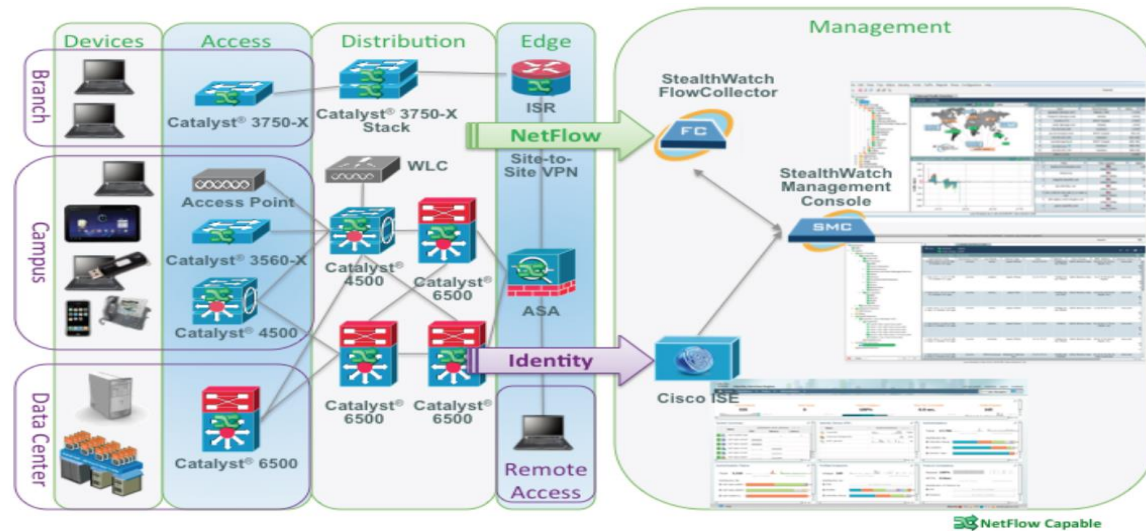


# CIS 3250

## Advanced Network Architectures



## Basic Subnetting

# Base 10 (Decimal) Number System

Digits (10): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

Number of:

	$10^4$	$10^3$	$10^2$	$10^1$	$10^0$
	<u>10,000's</u>	<u>1,000's</u>	<u>100's</u>	<u>10's</u>	<u>1's</u>
1,309		1	3	0	9
99				9	9
100			1	0	0

# Number System Rules

1. All digits start with 0
  2. A Base-n number system has n number of digits:
    - Decimal: Base-10 has 10 digits
    - Binary: Base-2 has 2 digits
    - Hexadecimal: Base-16 has 16 digits
  3. The first column is always the number of 1's
- Each of the following columns is n times the previous column (n = Base-n)

• <b>Base 10:</b>	<b>10,000</b>	<b>1,000</b>	<b>100</b>	<b>10</b>	<b>1</b>
• <b>Base 2:</b>	<b>16</b>	<b>8</b>	<b>4</b>	<b>2</b>	<b>1</b>
• <b>Base 16:</b>	<b>65,536</b>	<b>4,096</b>	<b>256</b>	<b>16</b>	<b>1</b>

Digits (2): 0, 1

Number of:

	$2^7$				$2^3$	$2^2$	$2^1$	$2^0$
	<u>128's</u>	<u>        </u>	<u>        </u>	<u>        </u>	<u>8's</u>	<u>4's</u>	<u>2's</u>	<u>1's</u>
Dec.								
2							1	0
10					1	0	1	0
17								
70								
130								
255								

Digits (2): 0, 1

Number of:

	$2^7$	$2^6$	$2^5$	$2^4$	$2^3$	$2^2$	$2^1$	$2^0$
	<u>128's</u>	<u>64's</u>	<u>32's</u>	<u>16's</u>	<u>8's</u>	<u>4's</u>	<u>2's</u>	<u>1's</u>
Dec.								
2							1	0
10					1	0	1	0
17				1	0	0	0	1
70		1	0	0	0	1	1	0
130	1	0	0	0	0	0	1	0
255	1	1	1	1	1	1	1	1

Digits (2): 0, 1

Number of:

