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IP Addressing and Subnetting

Module Objectives

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Upon completion, you will be able to:

- Discuss the Types of Network Addressing
- Discover the Binary counting system
- Explain the Form of an IP Address
  - Network ID
  - Host ID
- Discuss the Classes of IP Addresses
- Demonstrate the Function of the Mask
- Demonstrate the subnetting process to get the right answer!

Let’s Talk About Addressing!

- **Types of Addressing:**

  - Layer 2 – MAC Addresses (Media Access Control)

  0134.2345.12AB A MAC Address

  0134.23 Vendor Code

  45.12AB Serial Number

  - Layer 3 – Logical Addresses (IPv4 or IPX)

- **Assignment of IP Addresses:**

  - Static Addresses – assigned by an Administrator

  - Dynamic Addresses – DHCP

  - “Hierarchical” vs. “Flat” Addressing Schemes

Can You Count in Binary?

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We are Very Familiar with our Decimal System…

0 1 2 3 4 5 6 7 8 9…10 11 12 13…

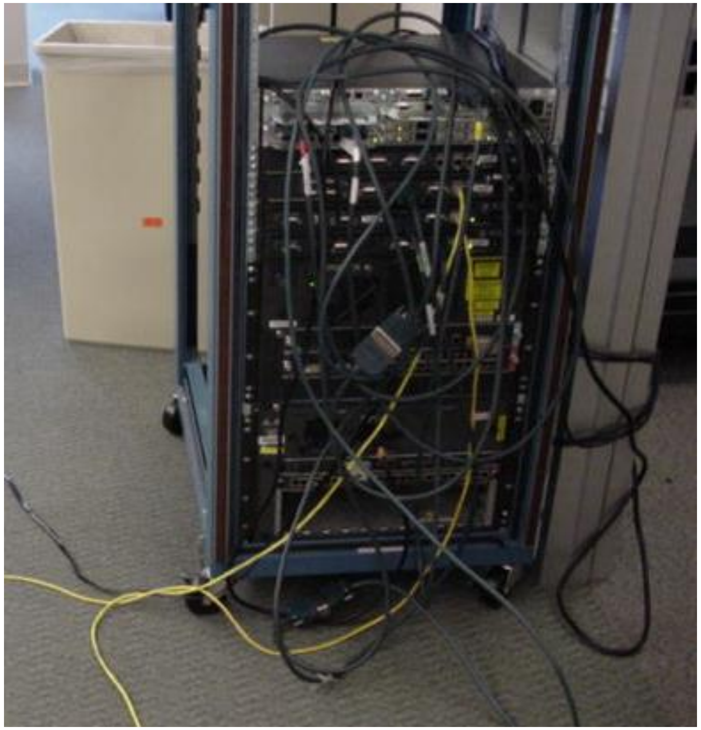
But,

We Need to Become Familiar with the Binary System…only 0’s and 1’s

0000 1 10 11 100 101 110 111 1000 1001…

0 1 2 3 4 5 6 7 8 9

Basics of An IPv4 Address



- Layer 3 (L3) Logical IP Addresses are comprised of 4 Octets, separated by a .
- The **Decimal** form looks like this:

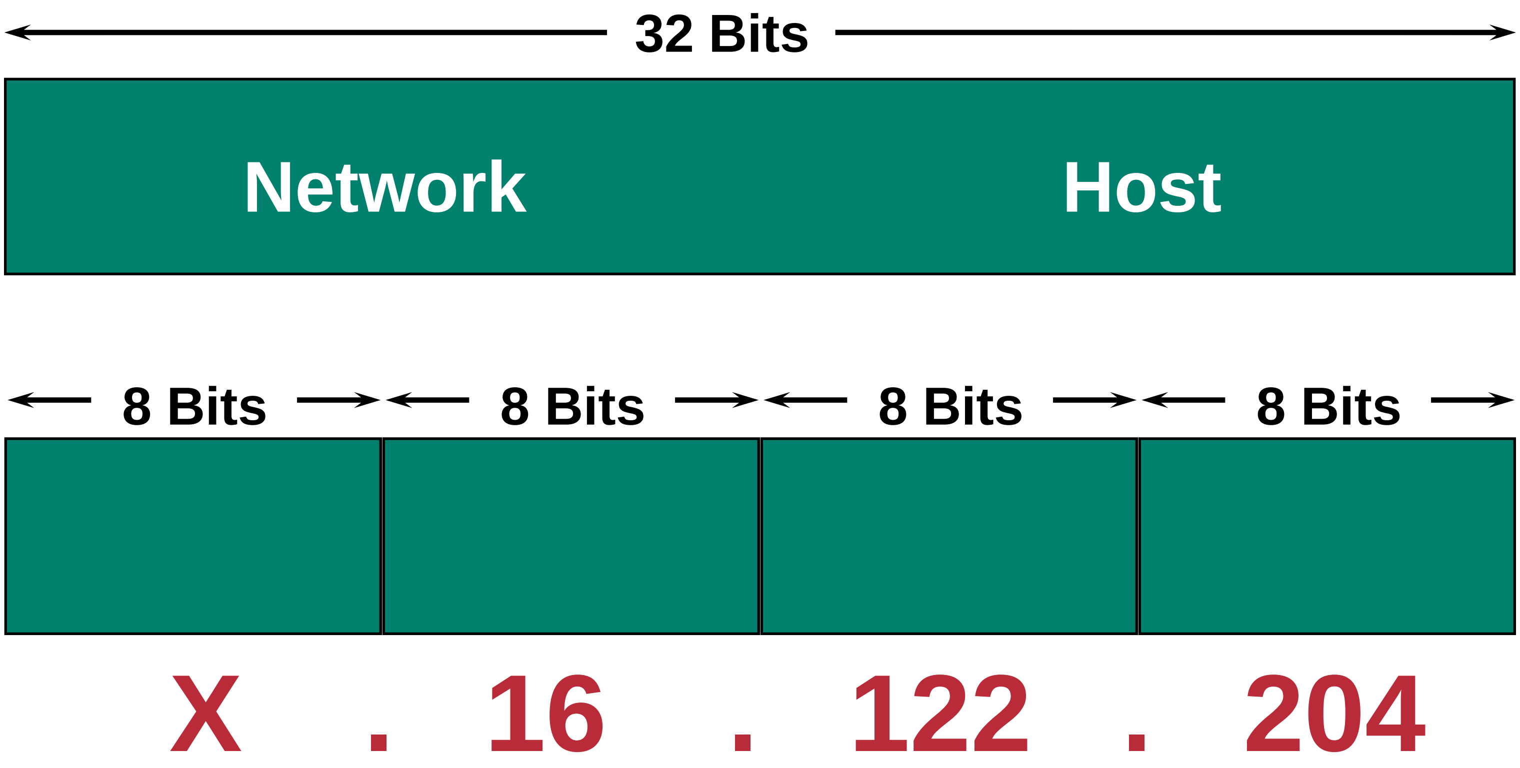
176.223.14.127

- The **Binary** form looks like:

128 64 32 16 8 4 2 1

10110000.11011111.00001110.01111111

IPv4 Addressing



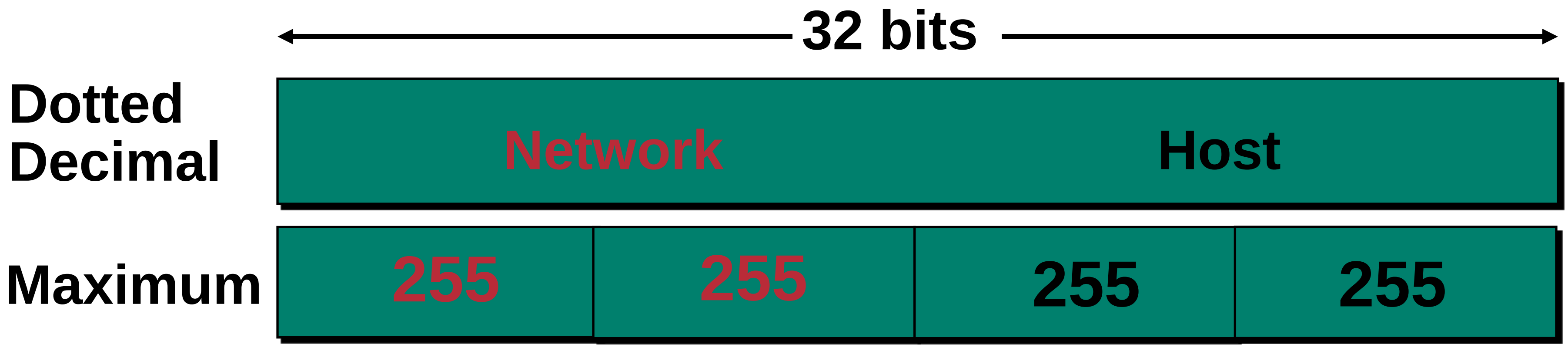
Basics of An IPv4 Address

- Each of the 4 Octets has 8 Bits
- Each of these Bits has a “Binary Value”
- Each Bit can only be a One or a Zero
- Let’s Look at One of the Octets – 8 Bits

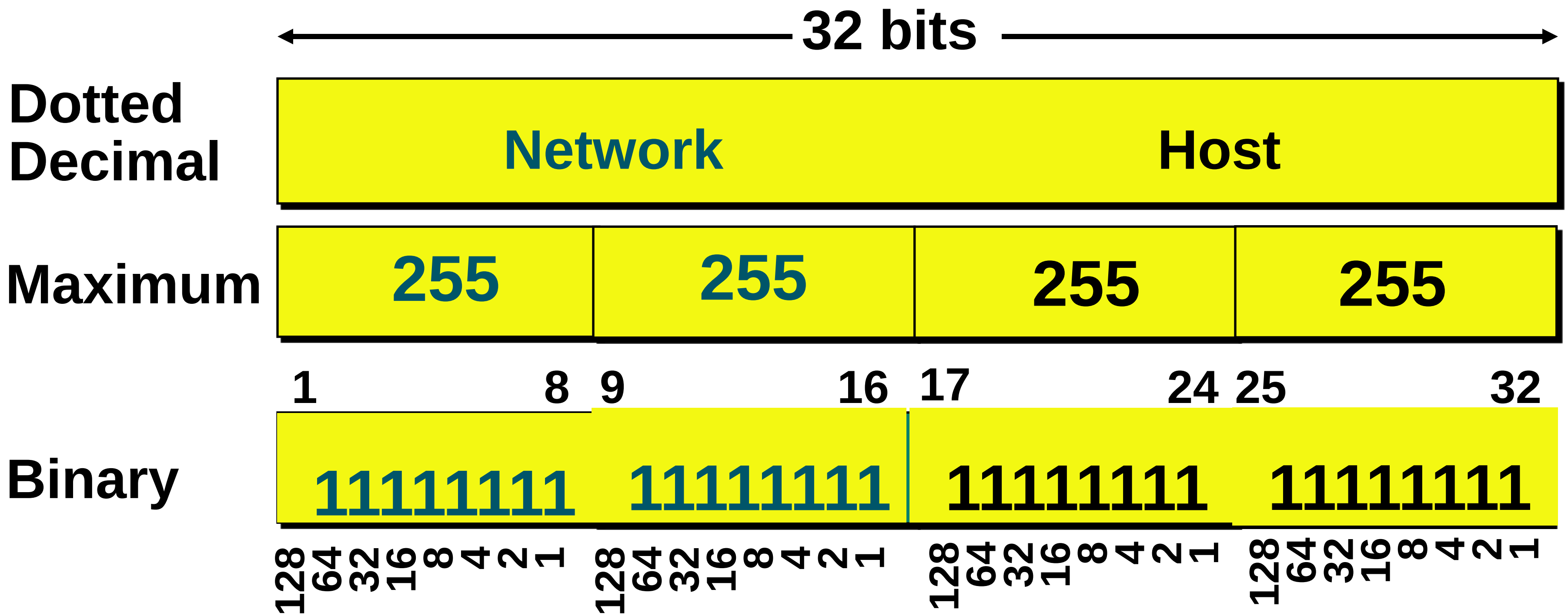
128	64	32	16	8	4	2	1

Each of these 8 bits has a distinct value, that starts at “1” from the right side and moving to the left, doubles each time to 2, 4, 8, 16, 32, 64, and finally 128, as shown above.

IPv4 Addressing



IPv4 Addressing



IPv4 Addressing

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32 bits

	Octet 1	Octet 2	Octet 3	Octet 4
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	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

IPv4 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

IPv4 Address Classes

Class A:

Bits:	1 – 8	9 – 16	17 – 24	25 – 32
	0NNNNNNN	Host	Host	Host

Range (1-127) – 16,777,214 hosts

Class B:

Bits:	1 – 8	9 – 16	17 – 24	25 – 32
	10NNNNNN	Network	Host	Host

Range (128-191) – 65,534 hosts

Class C:

Bits:	1 – 8	9 – 16	17 – 24	25 – 32
	110NNNNN	Network	Network	Host

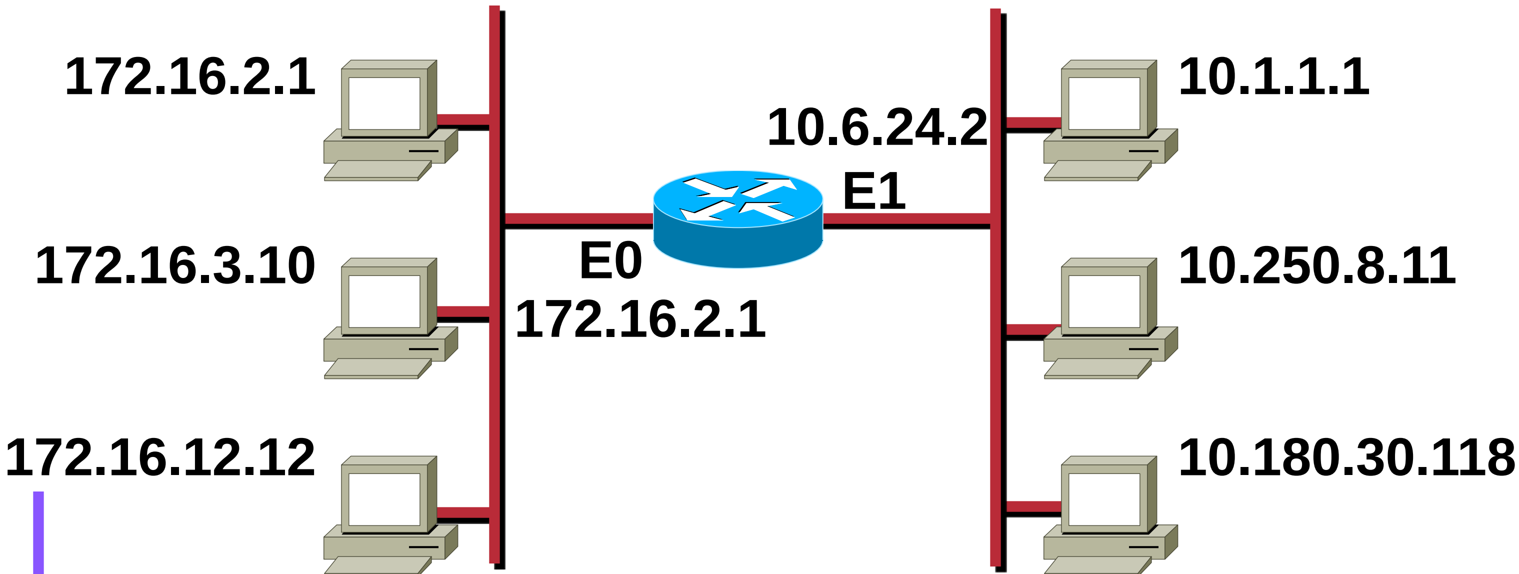
Range (192-223) – 254 hosts

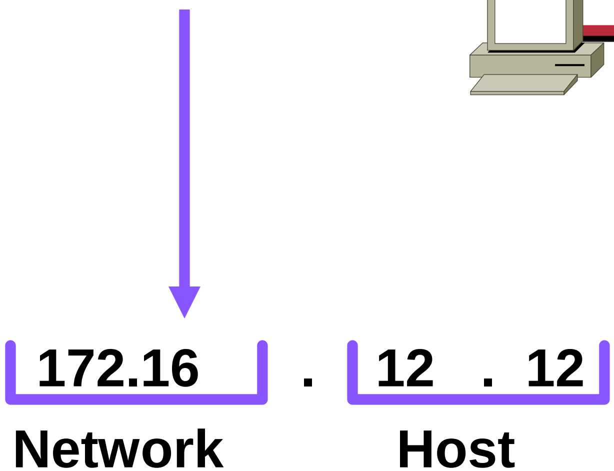
Class D:

Bits:	1 – 8	9 – 16	17 – 24	25 – 32
	1110MMMM	Multicast Group	Multicast Group	Multicast Group

Range (224-239)

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

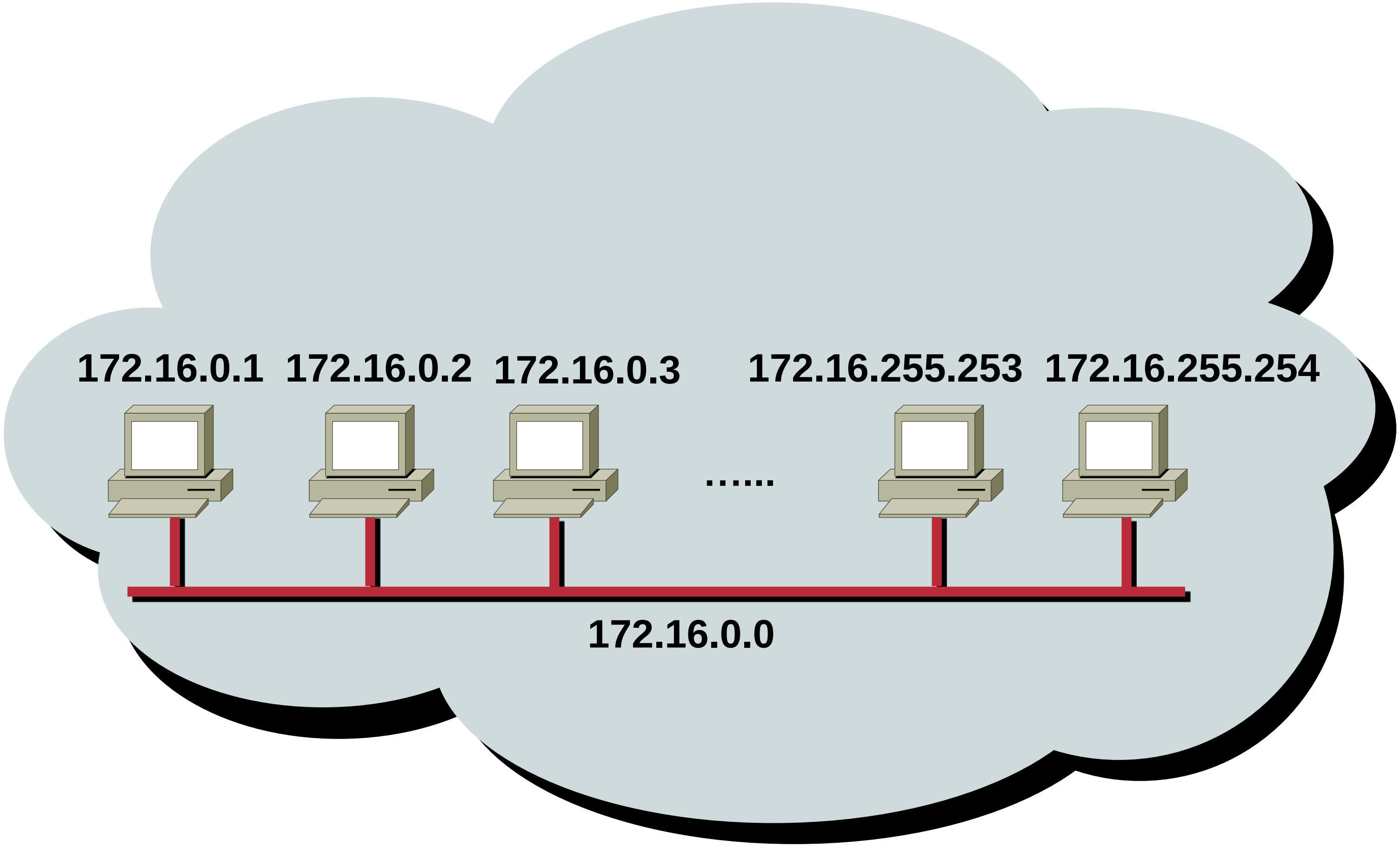
		16 15 14 13 12 11 10 9	8 7 6 5 4 3 2 1	N
10101100	00010000	00000000	00000000	1
		00000000	00000001	2
		00000000	00000011	3
		⋮	⋮	⋮
		11111111	11111101	65534
		11111111	11111110	65535
		11111111	11111111	65536

Remember 2^N-2 (where N is the number of host bits)

