Computer Networks II

Lecture No. 3

“IP Addressing”
Classes And Subnetting

4^{th} Year/ 1^{st} semester

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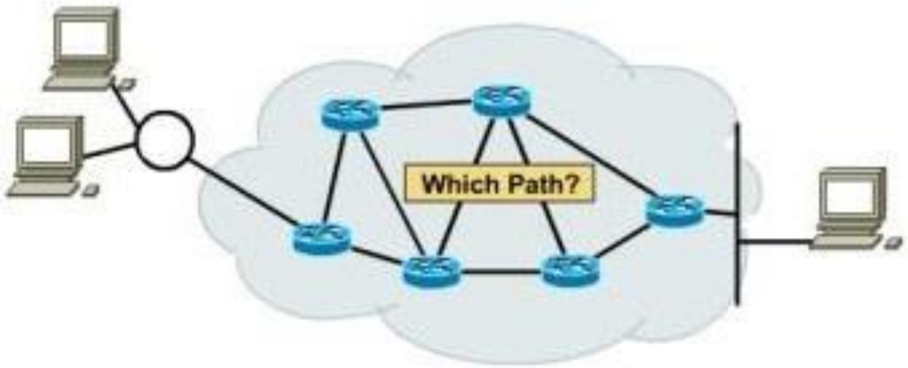
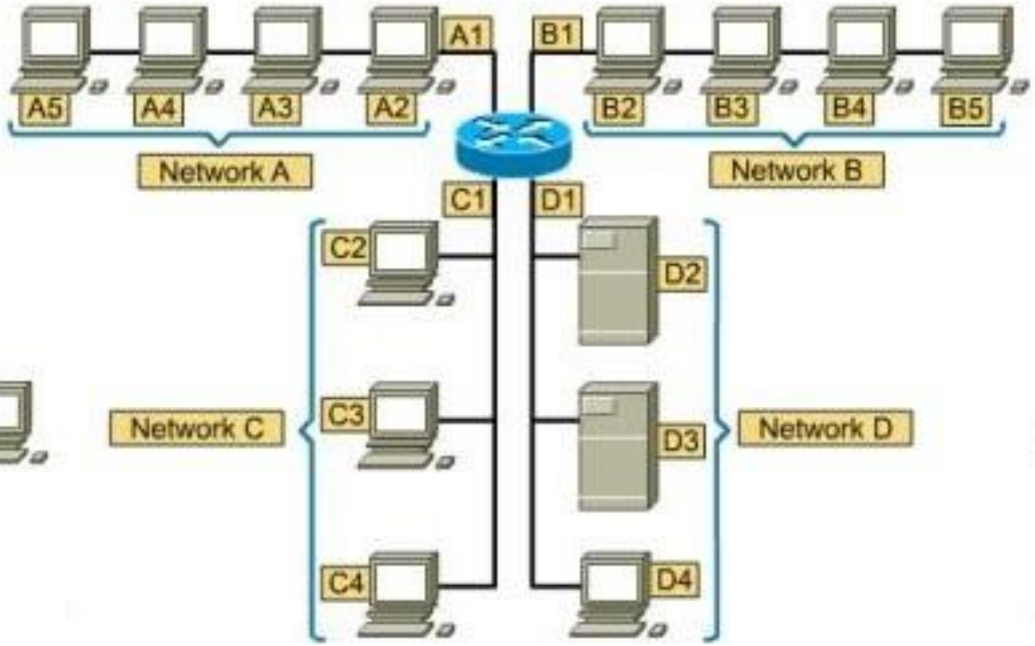
Identifying Network Users

- The **network layer** is responsible for *moving data through a set of networks.*
- **Protocols** that support network layer use *hierarchical addressing*
- **Protocols** that have no network layer only work on *small internal networks.*
- **Protocols** that have no network layer use a *flat addressing scheme* that does not scale well



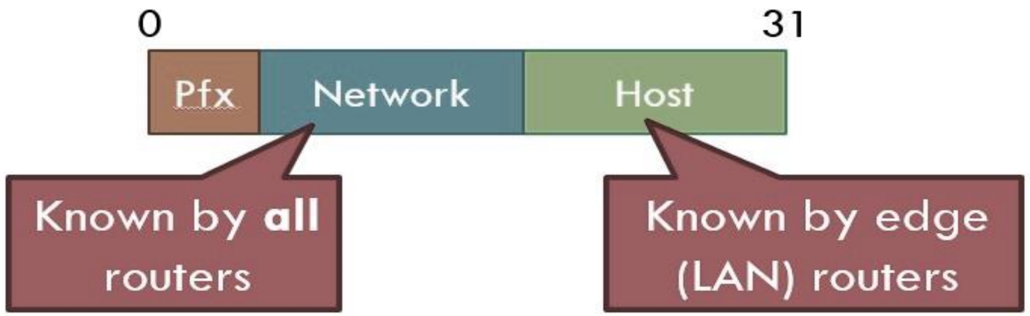


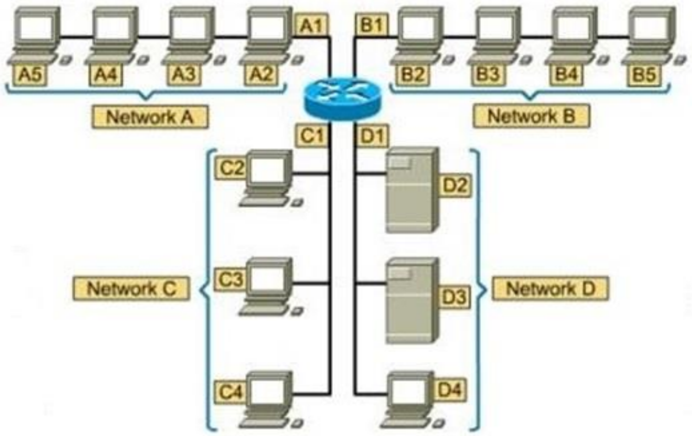
Flat versus Hierarchical

- Layer 2 - Flat addressing schemes
  - Next available
  - Social Security Number
  - MAC addresses

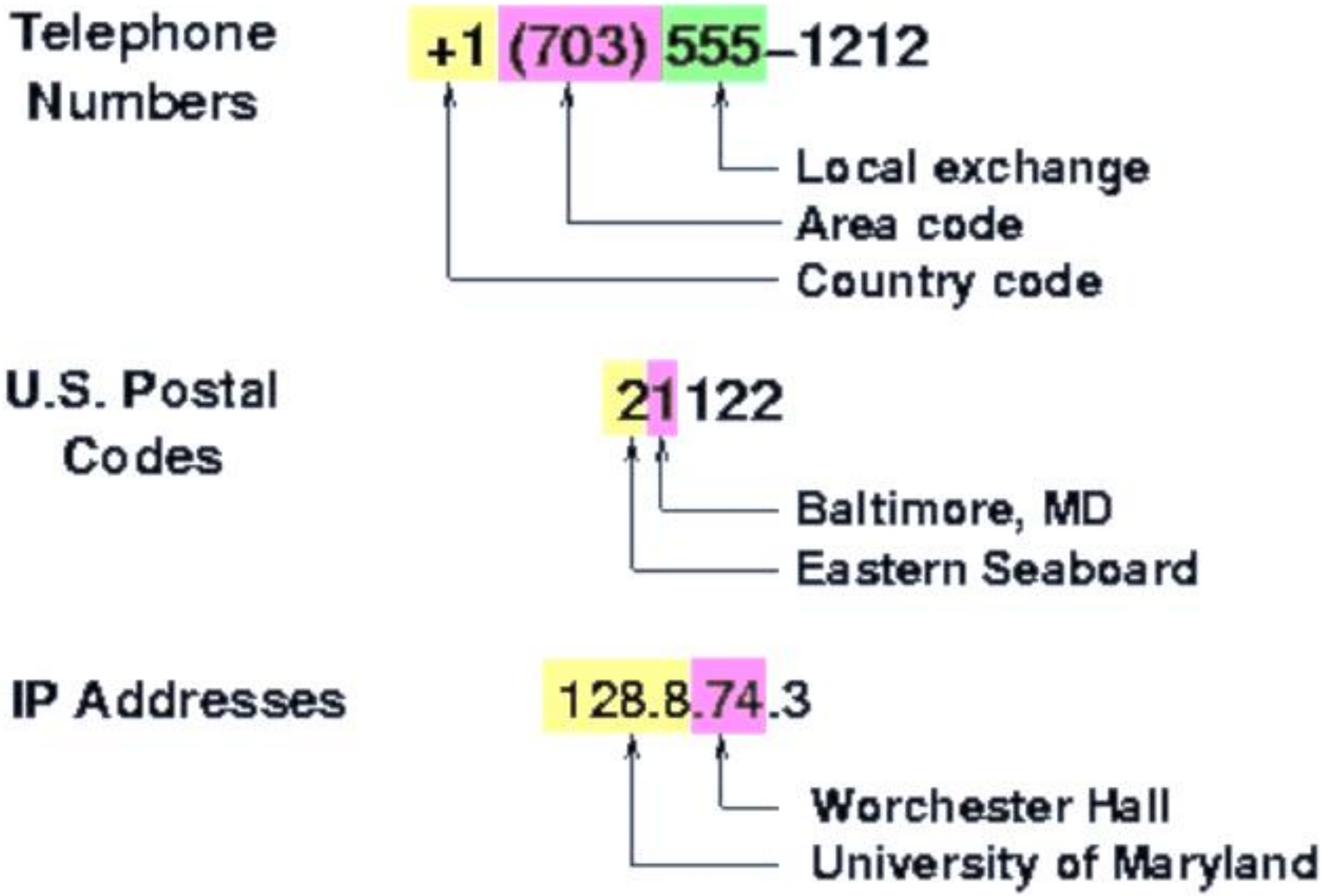
- Layer 3 - Hierarchical addressing schemes
  - Phone numbers
  - ZIP codes
  - IP addresses