	$2^7$	$2^6$	$2^5$	$2^4$	$2^3$	$2^2$	$2^1$	$2^0$
	<u>128's</u>	<u>64's</u>	<u>32's</u>	<u>16's</u>	<u>8's</u>	<u>4's</u>	<u>2's</u>	<u>1's</u>
Dec.		1	0	0	0	1	1	0
			1	0	1	0	0	0
	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0
172								
192								

Digits (2): 0, 1

Number of:

	$2^7$	$2^6$	$2^5$	$2^4$	$2^3$	$2^2$	$2^1$	$2^0$
	<u>128' s</u>	<u>64' s</u>	<u>32' s</u>	<u>16' s</u>	<u>8' s</u>	<u>4' s</u>	<u>2' s</u>	<u>1' s</u>
Dec.								
70		1	0	0	0	1	1	0
40			1	0	1	0	0	0
0	0	0	0	0	0	0	0	0
128	1	0	0	0	0	0	0	0
172	1	0	1	0	1	1	0	0
192	1	1	0	0	0	0	0	0

# Binary to/from Decimal

Convert Decimal to Binary

172.16.4.20

Separate and convert each  
decimal number separately

172

10101100

We start with the 172.

172 is greater than 128, place a 1 in the 128 position

- 128 and subtract 128

44 is less than 64, place a 0 in the 64 position

- 0

44 is greater than 32, place a 1 in the 32 position

- 32 and subtract 32

12 is less than 16, place a 0 in the 16 position

- 0

12 is greater than 8, place a 1 in the 8 position

- 8 and subtract 8

4 is equal to 4, place a 1 in the 4 position

- 4 and subtract 4

0 is less than 2, place a 0 in the 2 position

- 0

0 is less than 1, place a 0 in the 1 position

- 0

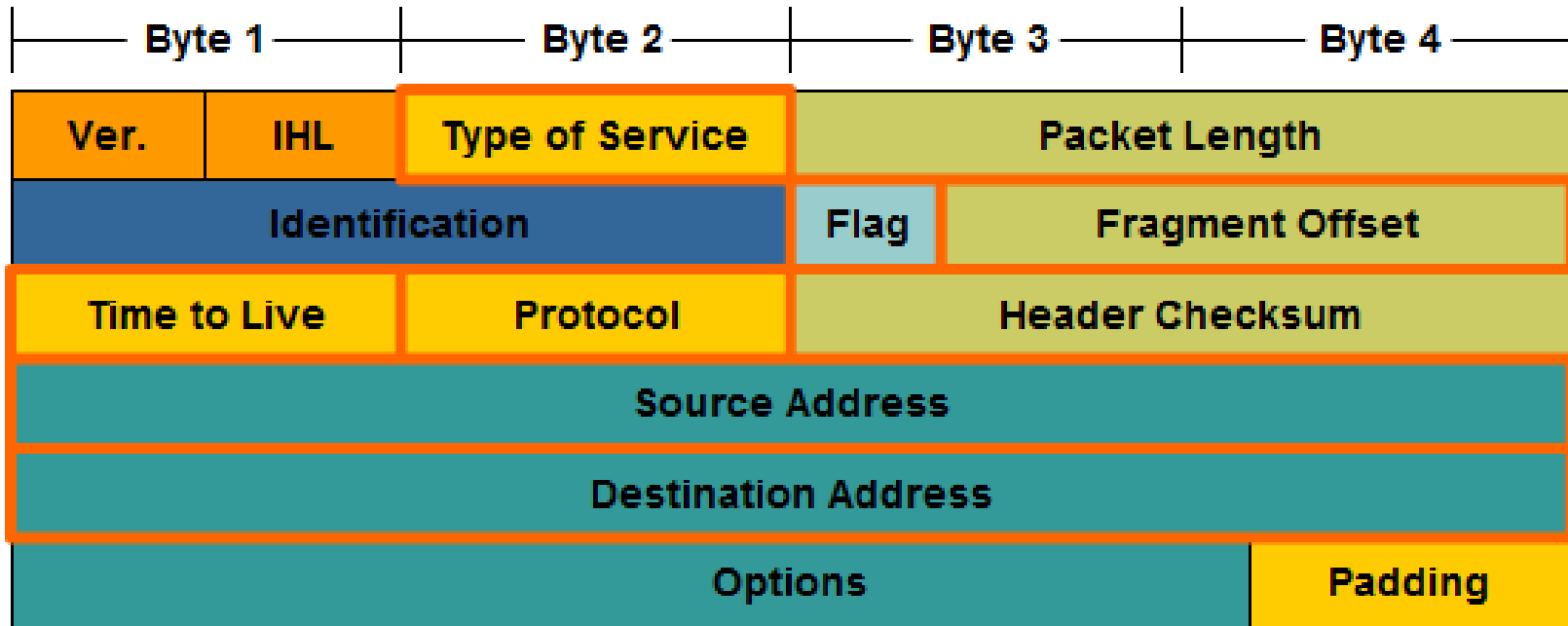
0 ALL DONE

Answer: 172 = 10101100



# IPv4 Addresses

# IPv4 Addresses



- IPv4 addresses are 32 bit addresses

# IPv4 Addresses

- IPv4 Addresses are 32 bit addresses:

1010100111000111010001011000100

10101001 11000111 01000101 10001001