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

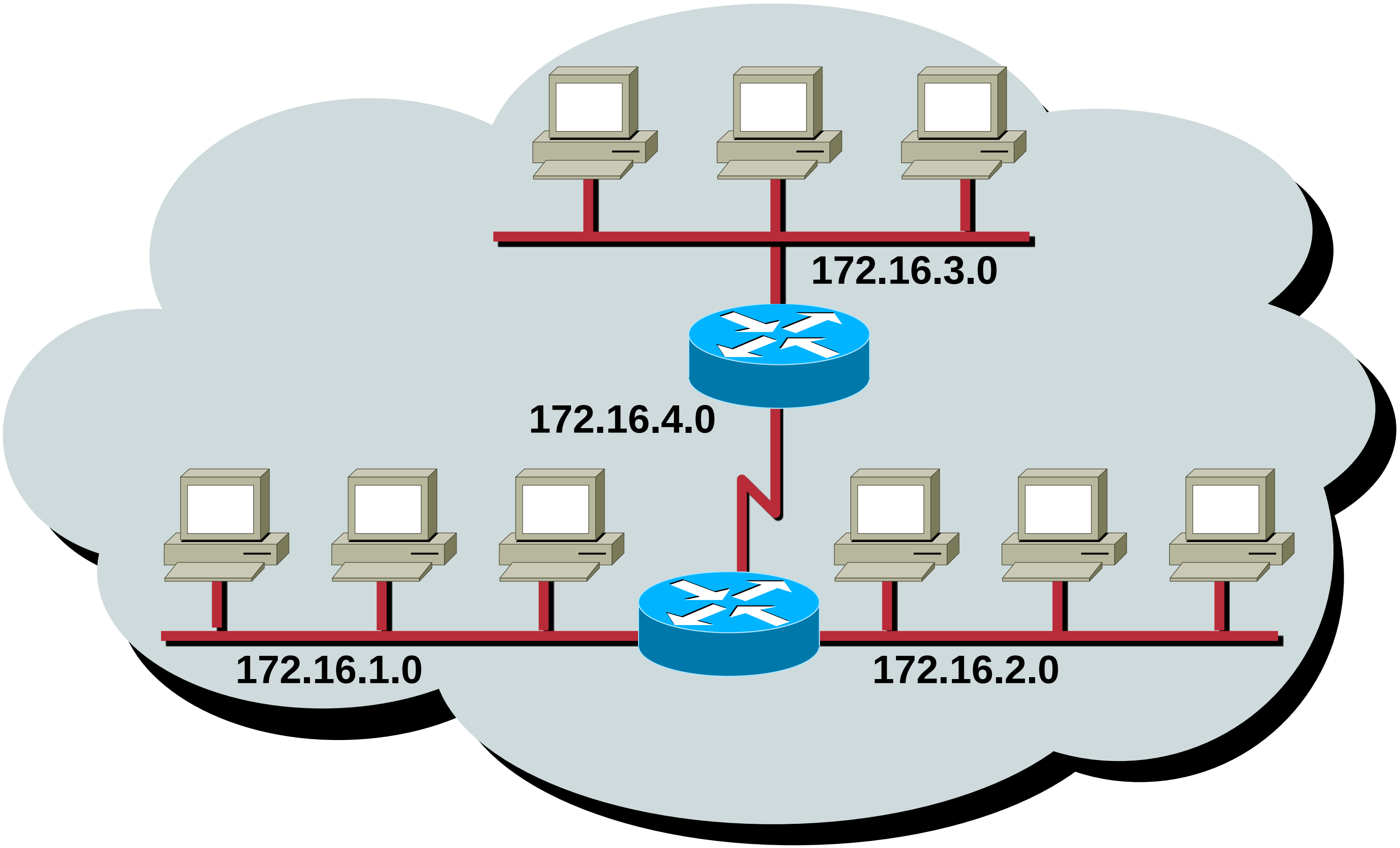
$$65536 - 2 = 65534$$

Addressing without Subnets



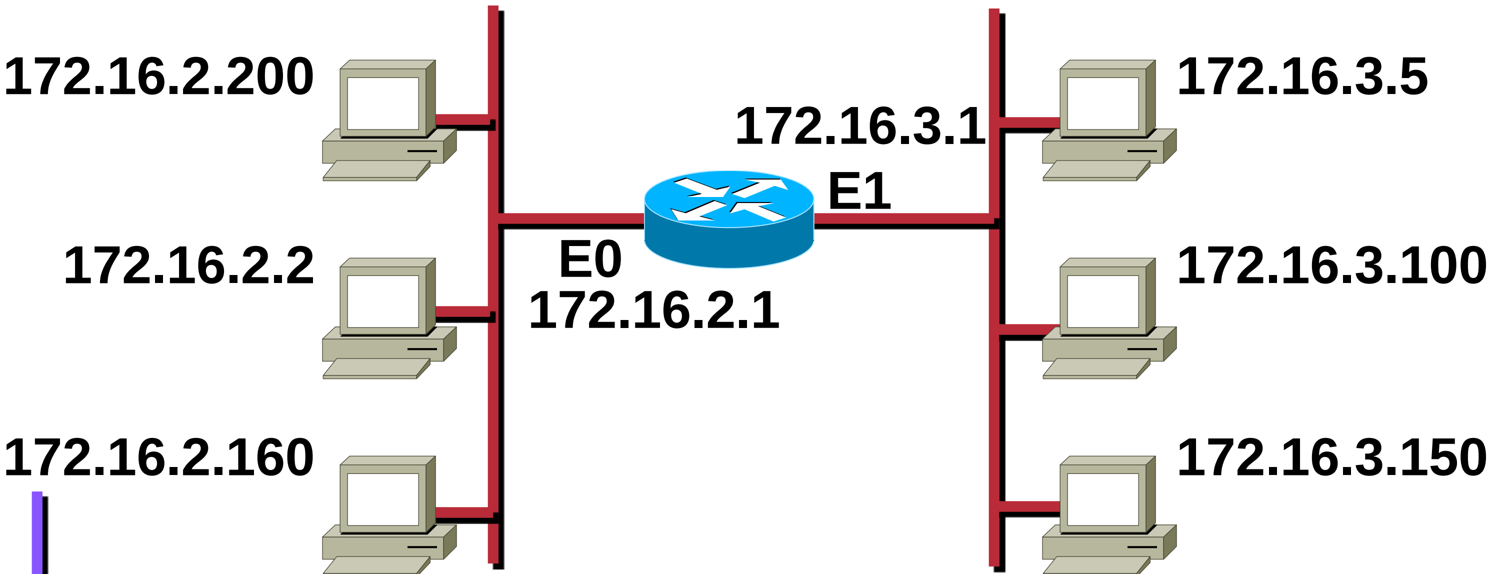
- **Network 172.16.0.0**

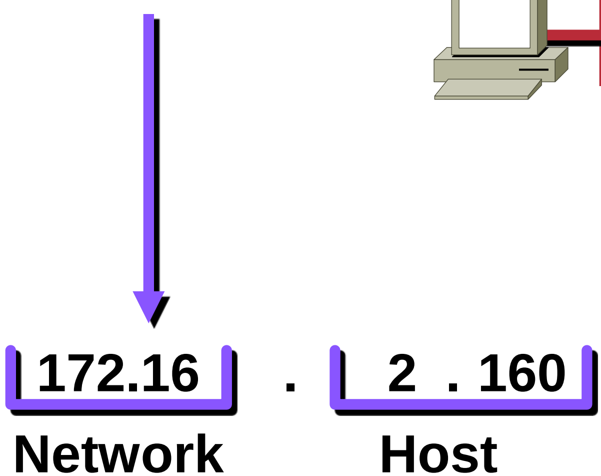
Addressing with Subnets



- **Network 172.16.0.0**

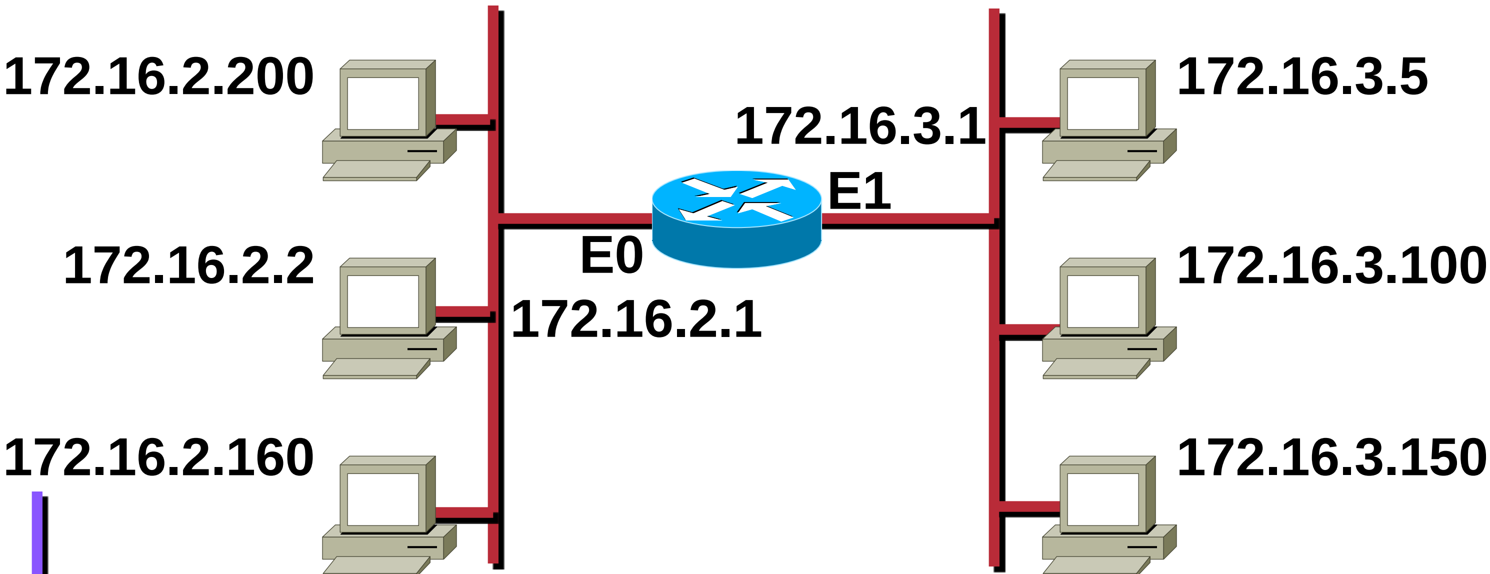
Subnet Addressing





New Routing Table Network	Interface
172.16.0.0	E0
172.16.0.0	E1

Subnet Addressing



172.16 . 2 . 160

Network Subnet Host

New Routing Table 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		
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

Know your two's

- $2^1 = 2$
- $2^2 = 4$
- $2^3 = 8$
- $2^4 = 16$
- $2^5 = 32$
- $2^6 = 64$
- $2^7 = 128$
- $2^8 = 256$
- $2^9 = 512$
- $2^{10} = 1024$
- $2^{11} = 2048$
- $2^{12} = 4096$
- $2^{13} = 8192$
- $2^{14} = 16384$
- $2^{15} = 32768$
- $2^{16} = 65536$

Know Your CIDR Values

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- 255.0.0.0 /8
- 255.128.0.0 /9
- 255.192.0.0 /10
- 255.224.0.0 /11
- 255.240.0.0 /12
- 255.248.0.0 /13
- 255.252.0.0 /14
- 255.254.0.0 /15
- 255.255.0.0 /16
- 255.255.128.0 /17
- 255.255.192.0 /18
- 255.255.224.0 /19
- 255.255.240.0 /20
- 255.255.248.0 /21
- 255.255.252.0 /22
- 255.255.254.0 /23
- 255.255.255.0 /24
- 255.255.255.128 /25
- 255.255.255.192 /26
- 255.255.255.224 /27
- 255.255.255.240 /28
- 255.255.255.248 /29
- 255.255.255.252 /30

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
- Without a subnet mask you cannot tell the host address nor the network it resides on!

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

Address	Subnet Mask	Class	Subnet
172.16.2.10	255.255.255.0	172.16.0.0 (class B)	172.16.2.0
10.6.24.20	255.255.240.0	10.0.0.0 (class A)	10.6.16.0
10.30.36.12	255.255.255.0	10.0.0.0 (class A)	10.30.36.0