- Hierarchical address scheme
  - Separate the address into a network and a host



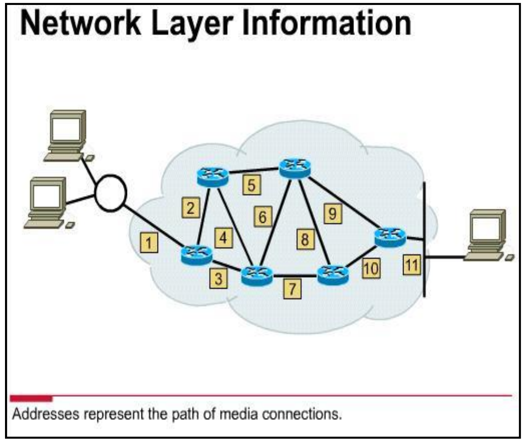


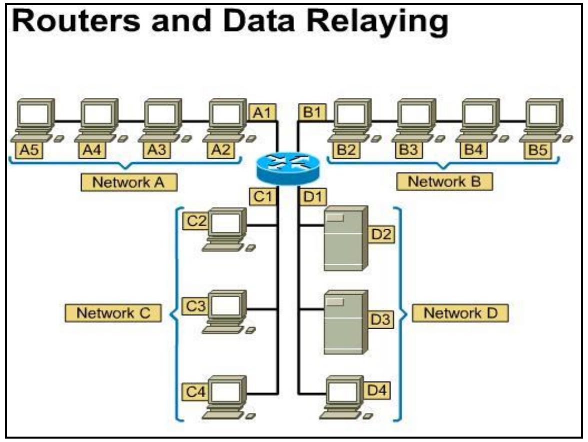
Hierarchical Addressing



Layer 3 Network Device

- **Routers** are internetworking devices which operate at OSI Layer 3 (the network layer).
- They tie together, or interconnect, network segments or entire networks.
- They **pass data packets** between networks based on Layer 3 information .
- **Routers** make **logical decisions** regarding the best path for the delivery of data on an internetwork and then direct packets to the appropriate output port and segment.
- **Routers** take packets from LAN devices (e.g. workstations) and, based on Layer 3 information, **forward** them through the network.
- In fact, routing is sometimes referred to as *Layer 3 switching .*

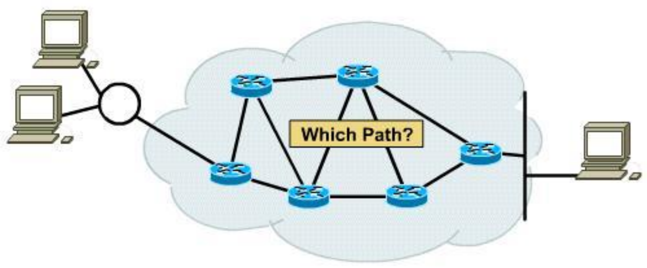




Path Determination

- *Path determination* occurs at Layer 3 (network layer).
- It **enables a router** to **evaluate** the **available paths** to a destination, and to establish the preferred handling of a packet.
- **Routing** services use network **topology** information when evaluating network paths.
- **Path determination** is the process that the router uses to choose the next hop in the path for the packet to travel to its destination.
- This process is also called **routing the packet**.

Network Layer: Path Determination



Layer 3 functions to find the best path through the internetwork.

Network Layer Addressing

- The **network address** helps the router identify a path within the network cloud.
- The router uses the network address to identify the destination network of a packet within an internetwork.
- In addition to the network address, network protocols use some form of **host, or node, address**.
- For some network layer protocols, a network **administrator assigns network host addresses** according to some predetermined internetwork addressing plan.
- For other network layer protocols, assigning host addresses is partially or completely **dynamic/automatic**.

Network Layer Datagram

- The Internet Protocol (IP) is the most popular implementation of a hierarchical network addressing scheme.
- IP is the network protocol the Internet uses.
- As information flows down the layers of the OSI model, the data is encapsulated at each layer.
- At the network layer, the data is encapsulated within packets (also known as **datagrams**).
- The Layer 3 packet/datagram becomes the Layer 2 data, which is then encapsulated into frames (as previously discussed).

Network Layer Field

- Similarly, the IP packet consists of the data from upper layers plus an IP header, which consists of:

IP Packet

0	4	8	16	19	24	31
VERS	HLEN	Service Type	Total Length			
Identification			Flags	Fragment Offset		
Time to Live		Protocol	Header Checksum			
Source IP Address						
Destination IP Address						
IP Options (If Any)						Padding
Data						
. . .						

IP Addressing & Subnetting

IP Address

	Internet Protocol version 4 (IPv4)	Internet Protocol version 6 (IPv6)
Deployed	1981	1999
Address Size	32-bit number	128-bit number
Address Format	Dotted Decimal Notation: 192.149.252.76	Hexadecimal Notation: 3FFE:F200:0234:AB00: 0123:4567:8901:ABCD
Prefix Notation	192.149.0.0/24	3FFE:F200:0234::/48
Number of Addresses	2^{32} = ~4,294,967,296	2^{128} = ~340,282,366, 920,938,463,463,374, 607,431,768,211,456

Classful Vs Classless Address(IPv4)

Classful Addressing:

- No such name, when classless addressing system came into existence then named as Classful.
- Each of the **IP address** belongs to a particular class that's why they are classful addresses.
- All the IP addresses that are available are divided into the five classes A,B,C,D and E.
- Class A,B and C address are frequently used
  - Class D is for **Multicast** and is rarely used **(IP TV)**
  - Class E is **reserved** and is not currently in use.

Classful Addressing (Disadvantages)

- It limits the flexibility and number of addresses
- Don’t send subnet information – sends complete network address.
    - Router supply to, its own locally config. subnet mask.
    - You have the same subnet mask in a classful network address.
- Only pass the Network address and not pass subnet mask
- i;e; 10.0.0.0
- Example: RIP v1, IGRP
- It follow the IP classes (A,B,C,E,F)
- All range of IPs have the same of subnet mask
- Default subnet mask

Classless Addressing

- Classless addressing system is also known as CIDR (Classless Inter-Domain Routing).
- Classless addressing is a way, to allocate and specify the Internet addresses used in inter-domain routing.
- More flexible than Classful IP Addresses.
- Pass both network address and subnet mask
- i;e 1.5.0.0   255.255.0.0
- Example; RIPv2, EIGRP, OSPF, ISIS

It does not follow the IP classes (A,B,C)

Different subnet mask of networks

Do not use default subnet mask

IPv4 Addressing

- 32 bit (4 octets) addresses consisting of two parts
  - Network
  - Host
- Typically represented in dotted decimal notation
  - Example address: 192.36.43.6 (decimal)
- The address is broken up into 4 octets
  - Minimum value for an octet is 0 (all bits 0)
  - Maximum value for an octet is 255 (all bits 1)
- Hierarchical Addressing Framework
  - Network.Host

IPv4 Addressing

- Classes of IP addresses:
  - **Class A** - 126 networks and 16,777,214 hosts per network
    - 8 bits allocated to network, 24 bits allocated to host
    - Default subnet mask – 255.0.0.0
    - First octet bit pattern - 0xxxxxxx
    - First octet range - 1 - 126
  - **Class B** - 16,383 networks and 65,534 hosts per network
    - 16 bits allocated to network, 16 bits allocated to host
    - Default subnet mask – 255.255.0.0
    - First octet bit pattern - 10xxxxxx
    - First octet range - 128 - 191

IPv4 Addressing

- Classes of IP addresses:
  - **Class C** - 2,097,151 networks and 254 hosts per network
    - 24 bits allocated to network, 8 bits allocated to host
    - Default subnet mask – 255.255.255.0
    - First octet bit pattern - 110xxxxx
    - First octet range - 192 - 223
  - **Class D** - Used for multicast
    - First octet bit pattern - 1110xxxx
    - First octet range - 224 - 239
  - **Class E** - Used for experiments or research
    - First octet bit pattern - 1111xxxx
    - First octet range - 240 - 254

