



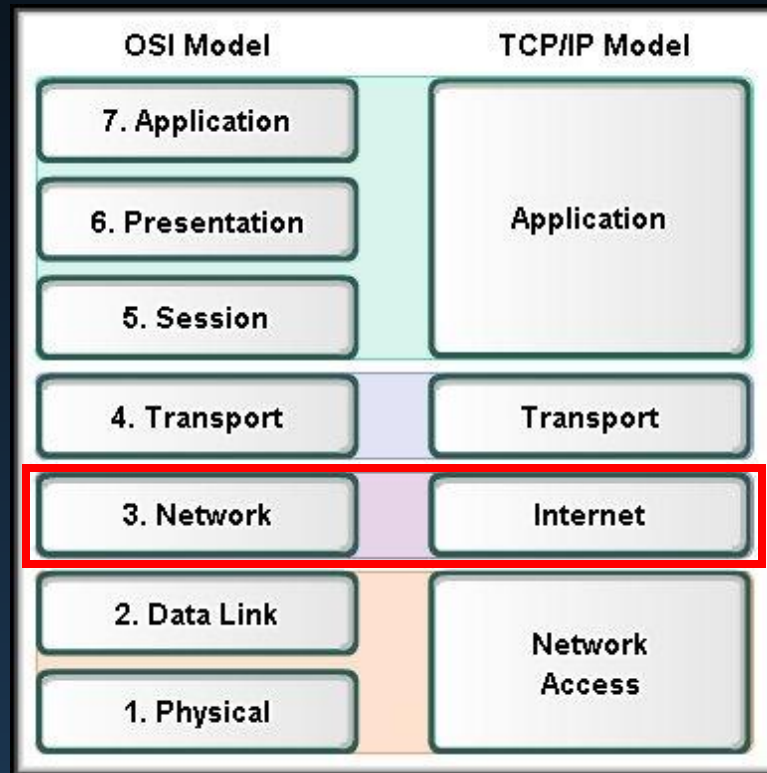
Chapter 6

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 be 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 **subnet** 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 <u>Useable</u> 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	$2^8 = 256$	$2^8 - 2 = 254$

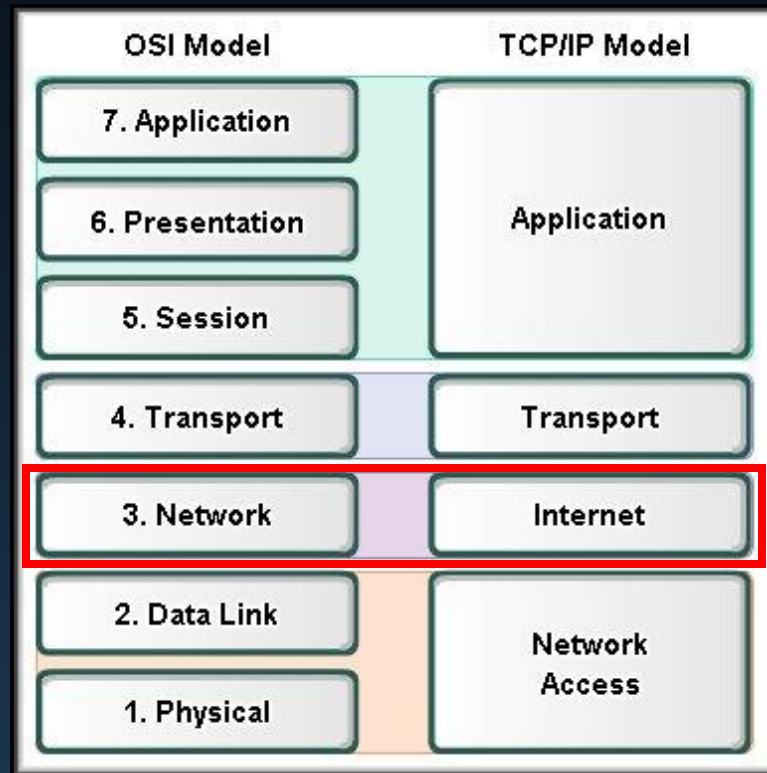
- As we will see, the formula ($2^{\text{number_of_bits}} - 2$ or $2^n - 2$) is an important part of assigning an IP address range to a network segment.

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



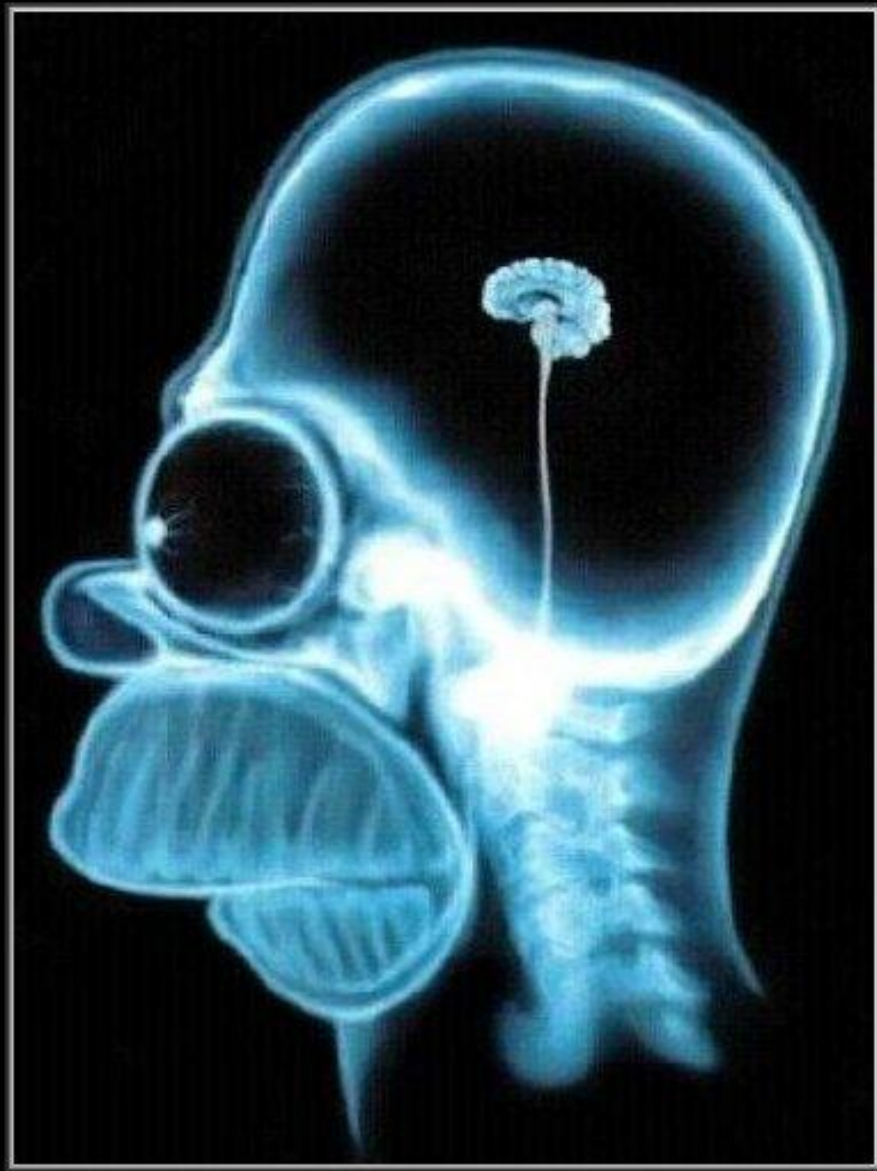
Calculating Addresses

- 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.

