



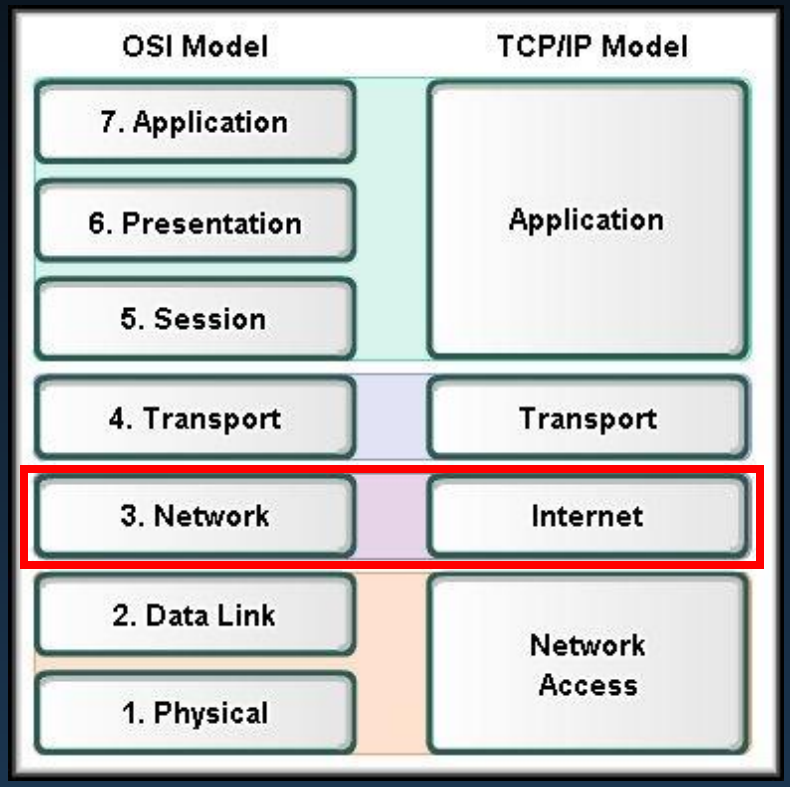
# Chapter 6

# Addressing the Network - IPV4

# Part II

# Addressing the Network: IPv4

## Legacy IPv4 Addressing



# Legacy IPv4 Addressing

- In the early 1980's, unicast address ranges were grouped into specific sizes or classes of address.
- Each class defined:
  - A specifically sized network.
  - Specific address blocks for these networks.

| Class | High Order Bits | First Octet Range | Number of Network Bits | Number of Host Bits | Number of Networks | Number of Hosts per Network |
|---|---|---|---|---|---|---|
| A | 0 | 0-127 | 8 | 24 | 128 | 16,777,216 |
| B | 10 | 128-191 | 16 | 16 | 16,384 | 65,536 |
| C | 110 | 192-223 | 24 | 8 | 2,097,152 | 256 |
| D | 1110 | 224-239 | Used for Multicasting to multiple hosts. | | | |
| E | 1111 | 240-255 | Reserved for research and development. | | | |

# IPv4 Classful Addressing

- Devices examined the first octet of the address and could determine the address range.
- The high order bits never change for each class.
  - Classful Addressing:
    - 192.168.23.2 is in the Class C range
    - Therefore – 24 network bits and 8 hosts bits.

| Class | High Order Bits | First Octet Range | Number of Network Bits | Number of Host Bits | Number of Networks | Number of Hosts per Network |
|---|---|---|---|---|---|---|
| A | 0 | 0-127 | 8 | 24 | 128 | 16,777,216 |
| B | 10 | 128-191 | 16 | 16 | 16,384 | 65,536 |
| C | 110 | 192-223 | 24 | 8 | 2,097,152 | 256 |

# IPv4 Classful Addressing

- In a classful addressing scheme, these divisions take place at the octet boundaries.
  - This may seem obvious now but is important to remember when we explore how to divide a single network into several smaller subnets (subnetting).

| Class | High Order Bits | First Octet Range | Number of Network Bits | Number of Host Bits | Number of Networks | Number of Hosts per Network |
|---|---|---|---|---|---|---|
| A | 0 | 0-127 | 8 | 24 | 128 | 16,777,216 |
| B | 10 | 128-191 | 16 | 16 | 16,384 | 65,536 |
| C | 110 | 192-223 | 24 | 8 | 2,097,152 | 256 |

# IPv4 Classful Addressing

- In the early 1990s, the subnet mask was added to IPv4.
  - The subnet mask allowed networks to subdivided or subnetted.
  - Each class was assigned a default subnet mask.

| Class | First Octet Range | Number of Network Bits | Number of Host Bits | Default Subnet Mask | Number of Networks | Number of Hosts per Network |
|---|---|---|---|---|---|---|
| A | 0-127 | 8 | 24 | 255.0.0.0 | 128 | 16,777,216 |
| B | 128-191 | 16 | 16 | 255.255.0.0 | 16,384 | 65,536 |
| C | 192-223 | 24 | 8 | 255.255.255.0 | 2,097,152 | 256 |

# IPv4 Classful Addressing

- Let's quickly review….
  - *In order to function properly with network devices, every IP network must contain three types of addresses:*
    - Network Address:
      - All HOST BITS are set to 0.
    - Host Address: HOST BITS will vary.
    - Broadcast Address:
      - All HOST BITS are set to 1.
  - *For a host to communicate directly with another host on the same network, they must have the same network portion.*

# IPv4 Classful Addressing

- SO:
  - For every IP address range that we assign to a network segment, we automatically lose two addresses….
    - One for the network address (sometimes called the wire address or subnetwork address)
    - One for the broadcast address for that network.

# IPv4 Classful Addressing

- Our numbers for the number of hosts per network have to change to allow for the special use of the network number and broadcast addresses.

| Class | Number of Network Bits | Number of Host Bits | Number Hosts Per Network | Number of Useable Hosts per Network |
|---|---|---|---|---|
| **A** | **8** | **24** | **$2^{24}$ = 16,777,216** | **$2^{24}$ - 2 = 16,777,214** |
| **B** | **16** | **16** | **$2^{16}$ = 65,536** | **$2^{16}$ - 2 = 65,534** |
| **C** | **24** | **8** | **$2^{8}$ = 256** | **$2^{8}$ - 2 = 254** |

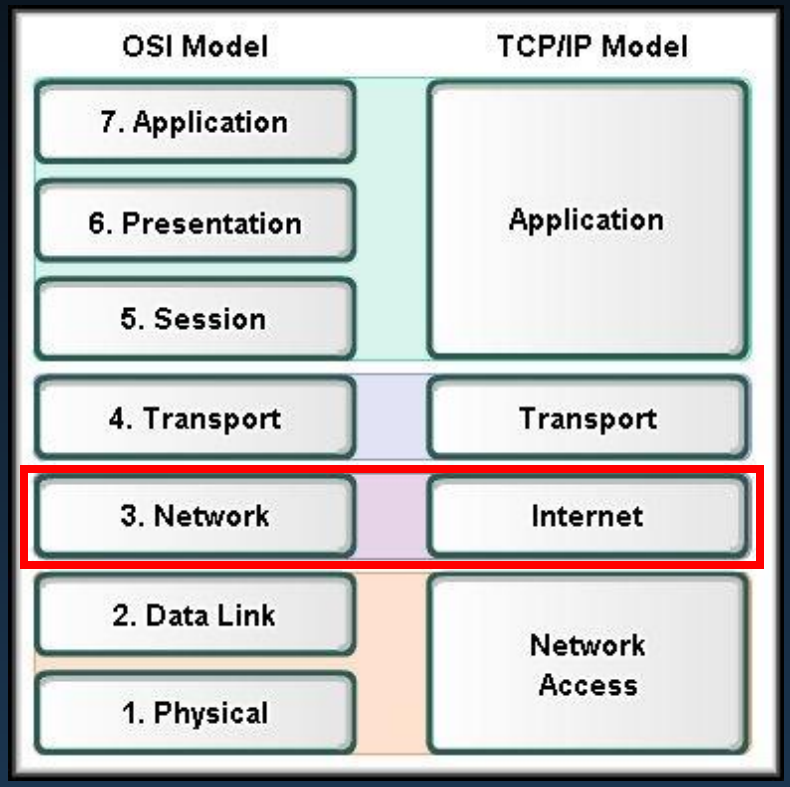
- As we will see, the formula ($2^{number\_of\_bits}$ - 2 or $2^{n}$ - 2) is an important part of assigning an IP address range to a network segment.

# IPv4 Classless Addressing

- The system currently in use is classless addressing.
  - Address blocks appropriate to the number of hosts are assigned to companies or organizations *without regard to the class*.
  - This is accomplished by subnetting with Variable Length Subnet Masking (VLSM).
  - *To understand classless addressing, you must first understand classful addressing.*

# Addressing the Network: IPv4

## Calculating Addresses



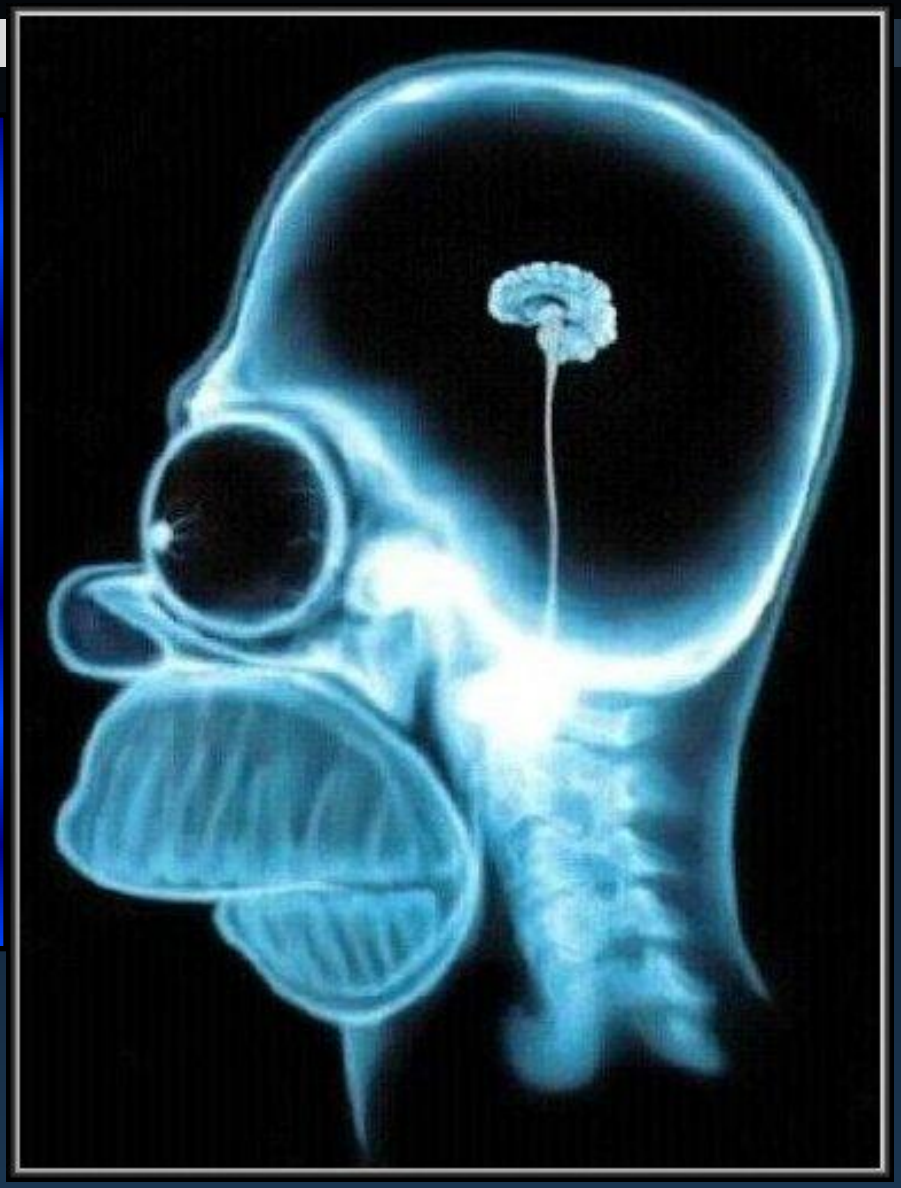
# Calculating Addresses

- Skills:
  - To work with an IPv4 network:
    - Find the network address for the host.
    - Find the broadcast address for the network.
    - Find what host addresses are available in the network.
    - Divide a large network into smaller networks.