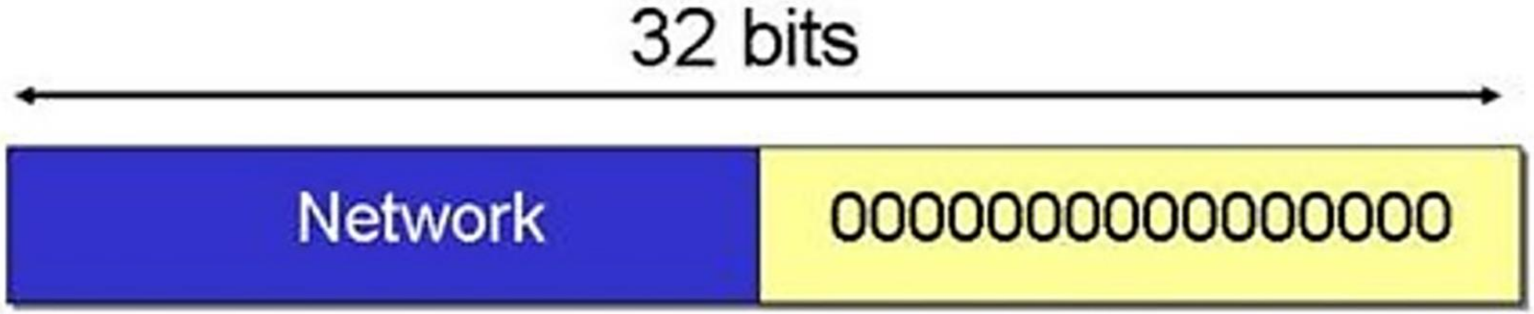
IPv4 Special Addresses

- Special IP addresses:
  - **Loopback** - 127.x.x.x has been designated as a loopback address
  - **Broadcast** - 255.255.255.255 used to send broadcast messages on the local network
    - Routers do not traditionally pass broadcast addresses
    - Generally the layer 3 broadcast is seen at layer 2 as 0xffffffffffff (MAC Address)
  - **All Hosts Broadcast** - All host bits set to 1
    - Known as a directed broadcast
  - **All Subnets Broadcasts**- All subnet bits set to 1
    - Rarely implemented in routers
  - **Multicast** – Defined by the leading address bits of *1110*
    - Includes the addresses from 224.0.0.0 to 239.255.255.255

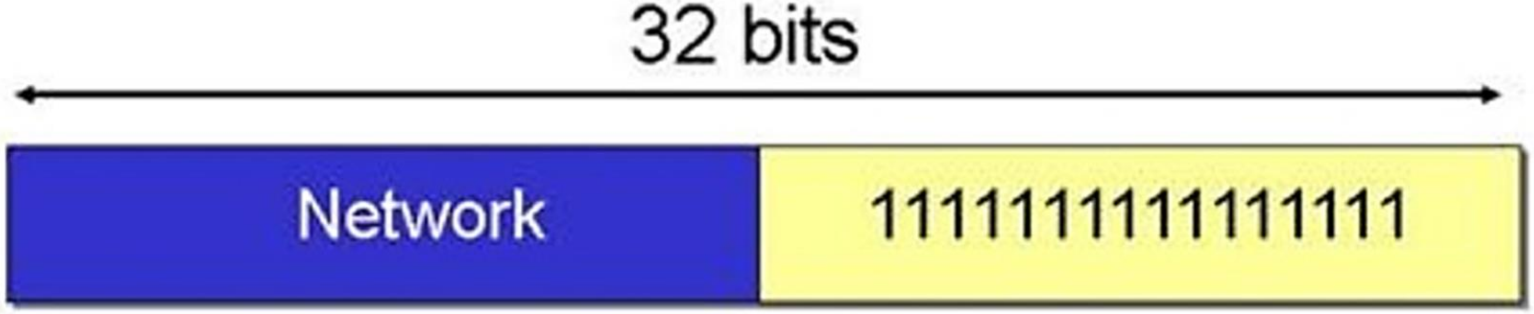
محجوز بكل احتمالاته لفحص كارت الشبكة يعمل ام لا ؟ وننتظر الرد منه

IPv4 Special Addresses

Network Address: Host Portion all zeros



Broadcast Address: Host Portion all ones



IPv4 Address Ranges

IP Address Class	First Octet Binary Value	First Octet Decimal Value	Possible Number of Hosts
Class A	1 - 126	00000001 to 01111110*	16,777,214
Class B	128 - 191	10000000 to 10111111	65,534
Class C	192 - 223	11000000 to 11011111	254

**127 (01111111) is a Class A address reserved for loopback and cannot be assigned to a network.*

Note: Class D (Multicast) range is 224-239

Binary to Decimal Conversion

Converting binary to decimal examples:

128	64	32	16	8	4	2	1: Bit values
0	0	0	0	0	0	0	0 = 0
0	0	0	0	1	1	1	1 = 15
0	1	0	1	0	1	0	1 = 85
1	0	0	0	0	0	1	1 = 131
0	0	0	1	0	1	1	0 = 22
1	1	1	1	1	1	1	1 = 255

What is the hex equivalent of each binary number?

Binary (Cont.)

Bits	Binary	Decimal
0	00000000	0
1	10000000	128
2	11000000	192
3	11100000	224
4	11110000	240
5	11111000	248
6	11111100	252
7	11111110	254
8	11111111	255

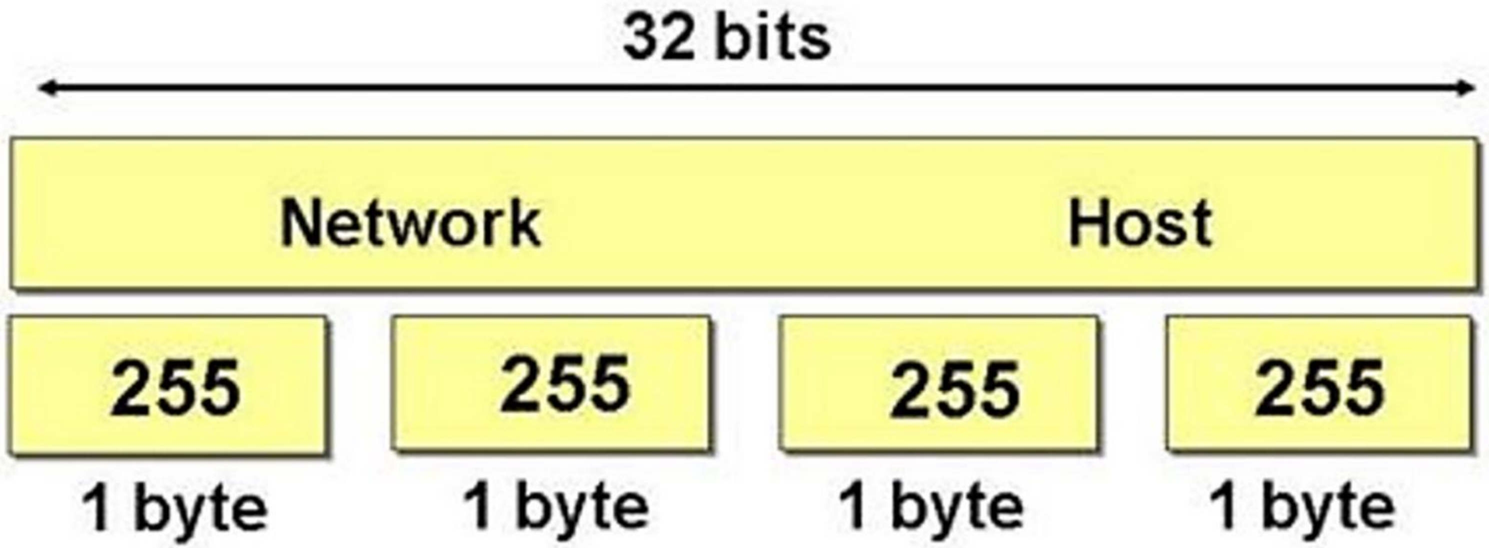
Math to memorize!

Subnet mask	Block Size
256-128	128
256-192	64
256-224	32
256-240	16
256-248	8
256-252	4
256-254	2
256-255	1

Powers of 2

$2^1=2$	$2^9=512$
$2^2=4$	$2^{10}=1,024$
$2^3=8$	$2^{11}=2,048$
$2^4=16$	$2^{12}=4,096$
$2^5=32$	$2^{13}=8,192$
$2^6=64$	$2^{14}=16,384$
$2^7=128$	$2^{15}=32,768$
$2^8=256$	$2^{16}=65,536$

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

Class A:	0NNNNNNN	Range (1-126)	00000000 = 0 01111111 = 127
Class B:	10NNNNNN	Range (128-191)	10000000 =128 10111111 = 191
Class C:	110NNNNN	Range (192-223)	11000000 = 192 11011111 = 223

Note: Class D range is 224-239 referred to as Multicast addresses

IP Address Ranges

10.0.0.0	Network Address
10.0.0.1	First valid host
10.255.255.254	Last valid host
10.255.255.255	Broadcast Address

172.16.0.0	192.168.10.0
172.16.0.1	192.168.10.1
172.16.255.254	192.168.10.254
172.16.255.255	192.168.10.255

IP Subnetting

Before subnetting:

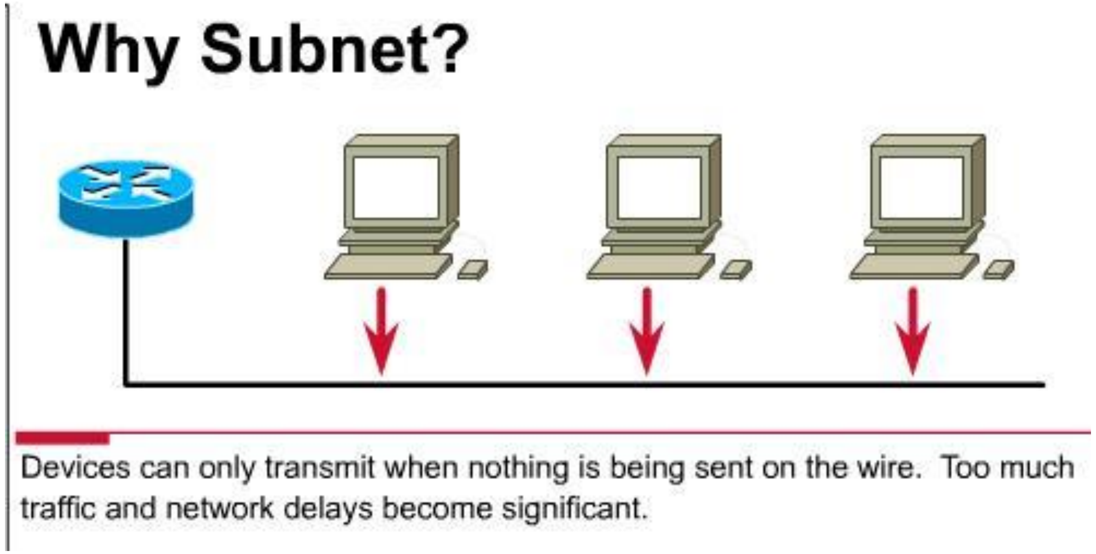
- In any network (or subnet) one can use most of the IP addresses for host addresses.

