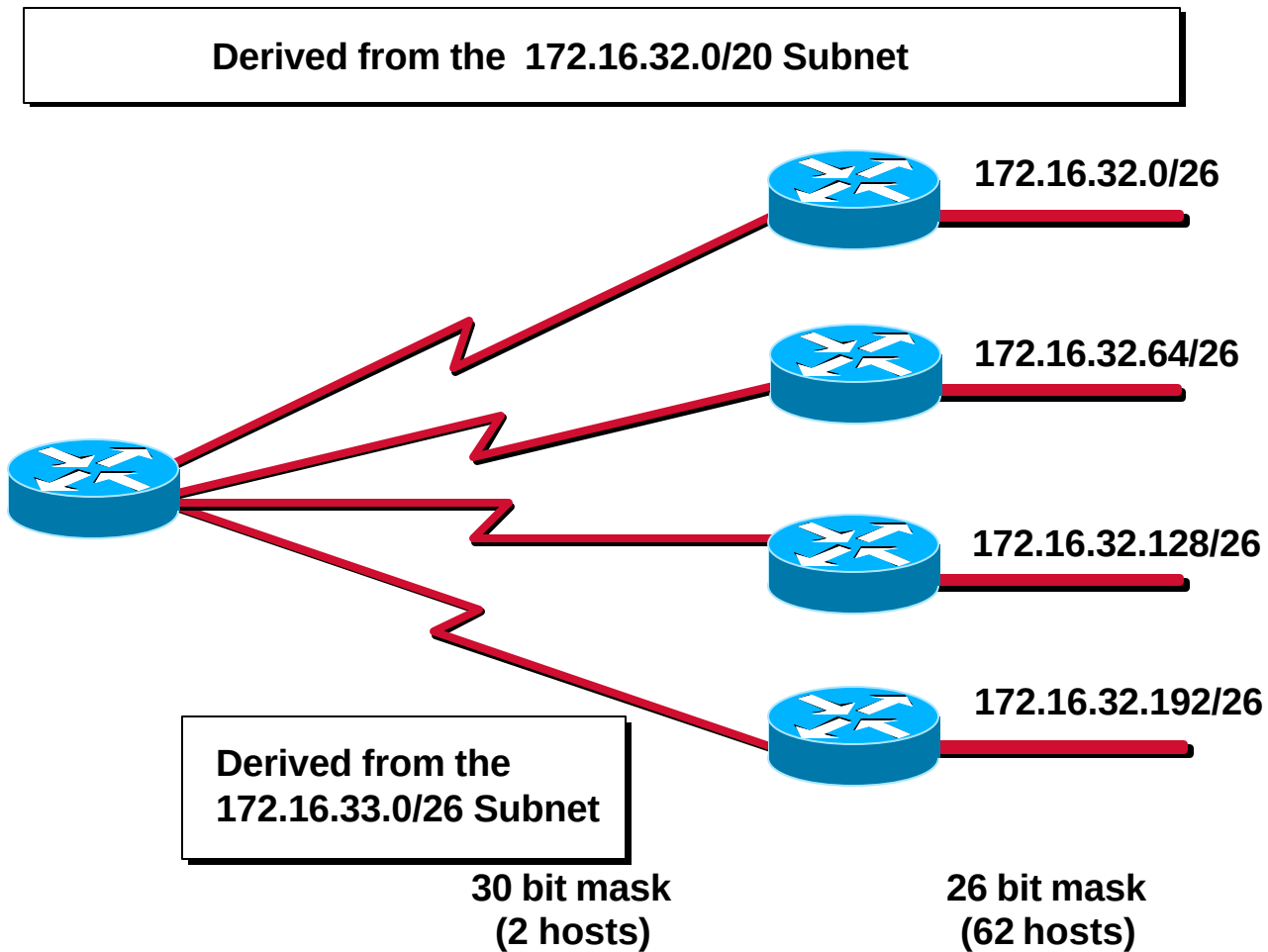


A Working VLSM Example (cont.)