- We use **dotted notation** (or **dotted decimal notation**) to represent the value of each byte (octet) of the IP address in decimal.

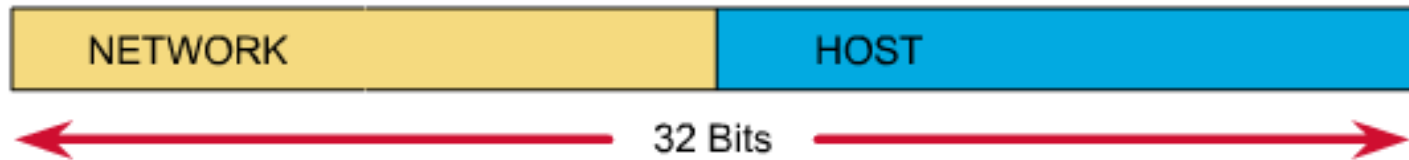
10101001 11000111 01000101 10001001  
169 . 199 . 69 . 137



# IPv4 Addresses

An IP address has two parts:

- **network number**
- **host number**



Which bits refer to the network number?

Which bits refer to the host number?

# IPv4 Addresses

Answer:

- Newer technology - **Classless IP Addressing**
  - The **subnet mask** determines the network portion and the host portion.
  - Value of first octet does NOT matter (older classful IP addressing)
  - Hosts and Classless Inter-Domain Routing (CIDR).
  - Classless IP Addressing is what is used within the Internet and in most internal networks.
- Older technology - **Classful IP Addressing (later)**
  - **Value of first octet** determines the network portion and the host portion.
  - Used with classful routing protocols like RIPv1.
  - The Cisco IP Routing Table is structured in a classful manner

# Types of Addresses

**Network Addresses** have all 0's in the host portion.

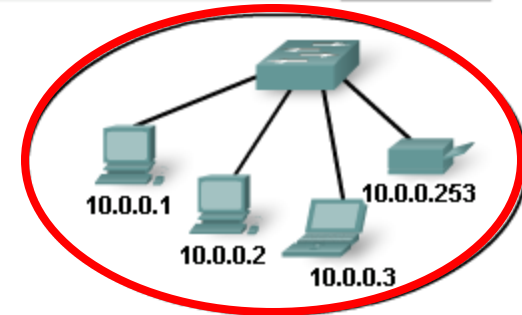
Network Address

Broadcast Address

Host Address

Network			Host
10	0	0	0
00001010	00000000	00000000	00000000
10	0	0	255
00001010	00000000	00000000	11111111
10	0	0	1
00001010	00000000	00000000	00000001

**Subnet Mask: 255.255.255.0**



- **Network address** - The address by which we refer to the network
- **Broadcast address** - A special address used to send data to all hosts in the network
- **Host addresses** - The addresses assigned to the end devices in the network

