NUMERIC SYSTEMS USED IN NETWORKING

Decimal - Binary - Hexadecimal Table

Decimal	Binary	Hexadecimal
0	00000000	00
1	00000001	01
2	00000010	02
3	00000011	03
4	00000100	04
5	00000101	05
6	00000110	06
7	00000111	07
8	00001000	08
9	00001001	09
10	00001010	0A
11	00001011	0B
12	00001100	0C
13	00001101	0D
14	00001110	0E
15	00001111	0F
16	00010000	10
32	00100000	20
64	01000000	40
128	10000000	80
255	11111111	FF

ASCII Code

Keyboard	Binary Codes
A	01000001
B	01000010
C	01000011
D	01000100
E	01000101
F	01000110
G	01000111
H	01001000

128	64	32	16	8	4	2	1

The Letter A

0	1	0	0	0	0	0	1

Data Units

Units	Definition	Bytes*	Bits*	Examples
Bit (b)	Binary digit,a 1 or 0	1	1	On/Off; Open/Closed +5 Volts or 0 Volts
Byte (B)	8 bits	1	8	Represent the letter "X" as ASCII code
Kilobyte (KB)	1 kilobyte = 1024 bytes	1000	8,000	Typical Email = 2 KB 10-page report = 10 KB Early PCs = 64 KB of RAM
Megabyte (MB)	1 megabyte = 1024 kilobytes = 1,048,576 bytes	1 million	8 million	Floppy disks = 1.44 MBTypical RAM = 32 MBCDROM = 650 MB
Gigabyte (GB)	1 gigabyte = 1024 megabytes = 1,073741,824 bytes	1 billion	8 billion	Typical Hard Drive = 40 GB or greater
Terabyte (TB)	1 terabyte = 1024 gigabytes = 1,099,511,627,778 bytes	1 trillion	8 trillion	Amount of data theoreti-cally transmittable in optical fiber in one second

* Common or approximate bytes or bits

Base 10 Numbering System

Place Value	1000 100 10 1
Base$^{\text{Exponent}}$	$10^3 = 1000$ $10^2 = 100$ $10^1 = 10$ $10^0 = 1$
Number of Symbols	10
Symbols	0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Rationale	Typical number of fingers equals ten

Base 2 Numbering System

Place Value	128 64 32 16 8 4 2 1
Base$^{\text{Exponent}}$	$2^7 = 128$ $2^3 = 8$ $2^6 = 64$ $2^2 = 4$ $2^5 = 32$ $2^1 = 2$ $2^4 = 16$ $2^0 = 1$
Number of Symbols	2
Symbols	0, 1
Rationale	Two-state (discrete binary) voltage systems made from transistors can be diverse, powerful, inexpensive, tiny and relatively immune to noise.

Decimal to Binary Conversion

128	64	32	16	8	4	2	1

Number	Divide	Result	Remainder
192	**/ 2 =**	96	0
96	**/ 2 =**	48	0
48	**/ 2 =**	24	0
24	**/ 2 =**	12	0
12	**/ 2 =**	6	0
6	**/ 2 =**	3	0
3	**/ 2 =**	1	1
1	**/ 2 =**	0	1