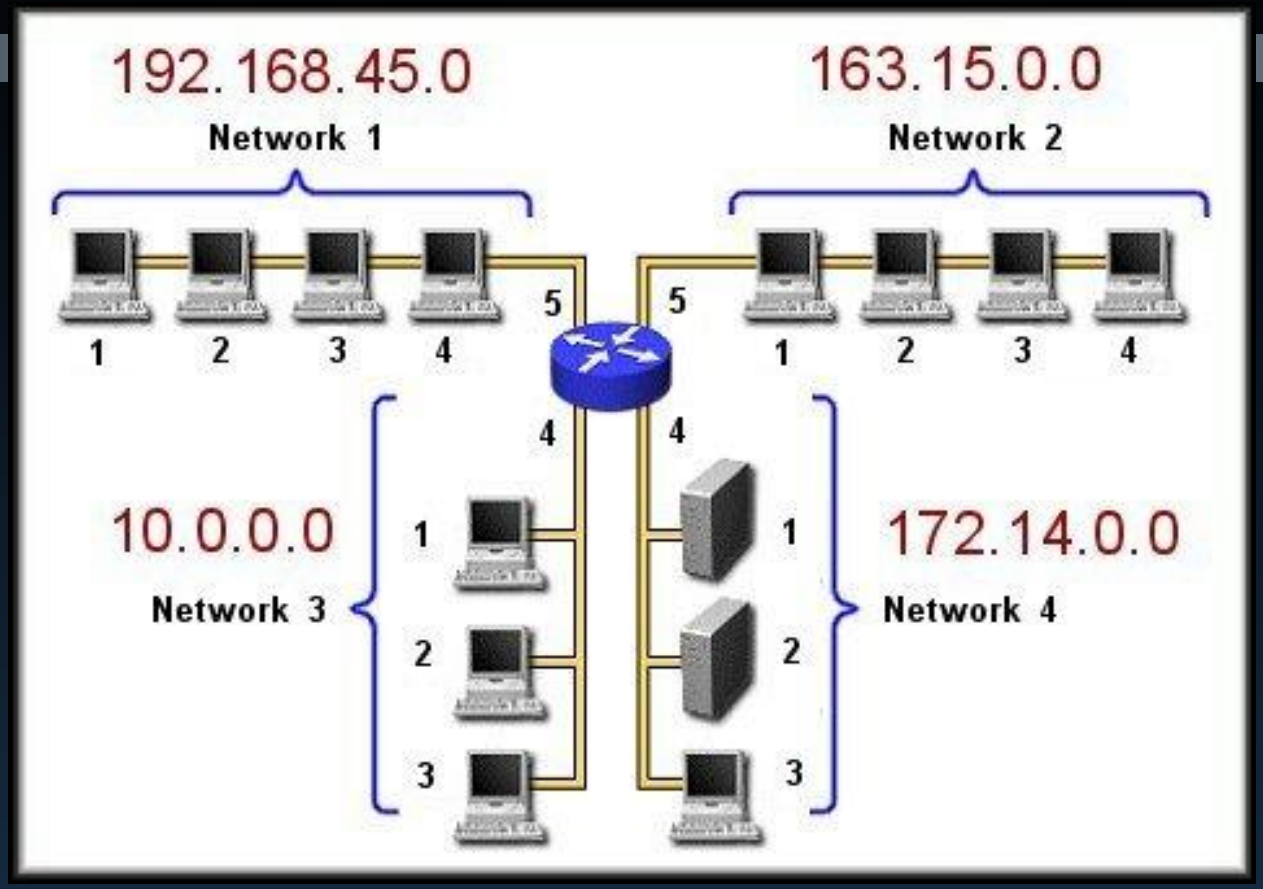
# Calculating Addresses

NO CALCULATORS OF ANY KIND...

DON'T WIND UP LIKE THIS!!!

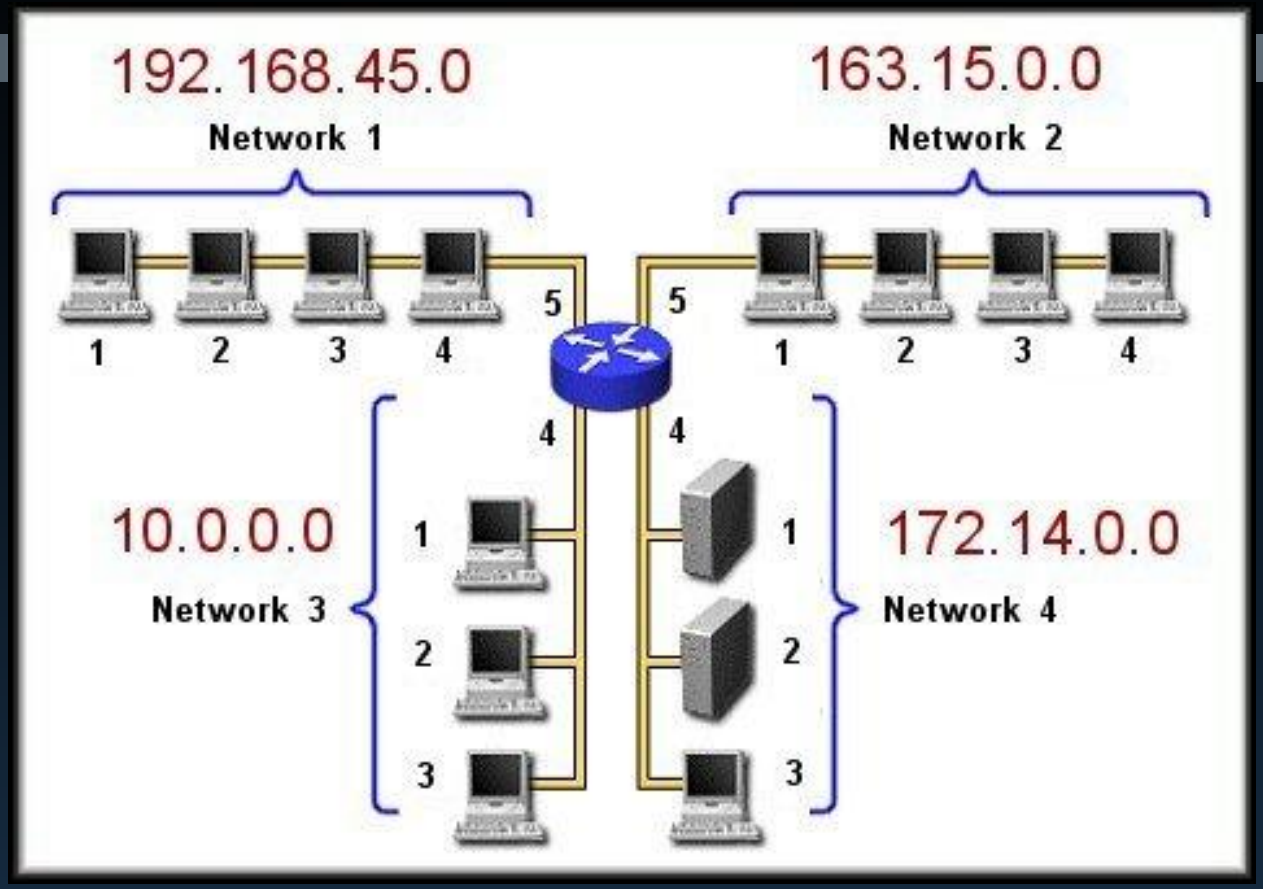


# The Network Number



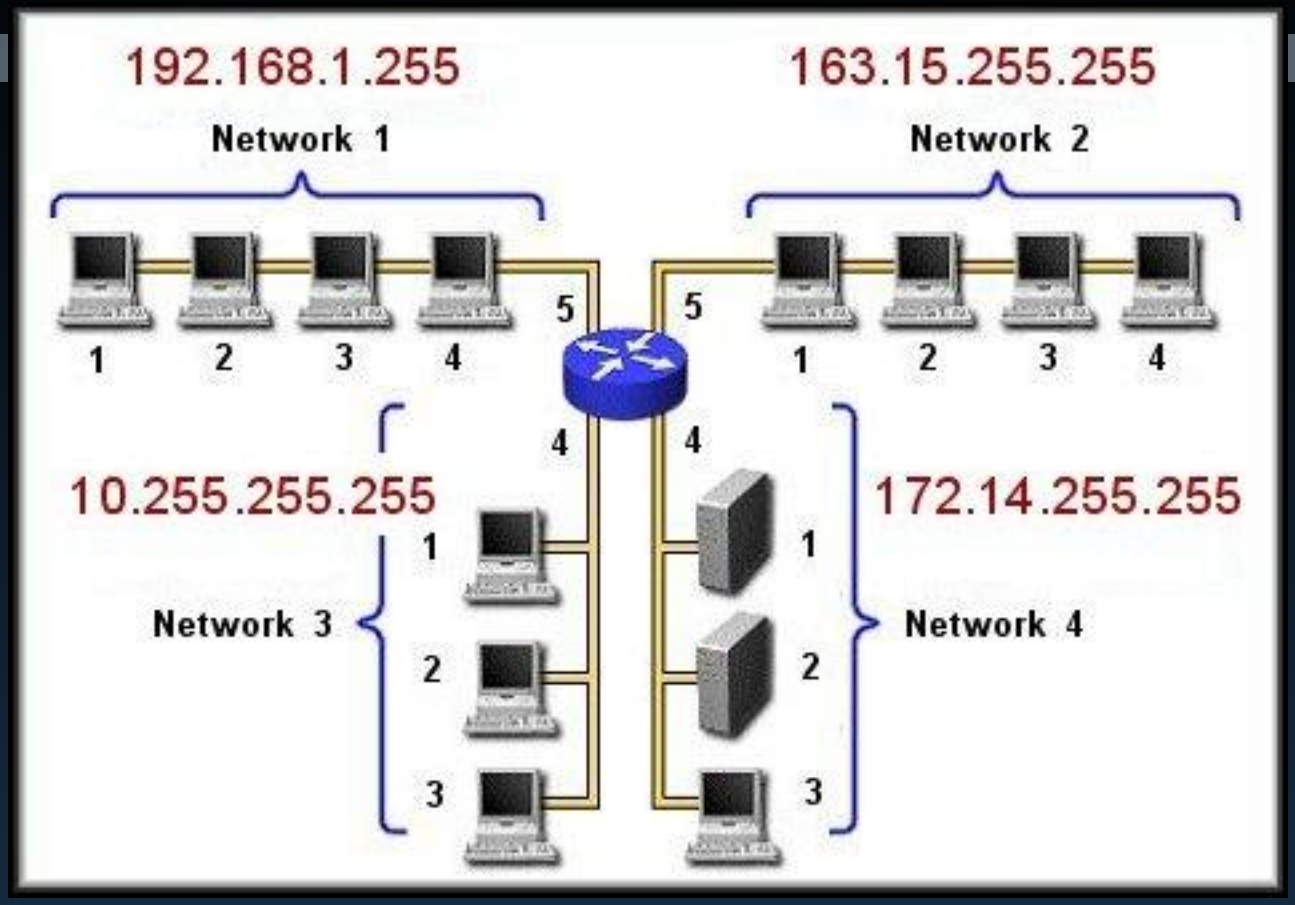

- A host on a network can communicate directly with other devices on the same network, only if all the devices have the same network number and the same subnet mask.