# Types of Addresses

**Broadcast Addresses have all 1's in the host portion.**

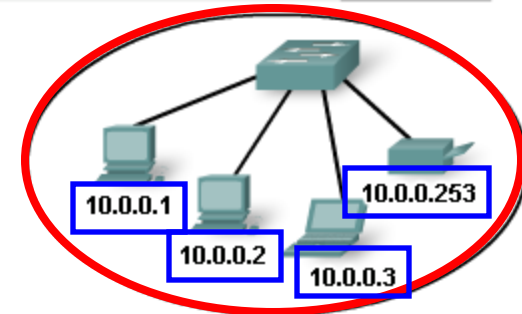
Network Address

Broadcast Address

Host Address

Network			Host
10	0	0	0
00001010	00000000	00000000	00000000
10	0	0	255
00001010	00000000	00000000	11111111
10	0	0	1
00001010	00000000	00000000	00000001

**Subnet Mask: 255.255.255.0**



- **Network address** - The address by which we refer to the network
- **Broadcast address** - A special address used to send data to all hosts in the network
- **Host addresses** - The addresses assigned to the end devices in the network

# Types of Addresses

Network Address

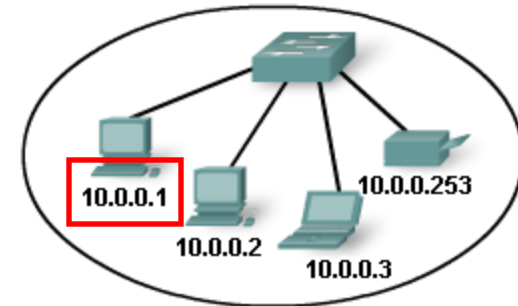
Broadcast Address

Host Address

Host Addresses can not have all 0's or all 1's in the host portion.

Subnet Mask: 255.255.255.0

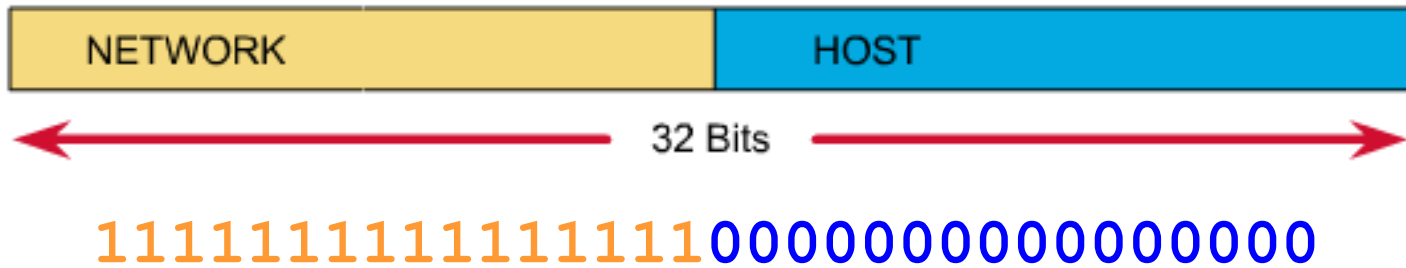
Network			Host
10	0	0	0
00001010	00000000	00000000	00000000
10	0	0	255
00001010	00000000	00000000	11111111
10	0	0	1
00001010	00000000	00000000	00000001



- **Network address** - The address by which we refer to the network
- **Broadcast address** - A special address used to send data to all hosts in the network
- **Host addresses** - The addresses assigned to the end devices in the network



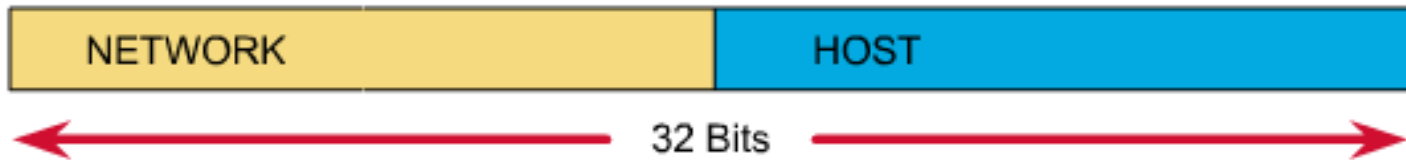
# Dividing the Network and Host Portions



## ● Subnet Mask

- Used to define the:
  - Network portion
  - Host portion
- 32 bits
- Contiguous set of 1's followed by a contiguous set of 0's
  - 1's: Network portion
  - 0's: Host portion