- One loses two addresses for every network or subnet.

1. Network Address - One address is reserved to that of the network.
2. Broadcast Address – One address is reserved to address all hosts in that network or subnet.

Purpose of Subnetting

- A primary reason for using subnets is to reduce the size of a broadcast domain.
- Broadcasts are sent to all hosts on a network or subnetwork.
- When broadcast traffic begins to consume too much of the available bandwidth, network administrators may choose to reduce the size of the broadcast domain.

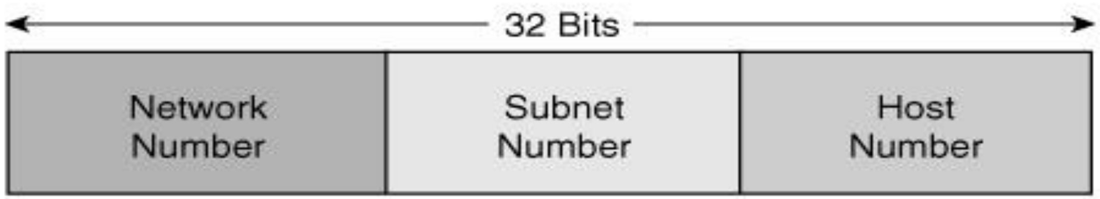


Important things to remember about Subnetting

- You can only subnet the host portion, you do not have control of the network portion.
- Subnetting does not give you more hosts, it only allows you to divide your larger network into smaller networks.
- When subnetting, you will actually lose host addresses:
  - For each subnet you lose the **address** of that subnet
  - For each subnet you lose the **broadcast** address of that subnet
  - **You "may" lose the first and last subnets**

Subnet Masking

- A subnet mask is a 32-bit number that acts as a counterpart to the IP address.
- Each bit in the mask corresponds to its counterpart bit in the IP address.
- Logical ANDing is applied to the address and mask.
- If a bit in the IP address corresponds to a 1 bit in the subnet mask, the IP address bit represents a network number.
- If a bit in the IP address corresponds to a 0 bit in the subnet mask, the IP address bit represents a host number.
- The subnet mask applied to an address ultimately determines the network and host portions of an IP address.



