CD4002/CN4002
Computer Systems and Networks

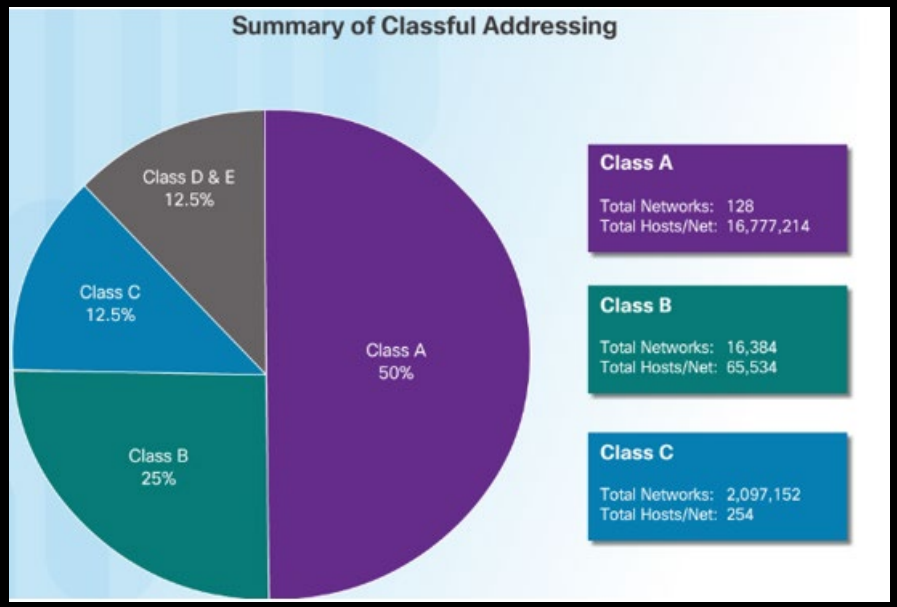
Topic:
Subnetting IP Networks

Objectives

- Understand the limitations of classful addressing.
- Explain how subnetting a network leads to better communication.
- Calculate IPv4 subnets for a /24, /16 and /8 prefix.

IPv4 Address Crisis

- Classful Addressing wasted addresses and exhausted the availability of IPv4 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.



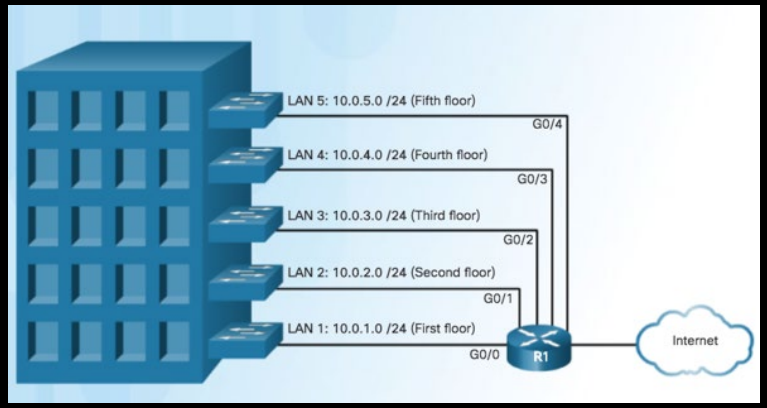
IP Address Crisis

- The goal, then, is to use owned addresses (or public addresses) as efficiently as possible to avoid waste.
  - Subnetting
  - CIDR (Classless Interdomain Routing)
  - Network Address Translation (NAT)

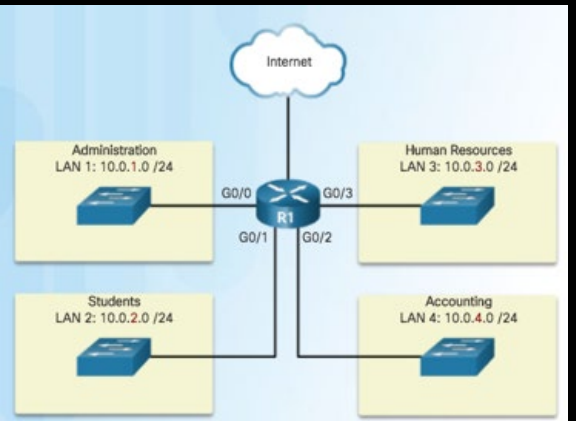
Reasons for Subnetting

- Reduces overall network traffic and improves network performance.
- Enables an administrator to implement security policies such as which subnets are allowed or not allowed to communicate together.