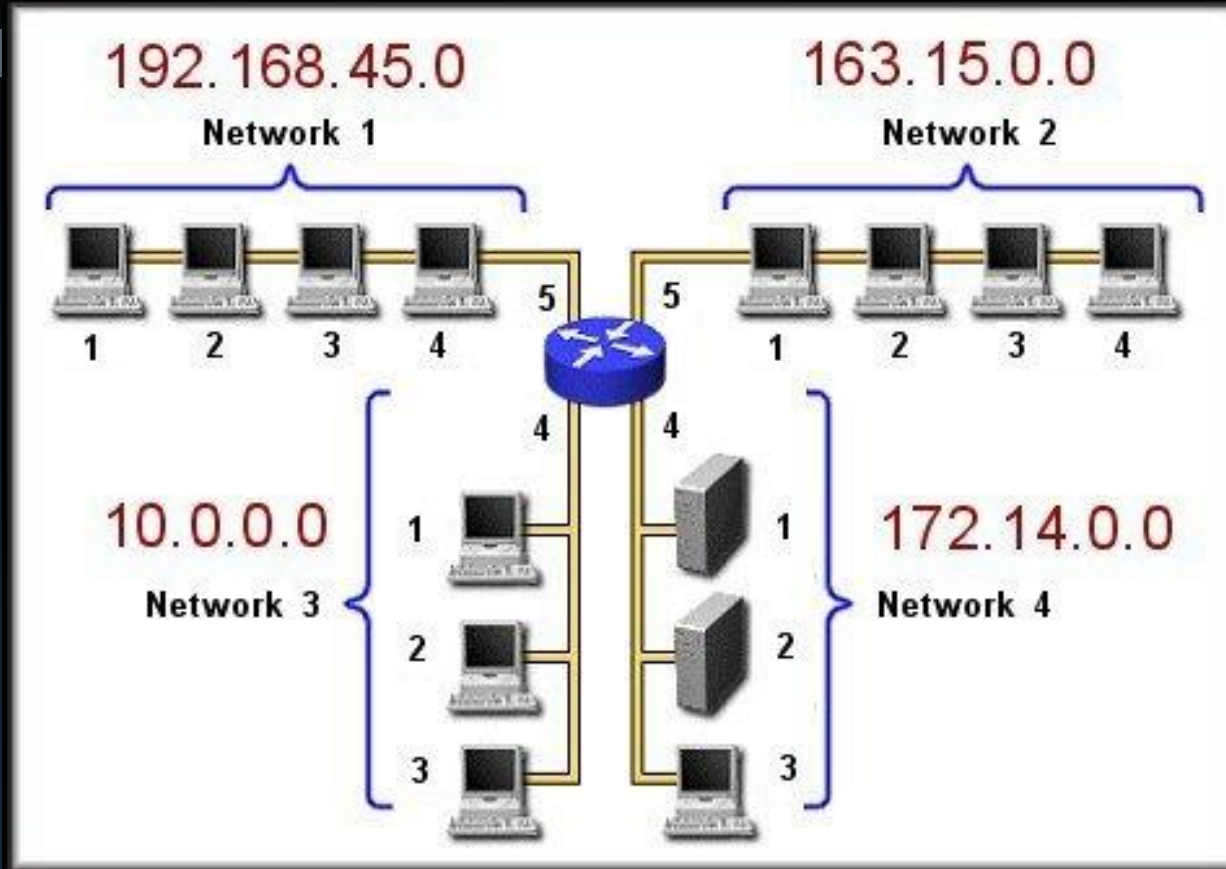
Calculating Addresses

NO CALCULATORS OF
ANY KIND...

DON'T WIND UP LIKE
THIS!!!