# Dividing the Network and Host Portions



11111111.11111111.00000000.00000000

Dotted decimal: 255 . 255 . 0 . 0

Slash notation: /16

## ● Expressed as:

- Dotted decimal
  - Ex: 255.255.0.0
- Slash notation or prefix length
  - /16 (the number of one bits)

# Network Addresses

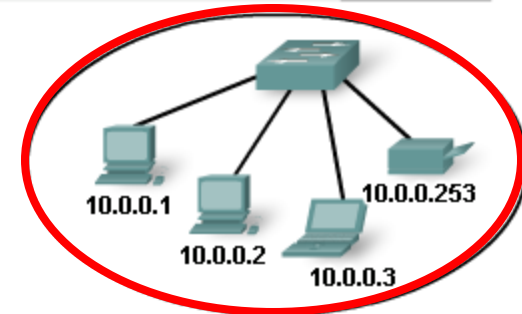
Network Address

Broadcast Address

Host Address

Network			Host
10	0	0	0
00001010	00000000	00000000	00000000
10	0	0	255
00001010	00000000	00000000	11111111
10	0	0	1
00001010	00000000	00000000	00000001

Subnet Mask: 255.255.255.0



- **Network address** - The address by which we refer to the network
  - All binary 0's in the host portion of the address (more later)

## Example 1

Network Address: 192.168.1.0  
Subnet Mask: 255.255.255.0

192.168.1.0  
Network Host

Network Address in binary:

network  
host

11000000.10101000.00000001.00000000

Subnet Mask in binary:

11111111.11111111.11111111.00000000

Prefix Length: /24

## Example 2

Network Address: 172.0.0.0

Subnet Mask: 255.0.0.0

172.0.0.0

Network Host

Network Address in binary:

network

host

10101100.00000000.00000000.00000000

Subnet Mask in binary:

11111111.00000000.00000000.00000000

Prefix Length : /8



### Example 3

Network Address: 172.0.0.0  
Subnet Mask: 255.255.0.0

172.0.0.0  
Network Host

Network Address in binary:

network  
host  
10101100.00000000.00000000.00000000  
Subnet Mask in binary:  
11111111.11111111.00000000.00000000

Prefix Length: /16



# Subnet Masks – Your Turn!

Underline the network portion of each address:

<u>Network Address</u>	<u>Subnet Mask</u>
172.0.0.0	255.0.0.0
172.16.0.0	255.255.0.0
192.168.1.0	255.255.255.0
192.168.0.0	255.255.0.0
192.168.0.0	255.255.255.0
10.1.1.0	/24
10.2.0.0	/16
10.0.0.0	/16

- What is the other portion of the address?

# Subnet Masks – Your Turn!

Underline the network portion of each address:

<u>Network Address</u>	<u>Subnet Mask</u>
<u>172.0.0.0</u>	255.0.0.0
<u>172.16.0.0</u>	255.255.0.0
<u>192.168.1.0</u>	255.255.255.0
<u>192.168.0.0</u>	255.255.0.0
<u>192.168.0.0</u>	255.255.255.0
<u>10.1.1.0</u>	/24
<u>10.2.0.0</u>	/16
<u>10.0.0.0</u>	/16

● What is the other portion of the address?

25 • Host portion for host addresses

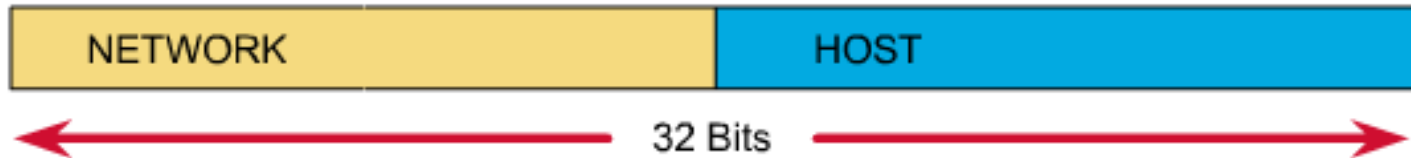


# Why the mask matters: Number of hosts!

Subnet Mask:	1st octet	2nd octet	3rd octet	4th octet
255.0.0.0 or /8	Network	Host	Host	Host
255.255.0.0 or /16	Network	Network	Host	Host
255.255.255.0 or /24	Network	Network	Network	Host

- The more host bits in the subnet mask means the more hosts in the network.
- Subnet masks do **not** have to end on “natural octet boundaries”

# IP Addresses



There is a tradeoff between:

- The number of network bits and the number of networks (subnets) you can have...