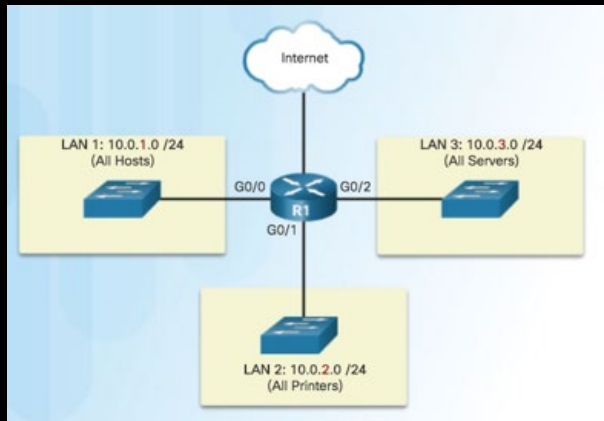
Communication between Networks



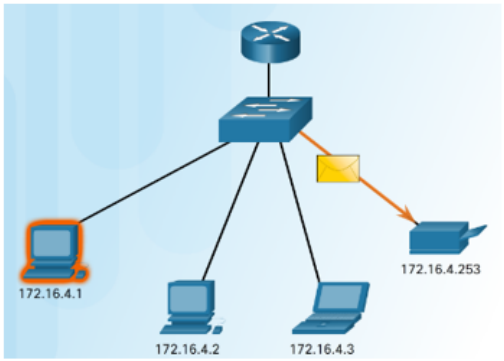
Subnetting by Location



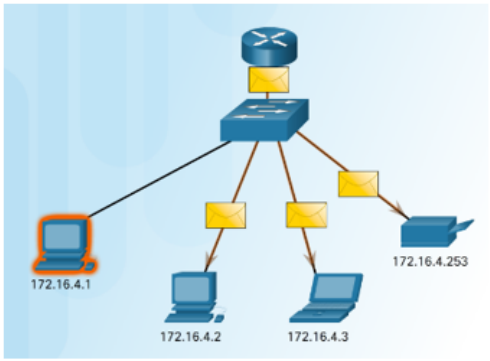
Subnetting by Device Type



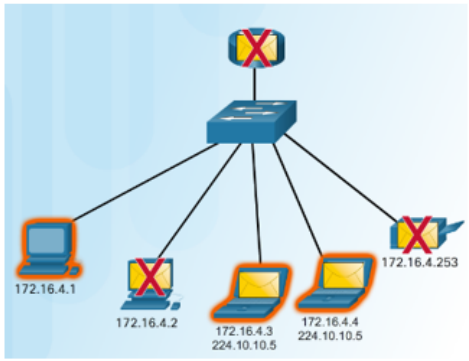
IPv4 Communication



- Unicast – one to one communication.



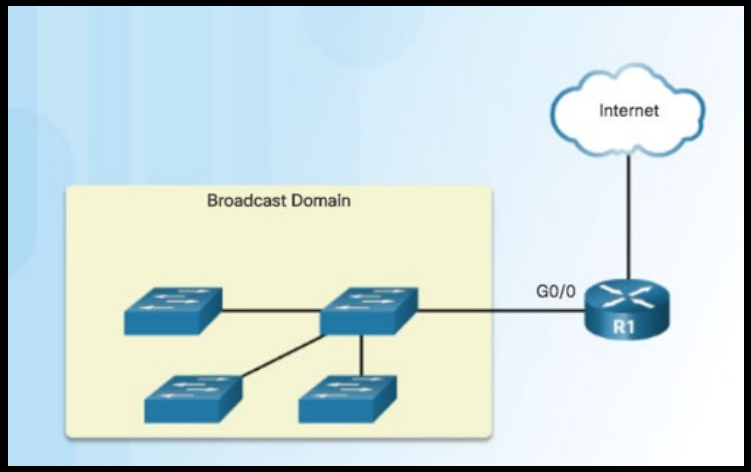
- Broadcast– one to all.



- Multicast – one to a select group.