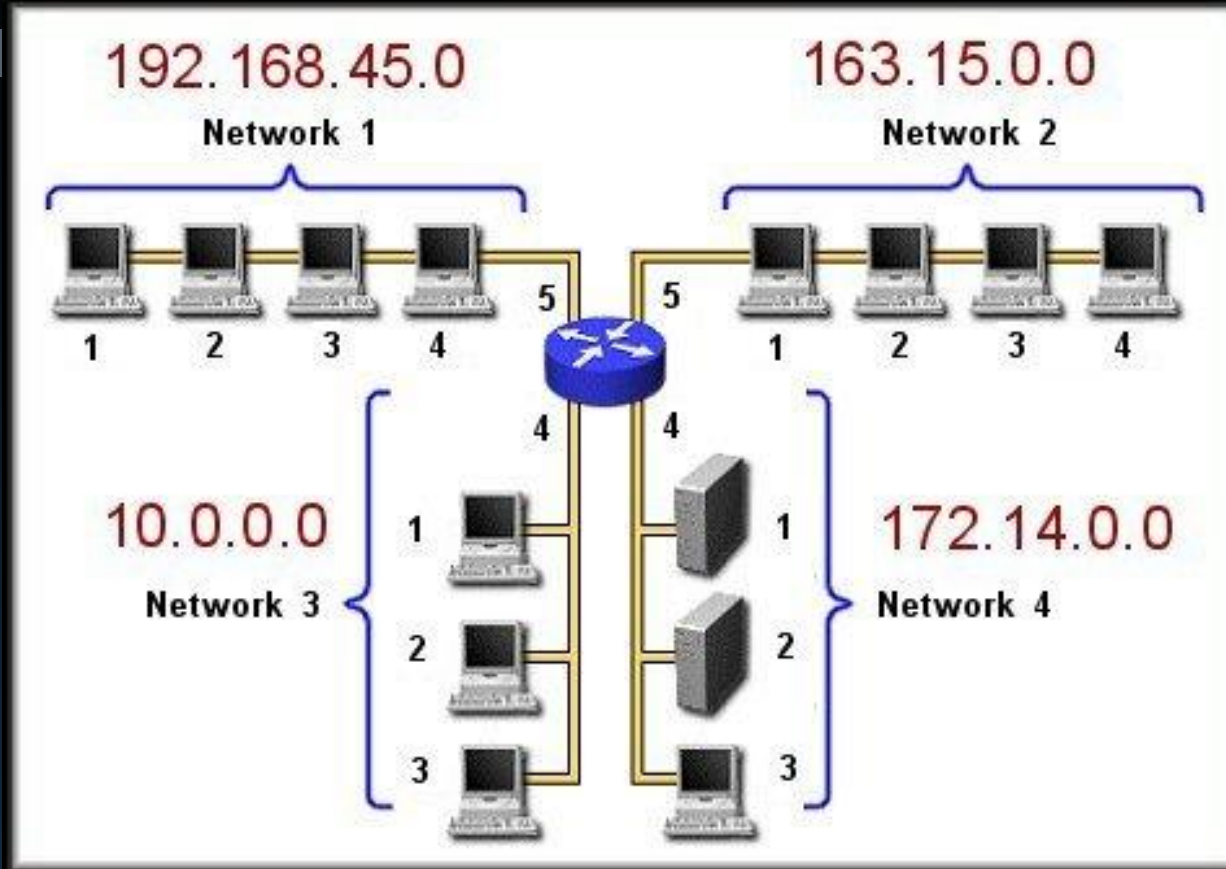


The Network Number



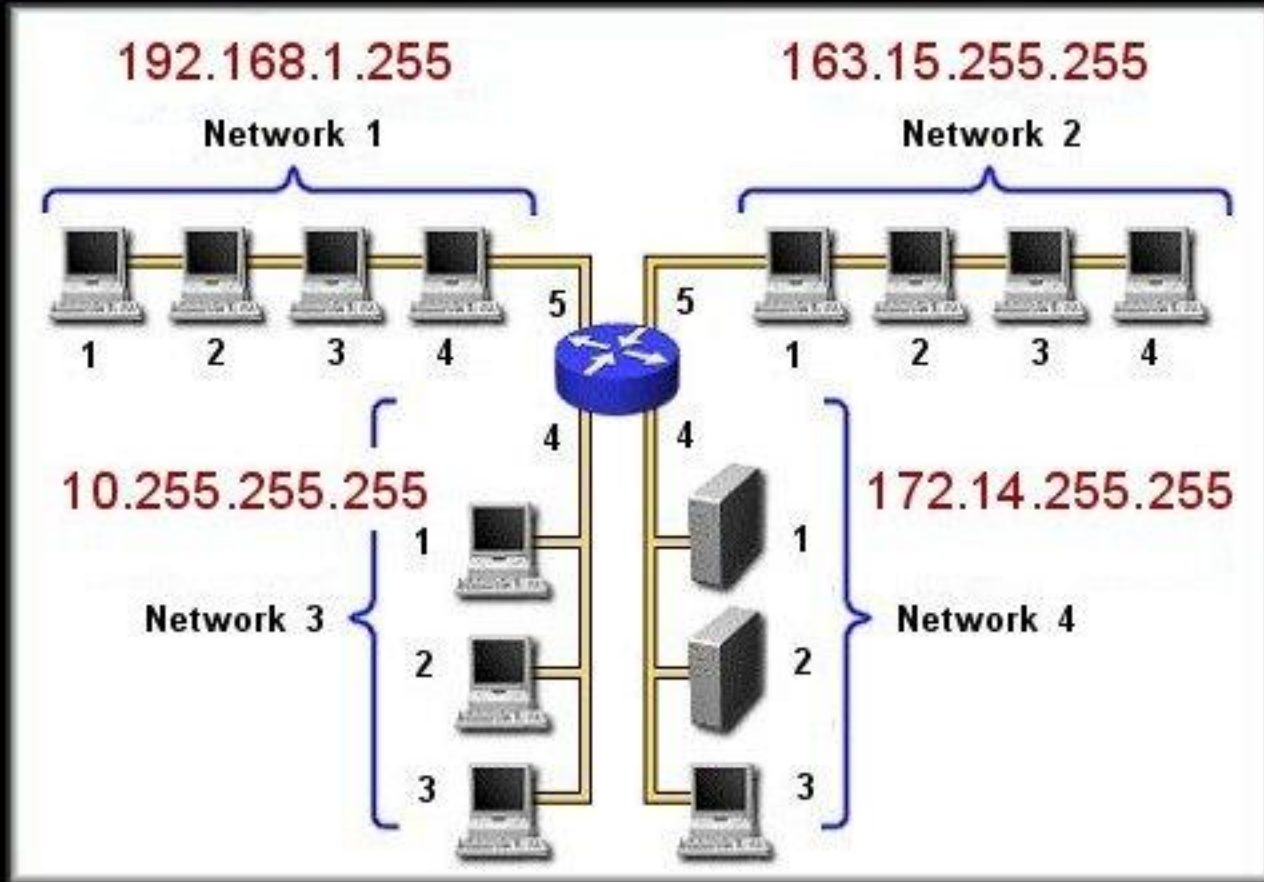
- A host on a network can communicate **directly** with other devices **on the same network**, only if all the devices have the **same network number** and the **same subnet mask**.

The Network Number



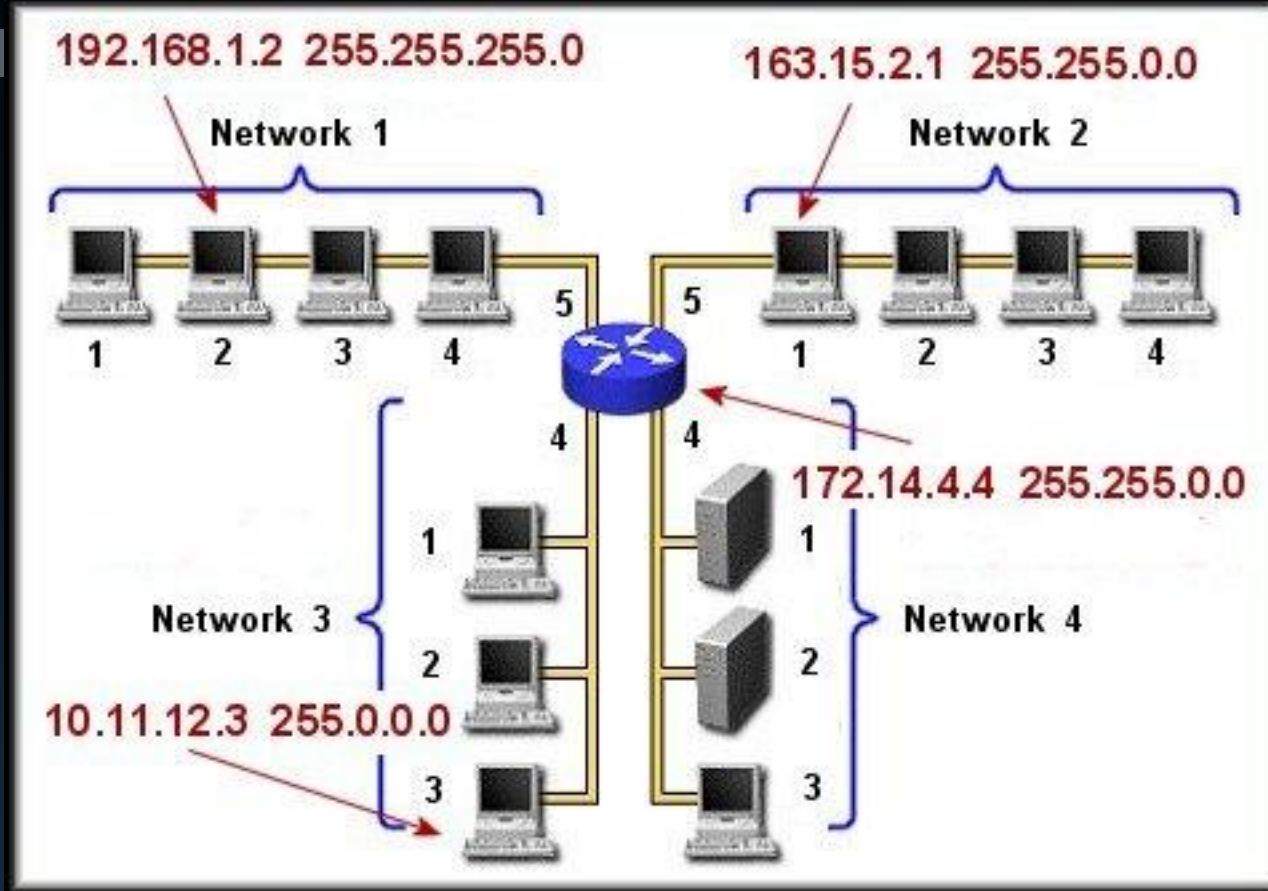
- Routers use the network number to build their routing tables so it **cannot be used for a host**.
- The IP address that indicates the network number has all **0 bits** in the **host portion** of the IP Address.

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:

11010010	00010100	01001101	00000001
210.	20.	77.	1
11010010	00010100	01001101	11111110
210.	20.	77.	254

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

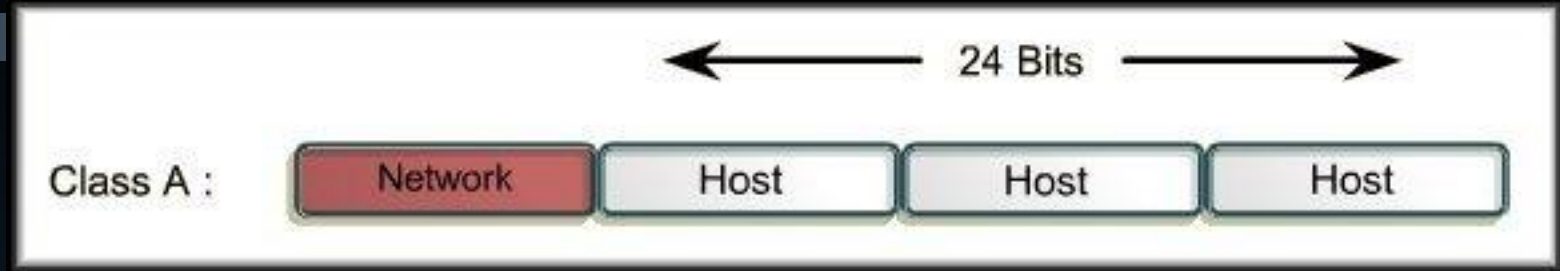
Classful IP Addressing – Class B

- 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:

10010010	01010100	00000000	00000001
146.	84.	0.	1
10010010	01010100	11111111	11111110
146.	84.	255.	254