# The Network Number



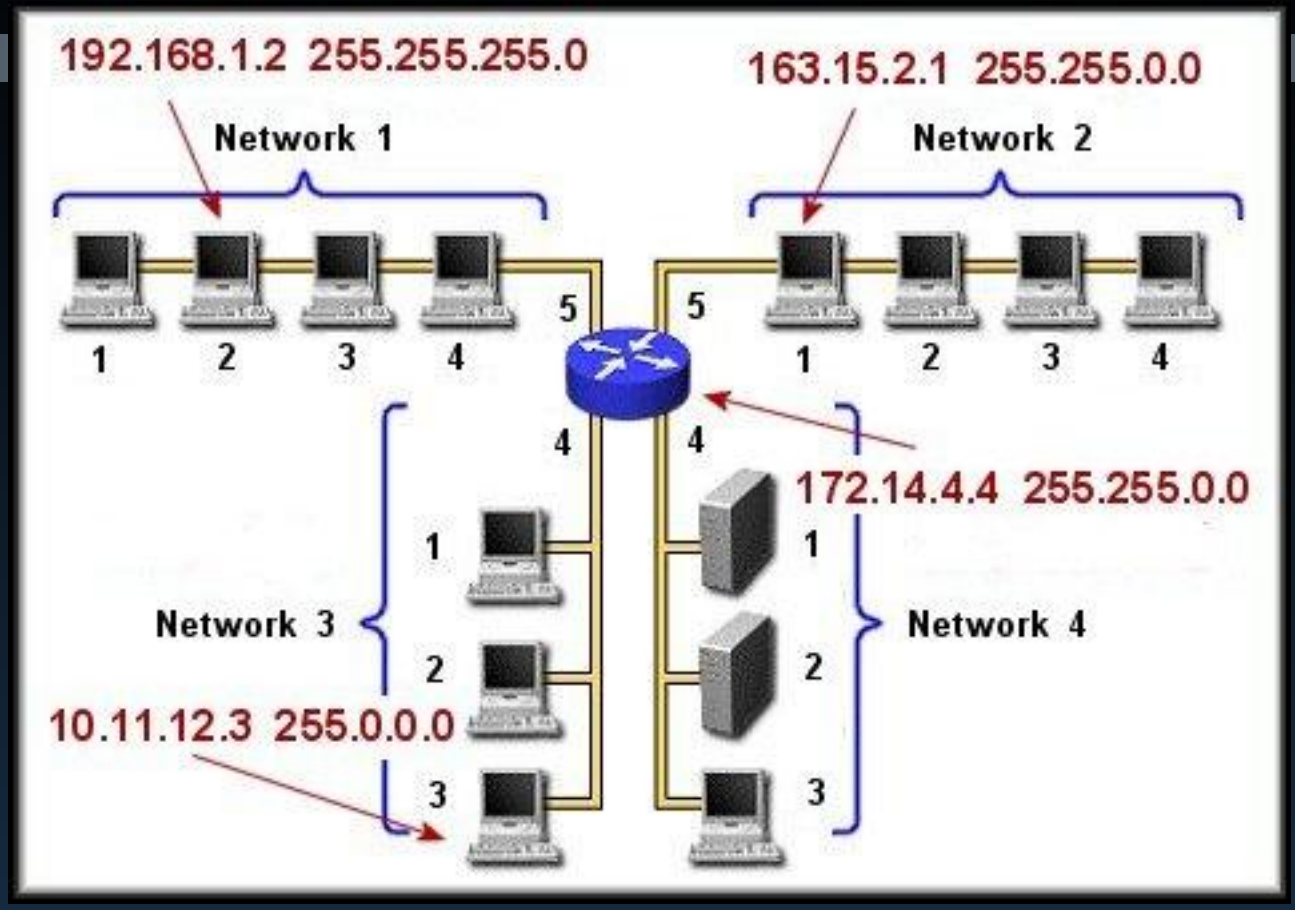

- Routers use the network number to build their routing tables so it cannot be used for a host.
- The IP address that indicates the network number has all 0 bits in the host portion of the IP Address.

# The Broadcast




- If a host needs to send a broadcast, it also uses the network number with all of the host bits set to 1.
- A broadcast address is used for that purpose only and cannot be assigned to a host.

# The Host Number



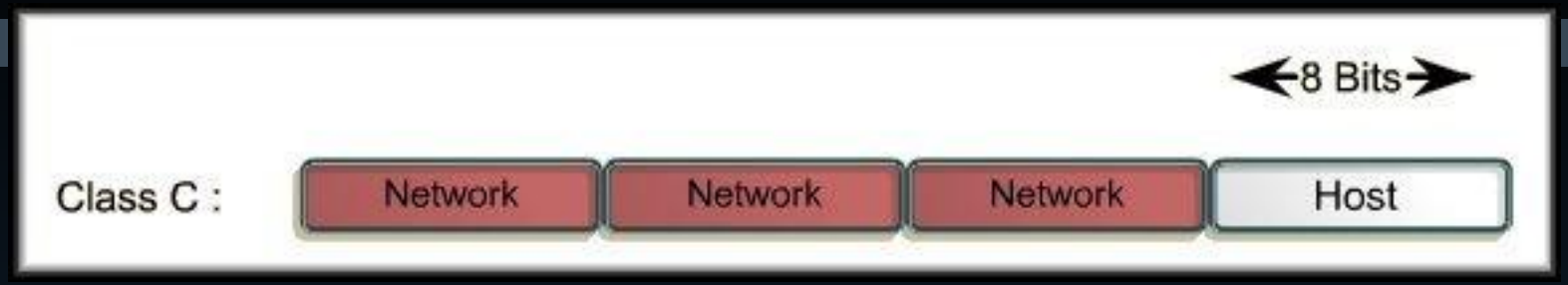

- The host number is the portion of the IP address that uniquely identifies the individual host on that network.

# The Subnet Mask

- Subnet Mask:
  - Let's not forget about the subnet mask.
    - Each class has a default or "natural" subnet mask based on the default number of bits used for the network and host portion.

| Class | Number of Network Bits | Number of Host Bits | Default Prefix | Default Subnet Mask |
|---|---|---|---|---|
| A | 8 | 24 | /8 | 255.0.0.0 |
| B | 16 | 16 | /16 | 255.255.0.0 |
| C | 24 | 8 | /24 | 255.255.255.0 |

# Classful IP Addressing – Class C




- Class C:
  - Address range: 192 - 223
  - Number of network bits: 24
  - Number of networks: 2,097,152
  - Number of host bits: 8
  - Number of hosts per network:
    - $2^8$ = 256
  - Number of Useable Hosts per network:
    - $2^8$ - 2 = 254
  - Default Subnet Mask: 255.255.255.0 or /24

# Classful IP Addressing – Class C

- We know from the Class C subnet mask (255.255.255.0):
  - The first 24 bits are the network number and the last 8 bits are the host numbers.
- The first host address (all 0's) is reserved for the network address.

| 11010010 | 00010100 | 01001101 | 00000000 |
|---|---|---|---|
| 210. | 20. | 77. | 0 |

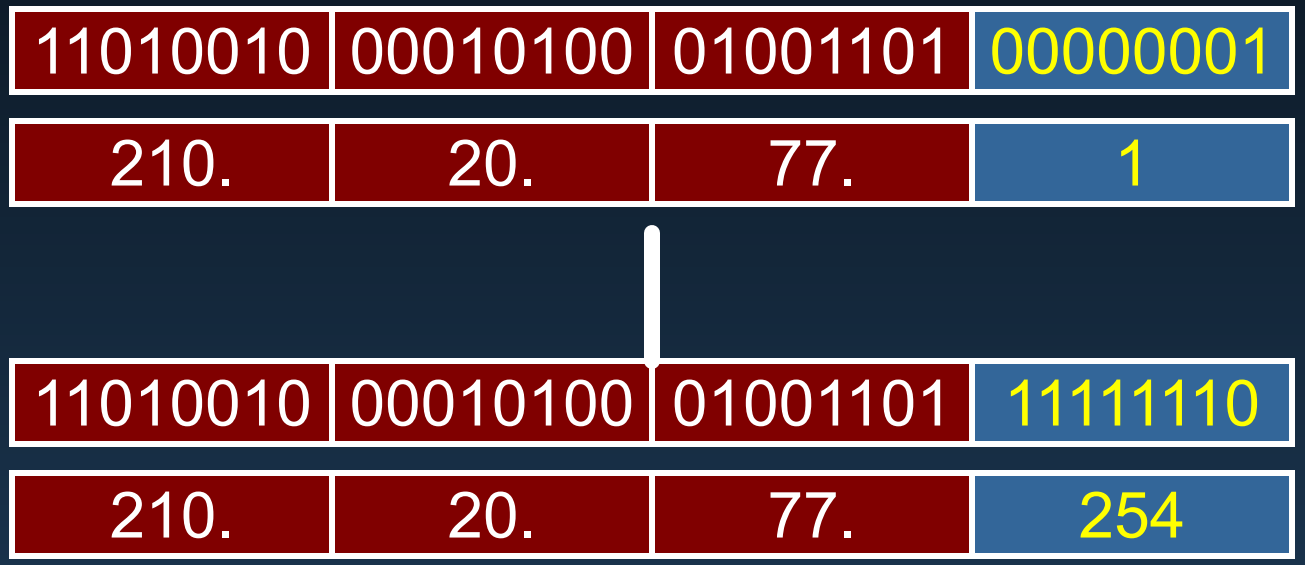
- The last host address (all 1's) is reserved for the broadcast address.

| 11010010 | 00010100 | 01001101 | 11111111 |
|---|---|---|---|
| 210. | 20. | 77. | 255 |

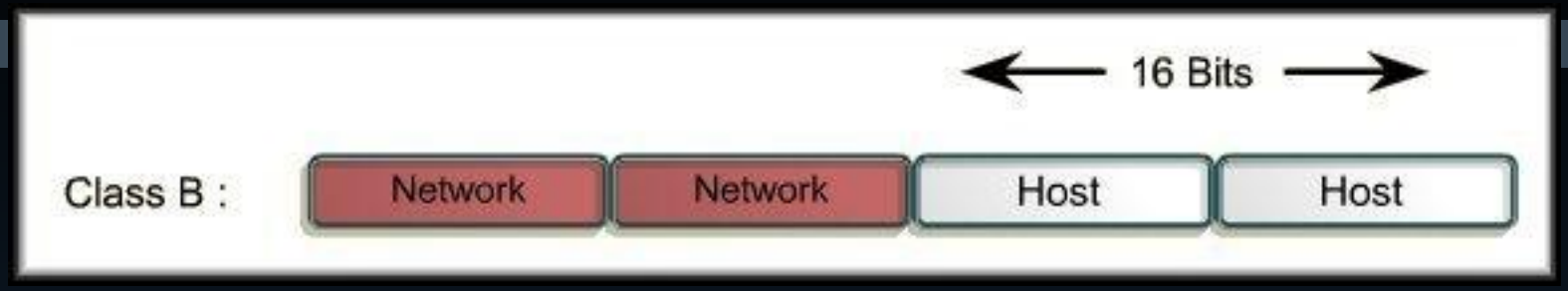
# Classful IP Addressing – Class C

- Because the host portion of the subnet mask is all zero's (255.255.255.0), the remaining host addresses can be used for individual hosts on the network.
  - The number of usable host addresses for the entire network is $2^8 - 2 = 254$

The range of available addresses is:



# Classful IP Addressing – Class B




- Class B:
  - Address range: 128 - 191
  - Number of network bits: 16
  - Number of networks: 16,384
  - Number of host bits: 16
  - Number of hosts per network:
    - $2^{16}$ = 65,536
  - Number of Useable Hosts per network:
    - $2^{16}$ - 2 = 65,534
  - Default Subnet Mask: 255.255.0.0 or /16

# Classful IP Addressing – Class B

- We know from the Class B subnet mask (255.255.0.0):
  - The first 16 bits are the network number and the last 16 bits are the host numbers.
- The first host address (all 0's) is reserved for the network address.

| 10010010 | 01010100 | 00000000 | 00000000 |
|---|---|---|---|
| 146. | 84. | 0. | 0 |

- The last host address (all 1's) is reserved for the broadcast address.