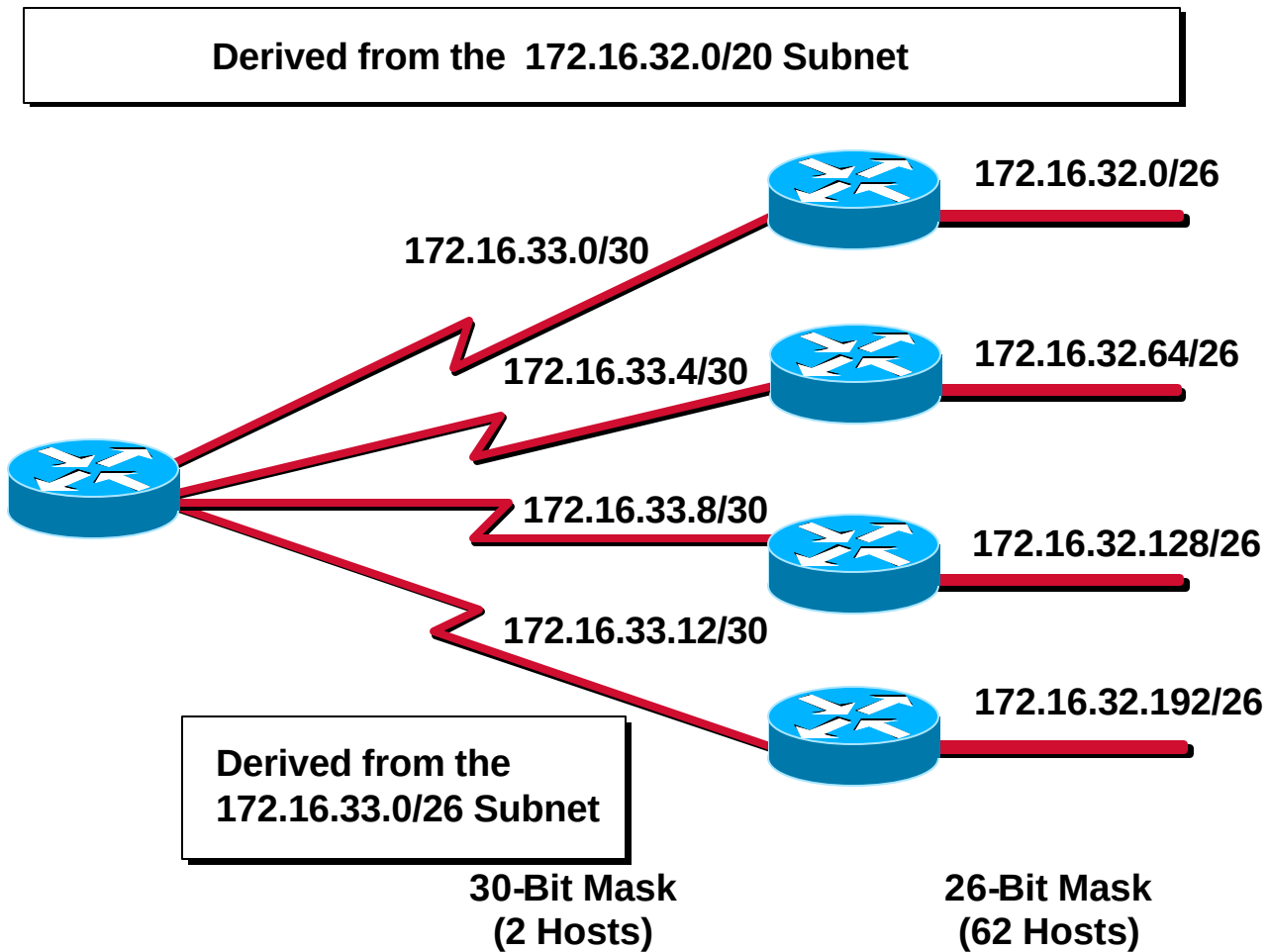
Derived from the 172.16.32.0/20 Subnet



A Working VLSM Example (cont.)