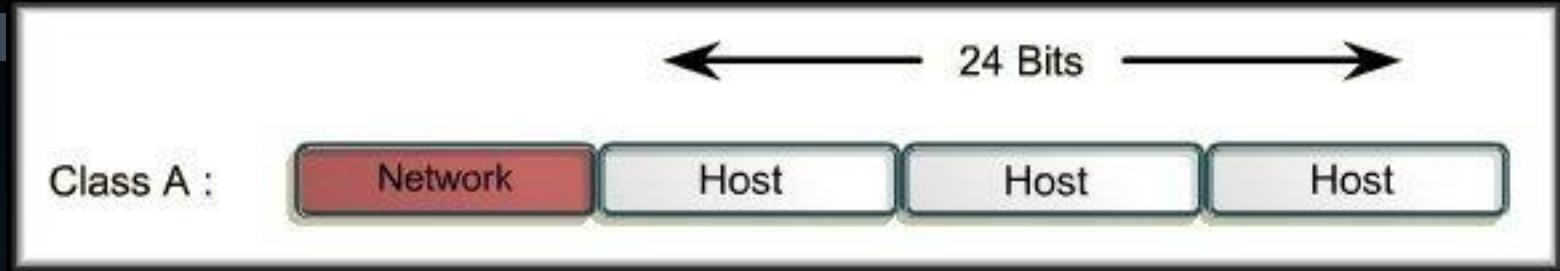
Classful IP Addressing – Class A



- **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

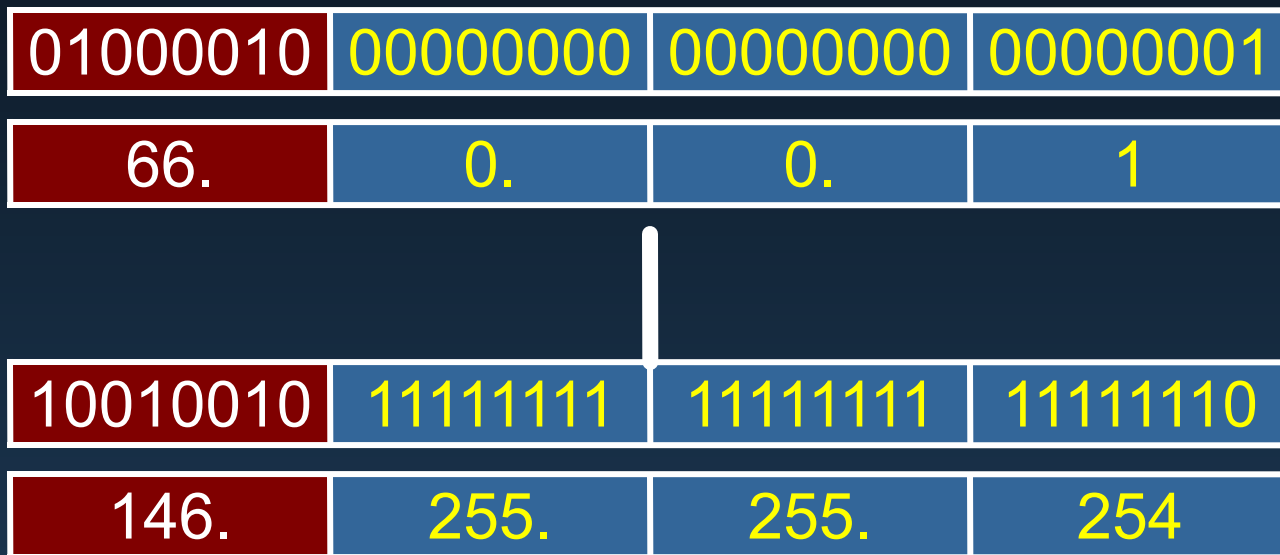
- The last host address (all 1's) is reserved for the broadcast address.

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

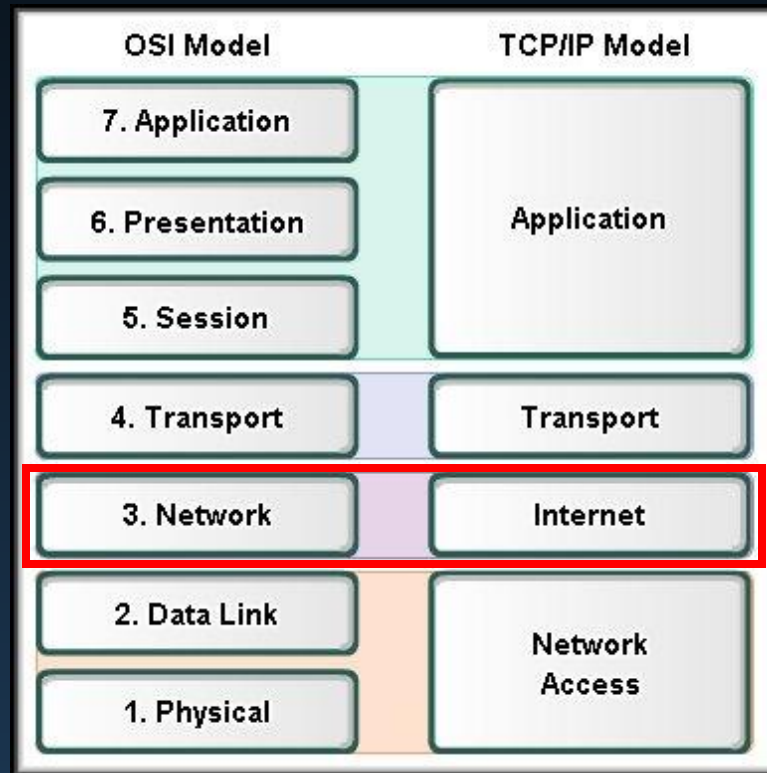
Broadcast Address is: 64.255.255.255

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

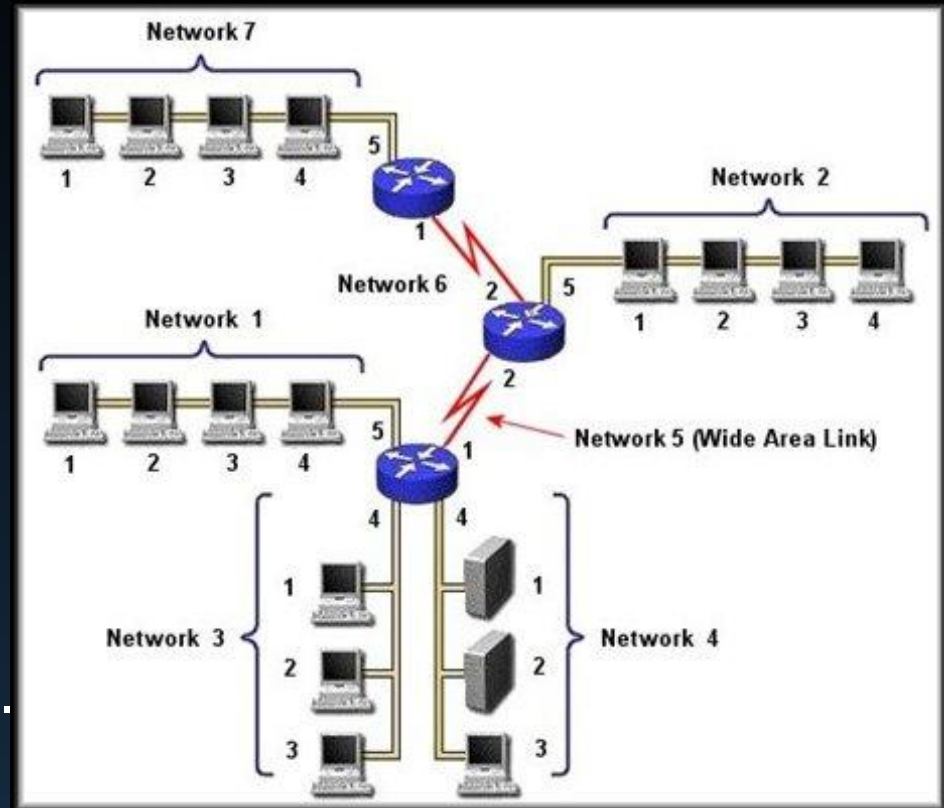
- The world is running short of available IP addresses.
- If every organization connected to the Internet used an entire Class A, B or C address:
 - The number of organizations would be limited and many IP addresses would be wasted.
 - **e.g.** An organization with 256 hosts owns a Class B address. 65,000 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.