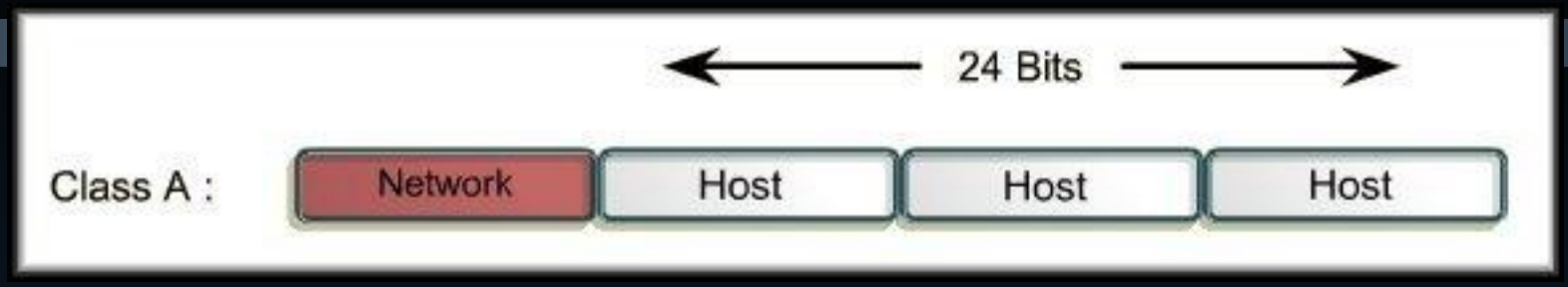
| 10010010 | 01010100 | 11111111 | 11111111 |
|---|---|---|---|
| 146. | 84. | 255. | 255 |

# Classful IP Addressing – Class B

- Because the host portion of the subnet mask is all zero's (255.255.0.0), the remaining host addresses can be used for individual hosts on the network.
  - The number of usable host addresses for the entire network is $2^{16} - 2 = 65,534$

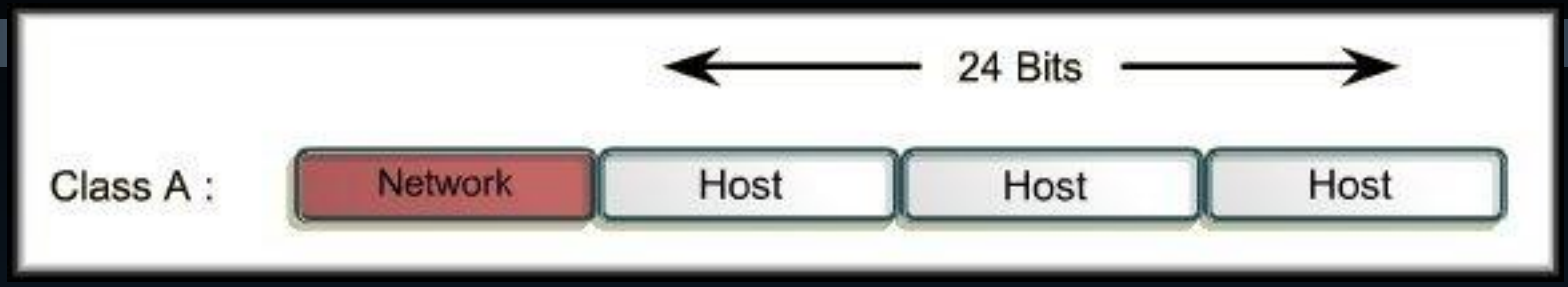
The range of available addresses is:

# Classful IP Addressing – Class A




- Class A:
  - Address range: 0 - 127
  - Number of network bits: 8
  - Number of networks: 126
  - Number of host bits: 24
  - Number of hosts per network:
    - $2^{24}$ = 16,777,216
  - Number of Useable Hosts per network:
    - $2^{24}$ - 2 = 16,777,214
  - Default Subnet Mask: 255.0.0.0 or /8

# Classful IP Addressing – Class A




- Class A (Usable Networks):
  - An address range of 0 –127 is 128 networks. The actual number of usable networks for Class A is 126.
    - Network 0 is reserved for special use for default routes.
    - Network 127 is reserved as a loopback network.
      - The address 127.0.0.1 is automatically available in every device after TCP/IP has been installed.
      - If you "ping" that address and get a good response, it means that TCP/IP is installed correctly.

# Classful IP Addressing – Class A

- We know from the Class A subnet mask (255.0.0.0):
  - The first 8 bits are the network number and the last 24 bits are the host numbers.
- The first host address (all 0's) is reserved for the network address.

| 01000010 | 00000000 | 00000000 | 00000000 |
|---|---|---|---|
| 66. | 0. | 0. | 0 |

- The last host address (all 1's) is reserved for the broadcast address.

| 01000010 | 11111111 | 11111111 | 11111111 |
|---|---|---|---|
| 66. | 255. | 255. | 255 |

# Classful IP Addressing – Class A

- Because the host portion of the subnet mask is all zero's (255.255.0.0), the remaining host addresses can be used for individual hosts on the network.
  - The number of usable host addresses for the entire network is $2^{24} - 2 = 16,777,216$

The range of available addresses is:

# Classful IP Addressing

- IP Address: 130.61.22.204 / 16

  Address Class: B

  Subnet Mask: 255.255.0.0

  Network Address is: 130.61.0.0

  Broadcast Address is: 130.61.255.255

  Number of Useable host addresses: $2^{16} - 2 = 65{,}534$

  What are they? 130.61.0.1 - 130.61.255.254

# Classful IP Addressing

- IP Address: 197.101.28.83 / 24

  Address Class: C

  Subnet Mask: 255.255.255.0

  Network Address is: 197.101.28.0

  Broadcast Address is: 197.101.28.255

  Number of Useable host addresses: $2^8 - 2 = 254$

  What are they? 197.101.28.1 - 197.101.28.254

# Classful IP Addressing

- IP Address: 64.133.65.101 / 8

  Address Class: A

  Subnet Mask: 255.0.0.0

  Network Address is: 64.0.0.0

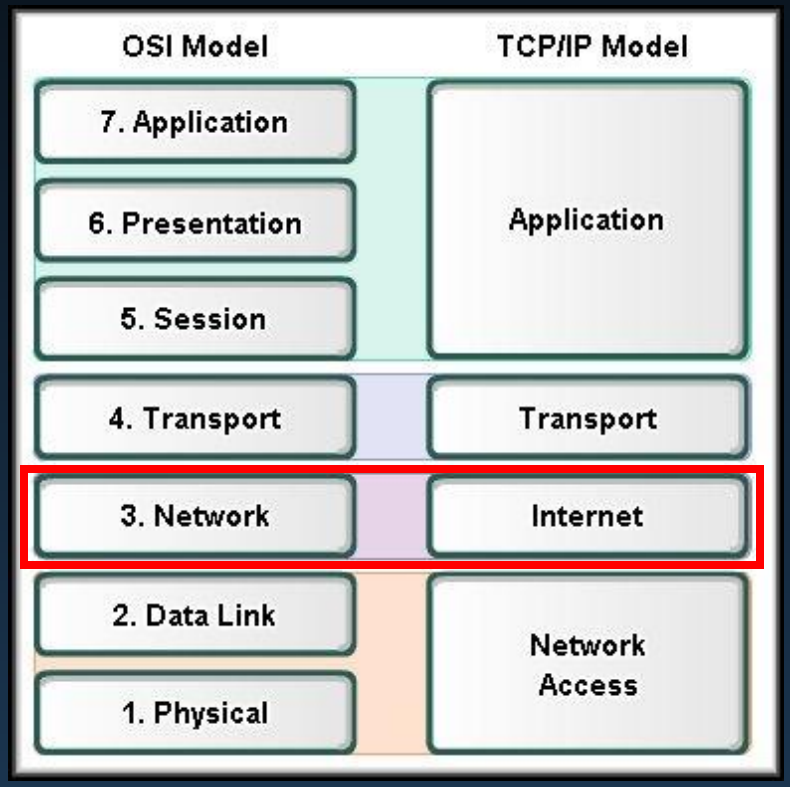
  Broadcast Address is: 64.255.255.255

  Number of Useable host addresses: $2^{24}$ - 2 = A Bunch!

  What are they? 64.0.0.1 - 64.255.255.254

# Addressing the Network: IPv4

## Basic Subnetting



# IP Address Crisis

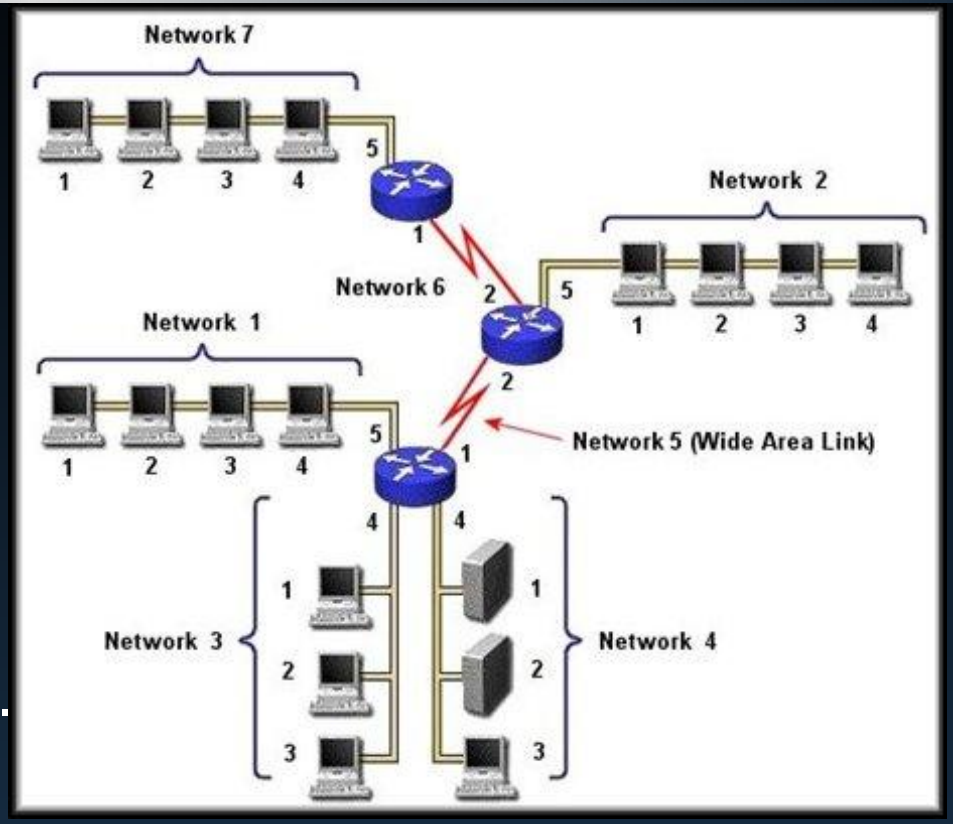
- The world is running short of available IP addresses.
- If every organization connected to the Internet used an entire Class A, B or C address:
  - The number of organizations would be limited and many IP addresses would be wasted.
    - e.g. An organization with 256 hosts owns a Class B address. 65,000 addresses not used.
  - Owning an address means that the organization has applied for and received that address range from the IANA.