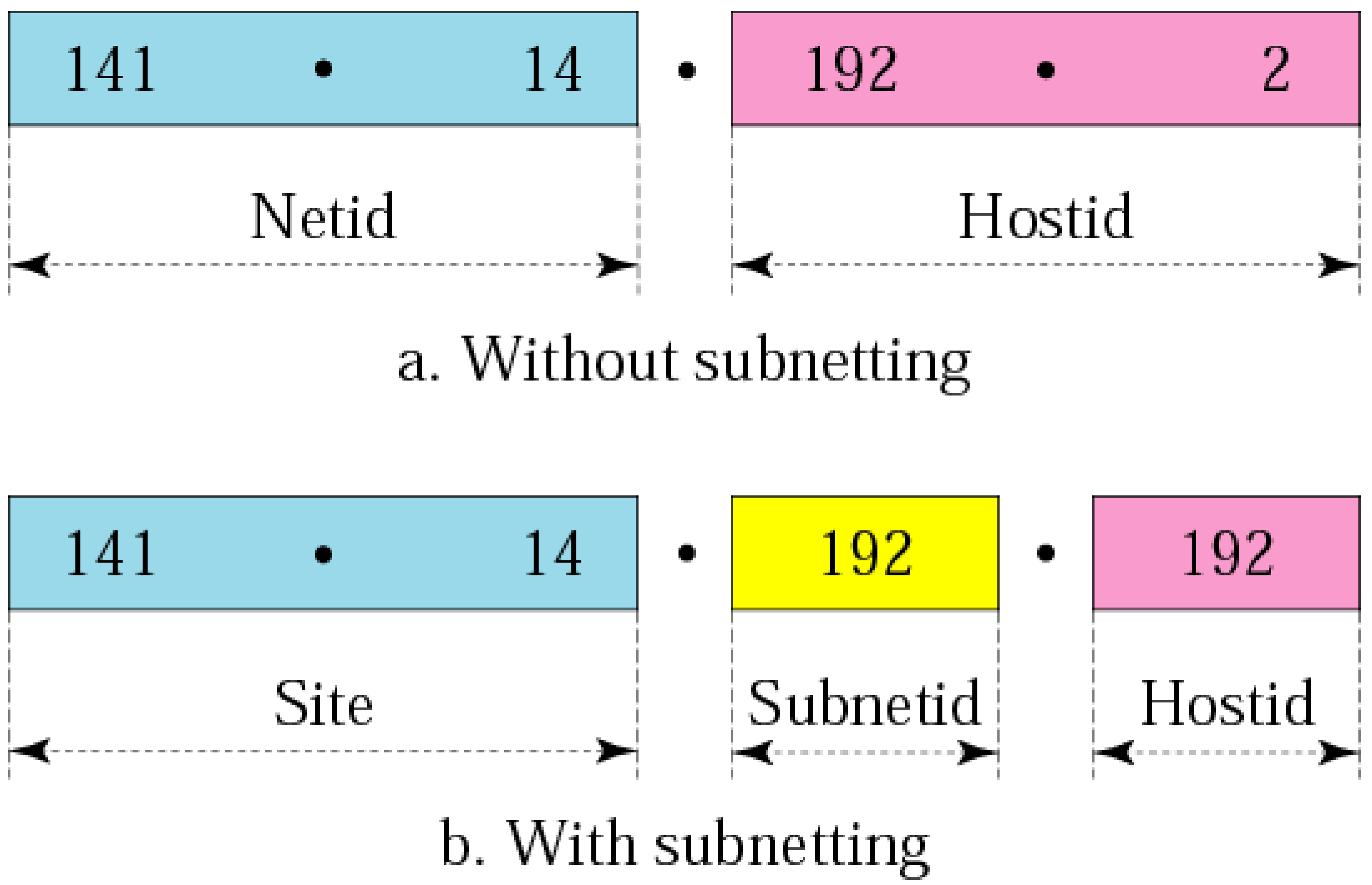
Subnet Masks

Class A default 255.0.0.0

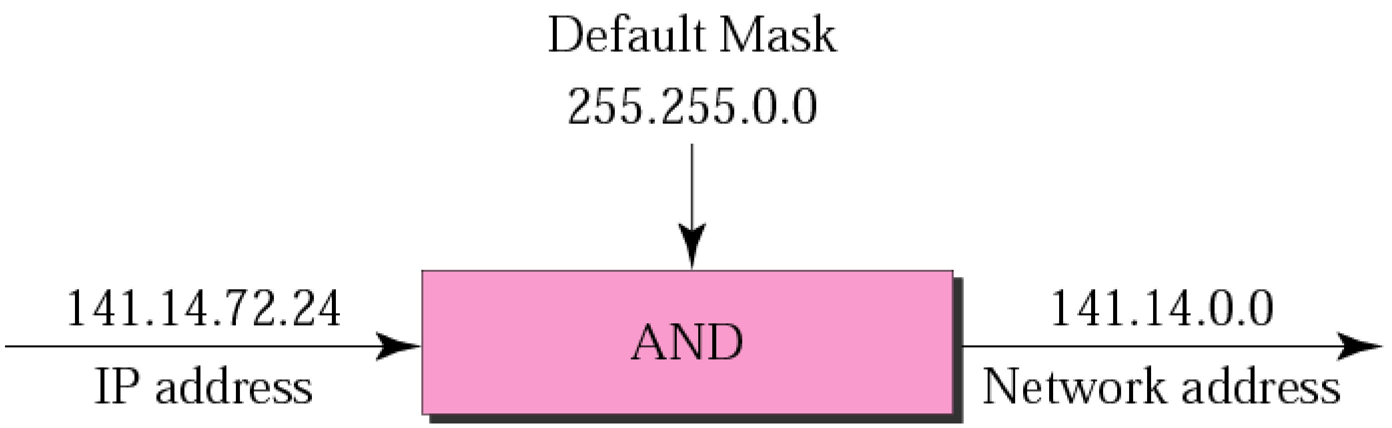
Class B default 255.255.0.0

Class C default 255.255.255.0

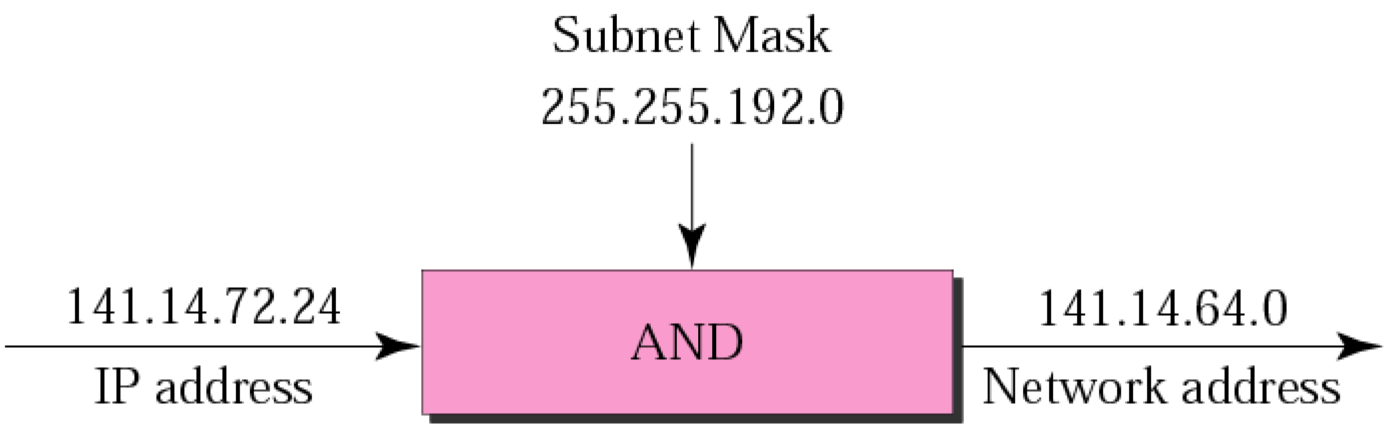
Addresses in a network with and without subnetting



Default mask and subnet mask

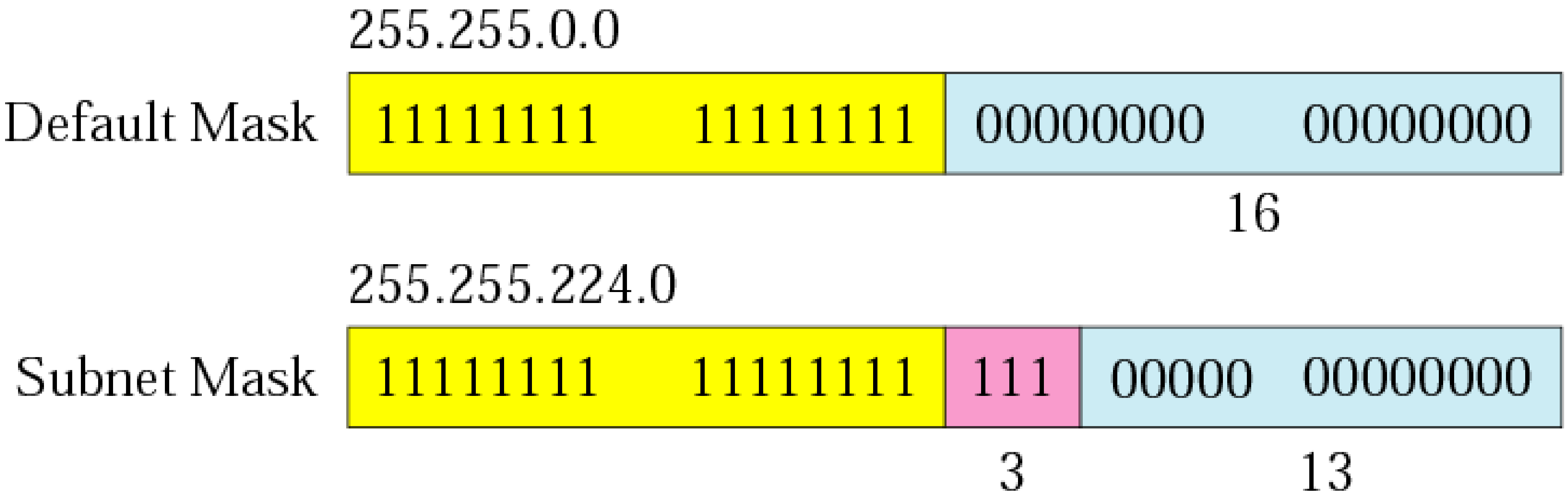


a. Without subnetting



b. With subnetting

Comparison of a default mask and a subnet mask



Valid Subnet Mask Values

128	64	32	16	8	4	2	1	Decimal Value
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 Example

	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

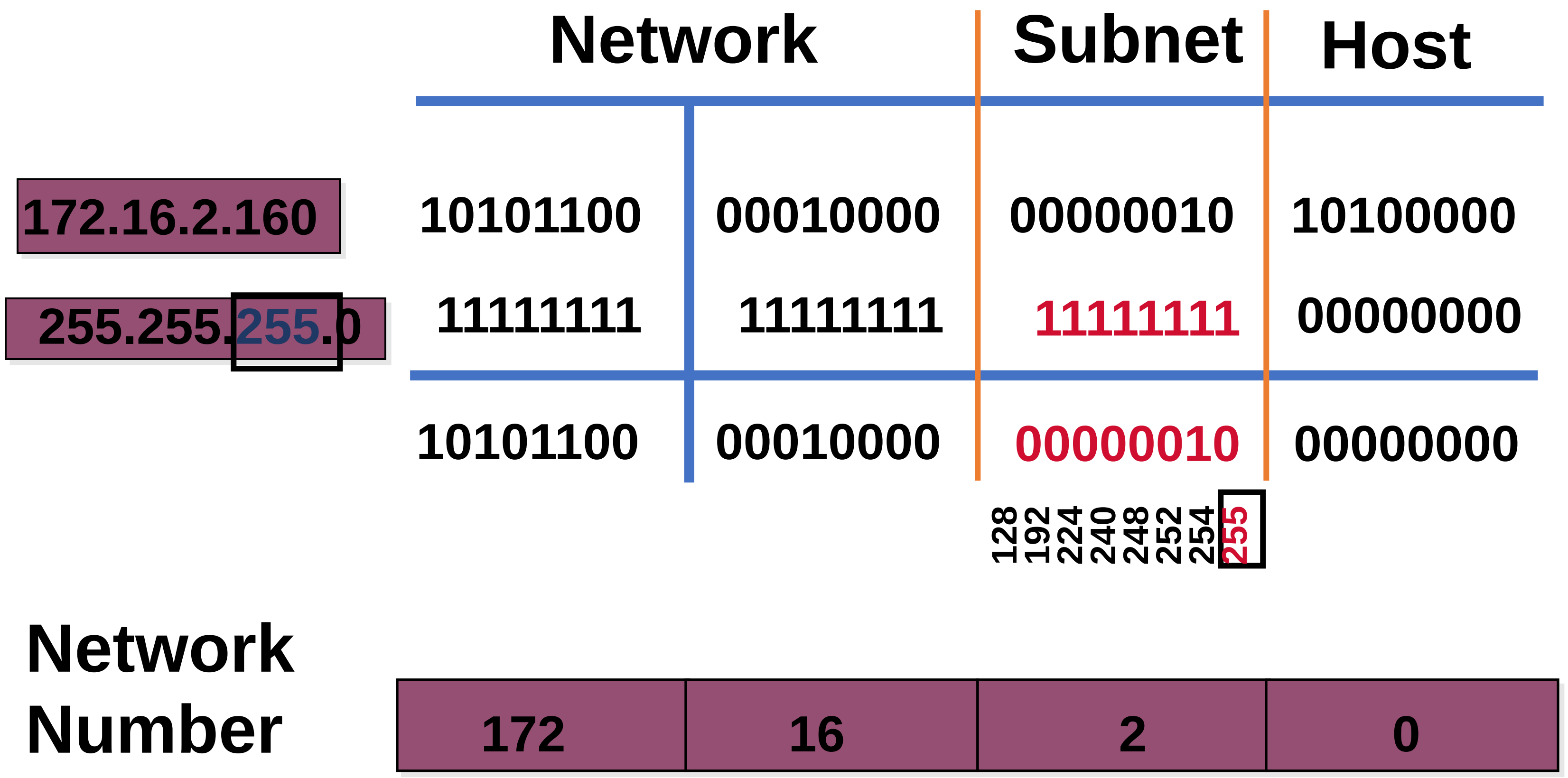
Also written as "/24" where 24 represents the number of 1s in the mask.