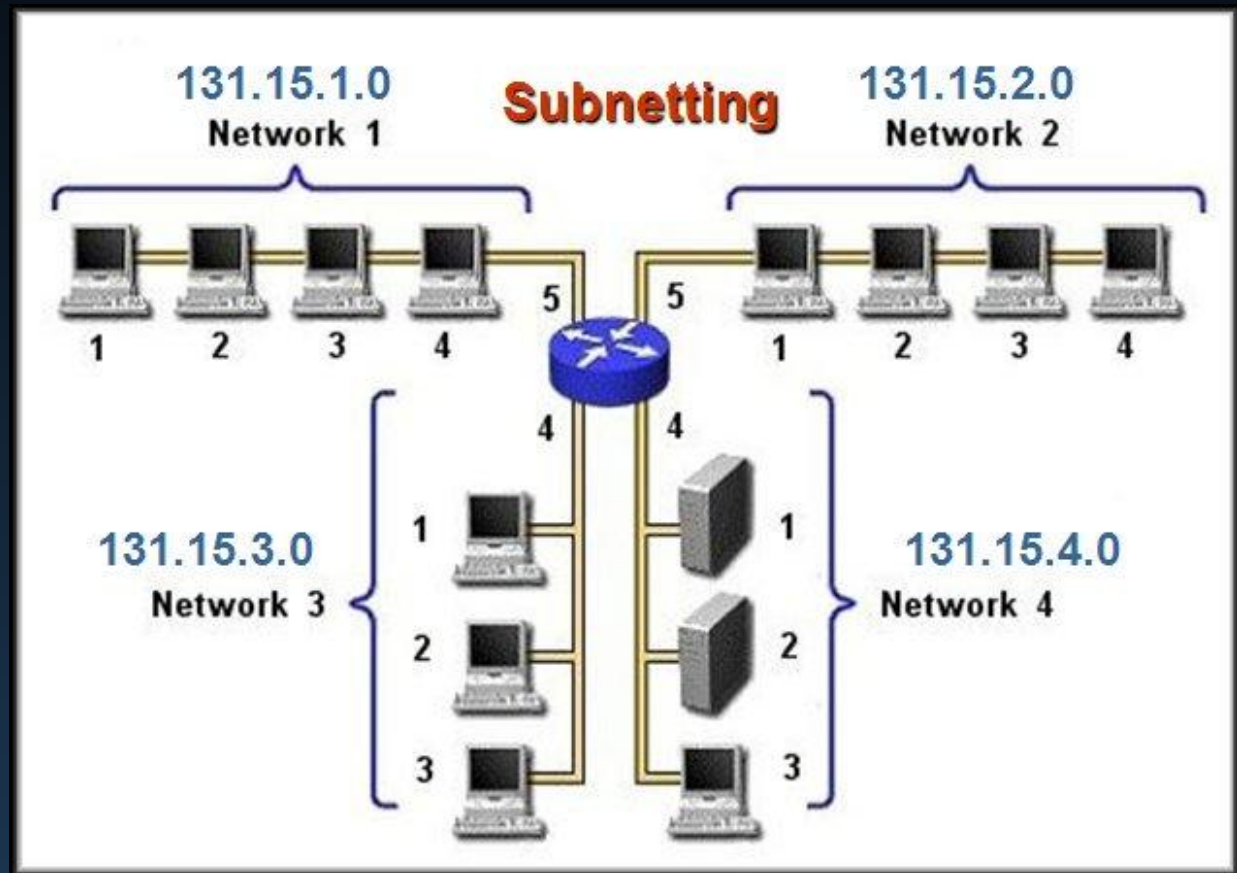
Why Multiple Segments?

- 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.

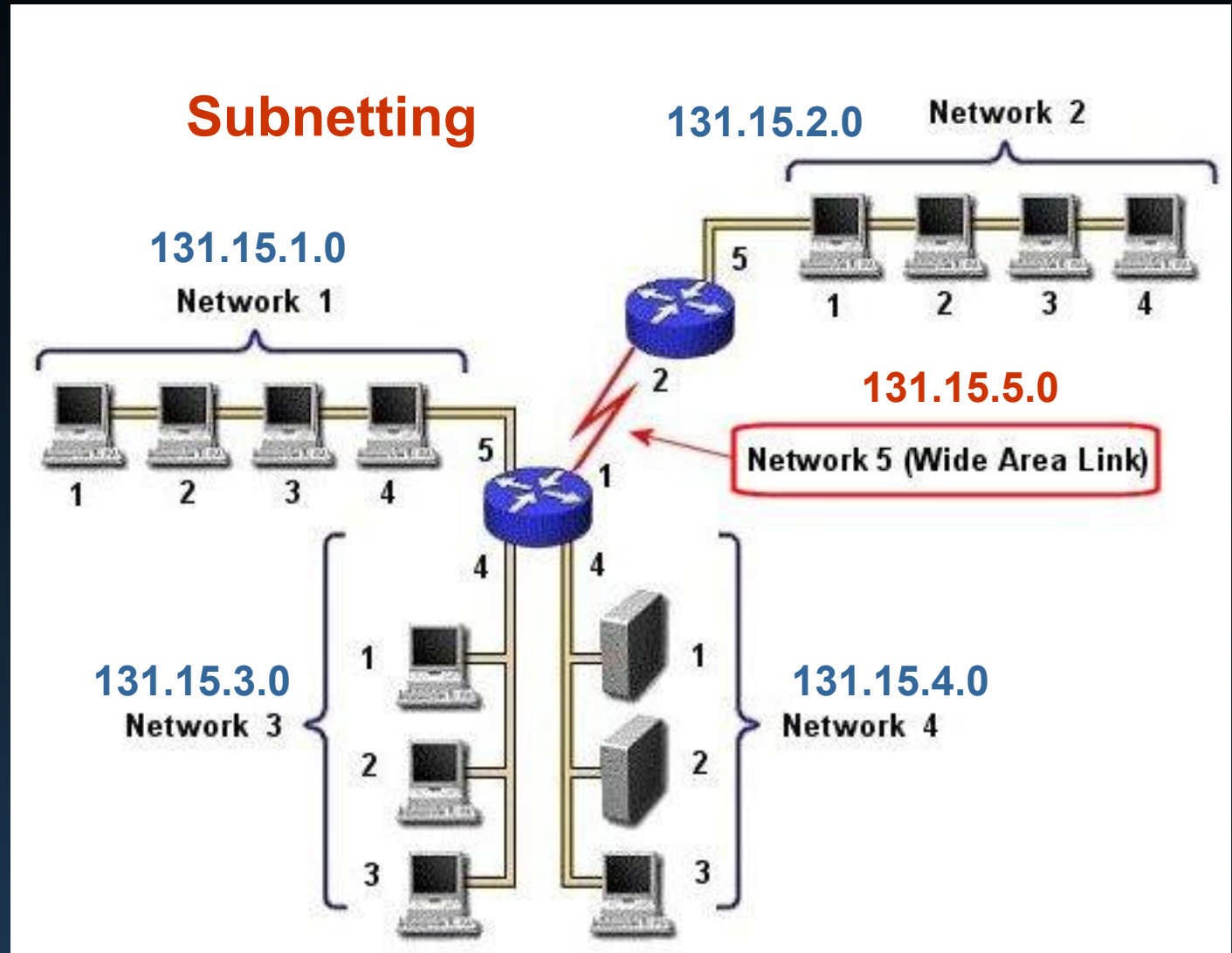


Why Multiple Segments?