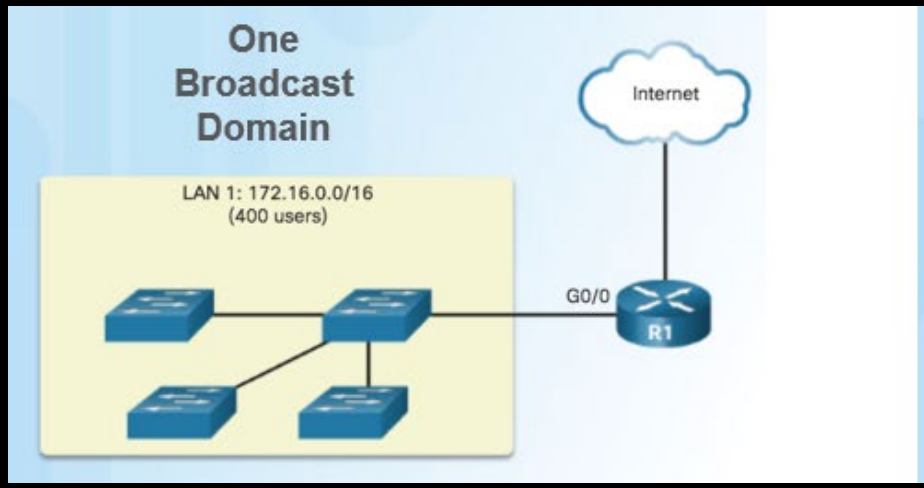
Broadcast Domains

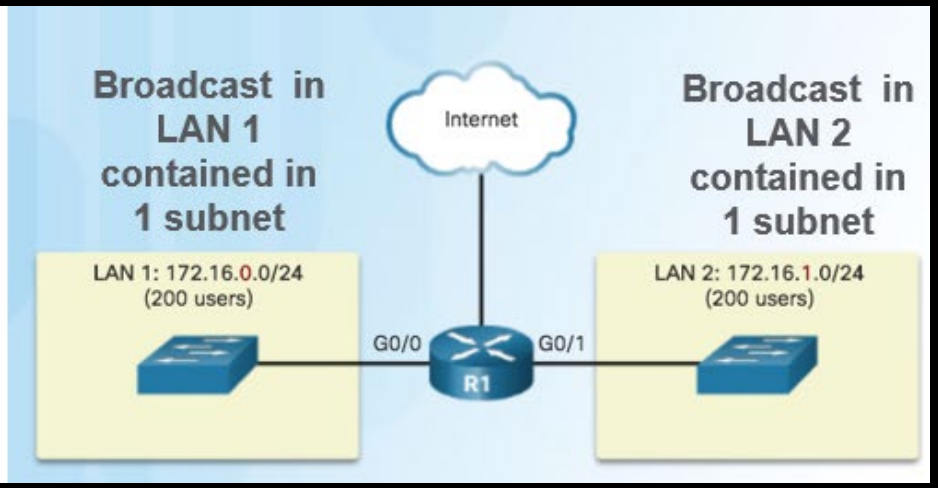
- Devices use broadcasts in a LAN to locate:
  - Other devices - Address Resolution Protocol (ARP) which sends a layer 2 broadcasts to known IPv4 address on the local network to discover the associated MAC address.
  - Services - Dynamic Host Configuration (DHCP) which sends broadcasts on the local network to locate a DHCP.
- Switches propagate broadcasts out all interfaces except the interface on which it was received.



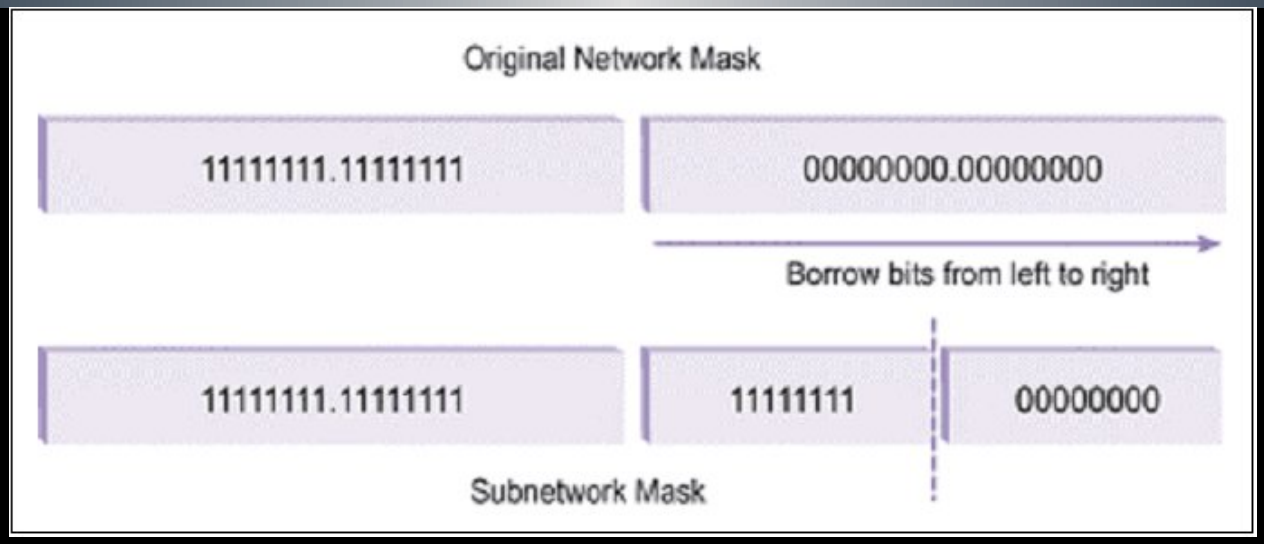
Problems with Large Broadcast Domains

- Hosts can generate excessive broadcasts and negatively affect the network.
  - Slow network operations due to the significant amount of traffic it can cause.
  - Slow device operations because a device must accept and process each broadcast packet.
- Solution: Reduce the size of the network to create smaller broadcast domains. These smaller network spaces are called subnets.