# IP Address Crisis

- The goal, then, is to use owned addresses (or public addresses) as efficiently as possible to avoid waste.
  - Subnetting
  - CIDR
  - Network Address Translation (NAT).
- It is also desirable to avoid waste within the organization when using private IP addressing.
  - Careful planning of the addressing scheme is key to a successful implementation.

# Why Multiple Segments?

- If organizations grow significantly, the physical segment and the logical network traffic can quickly become unmanageable.
- Solution? Break the larger network into smaller, more manageable segments.




Router: Each segment becomes physically smaller and each must have their own unique, logical, Layer 3 network address.

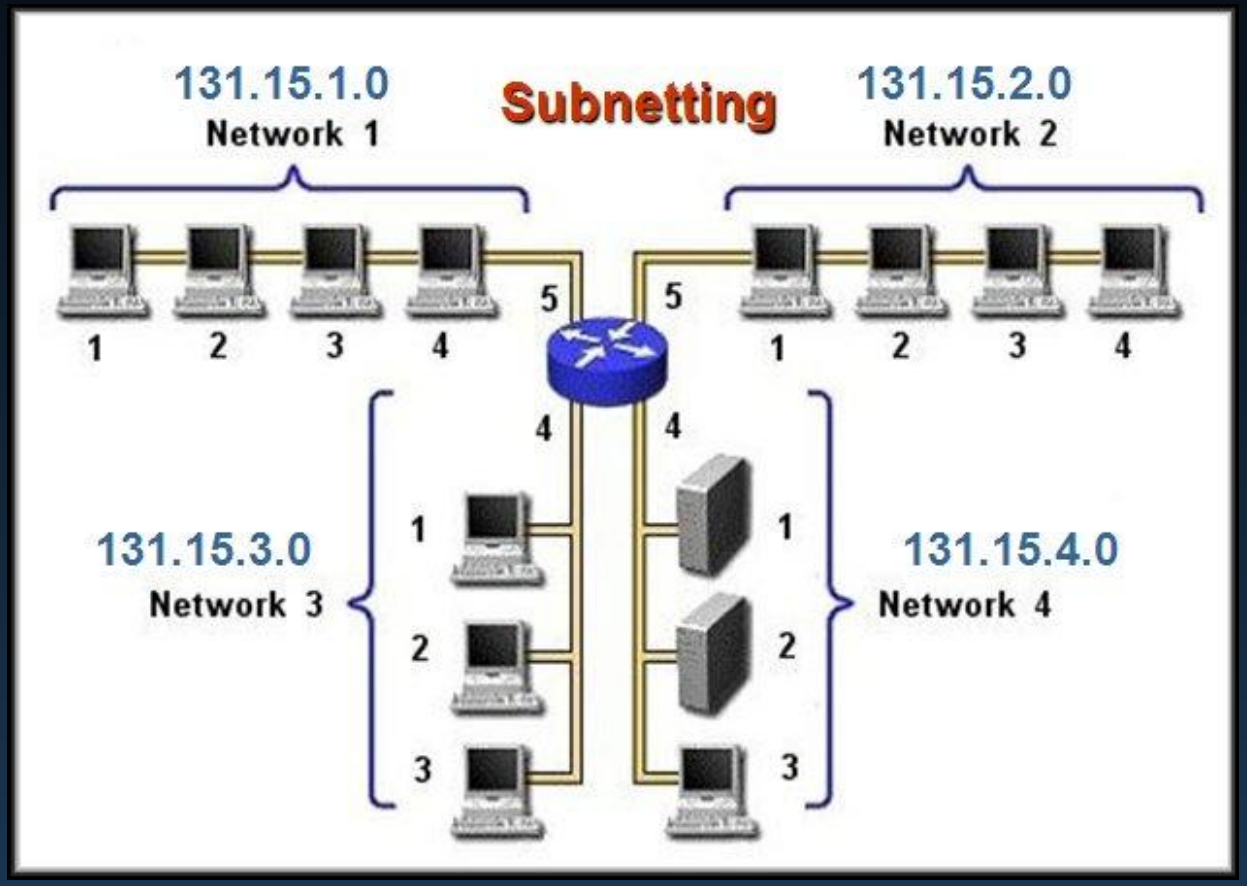
# Why Multiple Segments?

- This company has multiple networks connected by a router. The network number for each network must be unique.

The company IT headquarters has assigned a Class B address of

131.15.0.0

to use for ALL these networks.