Subnetting

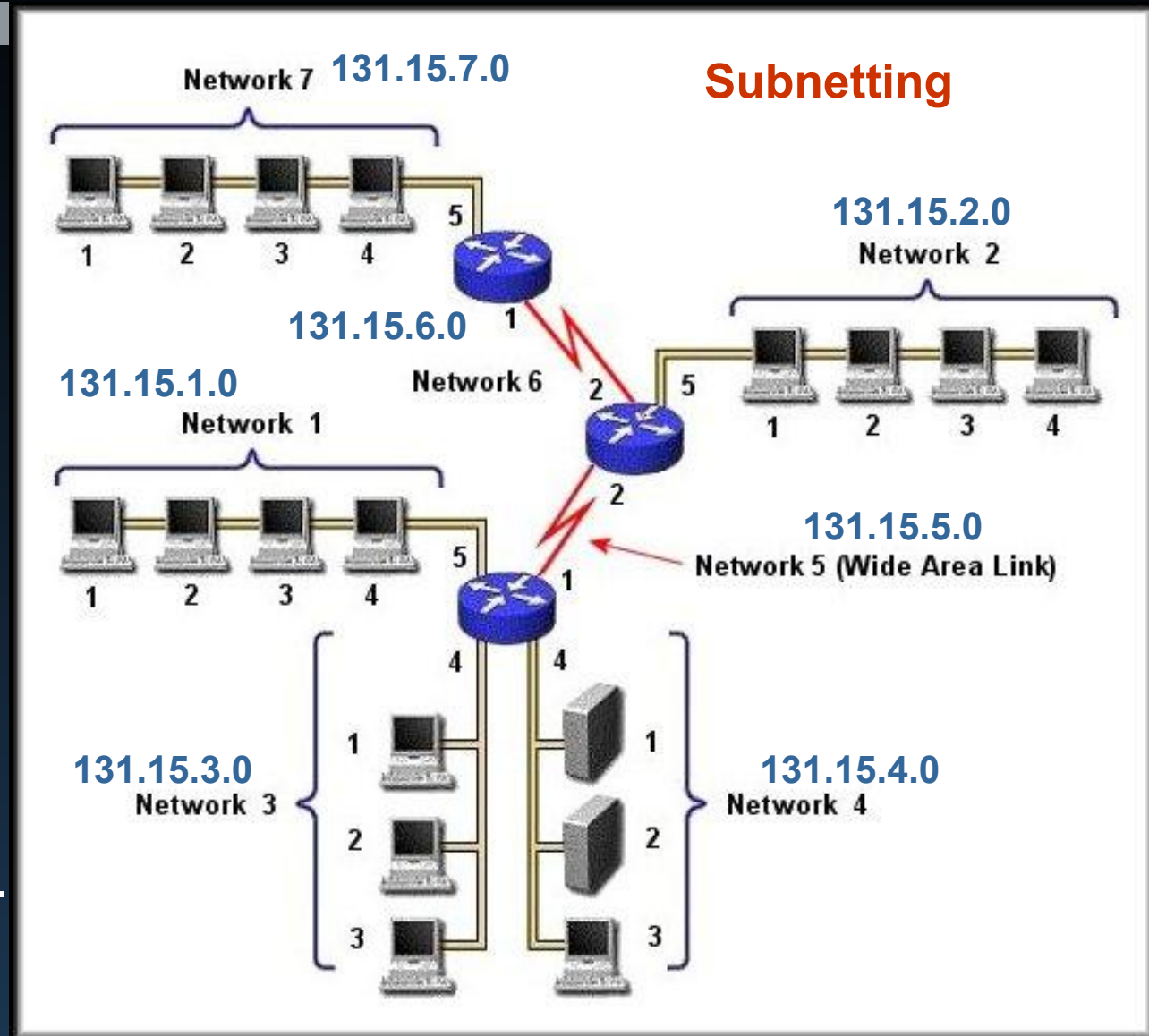
Class B
131.15.0.0

What happens here?

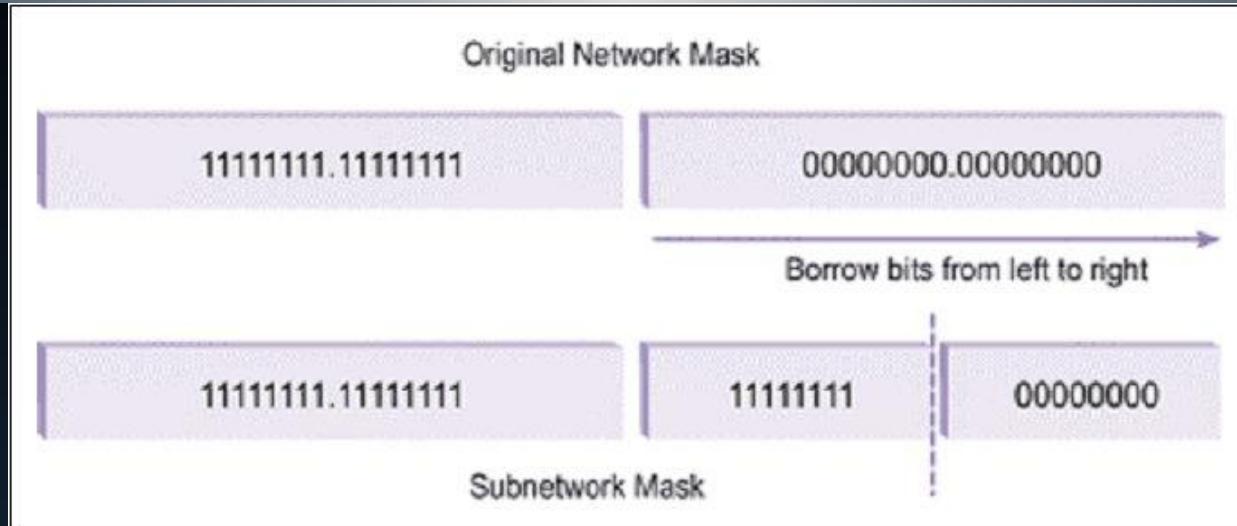


Why Multiple Segments?

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

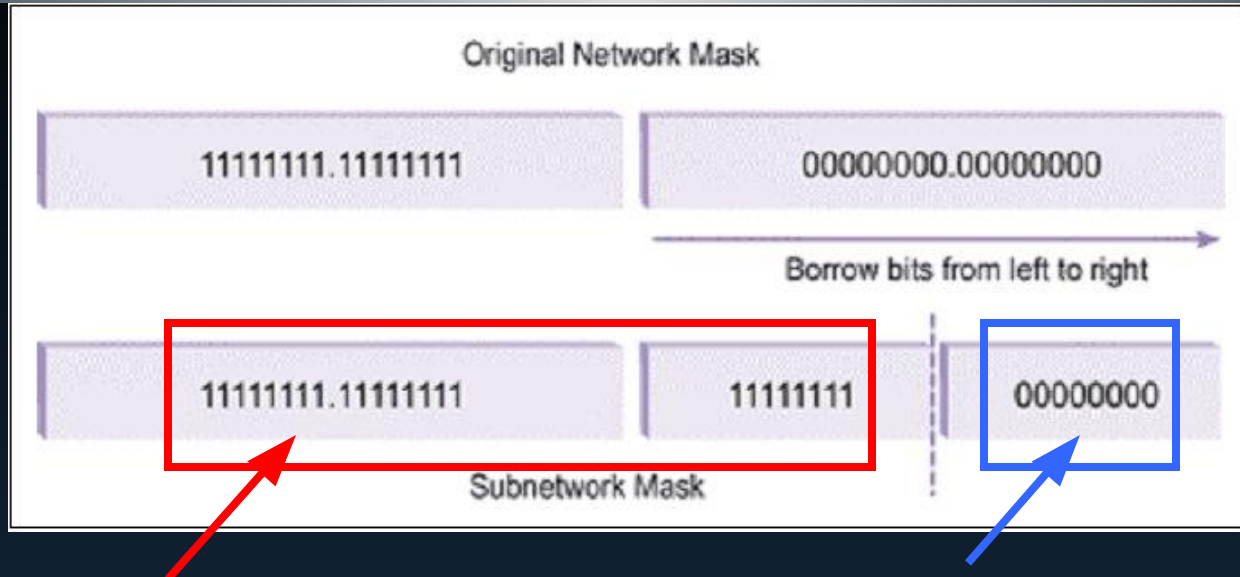


Creating a Subnet



- 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:** $2^{\text{number_of_borrowed_host_bits}}$
 - **Usable Hosts Per Subnet:**
 $2^{\text{number_of_remaining_host_bits}} - 2$