A Working VLSM Example (cont.)



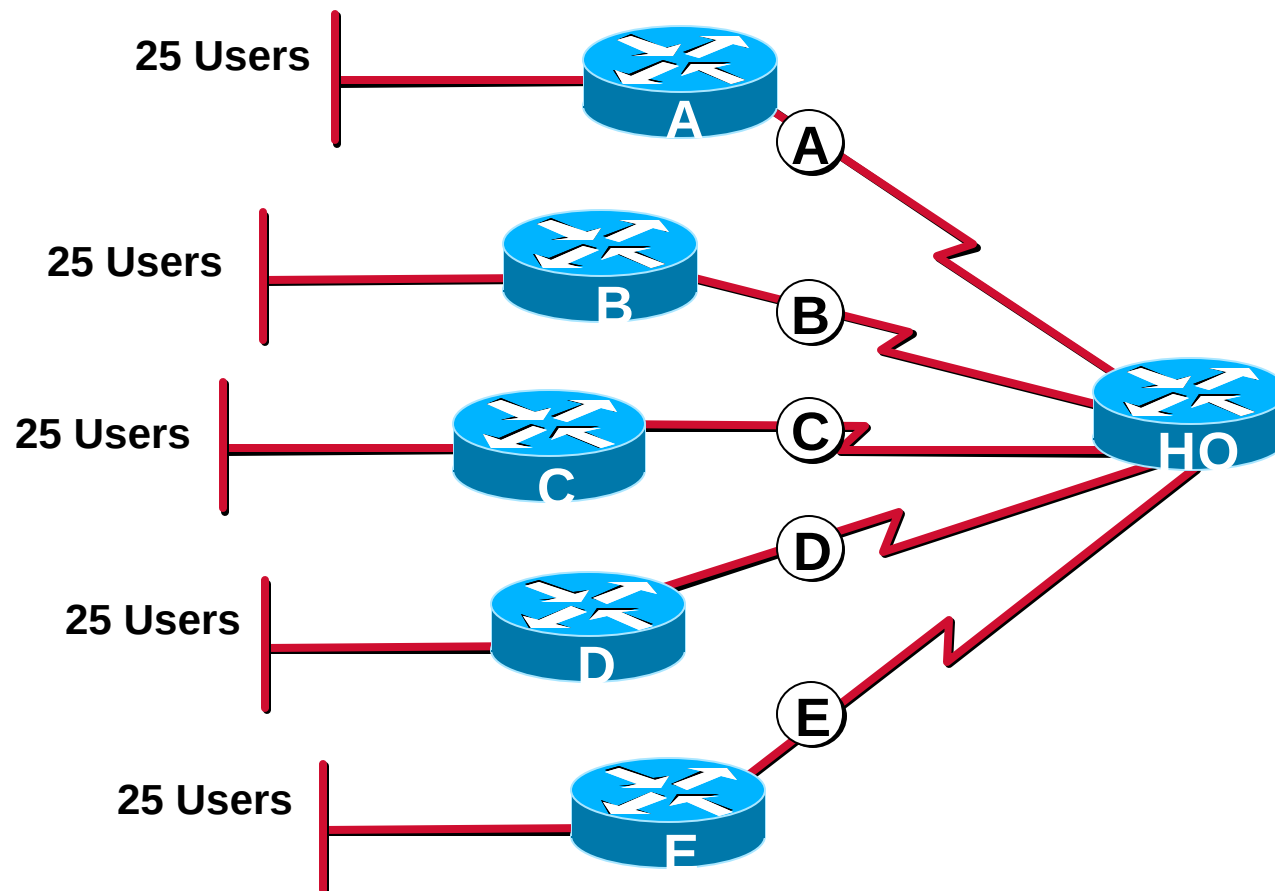


Written Exercise

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Written Exercise: Calculating VLSMs

Using VLSMs, define appropriate subnets for addressing the networks using 192.168.49.0/24.



Addresses for WAN Links

A Serial_____

B Serial_____

C Serial_____

D Serial_____

E Serial_____