AND

- The number of HOST bits and the number of hosts for each network you can have.

This will be examined more closely, later.

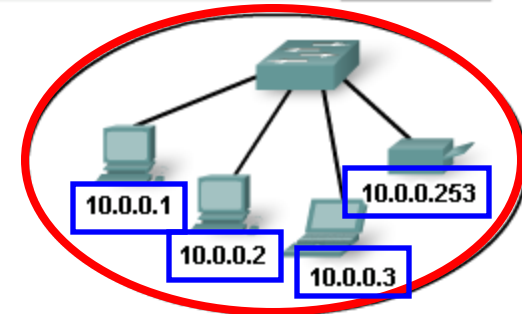
# Broadcast Addresses

Network Address

Broadcast Address

Host Address

Network			Host
10	0	0	0
00001010	00000000	00000000	00000000
10	0	0	255
00001010	00000000	00000000	11111111
10	0	0	1
00001010	00000000	00000000	00000001



- **Broadcast address** - A special address used to send data to all hosts in the network
  - All binary 1's in the host portion of the address (more later)

# Subnet Masks – Your Turn!

**What is the broadcast address of each network:**

<u>Network Address</u>	<u>Subnet Mask</u>	<u>Broadcast Address</u>
172.0.0.0	255.0.0.0	
172.16.0.0	255.255.0.0	
192.168.1.0	255.255.255.0	
192.168.0.0	255.255.0.0	
192.168.0.0	255.255.255.0	
10.1.1.0	/24	
10.2.0.0	/16	
10.0.0.0	/16	

## Subnet Masks – Your Turn!

**What is the broadcast address of each network:**

<u>Network Address</u>	<u>Subnet Mask</u>	<u>Broadcast Address</u>
172.0.0.0	255.0.0.0	172.255.255.255
172.16.0.0	255.255.0.0	172.16.255.255
192.168.1.0	255.255.255.0	192.168.1.255
192.168.0.0	255.255.0.0	192.168.255.255
192.168.0.0	255.255.255.0	192.168.0.255
10.1.1.0	/24	10.1.1.255
10.2.0.0	/16	10.2.255.255
10.0.0.0	/16	10.0.255.255

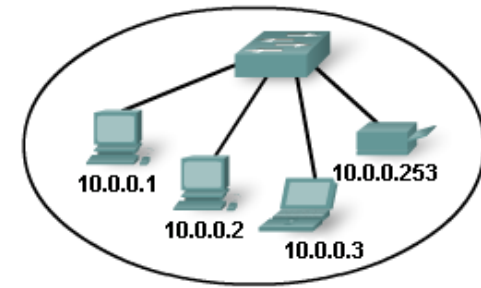
# Bringing it all together

Network Address

Broadcast Address

Host Address

Network			Host
10	0	0	0
00001010	00000000	00000000	00000000
10	0	0	255
00001010	00000000	00000000	11111111
10	0	0	1
00001010	00000000	00000000	00000001



- Subnet Mask divides Network portion and Host portion:
  - 1's: Network portion
  - 0's: Host portion
- Network address:
  - All 0's in the host portion of the address
- Broadcast address:
  - All 1's in the host portion of the address

## Bringing it all together

- Convert these addresses and masks to Binary (to be used later)

```
Network: 172.0.0.0  10101100.00000000.00000000.00000000
Mask:      255.0.0.0  -----
          172.255.255.255
Broadcast Address
```

```
Network: 172.16.0.0 10101100.00010000.00000000.00000000
Mask:      255.255.0.0 11111111.11111111.00000000.00000000
          172.16.255.255
Broadcast Address
```



# Bringing it all together

- Convert these addresses and masks to Binary (to be used later)

```
Network: 192.168.1.0   11000000.10101000.00000001.00000000
Mask:    255.255.255.0
Bcst:    192.168.1.255  -----
```

```
Network: 192.168.0.0   11000000.10101000.00000000.00000000
Mask:    255.255.0.0   11111111.11111111.00000000.00000000
Bcst:    192.168.255.255 11000000.10101000.11111111.11111111
```

```
Network: 192.168.0.0
Mask:    255.255.255.0 11111111.11111111.11111111.00000000
Bcst:    192.168.0.255
```