Subnets and Useable Hosts – Class C

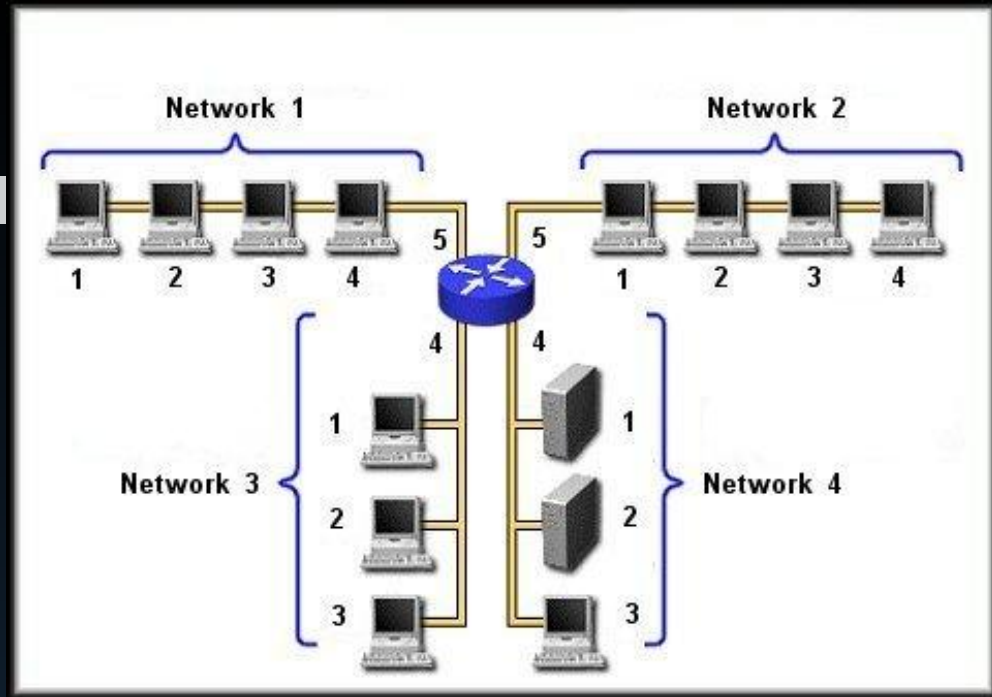
- Default: 255.255.255.0 - 24 network bits and 8 host bits

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

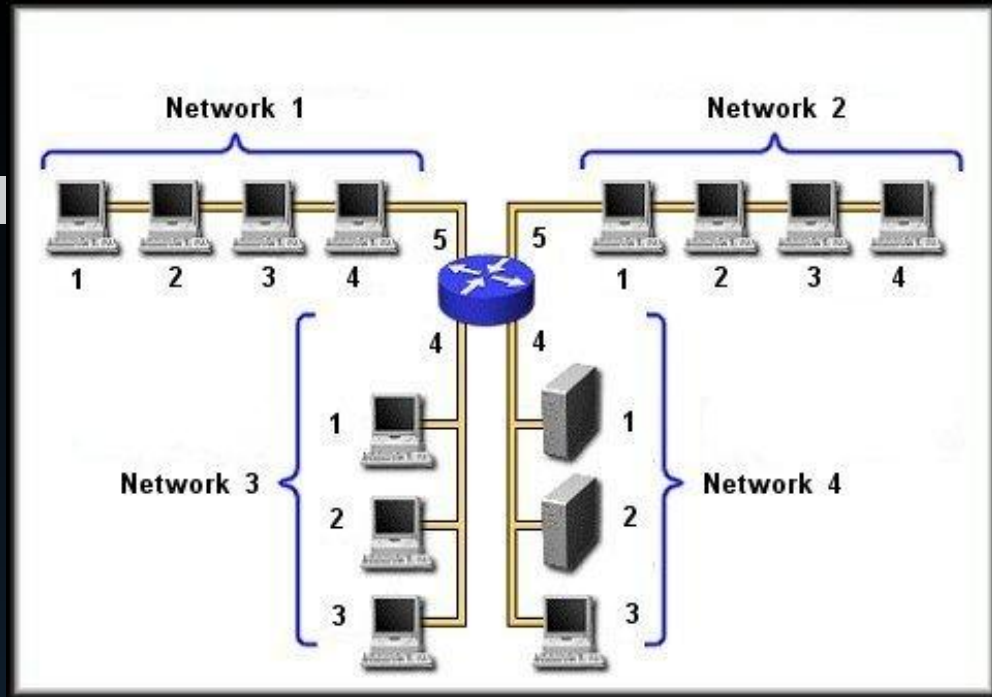
- This is our network and we have decided to use the private Class C network: **192.168.80.0**
- We need **4 networks** with addresses for **5 hosts** and want to leave room for some **future expansion**.



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 $2^{\text{number_of_host_bits}}$ yields the "magic" number.
- We have 5 host bits remaining so.....
 - $2^5 = 32$ - our "magic" number.