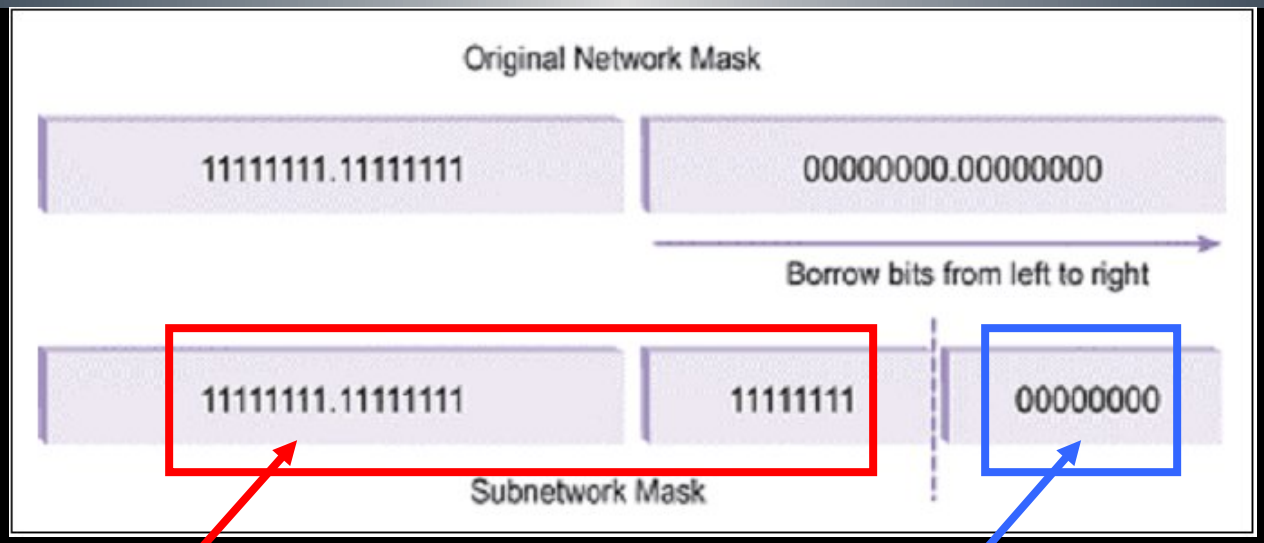


Creating a Subnet



- 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:

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

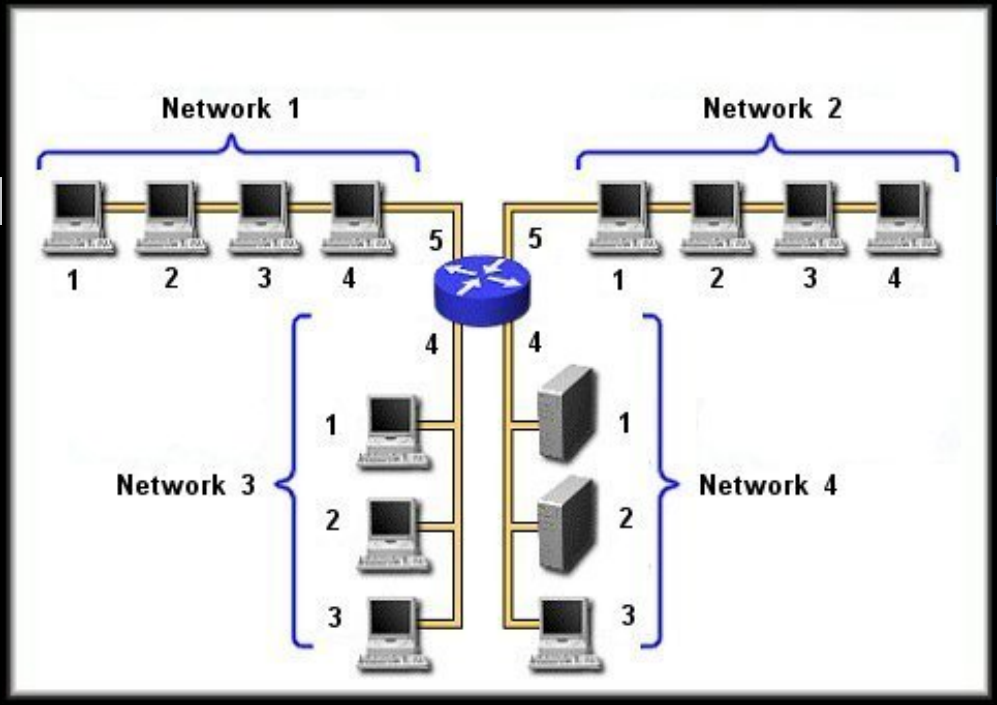
Subnets and Useable Hosts – Class C

- 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

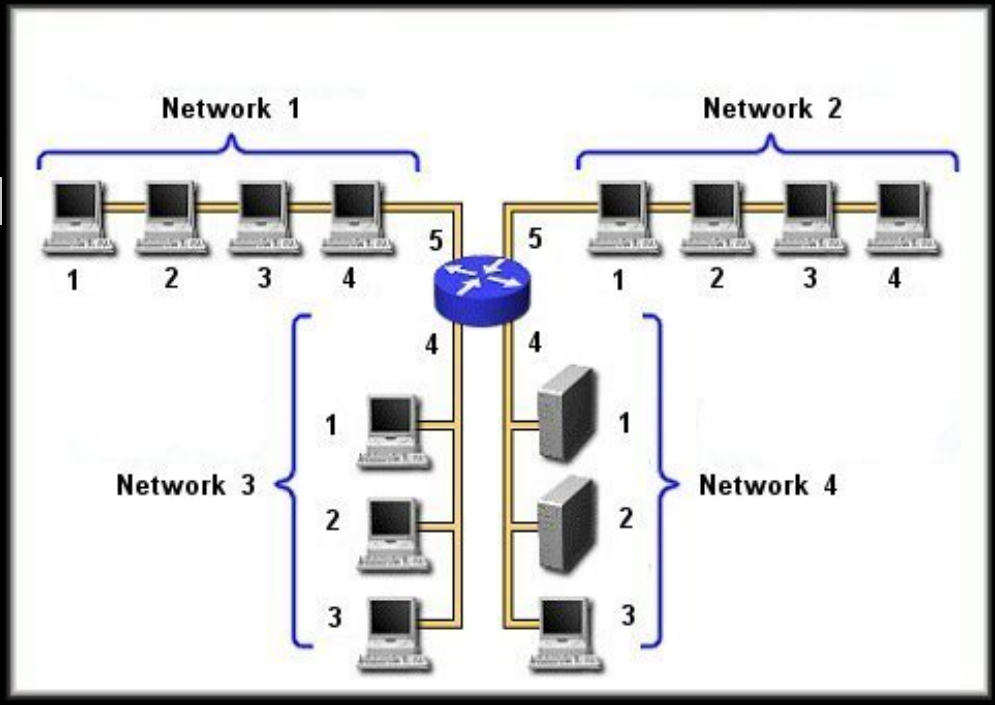
Subnetting - Class C



- 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

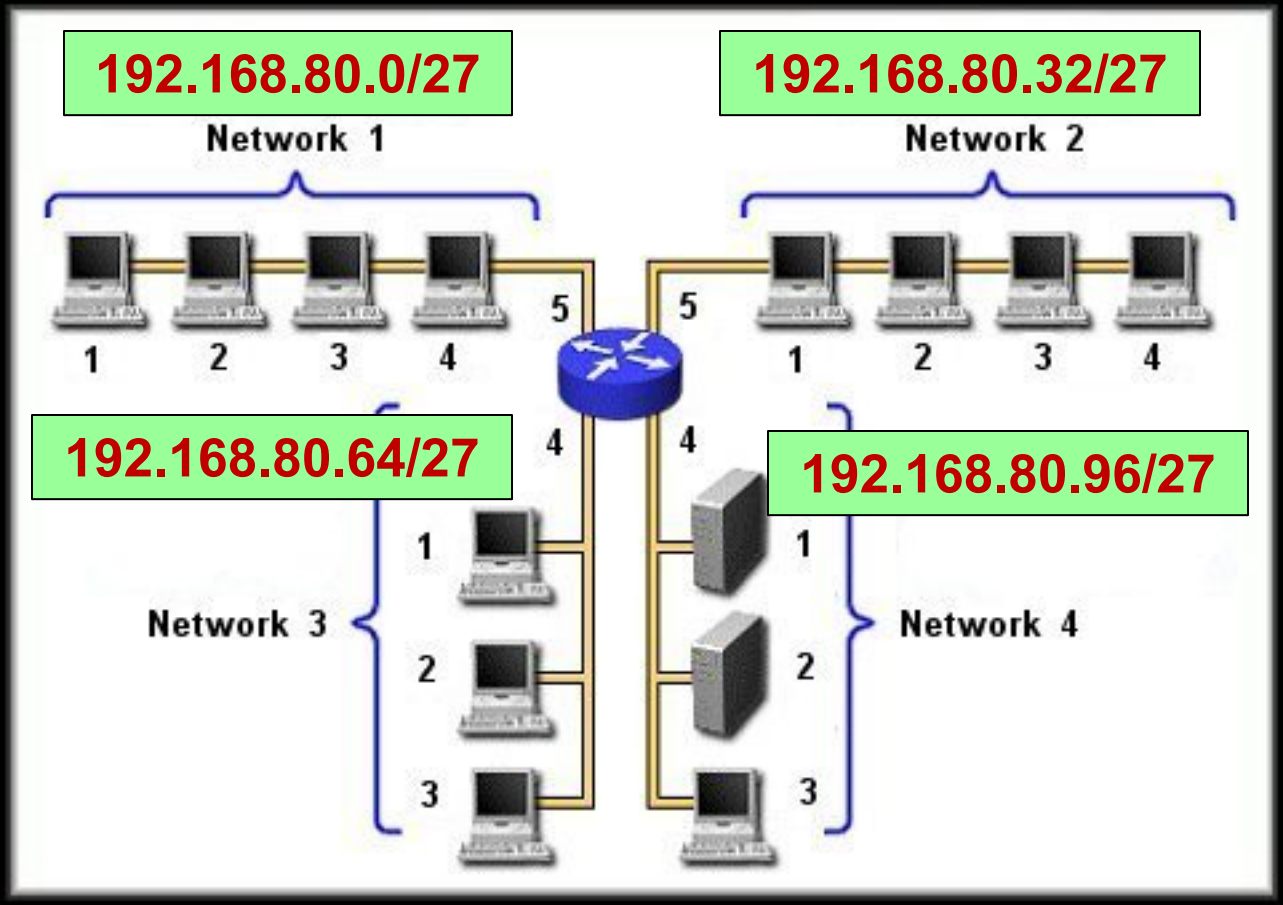
- To make the job of subnetting easier, there is a method that allows you to calculate a "magic" number.
- The magic number we're looking for is the number of addresses in each network, including the network, broadcast and host range.
- The calculation $2^{number\_of\_host\_bits}$ yields the "magic" 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