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

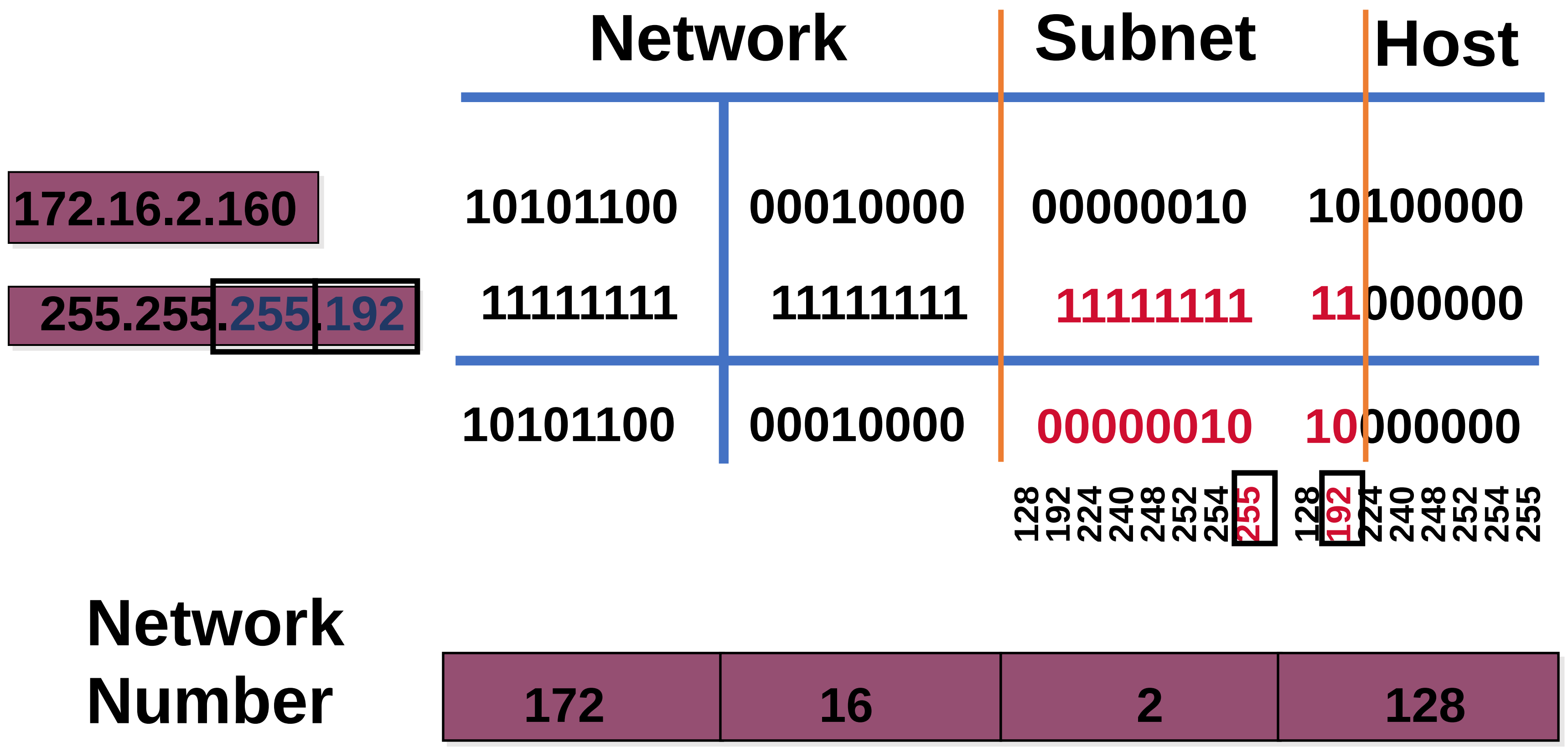
- Subnets not in use—the default

Subnet Mask with Subnets



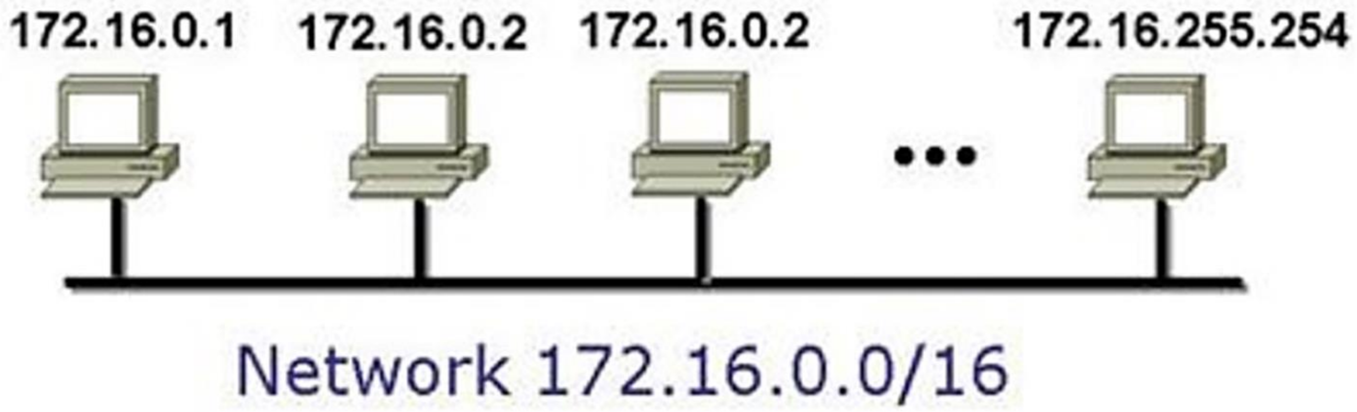
- Network number extended by eight bits

Subnet Mask with Subnets (cont.)



• Network number extended by ten bits

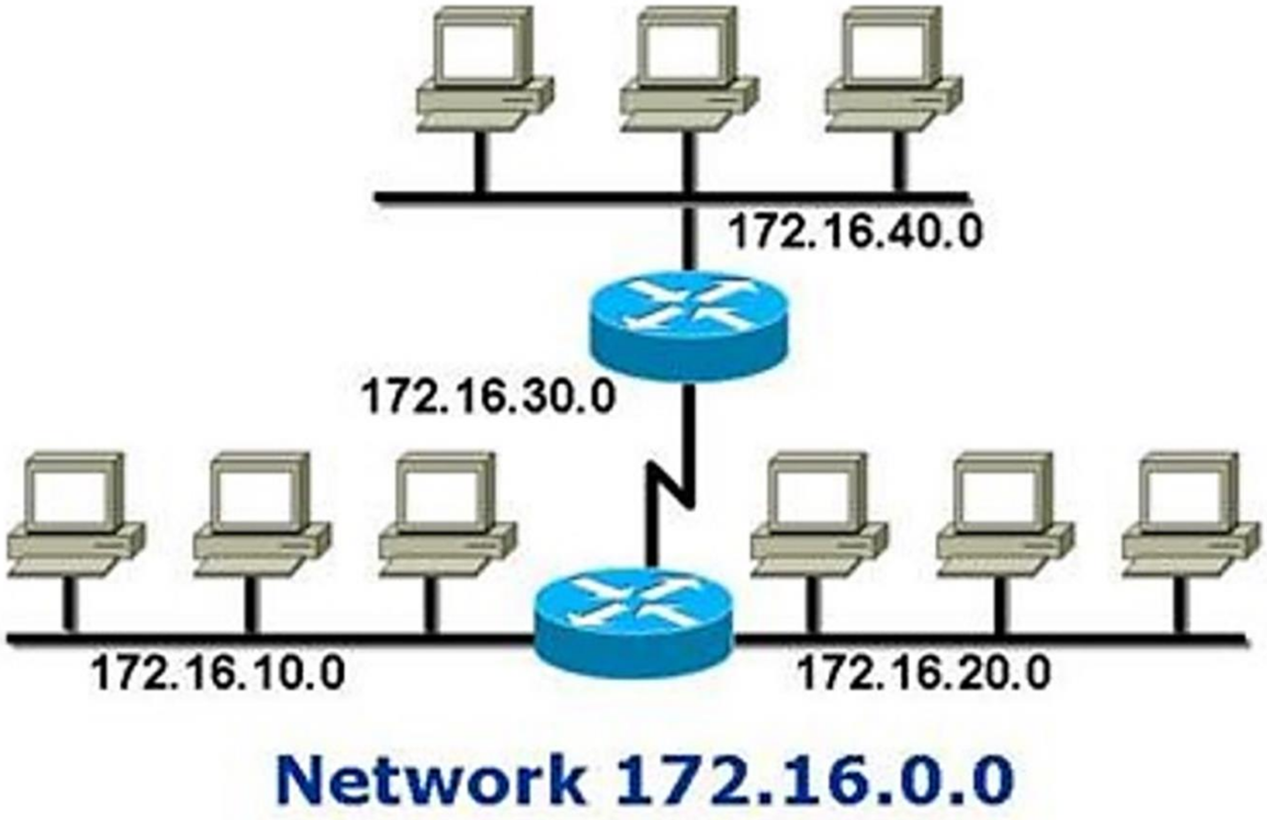
Addressing without Subnets



Creates one flat network.

Inefficient use of address space.

Addressing with Subnets



How do you determine the mask to use?

- Count the number of subnets in the network, and remember to think about growth
- Count the number of hosts in each subnet, and remember to think about growth

After you choose a possible subnet mask…

First ask the following questions:

1. **How many subnets does this mask provide? Does it meet my business requirements?**
2. **How many hosts per subnet? Does it meet my business requirements?**

If the answers from questions one and two do not meet your business requirements, keep trying other masks until you meet your business requirements

Once you find your mask…

You need to answer four more questions for each subnet:

3. **What is the subnet address?**
4. **What is the broadcast address?**
5. **What is the first valid host address?**
6. **What is the last valid host address?**

Now, here is how to get Six Answers!