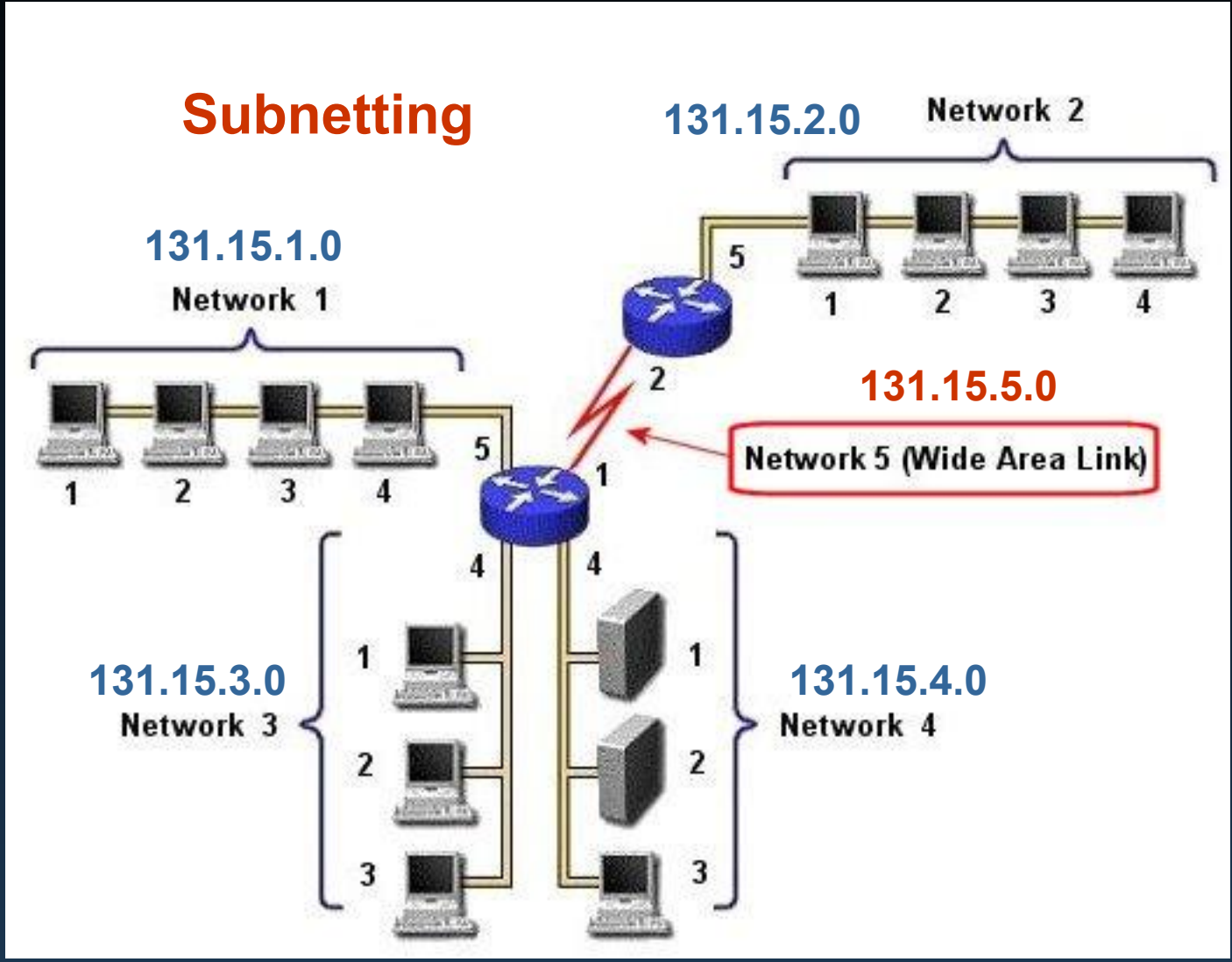


# Why Multiple Segments?

Class B

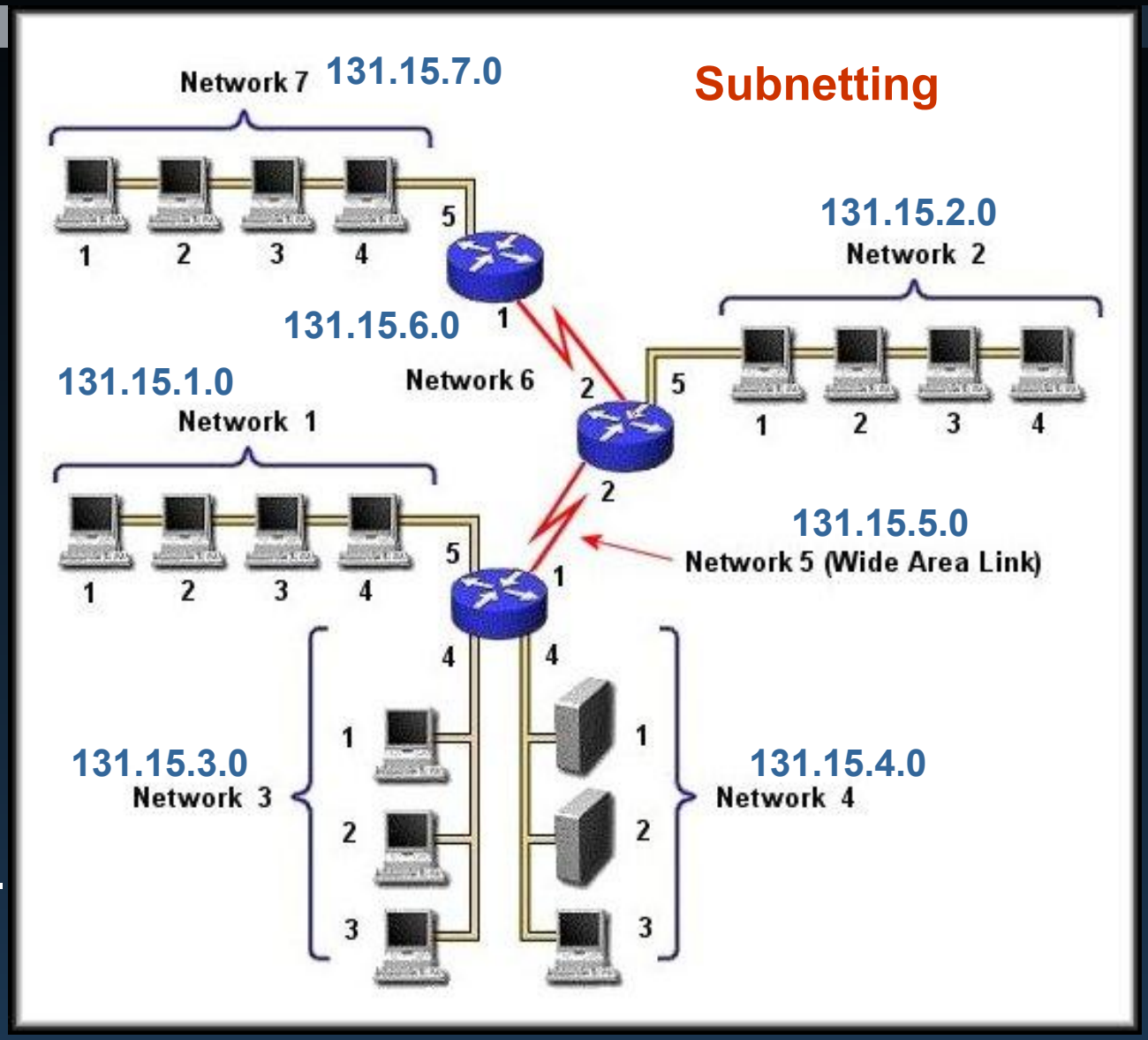
131.15.0.0

What happens here?

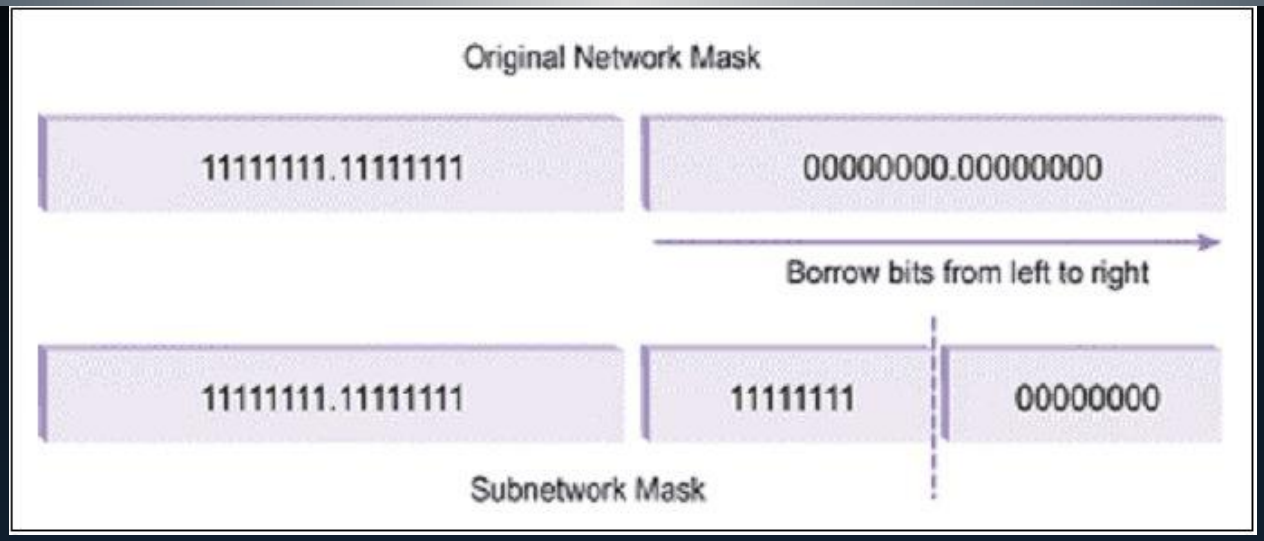


# Why Multiple Segments?

- Network numbers MUST be unique.
- You should:
  - Plan what you need.
  - Plan for the future.
  - Make efficient use of addresses.

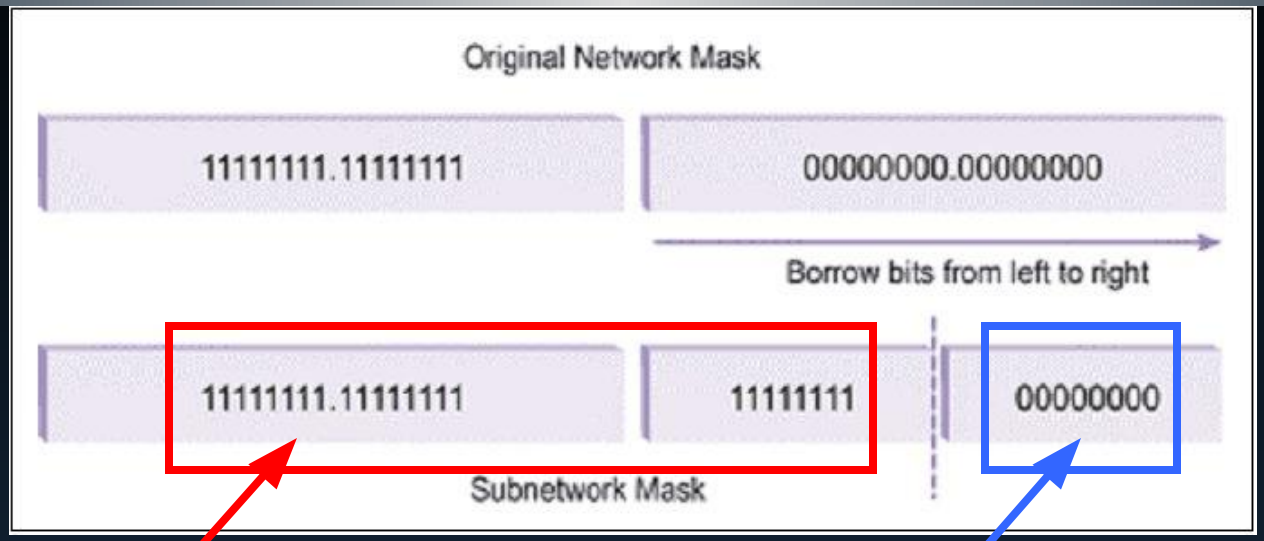


# Creating a Subnet




- To subnet a network, the IP address host portion of the subnet mask is divided into two parts.
  - Bits are borrowed from the host portion and assigned to the network portion to create a new network address.
  - The new network address covers a smaller portion of the original network number.
    - It is a sub-network of the original or a subnet.

# Creating a Subnet




- The borrowed bits become part of the network portion of the IP Address and form the network number.
- The remaining host bits become the host portion and are used to identify individual network hosts and create broadcasts for the new subnet.

# Creating a Subnet

- The subnet mask changes to reflect the new network/host bit assignment.
  - The same subnet mask applies to ALL networks derived from the subnetting process.
  - Original Subnet Mask: 255.255.0.0
    11111111.11111111.00000000.00000000
  - Borrow 8 bits:
    11111111.11111111.11111111.00000000
  - New Subnet Mask: 255.255.255.0

# Creating a Subnet - The Rules

- Host bits must be borrowed in descending order, starting with the left-most bit position and working to the right.
- A minimum of two bits must remain for host addresses.
- A remaining host mask of all 0's or all 1's cannot be assigned as a host address.
- To determine the number of subnets or hosts:
  - Subnets: $2^{number\_of\_borrowed\_host\_bits}$
  - Usable Hosts Per Subnet:

$$2^{number\_of\_remaining\_host\_bits} - 2$$

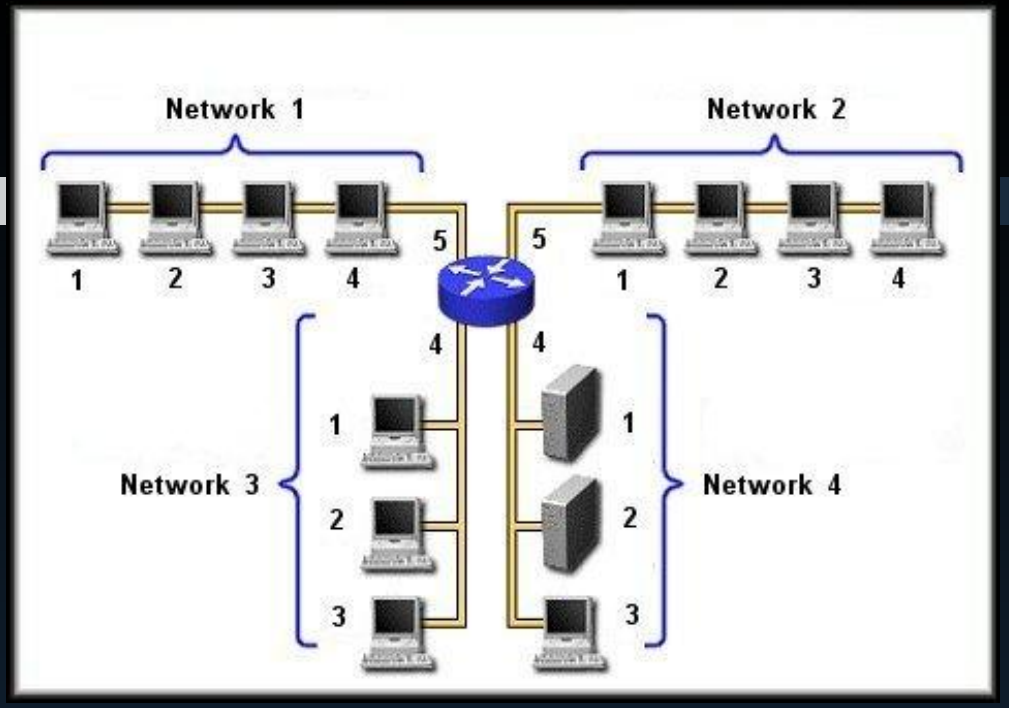
# Subnets and Useable Hosts – Class C

- Default: 255.255.255.0 - 24 network bits and 8 host bits

| Borrowed Bits | Number of Subnets | Number of Usable Hosts | Subnet Mask | Prefix |
|---|---|---|---|---|
| 0 | 0 (default) | $2^8$ - 2 = 254 | 255.255.255.0 | /24 |
| 1 | $2^1$ = 2 | $2^7$ - 2 = 126 | 255.255.255.128 | /25 |
| 2 | $2^2$ = 4 | $2^6$ - 2 = 62 | 255.255.255.192 | /26 |
| 3 | $2^3$ = 8 | $2^5$ - 2 = 30 | 255.255.255.224 | /27 |
| 4 | $2^4$ = 16 | $2^4$ - 2 = 14 | 255.255.255.240 | /28 |
| 5 | $2^5$ = 32 | $2^3$ - 2 = 6 | 255.255.255.248 | /29 |
| 6 | $2^6$ = 64 | $2^2$ - 2 = 2 | 255.255.255.252 | /30 |
| 7 | $2^7$ = 128 | $2^1$ - 2 = 0 | unusable | |