- 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 = $2^4 = 16$

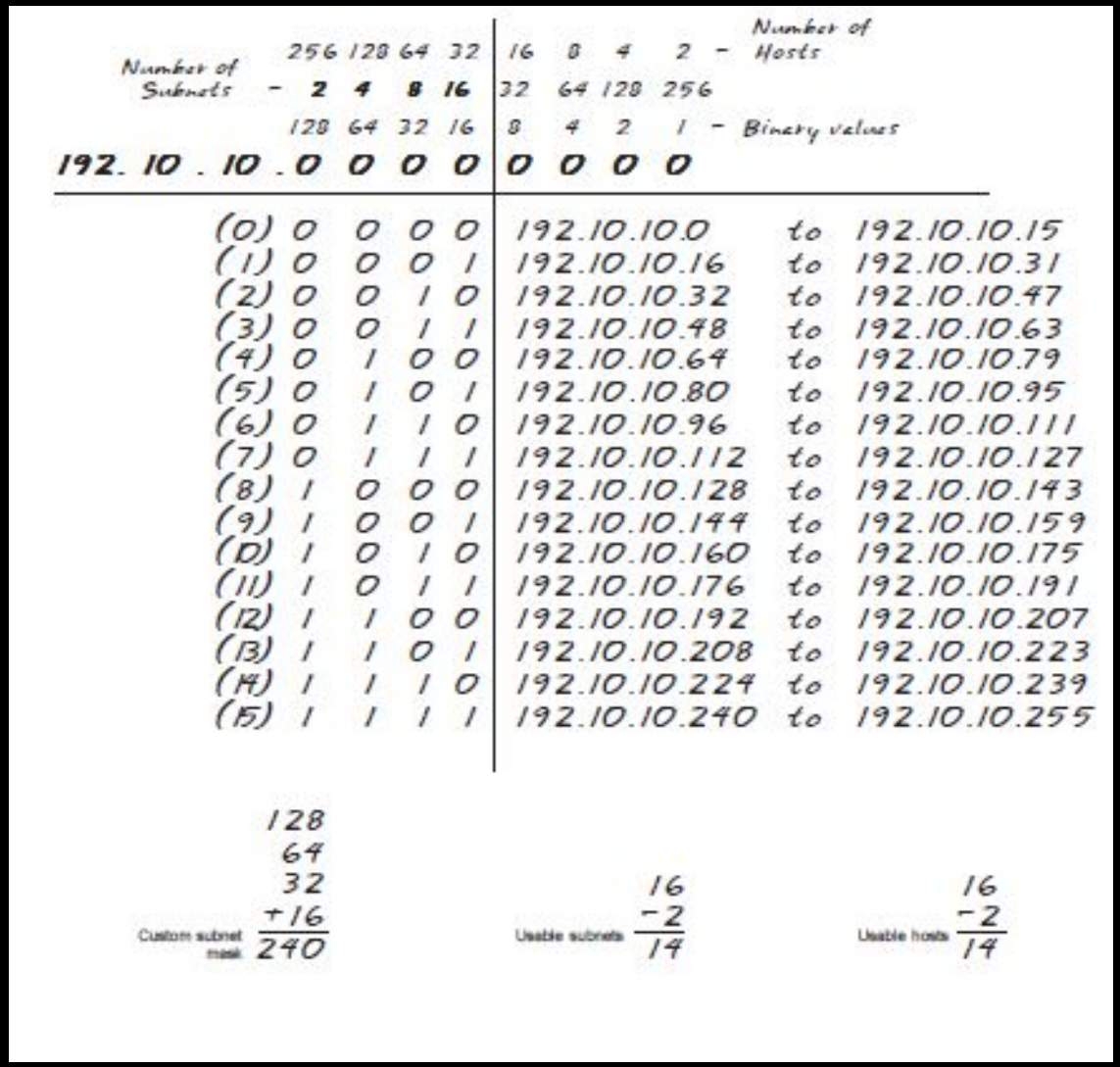
ID	Network Address	Subnet Address Range	Broadcast Address
0	172.25.0.0	172.25.0.1 to 172.25.15.254	172.25.15.255
1	172.25.16.0	172.25.16.1 to 172.25.31.254	172.25.31.255
2	172.25.32.0	172.25.32.1 to 172.25.47.254	172.25.47.255
3	172.25.48.0	172.25.48.1 to 172.25.63.254	172.25.63.255
4	172.25.64.0	172.25.64.1 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

Problem 1

- Network address: 192.10.10.0; Number of needed subnets: 14

Address class	C
Default subnet mask	255.255.255.0
New subnet mask	255.255.255.240
Total number of subnets	16
Total number of host addresses	16
Number of usable addresses	14
Number of bits borrowed	4
What is the 4th subnet range?	192.10.10.48 to 192.10.10.63
What is the subnet number for the 8th subnet?	192.10.10.112
What is the subnet broadcast address for the 13th subnet?	192.10.10.207
What are the assignable addresses for the 9th subnet?	192.10.10.129 to 192.10.10.142

Solving Problem 1



Number of Subnets	256 128 64 32	16 8 4 2	Number of Hosts
	- 2 4 8 16	32 64 128 256	
	128 64 32 16	8 4 2 1	- Binary values
192. 10 . 10 .	0 0 0 0	0 0 0 0	
(0)	0 0 0 0	192.10.10.0	to 192.10.10.15
(1)	0 0 0 1	192.10.10.16	to 192.10.10.31
(2)	0 0 1 0	192.10.10.32	to 192.10.10.47
(3)	0 0 1 1	192.10.10.48	to 192.10.10.63
(4)	0 1 0 0	192.10.10.64	to 192.10.10.79
(5)	0 1 0 1	192.10.10.80	to 192.10.10.95
(6)	0 1 1 0	192.10.10.96	to 192.10.10.111
(7)	0 1 1 1	192.10.10.112	to 192.10.10.127
(8)	1 0 0 0	192.10.10.128	to 192.10.10.143
(9)	1 0 0 1	192.10.10.144	to 192.10.10.159
(10)	1 0 1 0	192.10.10.160	to 192.10.10.175
(11)	1 0 1 1	192.10.10.176	to 192.10.10.191
(12)	1 1 0 0	192.10.10.192	to 192.10.10.207
(13)	1 1 0 1	192.10.10.208	to 192.10.10.223
(14)	1 1 1 0	192.10.10.224	to 192.10.10.239
(15)	1 1 1 1	192.10.10.240	to 192.10.10.255