## Bringing it all together

- Convert these addresses and masks to Binary (to be used later)

Network: 10.1.1.0    00001010.00000001.00000001.00000000

Mask: /24

Bcast: 10.1.1.255    -----

Network: 10.2.0.0    00001010.00000010.00000000.00000000

Mask: /16            11111111 11111111 00000000 00000000

Bst:10.2.255.255

Network 10.0.0.0    -----

Mask: /16            11111111.11111111.00000000.00000000

Bcast10.0.255.255



# Host IP Addresses



**192.168.10.100/24**

- Host IP Addresses contain:
  - Network portion of the address
  - Unique combination of 0's and 1's in the host portion of the address
    - Cannot be all 0's (network address)
    - Cannot be all 1's (broadcast address)
- Hosts have subnet masks to determine network portion (later)

## Range of hosts – Your Turn!

- Host addresses are all addresses between the network address and the broadcast address.
- What is the range of host addresses for each network?

<u>Network Address</u>	<u>Subnet Mask</u>	<u>Broadcast Address</u>
172.0.0.0	255.0.0.0	172.255.255.255
172.16.0.0	255.255.0.0	172.16.255.255
192.168.1.0	255.255.255.0	192.168.1.255
192.168.0.0	255.255.0.0	192.168.255.255
192.168.0.0	255.255.255.0	192.168.0.255
10.1.1.0	/24	10.1.1.255
10.2.0.0	/16	10.2.255.255
10.0.0.0	/16	10.0.255.255

## Range of hosts – Your Turn!

<u>Network Address</u>	<u>Subnet Mask</u>	<u>Broadcast Address</u>
172.0.0.0	255.0.0.0	172.255.255.255
172.0.0.1 through	172.255.255.254	
172.16.0.0	255.255.0.0	172.16.255.255
172.16.0.1 through	172.16.255.254	
192.168.1.0	255.255.255.0	192.168.1.255
192.168.1.1 through	192.168.1.254	
192.168.0.0	255.255.255.0	192.168.255.255
192.168.0.1 through	192.168.255.254	
192.168.0.0	255.255.255.0	192.168.0.255
192.168.0.1 through	192.168.0.254	



## Range of hosts – Your Turn!

<u>Network Address</u>	<u>Subnet Mask</u>	<u>Broadcast Address</u>
10.1.1.0	/24	10.1.1.255
10.2.0.0	/16	10.2.255.255
10.0.0.0	/16	10.0.255.255

# Range of hosts – Your Turn!

- Host Addresses in binary

172.0.0.0 (net)	10101100.00000000.00000000.00000000
255.0.0.0 (SM)	11111111.00000000.00000000.00000000
172.0.0.1	10101100.00000000.00000000.00000001
172.255.255.254	10101100.-----
172.255.255.255 (broadcast)	10101100.-----

172.16.0.0 (net)	10101100.00010000.00000000.00000000
255.255.0.0 (SM)	11111111.11111111.00000000.00000000
172.16.0.1	10101100.00010000.00000000.00000001
172.16.255.254	10101100.00010000.11111111.11111110
172.16.255.255 (broadcast)	10101100.00010000.-----



# Range of hosts – Your Turn!

- Host Addresses in binary

192.168.1.0 (net)	11000000.10101000.00000001.00000000
255.255.255.0 (SM)	11111111.11111111.11111111.00000000
192.168.1.1	11000000.10101000.00000001.00000001
192.168.1.254	11000000.10101000.00000001.
192.168.1.255 (broadcast)	11000000.10101000.00000001.