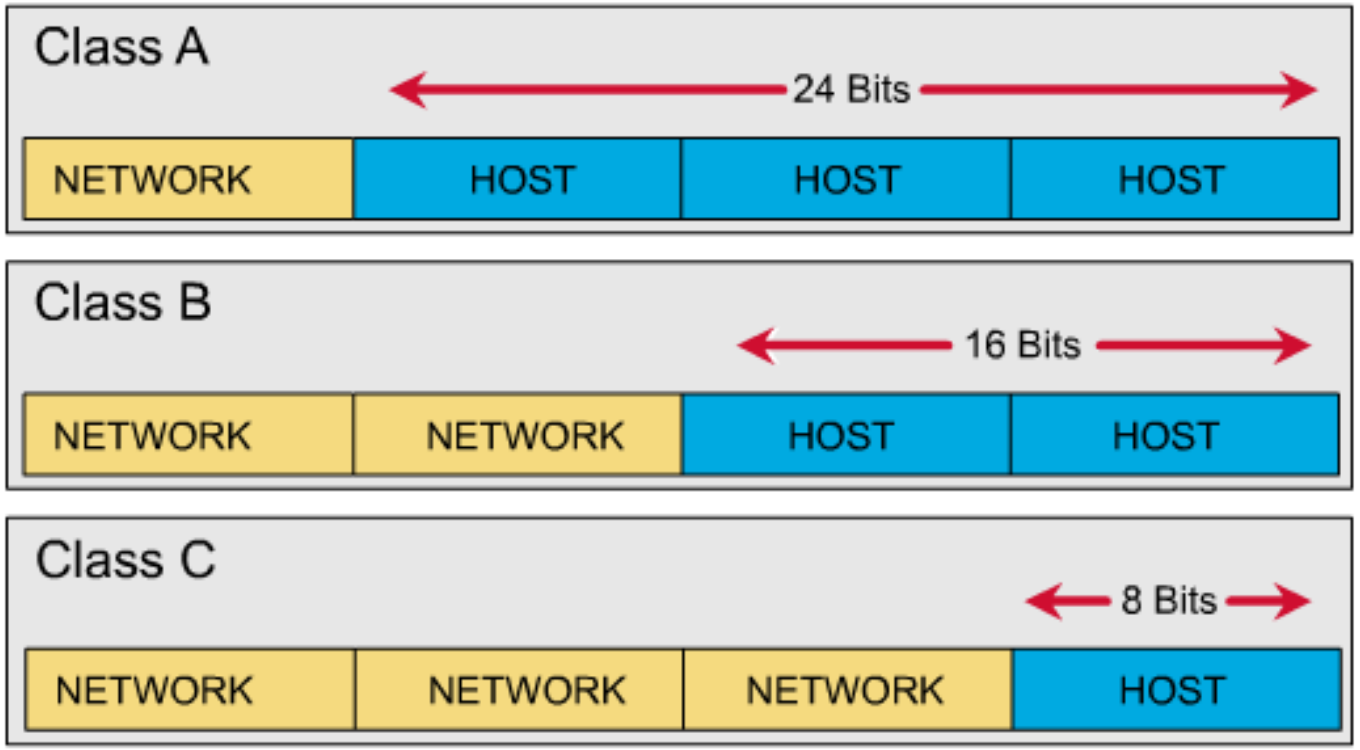
Binary to Decimal Conversion

128	64	32	16	8	4	2	1
1	1	0	0	0	0	0	0
1	0	0	1	1	0	0	1
1	1	1	1	1	1	1	1

Dotted Decimal Notation

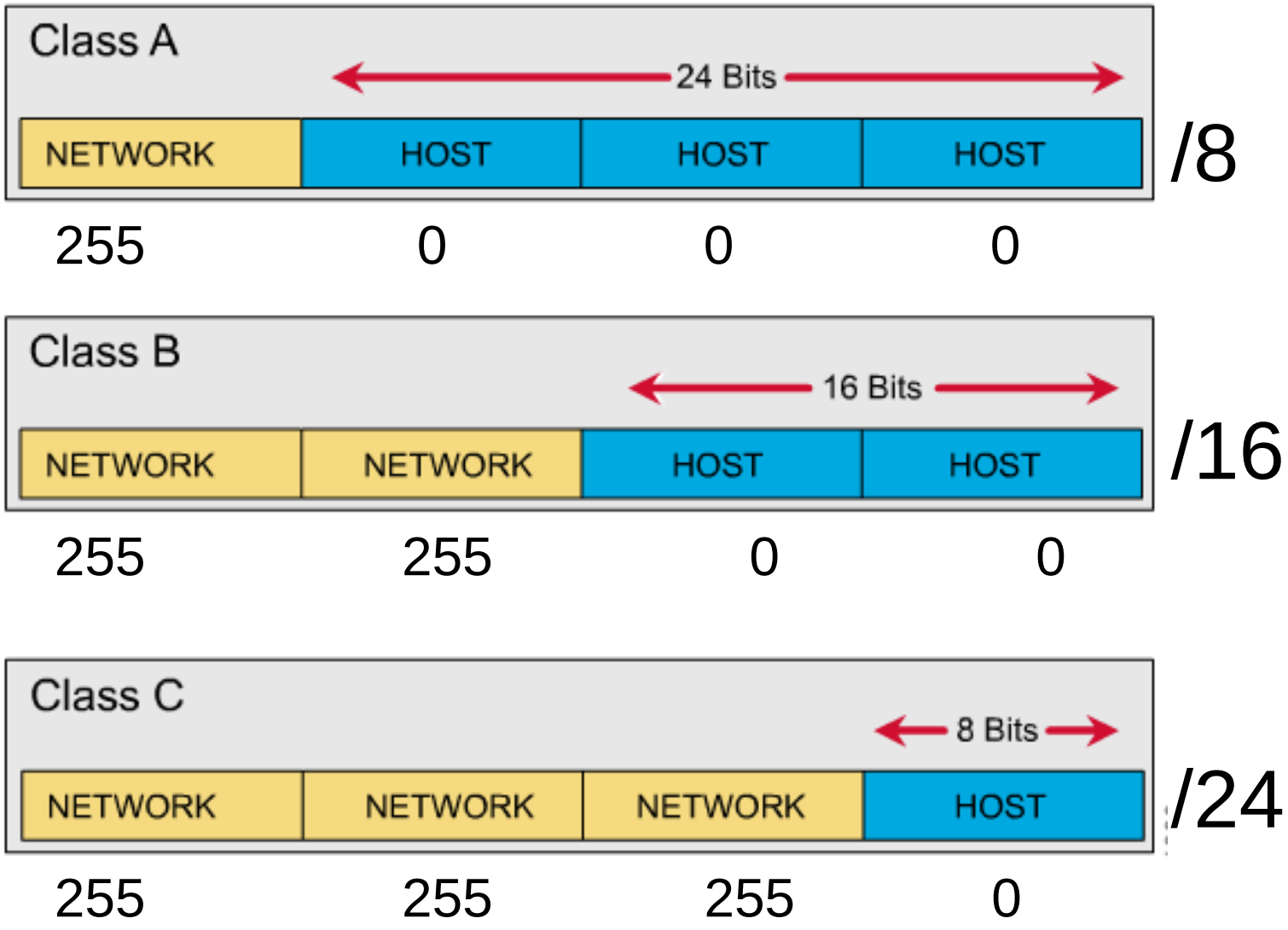
Binary	11001000		01110010		00000110		00110011
Decimal	200	.	114	.	6	.	51
	number	dot	number	dot	number	dot	number