Custom subnet mask: 128 + 64 + 32 + 16 = 240

Usable subnets: 16 − 2 = 14

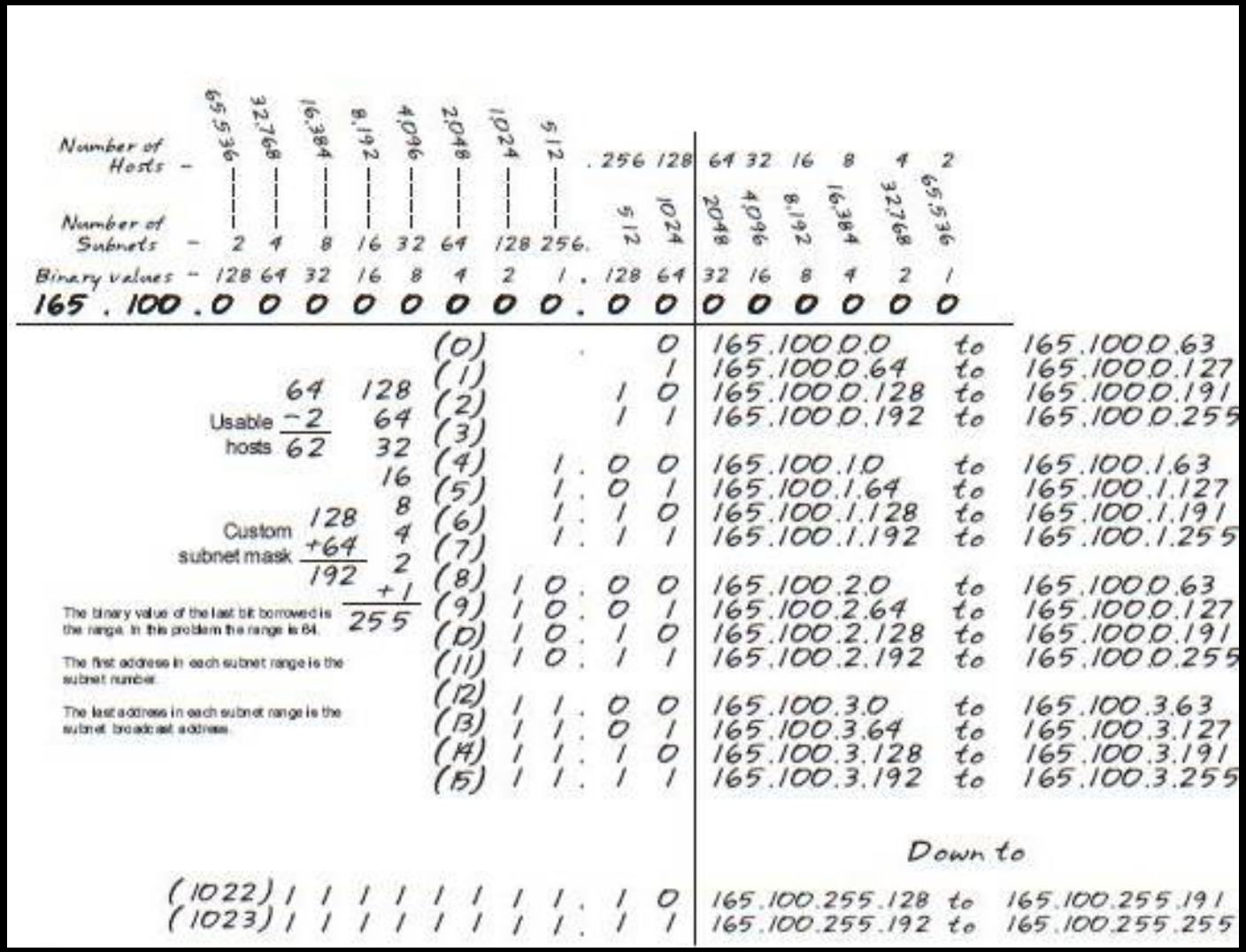
Usable hosts: 16 − 2 = 14

Problem 2

- Network address: 165.100.0.0; Number of needed subnets: 1000

Address class	B
Default subnet mask	255.255.0.0
New subnet mask	255.255.255.192
Total number of subnets	1024
Total number of host addresses	64
Number of usable addresses	62
Number of bits borrowed	10
What is the 15th subnet range?	165.100.3.128 to 165.100.3.191
What is the subnet number for the 6th subnet?	165.100.1.64
What is the subnet broadcast address for the 6th subnet?	165.100.1.127
What are the assignable addresses for the 9th subnet?	165.100.2.1 to 165.100.0.62