Leave at least 2

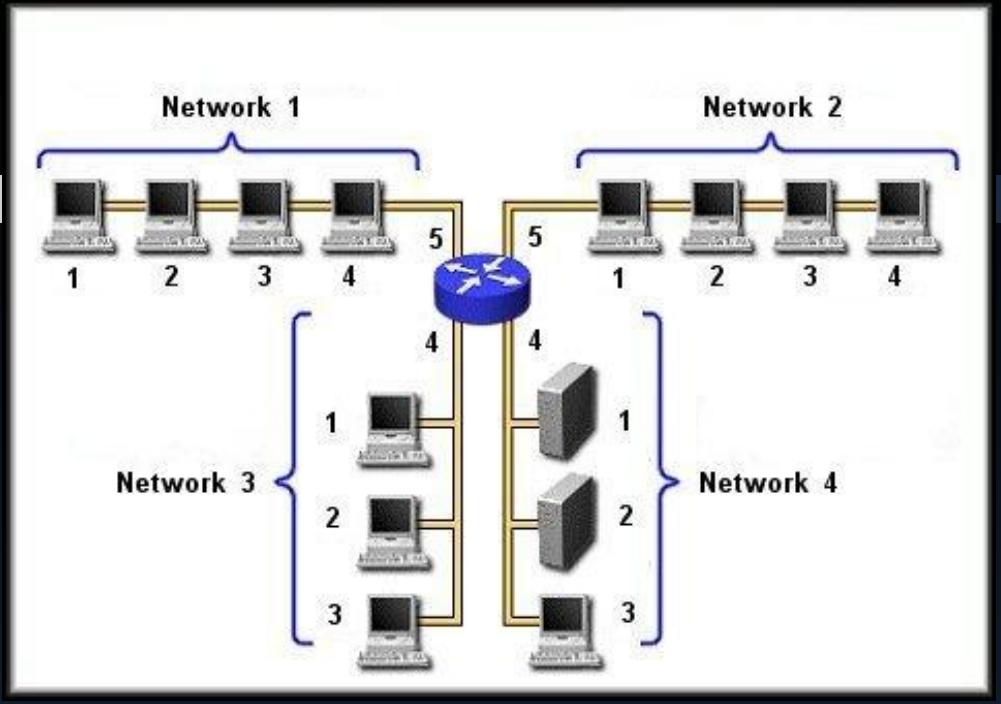
# Subnetting - Class C




- This is our network and we have decided to use the private Class C network: 192.168.80.0
- We need 4 networks with addresses for 5 hosts and want to leave room for some future expansion.

| Borrowed Bits | Number of Subnets | Number of Usable Hosts | Subnet Mask | Prefix |
|---|---|---|---|---|
| 2 | $2^2 = 4$ | $2^6 - 2 = 62$ | 255.255.255.192 | /26 |
| 3 | $2^3 = 8$ | $2^5 - 2 = 30$ | 255.255.255.224 | /27 |
| 4 | $2^4 = 16$ | $2^4 - 2 = 14$ | 255.255.255.240 | /28 |
| 5 | $2^5 = 32$ | $2^3 - 2 = 6$ | 255.255.255.248 | /29 |

# Subnetting - Class C

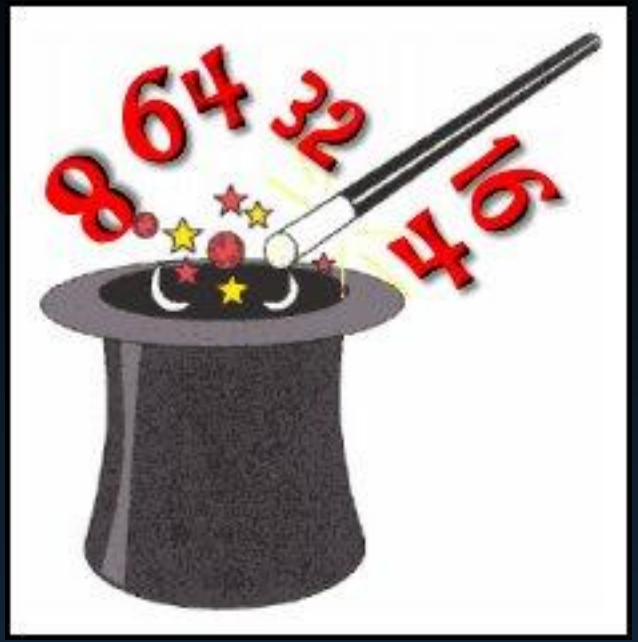



- Looking at the table, we see that borrowing 3 bits gives us 8 subnets with 30 useable hosts on each network.
- This choice meets the current requirements and leaves room for expansion.

| Borrowed Bits | Number of Subnets | Number of Usable Hosts | Subnet Mask | Prefix |
|---|---|---|---|---|
| 2 | $2^2 = 4$ | $2^6 - 2 = 62$ | 255.255.255.192 | /26 |
| 3 | $2^3 = 8$ | $2^5 - 2 = 30$ | 255.255.255.224 | /27 |
| 4 | $2^4 = 16$ | $2^4 - 2 = 14$ | 255.255.255.240 | /28 |
| 5 | $2^5 = 32$ | $2^3 - 2 = 6$ | 255.255.255.248 | /29 |

# Magic Numbers

- To make the job of subnetting easier, there is a method that allows you to calculate a "magic" number.
- The magic number we're looking for is the number of addresses in each network, including the network, broadcast and host range.



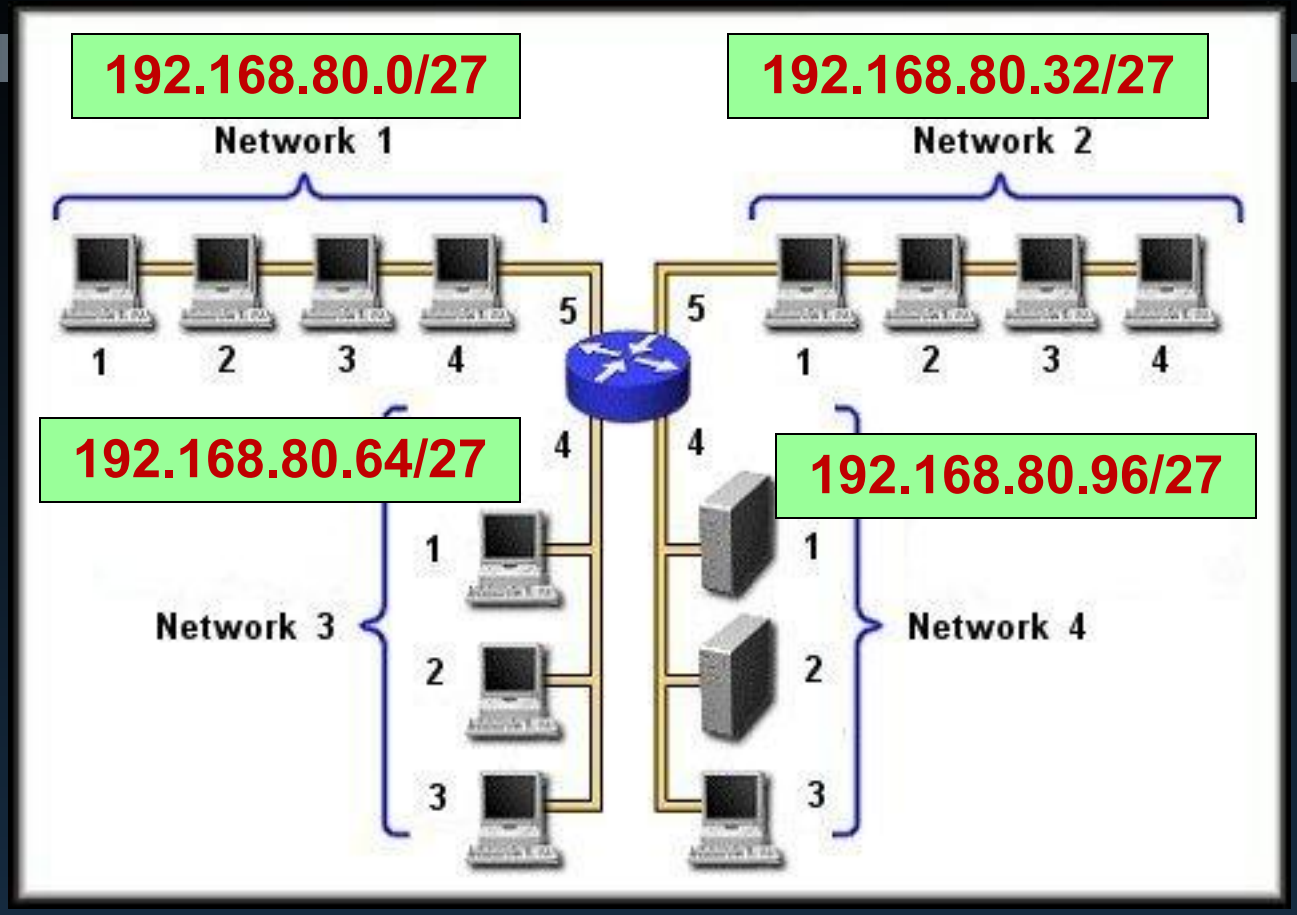

- The calculation $2^{number\_of\_host\_bits}$ yields the "magic" number.
- We have 5 host bits remaining so…..
  - $2^5 = 32$ - our "magic" number.

# Subnetting - Class C

- Network: 192.168.80.0 Subnet Mask: 255.255.255.224
- Network: 27 bits Host: 5 bits Magic Number: $2^5 = 32$

| ID | Network Address | Subnet Address Range | Broadcast Address |
|---|---|---|---|
| 0 | 192.168.80.0 | 192.168.80.1 – 192.168.80.30 | 192.168.80.31 |
| 1 | 192.168.80.32 | 192.168.80.33 – 192.168.80.62 | 192.168.80.63 |
| 2 | 192.168.80.64 | 192.168.80.65 – 192.168.80.94 | 192.168.80.95 |
| 3 | 192.168.80.96 | 192.168.80.97 – 192.168.80.126 | 192.168.80.127 |
| 4 | 192.168.80.128 | 192.168.80.129 – 192.168.80.158 | 192.168.80.159 |
| 5 | 192.168.80.160 | 192.168.80.161 – 192.168.80.190 | 192.168.80.191 |
| 6 | 192.168.80.192 | 192.168.80.193 – 192.168.80.222 | 192.168.80.223 |
| 7 | 192.168.80.224 | 192.168.80.225 – 192.168.80.254 | 192.168.80.255 |

# Subnetting – Class C




- Result is 8 subnets with 30 useable hosts each.
- Allows the expansion of hosts in each network and the addition of two more networks without changing our IP Addressing scheme.