1. $2^{\text{subnet bits}}$ = amount of subnets
2. $2^{\text{host bits}}-2$ = amount of hosts per subnet (-2 for broadcast and subnet number)
3. 256-subnet mask = base number
4. Broadcast address = next subnet –1.
5. First valid host = subnet + 1
6. Last valid host = broadcast – 1

(Valid hosts must not be all 0's or all 1's)

Subnet bits-> no of ones in subnet mask(host part)

host bits-> no of zeros in subnet mask(host part)

Base no → hop between networks

Classless Inter-Domain Routing (CIDR)

255.0.0.0 = /8

255.255.0.0 = /16

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

✓**CIDR – Classless Interdomain Routing**

What do you know?

When we see a CIDR or subnet mask, we need to ask "what do we know about this?"

For example, what do you know about a /25?

- 128 mask (10000000)
- 1 bits on, 7 bits off
- Block size of 128 (256 – 128 = 128)
- 2 subnets, 126 hosts on each subnet

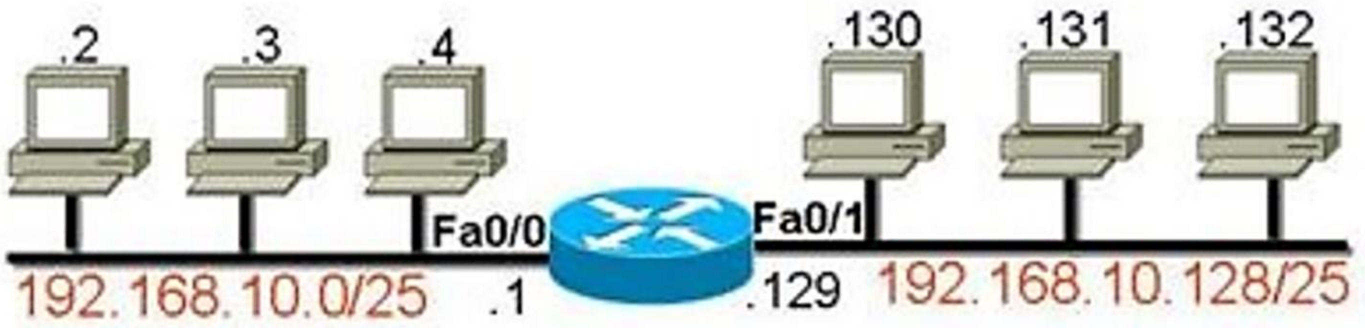
Easy Subnetting

192.168.10.0 : Network Address
255.255.255.128 : Subnet Mask
$2^1=2$: Number of subnets
$2^7-2=126$: Number of hosts per subnet
256-128=**128** : Block Size

0	128	Network
1	129	First Host
126	254	Last Host
127	255	Broadcast

Net	192.168.10.0	192.168.10.128
First host	192.168.10.1	192.168.10.129
Last host	192.168.10.126	192.168.10.254
Broad cast	192.168.10.127	192.168.10.255

Now, implement it…




```
Router# show ip route
[output cut]
C    192.168.10.0 is directly connected FastEthernet 0/0
C    192.168.10.128 is directly connected FastEthernet 0/1
```

What do we know?

If you have a /27, what do you know?

- 224 mask (11100000)
- 3 bits on, 5 bits off
- Block size of 32 (256 – 224 = 32)
- 8 subnets, 30 hosts on each subnet

What do we know?

If you have a /30, what do you know?

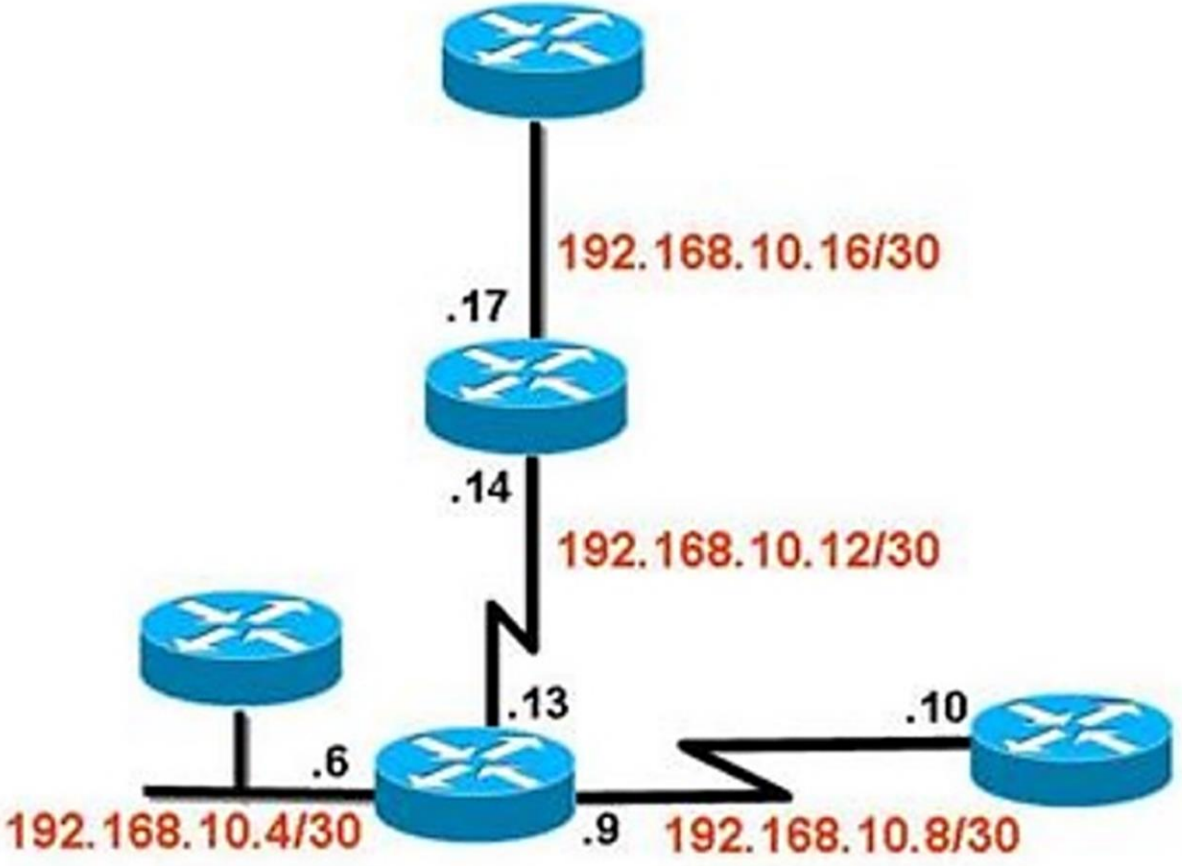
- 252 mask (11111100)
- 6 bits on, 2 bits off
- Block size of 4 (256 – 252 = 4)
- 64 subnets, 2 hosts on each subnet

Easy Subnetting

192.168.10.0 : Network Address
255.255.255.252 : Subnet Mask
2^6=64 : Number of subnets
2^2-2=2 : Number of hosts per subnet
256-252=**4** : Block Size

0	4	8	12	16...	252	Network
1	5	9	13	17...	253	First Host
2	6	10	14	18...	254	Last Host
3	7	11	15	19...	255	Broadcast

Now Implement it….



This mask works well on WAN (point-to-point) links

Very Easy Subnetting

192.168.10.68/26

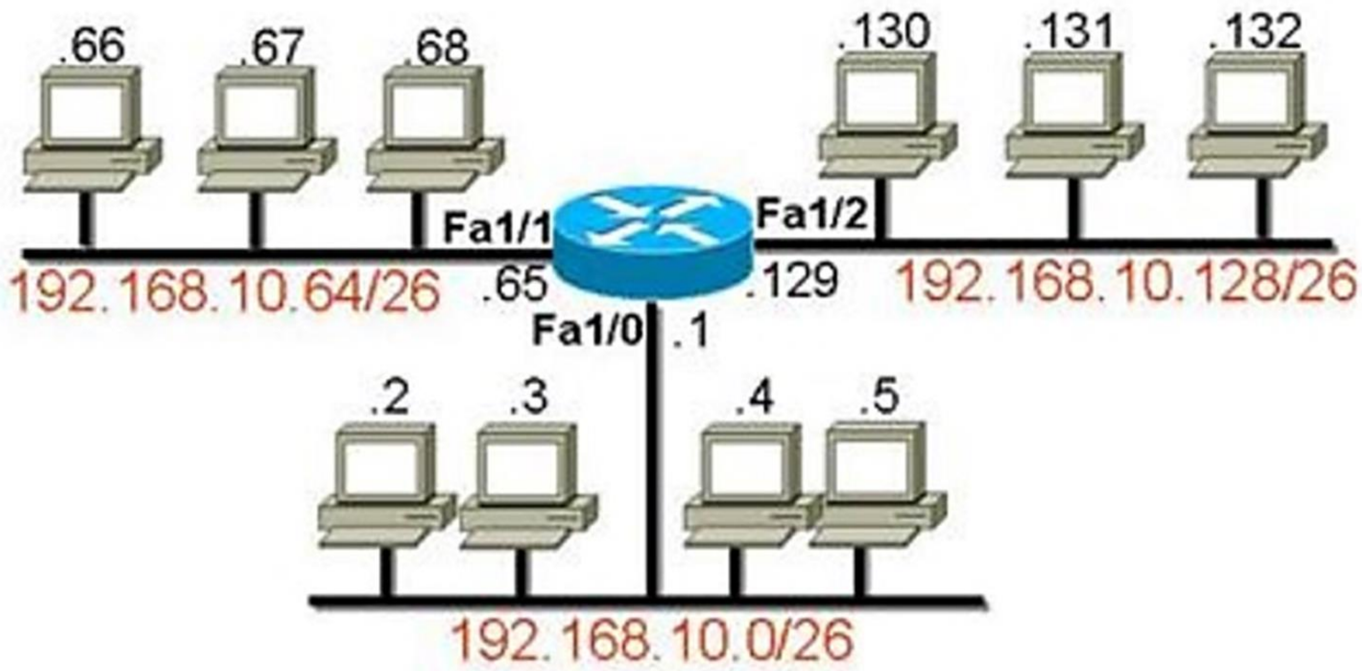
When viewing an IP address and subnet mask, just answer three easy questions:

What is the subnet?