Solving Problem 2

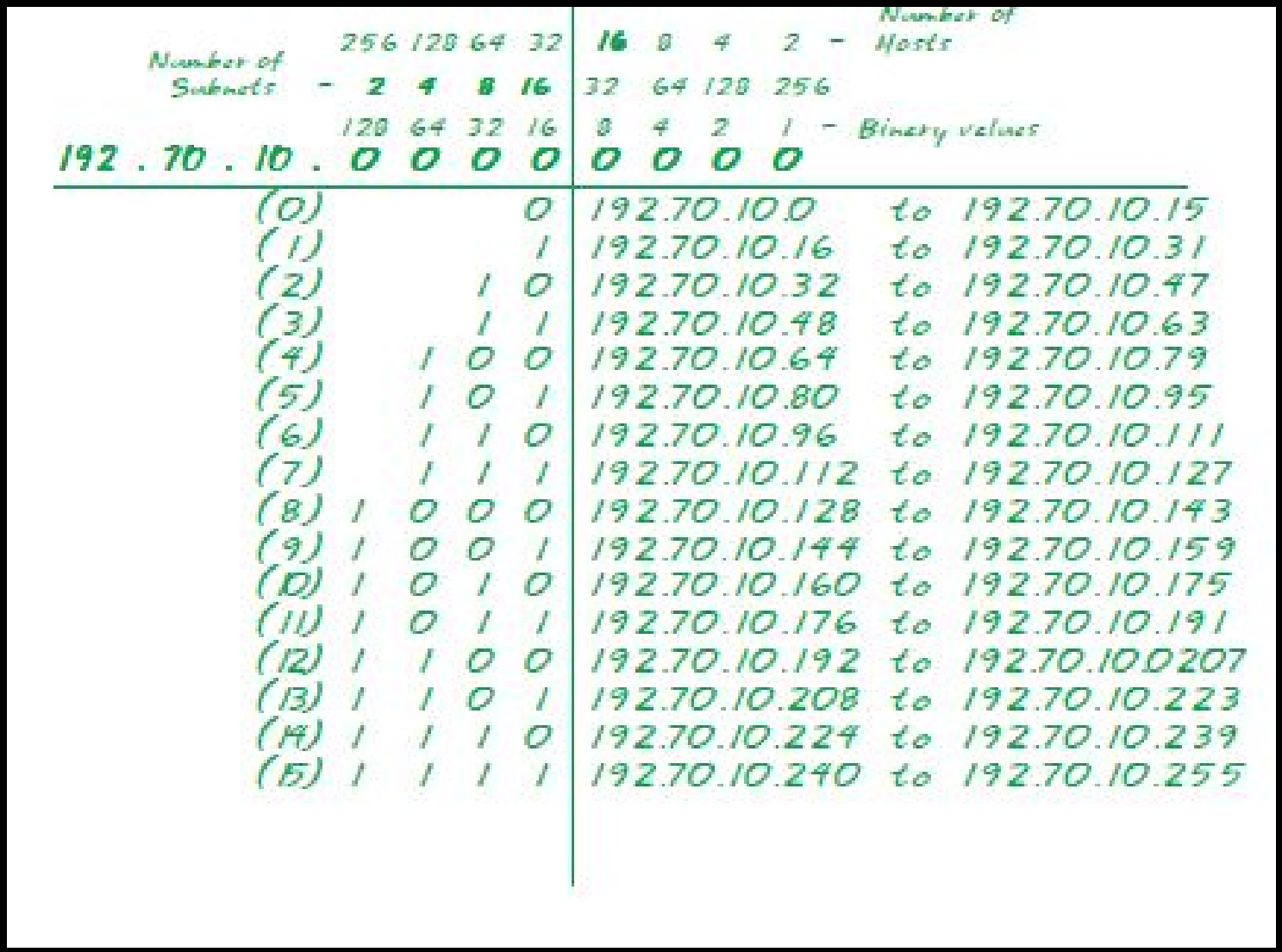


Problem 3

- Network address: 192.70.10.0; Number of needed subnets: 10

Address class	C
Default subnet mask	255.255.255.0
New subnet mask	255.255.255.240
Total number of subnets	16
Total number of host addresses	16
Number of usable addresses	14
Number of bits borrowed	4
What is the 9th subnet range?	192.70.10.128 to 192.70.10.143
What is the subnet number for the 4th subnet?	192.70.10.48
What is the subnet broadcast address for the 12th subnet?	192.70.10.191
What are the assignable addresses for the 10th subnet?	192.70.10.145 to 192.70.10.158

Solving Problem 3



Number of Subnets	256 128 64 32	16 8 4 2	Number of Hosts
	2 4 8 16	32 64 128 256	
	128 64 32 16	8 4 2 1	Binary values
192.70.10.	0 0 0 0	0 0 0 0	
(0)		0	192.70.10.0 to 192.70.10.15
(1)		1	192.70.10.16 to 192.70.10.31
(2)		1 0	192.70.10.32 to 192.70.10.47
(3)		1 1	192.70.10.48 to 192.70.10.63
(4)	1 0 0		192.70.10.64 to 192.70.10.79
(5)	1 0 1		192.70.10.80 to 192.70.10.95
(6)	1 1 0		192.70.10.96 to 192.70.10.111
(7)	1 1 1		192.70.10.112 to 192.70.10.127
(8)	1 0 0 0		192.70.10.128 to 192.70.10.143
(9)	1 0 0 1		192.70.10.144 to 192.70.10.159
(10)	1 0 1 0		192.70.10.160 to 192.70.10.175
(11)	1 0 1 1		192.70.10.176 to 192.70.10.191
(12)	1 1 0 0		192.70.10.192 to 192.70.10.0207
(13)	1 1 0 1		192.70.10.208 to 192.70.10.223
(14)	1 1 1 0		192.70.10.224 to 192.70.10.239
(15)	1 1 1 1		192.70.10.240 to 192.70.10.255