Broadcast Addresses

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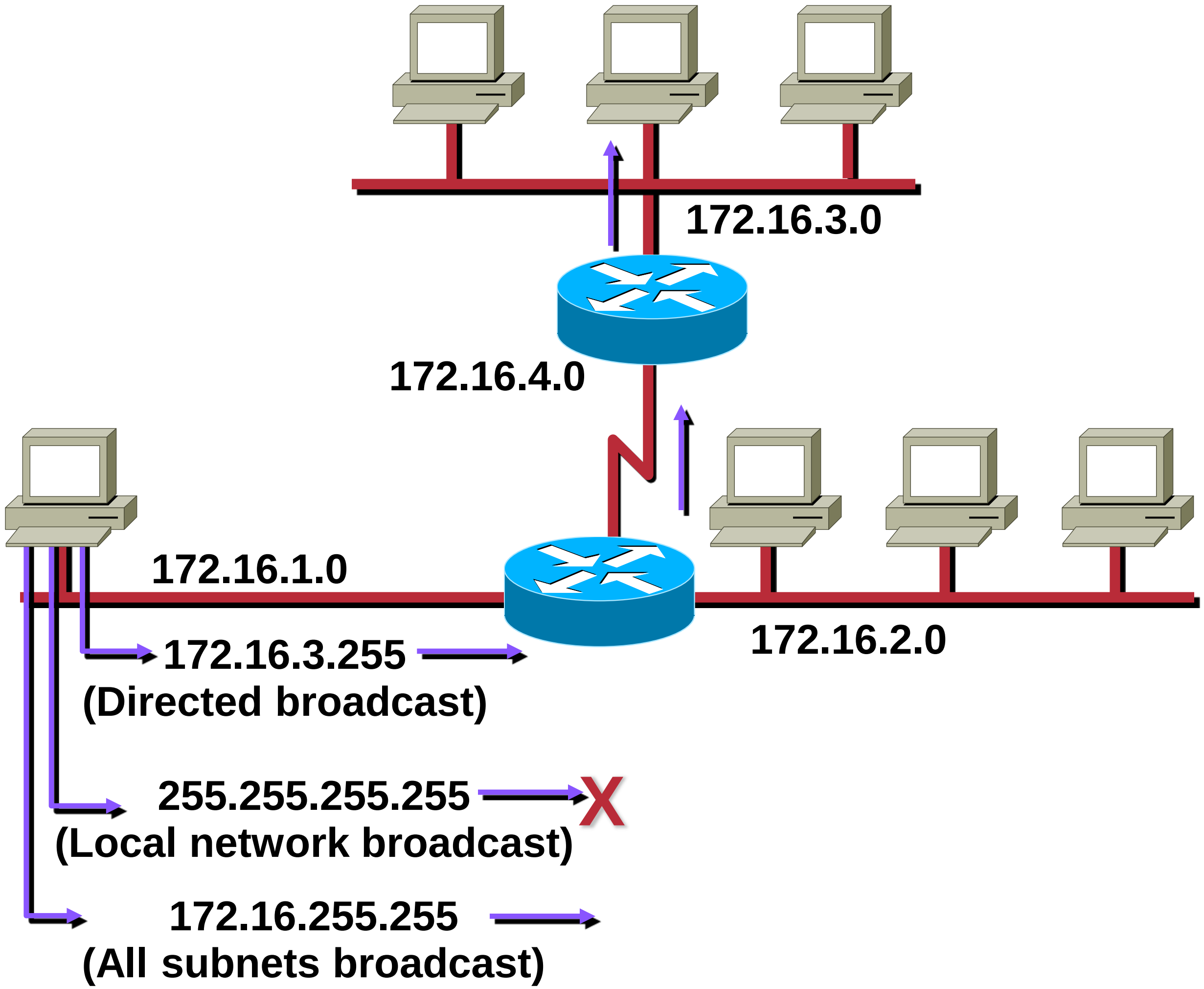

Subnetting the Fast Way – Just answer these 5 questions

- How many subnets does the subnet mask produce?

  2^x = number of subnets, where x is number of subnet masked bits (1 bits)

- How many valid hosts per subnet are available?

  $2^y - 2$ = number of hosts per subnet, where y is the number unmasked bits (0 bits)

- What are the valid subnets?

  256 – subnet mask = block size (or subnet increment number)

  Example: 256 – 192 = 64 block size

  Start counting from 0 in block size increments (ex: 0, 64, 128, 192) – these are your subnets

- What's the broadcast address of each subnet?

  Address right before the next higher subnet

- What are the valid hosts in each subnet?

  Numbers between the subnet addresses, excluding all zeroes and all ones

Example using address 192.168.23.5 255.255.255.240

- How many subnets does the subnet mask produce? 2^x (x = subnet masked bits (1 bits)

  X = 4, thus 16 subnets

- How many valid hosts per subnet are available? $2^y - 2$ (y = number of unmasked bits (0 bits)

  Y = 4, thus 14 hosts

- What are the valid subnets? 256 – mask = block size (ex: 256 – 192 = 64) block size. Start counting from 0 in block size increments (ex: 0, 64, 128, 192) – these are your subnets

  256 – 240 = 16 (blocksize), thus our subnet is 192.168.23.0 and next subnet is 16

- What's the broadcast address of each subnet? Address right before the next higher subnet

  192.168.23.15

- What are the valid hosts in each subnet? Numbers between the subnet addresses, excluding all zeroes and all ones

  192.168.23.1 – 192.168.23.14

Addressing Summary Example

	172	16	2	160	
172.16.2.160	10101100	00010000	00000010	10100000	Host 1
255.255.255.192					Mask
					Subnet 4
					Broadcast
					First
					Last

Addressing Summary Example

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	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	7

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)
				10000000	Subnet (4)
					Broadcast
					First
					Last

(3)

Addressing Summary Example

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	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	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
					Last	

Addressing Summary Example

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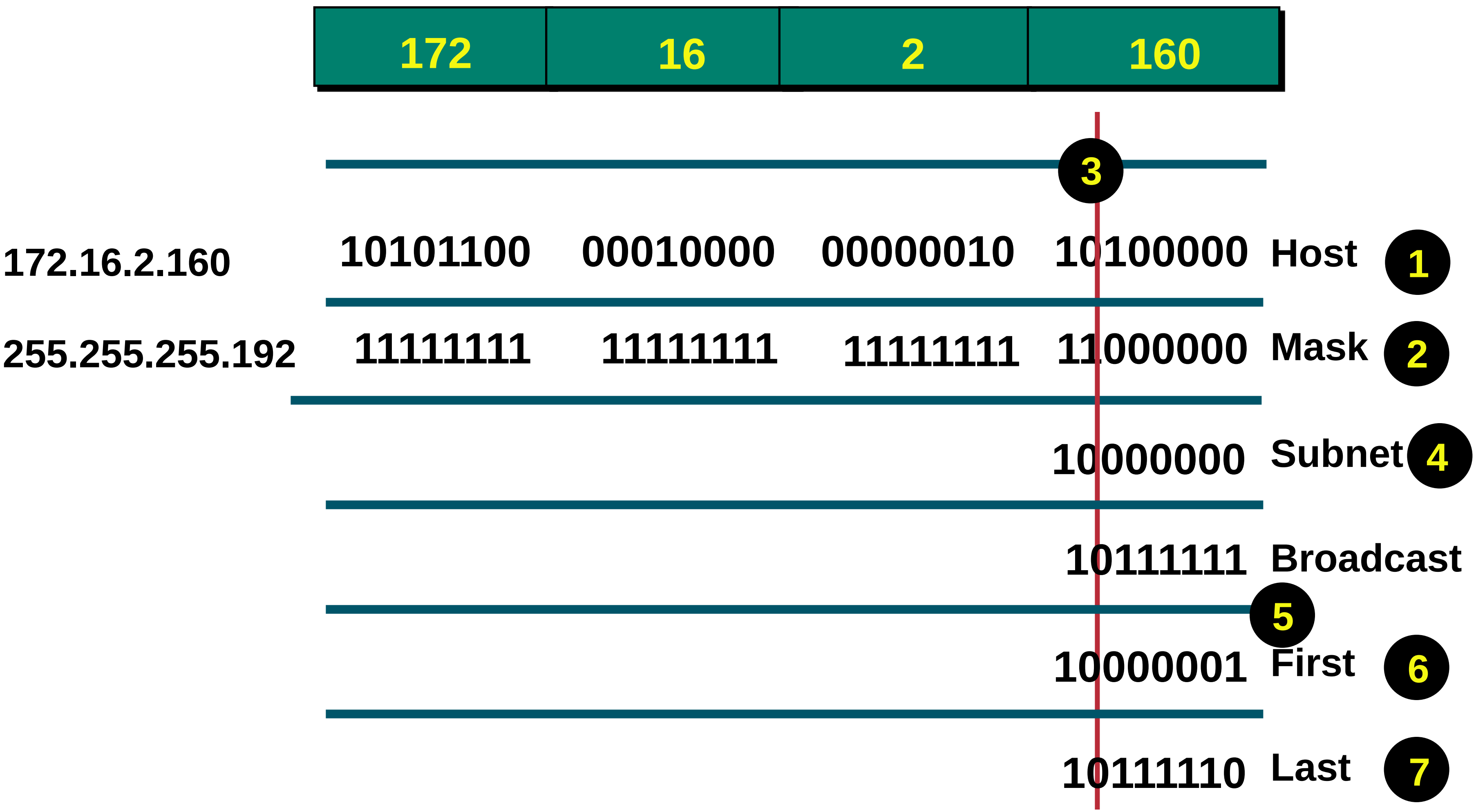