What is the broadcast address?

What is the valid host range?

Now Implement it….



Router# **show ip route**
[output cut]
C 192.168.10.0 is directly connected FastEthernet1/ 0
C 192.168.10.64 is directly connected FastEthernet 1/1
C 192.168.10.128 is directly connected FastEthernet 1/2

192.168.10.68	255.255.255.192
192.168.10.64	Subnet
192.168.10.65	First Host
192.168.10.126	Last Host
192.168.10.127	Broadcast

Subnet Question

- You have a class C /28 subnet mask. Which are valid hosts?

A. 192.168.28.33	• Is a valid host
B. 192.168.28.112	• Is a subnet address
C. 192.168.28.119	• Is a valid host
D. 192.168.28.126	• Is a valid host
E. 192.168.28.175	• Is a broadcast address
F. 192.168.28.208	• Is a subnet address

Since this is a 240 mask (block size of 16) our valid subnets are 0, 16, 32, 48, 64, 80, 96, 112, 128, 144, 160, 176, 192, 208, 224 and 240.

Solution: We must find the following:

IP Address 192.168.28.33

Subnet Mask 255.255.255.240

11000000 1000000 00011100 00100001

11111111 11111111 11111111 11110000

11000000 1000000 00011100 00100000

The subnet address is 192.168.28.32

Network address is 192.168.28.0

2^4=16 Number of subnets

2^4-2=14 Number of hosts per subnet

256-240=16 Block Size (Hop)

0	16	32	48	64	80	96	112	128	144	160	176	192	208	224	240	Network
1	17	33	49	65	81	97	113	129	145	161	177	193	209	225	241	First Host
14	30	46	62	78	94	110	126	142	158	174	190	206	222	238	254	Last Host
15	31	47	63	79	95	111	127	143	159	175	191	207	223	239	255	Broadcast

Examples: 192.168.28.33 Host

192.168.28.175 Broadcast

192.168.28.112 subnet address

192.168.28.208 subnet address

Note: All numbers in the table represent Host part in IP Address because it is Class C

Subnet Example

Network address 172.19.0.0 with /16 network mask

Network	Network	Host	Host
172	19	0	0

Using Subnets: subnet mask **255.255.255.0** or /24

	Network	Network	Subnet	Host
Network Mask: 255.255.0.0 or /16	11111111	11111111	00000000	00000000
Subnet Mask: 255.255.255.0 or /24	11111111	11111111	11111111	00000000

- Applying a mask which is larger than the default subnet mask, will divide your network into subnets.
- Subnet mask used here is 255.255.255.0 or /24

Subnet Example

Network address 172.19**.0.0 with /16 network mask**

Using Subnets: **subnet mask** 255.255.255.0 or /24

Network	Network	Subnet	Host
172	19	0	Host
172	19	1	Host
172	19	2	Host
172	19	3	Host
172	19	etc.	Host
172	19	254	Host
172	19	255	Host

Subnets

255 Subnets

2^8 - 1

Cannot use last subnet as it contains broadcast address

Subnet Example

Network address **172.19.0.0 with /16 network mask**

Using Subnets: **subnet mask** 255.255.255.0 or /24

Network	Network	Subnet	Host
172	19	0	0
172	19	1	0
172	19	2	0
172	19	3	0
172	19	etc.	0
172	19	254	0
172	19	255	0

Subnets Addresses

255 Subnets

2^8 - 1

Cannot use last subnet as it contains broadcast address

Subnet Example

Class B address 172.19.0.0 **with /16 network mask**

Using Subnets: **subnet mask** 255.255.255.0 or /24

Network	Network	Subnet	Hosts		Hosts Addresses
172	19	0	1	→	254
172	19	1	1	→	254
172	19	2	1	→	254
172	19	3	1	→	254
172	19	etc.	1	→	254
172	19	254	1	→	254
172	19	255	Host		

Each subnet has 254 hosts, $2^8 - 2$

Subnet Example

Network address **172.19.0.0 with /16 network mask**

Using Subnets: **subnet mask** 255.255.255.0 or /24

Network	Network	Subnet	Host
172	19	0	255
172	19	1	255
172	19	2	255
172	19	3	255
172	19	etc.	255
172	19	254	255
172	19	255	255

Broadcast Addresses

255 Subnets

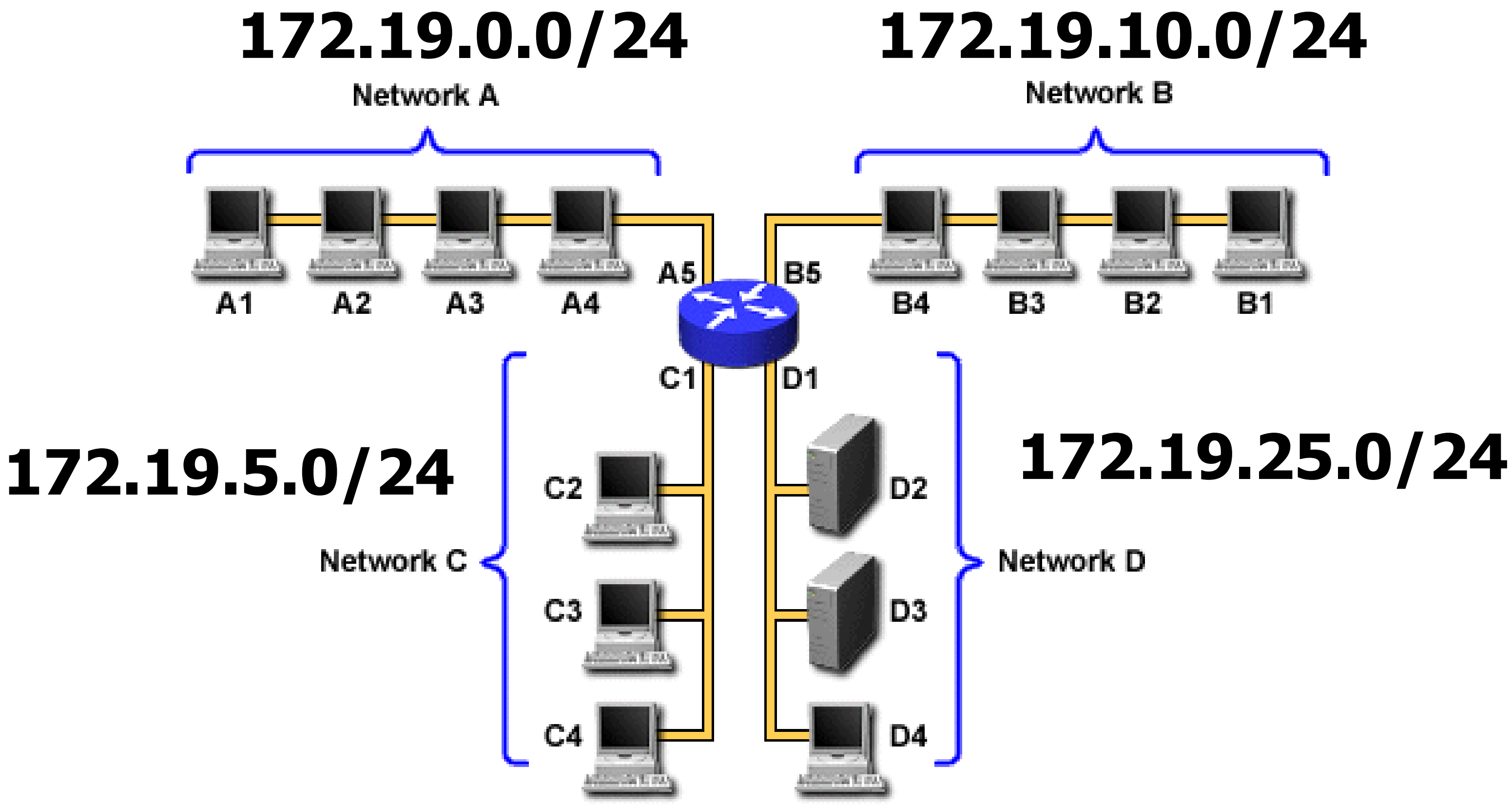
$2^8 - 1$

Cannot use last subnet as it contains broadcast address

Subnet Example

Network address 172.19**.0.0 with /16 network mask**

Using Subnets: subnet mask 255.255.255.0 or /24



Thank you for listening