192.168.0.0 (net)	11000000.10101000.00000000.00000000
255.255.0.0 (SM)	11111111.11111111.00000000.00000000
192.168.0.1	11000000.10101000.00000000.00000001
192.168.255.254	11000000.10101000.11111111.11111110
192.168.255.255 (broadcast)	11000000.10101000.-----



## Range of hosts – Your Turn!

### ● Host Addresses in binary

192.168.0.0 (net)	11000000.10101000.00000000.00000000
255.255.255.0 (SM)	11111111.11111111.11111111.
192.168.0.1	11000000.10101000.00000000.-----
192.168.0.254	11000000.10101000.00000000.11111110
192.168.0.255 (broadcast)	11000000.10101000.00000000.11111111



## Range of hosts – The rest...

### Host Addresses in binary

10.1.1.0 (net)	00001010.00000001.00000001.00000000
/24 (SM)	11111111.11111111.11111111.00000000
10.1.1.1	00001010.00000001.00000001.00000001
10.1.1.254	00001010.00000001.00000001.
10.1.1.255 (broadcast)	00001010.00000001.00000001.
10.2.0.0 (net)	00001010.00000010.00000000.00000000
/16 (SM)	11111111.11111111.00000000.00000000
10.2.0.1	00001010.00000010.00000000.00000001
10.2.255.254	00001010.00000010.11111111.11111110
10.2.255.255 (broadcast)	00001010.00000010.



## Range of hosts – The rest...

- **Host Addresses in binary**

10.0.0.0 (net)

00001010.00000000.00000000.00000000

/16 (SM)

11111111.11111111.0000

10.0.0.1

00001010.00000000.00000000.00000001

10.0.255.254

00001010.00000000.11111111.11111110

10.0.255.255

00001010.00000000.11111111.11111111

(broadcast)



## Subnet Masks: Non-Natural Boundaries

- Subnet masks do not have to end on natural octet boundaries
- Convert these to binary:

<u>Network Address</u>	<u>Subnet Mask</u>
172.1.16.0	255.255.240.0
192.168.1.0	255.255.255.224

## Subnet Masks: Non-Natural Boundaries

- Subnet masks do not have to end on natural octet boundaries

172.1.16.0

10101100.00000001.00010000.00000000

255.255.240.0

11111111.11111111.11110000.00000000

- What is the range of host addresses in dotted-decimal and binary?
- What is the broadcast address?
- How many host addresses?

# Subnet Masks: Non-Natural Boundaries

- Subnet masks do not have to end on natural octet boundaries

172.1.16.0	10101100.00000001.00010000.00000000
255.255.240.0	11111111.11111111.11110000.00000000
172.1.16.1	10101100.00000001.00010000.00000001
172.1.16.2	10101100.00000001.00010000.00000000
172.1.16.3	10101100.00000001.00010000.00000000
...	
172.1.16.255	10101100.00000001.00010000.00000000
172.1.17.0	10101100.00000001.00010000.00000000
172.1.17.1	10101100.00000001.00010000.00000000
...	
172.1.31.254	10101100.00000001.00010000.00000000



# Subnet Masks: Non-Natural Boundaries

- Subnet masks do not have to end on natural octet boundaries

172.1.16.0	10101100.00000001.00010000.00000000
255.255.240.0	11111111.11111111.11110000.00000000

172.1.16.1	10101100.00000001.00010000.00000001
------------	-------------------------------------

...

172.1.31.254	10101100.00000001.0001
--------------	------------------------

172.1.31.255 (broadcast)	10101100.00000001.0001
-----------------------------	------------------------

Number of hosts:  $2^{12} - 2 = 4,096 - 2 = 4,094$  hosts



# Subnet Masks: Non-Natural Boundaries

- Subnet masks do not have to end on natural octet boundaries

192.168.1.0	11000000.10101000.00000001.00000000
255.255.255.224	11111111.11111111.11111111.11100000
192.168.1.1	11000000.10101000.00000001.00000001
192.168.1.2	11000000.10101000.00000001.00000000
192.168.1.3	11000000.10101000.00000001.00000000
...	
192.168.1.29	11000000.10101000.00000001.00000000
192.168.1.30	11000000.10101000.00000001.00000000
192.168.1.31 (broadcast)	11000000.10101000.00000001.00000000



# Subnet Masks: Non-Natural Boundaries

- Subnet masks do not have to end on natural octet boundaries

192.168.1.0	11000000.10101000.00000001.00000000
255.255.255.224	11111111.11111111.11111111.11100000

192.168.1.1	11000000.10101000.00000001.00000001
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...

192.168.1.30	11000000.10101000.00000001.000
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192.168.1.31 (broadcast)	11000000.10101000.00000001.000
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Number of hosts:  $2^5 - 2 = 32 - 2 = 30$  hosts