Addressing Summary Example

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	172	16	2	160		
172.16.2.160	10101100	00010000	00000010	10100000	Host	1
255.255.255.192	11111111	11111111	11111111	11000000	Mask	2
	10101100	00010000	00000010	10000000	Subnet	4
	10101100	00010000	00000010	10111111	Broadcast	5
	10101100	00010000	00000010	10000001	First	6
	10101100	00010000	00000010	10111110	Last	7

3

8

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

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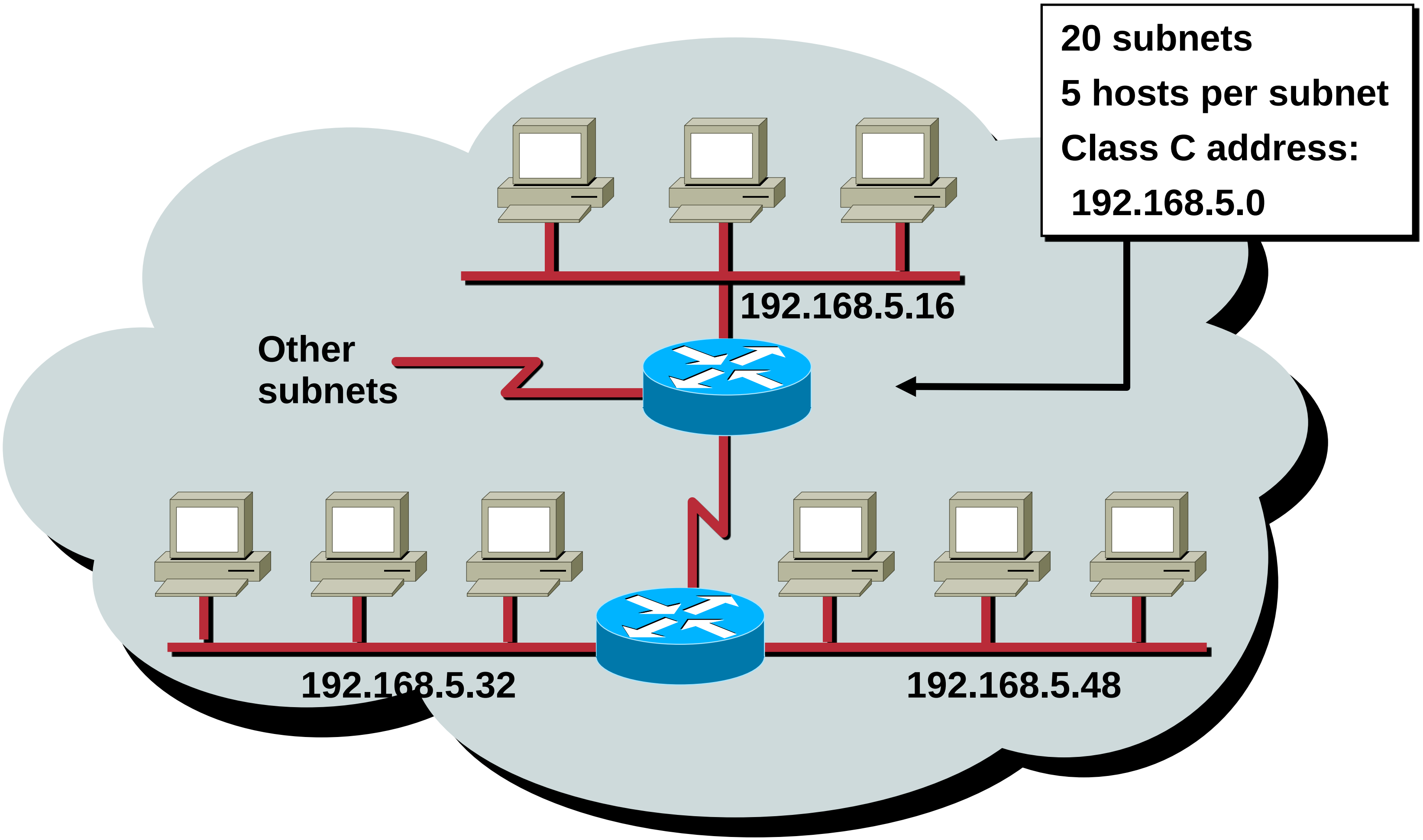
IP Host Address: 172.16.2.121
Subnet Mask: 255.255.255.0

	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

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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

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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

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

Oh, One (or three) Last Thing(s)!

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- Address depletion makes it necessary to better manage an address space. This can be accomplished by subnetting a given network address.
- Subnetting is accomplished by borrowing, I like to say stealing, a bit from the host space and providing it to the network space.
- Remember that every time you subnet, you are increasing the # of networks (subnets) at the cost of # of hosts.

All Zeros and All Ones Subnets

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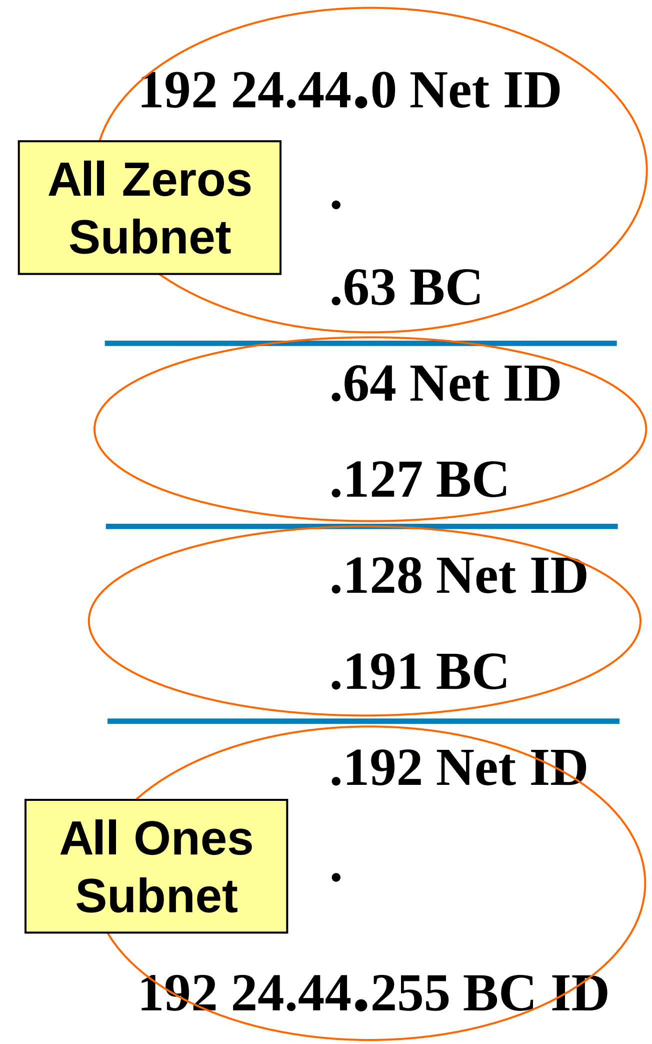
RFC 1878 states:

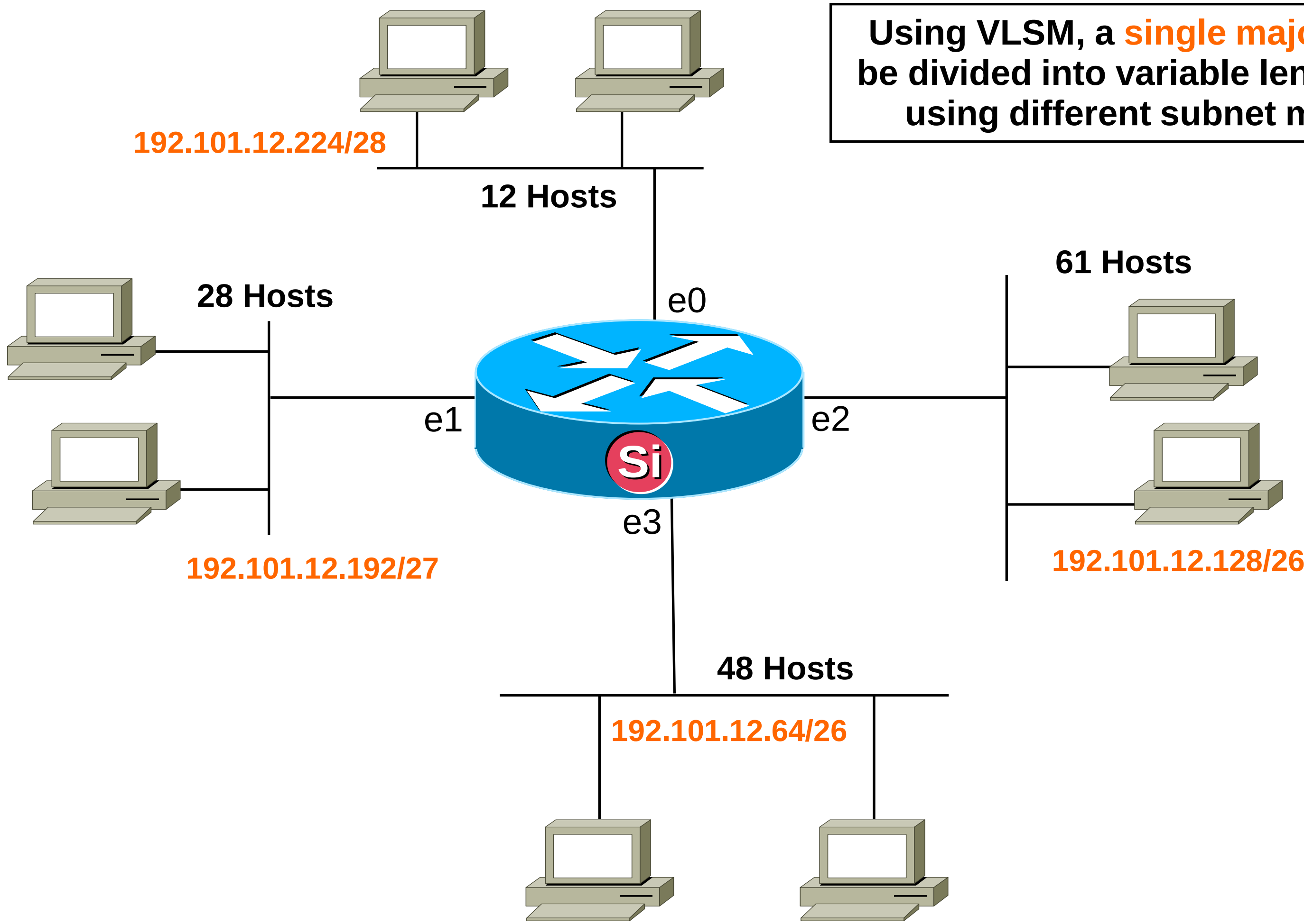
"This practice of excluding the "all-zeros subnet" and the "all-ones subnet" is obsolete! Modern software will be able to utilize all definable sub-networks."

Today, the use of subnet zero and the all-ones subnet is generally accepted and most vendors support their use, though, on certain networks (and the CCNA Exam), particularly the ones using legacy software, the use of subnet zero and the all-ones subnet can lead to problems.



VLSM - Variable Length Subnet Mask

Using VLSM, a single major network can be divided into variable length subnets by using different subnet mask lengths



Introduction to IPv6

A Need for IPv6?

- IETF IPv6 WG began in early 90s, to solve addressing growth issues, but CIDR, NAT/PAT,…were developed
- IPv4 32 bit address = 4 billion hosts – est 250million usable

  ~40% of the IPv4 address space is still unused which is different from unallocated. The growing number of Internet connected devices & appliances will eventually deplete the IPv4 address space – estimate by 2011

- IP is everywhere

  Data, voice, audio and video integration is a reality

  Regional registries apply a strict allocation control

- So, major compelling reason: More IP addresses

  Aggregation, Multihoming, AutoConfiguration, Renumbering

- Simpler Header aligned on 64 bit boundary
- Also get enhanced features like, Security (IPSec), QOS, Mobile IP
- No Broadcast, No Checksums

Why Not NAT

- It was created as a temp solution
- NAT breaks the end-to-end model
- Growth of NAT has slowed down growth of transparent applications
- No easy way to maintain states of NAT in case of node failures
- NAT breaks security
- NAT complicates mergers, double NATing is needed for devices to communicate with each other

IPv6 Addressing

IPv4 32-bits

IPv6 128-bits

2^{32} = 4,294,967,296

2^{128} = 340,282,366,920,938,463,463,374,607,431,768,211,456

$2^{128} = 2^{32} * 2^{96}$

2^{96} = 79,228,162,514,264,337,593,543,950,336 times the number of possible IPv4 Addresses (79 trillion trillion)

Addressing Format

Representation

- 16-bit hexadecimal numbers
- Numbers are separated by (:)
- Hex numbers are not case sensitive
- Abbreviations are possible

  Leading zeros in contiguous block could be represented by (::)

  Example:

  2001:0db8:0000:130F:0000:0000:087C:140B

  2001:0db8:0:130F::87C:140B

  Double colon only appears once in the address

Addressing

Prefix Representation

- **Representation of prefix is just like CIDR**
- **In this representation you attach the prefix length**
- **Like v4 address:**

  198.10.0.0/16

- **V6 address is represented the same way:**

  2001:db8:12::/48

- **Only leading zeros are omitted. Trailing zeros are not omitted**

  2001:0db8:0012::/48 = 2001:db8:12::/48

  2001:db8:1200::/48 ≠ 2001:db8:12::/48