# Subnetting – Class A or Class B

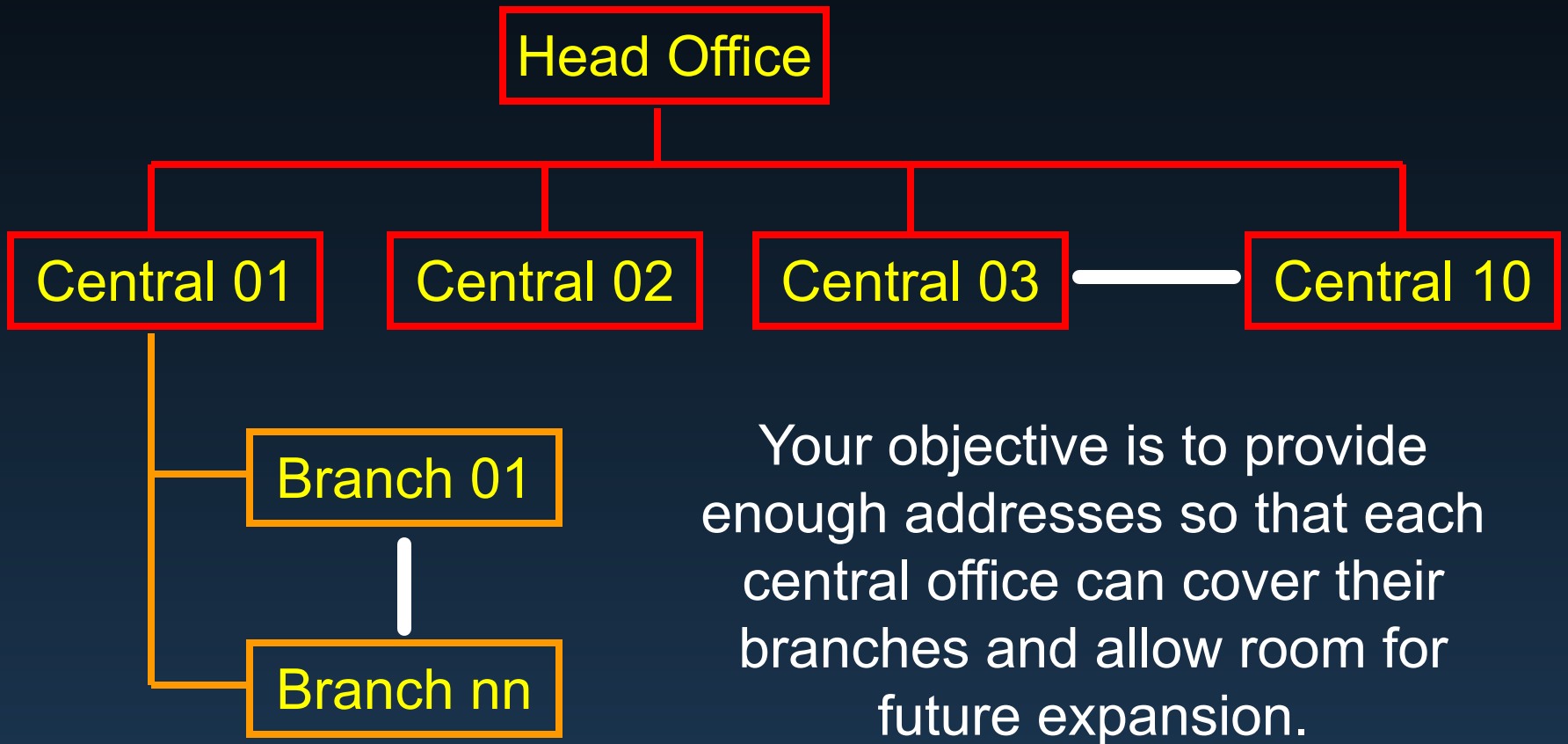
- The subnetting process for class A and B networks is the same. You are simply working with more bits.
  - Determine what is required.
    - Number of networks and number of hosts per network.
  - Determine the number of bits to be borrowed.
  - Determine your magic number.
  - Subnet to produce the ranges for each subnetwork.

# Subnetting - Class B

- Let's try one.
  - You are the network administrator for a world-wide organization with 7,500 users.
    (Yep – the head IT honcho!)
  - You have 10 world-wide central offices and each of those have their own networks and branch offices. Central and Branch office networks range from 100 to 3,000 users.
  - You have decided that a Class B network will be sufficient for your needs and you must subnet the network to include yourself and the central offices.
    - Each central office handles their own network maintenance and it will be up to them to further subnet the network you design.

# Subnetting - Class B

- You have decided to use the Class B private address of
  - 172.25.0.0 / 16




Your objective is to provide enough addresses so that each central office can cover their branches and allow room for future expansion.

# Subnetting - Class B

## Head Office + 10 Central Offices ---100 to 3,000 users each

| Borrowed Bits | Number of Subnets | Number of Usable Hosts | Subnet Mask | Prefix |
|---|---|---|---|---|
| 0 | 0 (default) | $2^{16}$ - 2 = 65,534 | 255.255.0.0 | /16 |
| 1 | $2^{1}$ = 2 | $2^{15}$ - 2 = 32,766 | 255.255.128.0 | /17 |
| 2 | $2^{2}$ = 4 | $2^{14}$ - 2 = 16,382 | 255.255.192.0 | /18 |
| 3 | $2^{3}$ = 8 | $2^{13}$ - 2 = 8,190 | 255.255.224.0 | /19 |
| 4 | $2^{4}$ = 16 | $2^{12}$ - 2 = 4,094 | 255.255.240.0 | /20 |
| 5 | $2^{5}$ = 32 | $2^{11}$ - 2 = 2,046 | 255.255.248.0 | /21 |
| 6 | $2^{6}$ = 64 | $2^{10}$ - 2 = 1,022 | 255.255.252.0 | /22 |
| 7 | $2^{7}$ = 128 | $2^{9}$ - 2 = 510 | 255.255.254.0 | /23 |
| 8 | $2^{8}$ = 256 | $2^{8}$ - 2 = 254 | 255.255.255.0 | /24 |

# Subnetting – Class B

- Determining your magic number – Class A and B.
  - The trick here in determining the magic number is to *only work with the remaining host bits up to a total of 8*.
    - The rest of the bits will fall in line as host bits.
    - e.g.

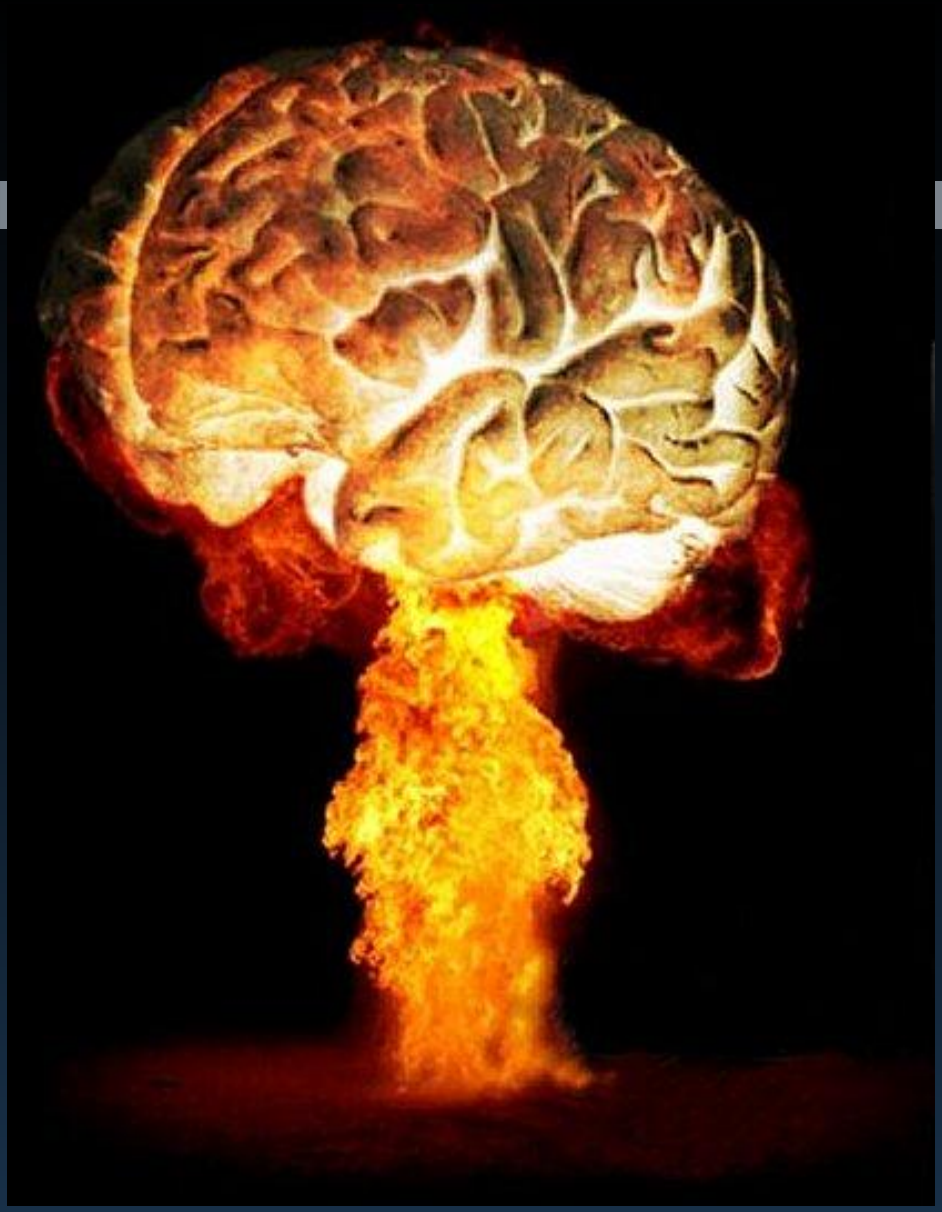
      Borrow 4 bits – subnet mask 255.255.240.0

      11111111.11111111.11110000.00000000

      4 remaining host bits:

      11111111.11111111.11110000.00000000
    - Magic Number = $2^4 = 16$

| ID | Network Address | Subnet Address Range | Broadcast Address |
|---|---|---|---|
| 0 | 172.25.0.0 | 172.25.0.1 to 172.25.15.254 | 172.25.15.255 |
| 1 | 172.25.16.0 | 172.25.16.1 to 172.25.31.254 | 172.25.31.255 |
| 2 | 172.25.32.0 | 172.25.32.1 to 172.25.47.254 | 172.25.47.255 |
| 3 | 172.25.48.0 | 172.25.48.1 to 172.25.63.254 | 172.25.63.255 |
| 4 | 172.25.64.0 | 172.25.64.1 to 172.25.79.254 | 172.25.79.255 |
| 5 | 172.25.80.0 | 172.25.80.1 to 172.25.95.254 | 172.25.95.255 |
| 6 | 172.25.96.0 | 172.25.96.1 to 172.25.111.254 | 172.25.111.255 |
| 7 | 172.25.112.0 | 172.25.112.1 to 172.25.127.254 | 172.25.127.255 |
| 8 | 172.25.128.0 | 172.25.128.1 to 172.25.143.254 | 172.25.143.255 |
| 9 | 172.25.144.0 | 172.25.144.1 to 172.25.159.254 | 172.25.159.255 |
| 10 | 172.25.160.0 | 172.25.160.1 to 172.25.175.254 | 172.25.175.255 |
| 11 | 172.25.176.0 | 172.25.176.1 to 172.25.191.254 | 172.25.191.255 |
| 12 | 172.25.192.0 | 172.25.192.1 to 172.25.207.254 | 172.25.207.255 |
| 13 | 172.25.208.0 | 172.25.208.1 to 172.25.223.254 | 172.25.223.255 |
| 14 | 172.25.224.0 | 172.25.224.1 to 172.25.239.254 | 172.25.239.255 |
| 15 | 172.25.240.0 | 172.25.240.1 to 172.25.255.254 | 172.25.255.255 |



*Your turn to do STUFF!*