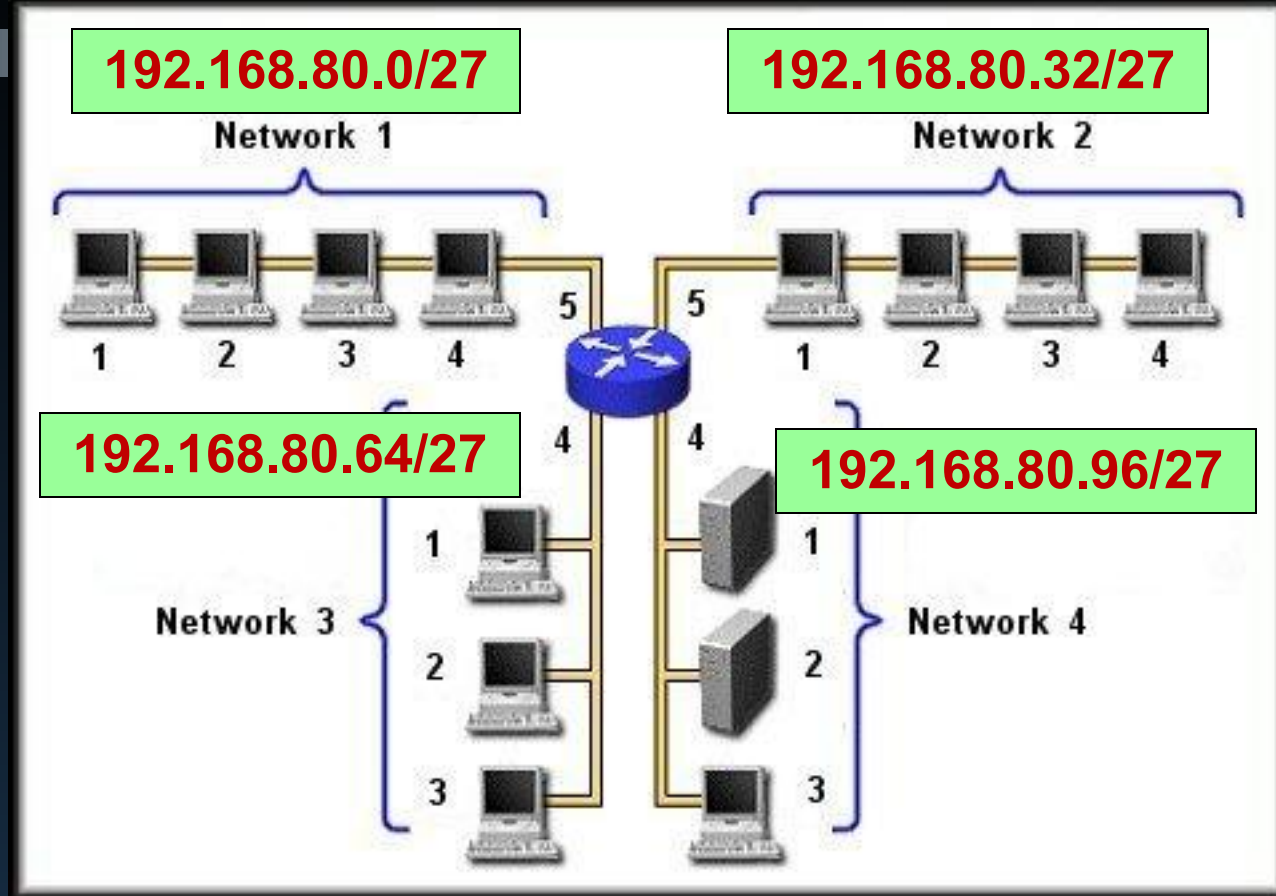


Subnetting - Class C

- 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

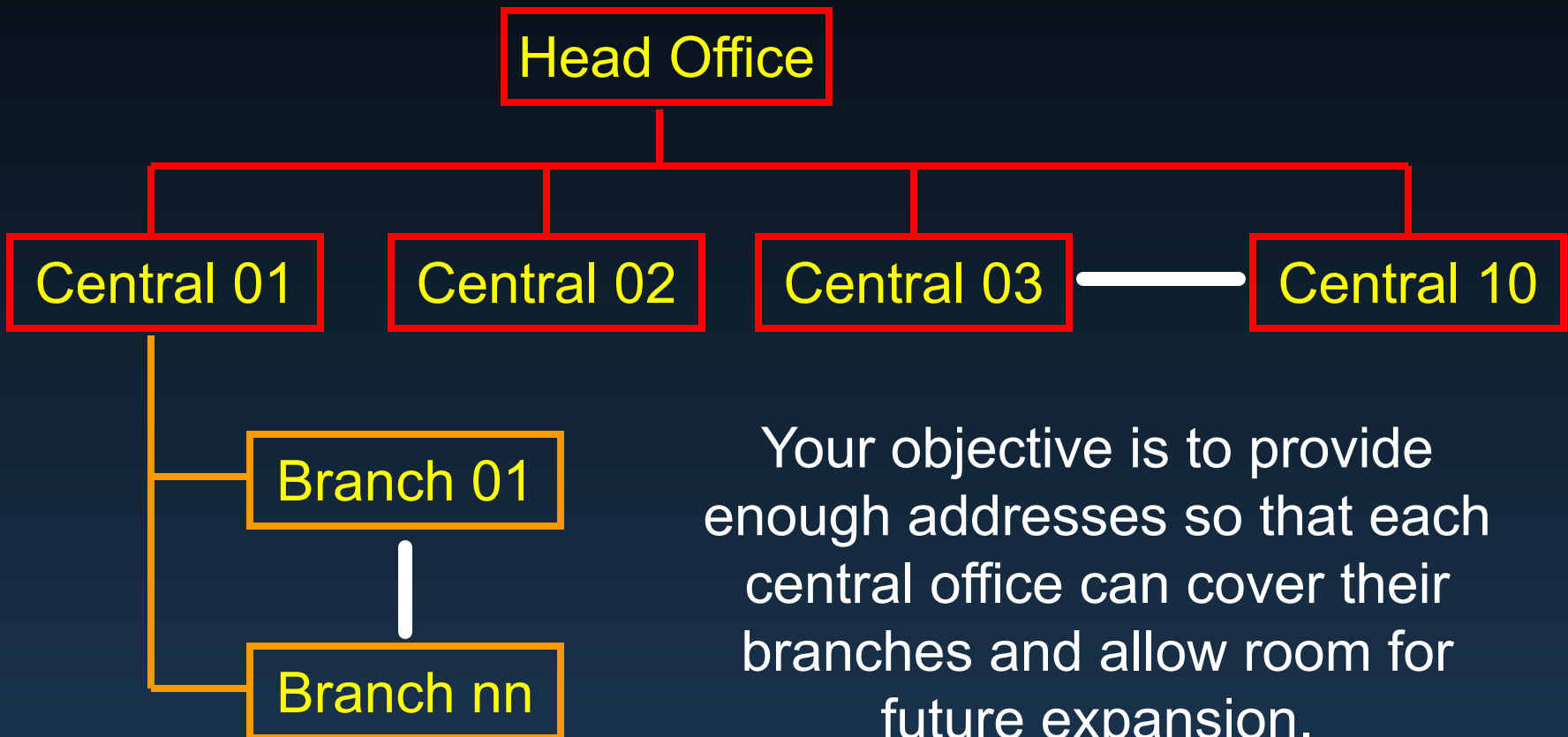
- The subnetting process for class A and B networks is the same. **You are simply working with more bits.**
 - Determine what is required.
 - Number of networks and number of hosts per network.
 - Determine the number of bits to be borrowed.
 - Determine your magic number.
 - Subnet to produce the ranges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



Subnetting - Class B

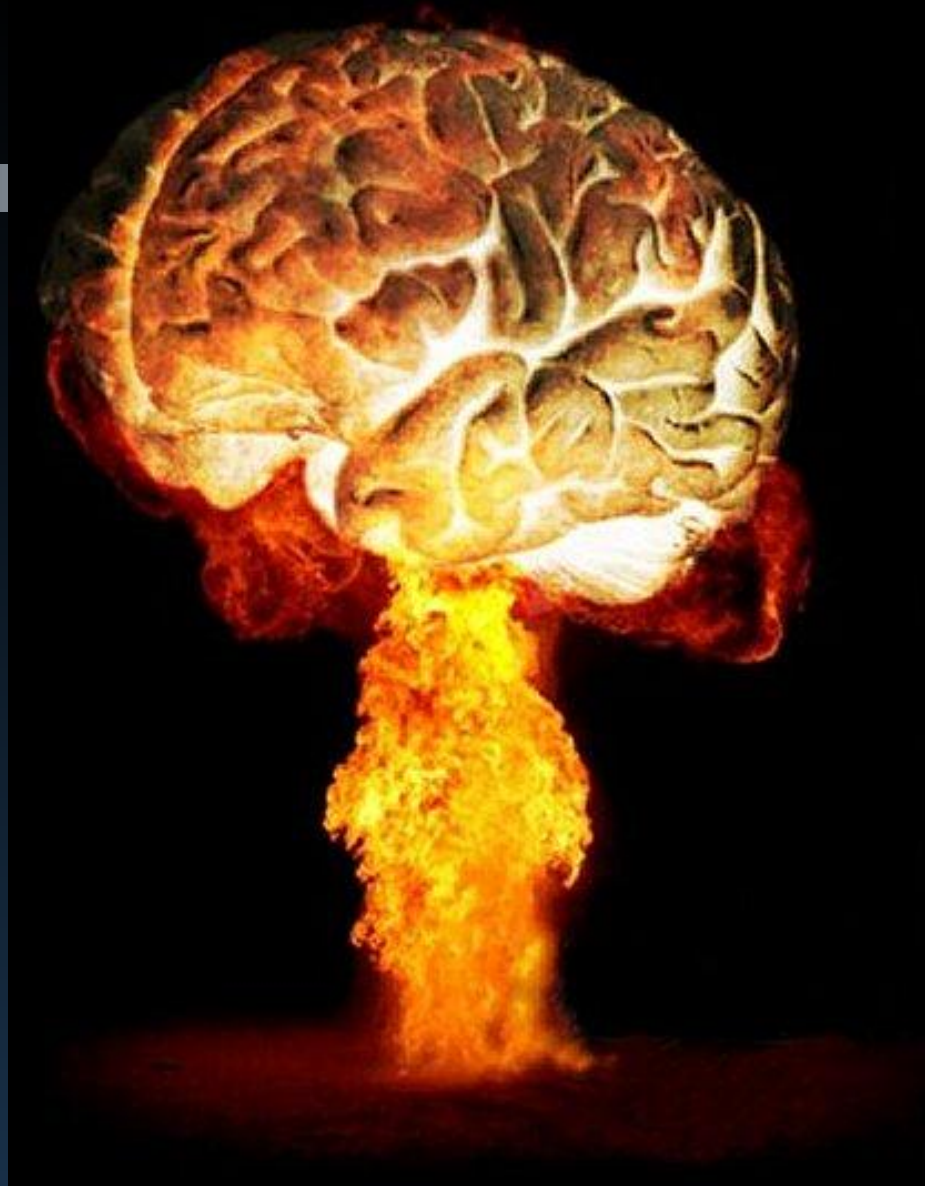
Head Office + 10 Central Offices ---100 to 3,000 users each

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!