IP Address Classes



Class "C" is the final commercial class of addresses. With eight bits for the host address, only two hundred fifty four hosts are allowed. Most smaller organizations use a class "C" or several class "C" addresses. As you'll see later, two addresses are always reserved: one for the network, and one for the broadcast address.

IP Address Classes

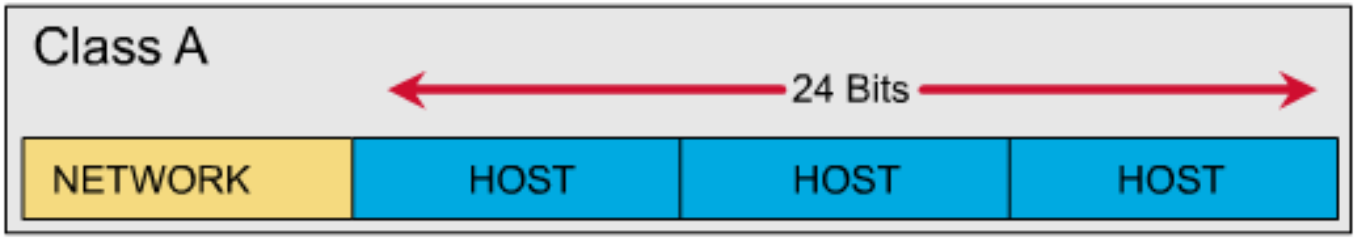


Address Classes

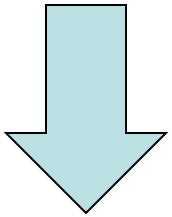
Cls	1st Octet Decimal Range	1st Octet High Order Bits	Network / Host ID (N=Network, H=Host)	Default Subnet Mask	Number of Networks	Hosts per Network (usable addresses)
A	1 – 126*	0	N.H.H.H	255.0.0.0	126 ($2^7 - 2$)	16,777,214 ($2^{24} - 2$)
B	128 – 191	1 0	N.N.H.H	255.255.0.0	16,382 ($2^{14} - 2$)	65,534 ($2^{16} - 2$)
C	192 – 223	1 1 0	N.N.N.H	255.255.255.0	2,097,150 ($2^{21} - 2$)	254 ($2^8 - 2$)
D	224 – 239	1 1 1 0	Reserved for Multicasting			
E	240 – 254	1 1 1 1 0	Experimental, used for research			

Binary to Decimal Conversion

IP Address Classes



126.10.15.0



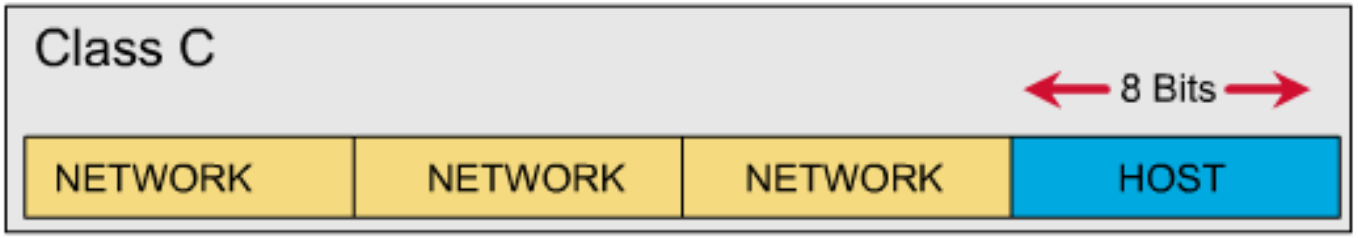
128	64	32	16	8	4	2	1
0	1	1	1	1	1	1	1

Binary to Decimal Conversion

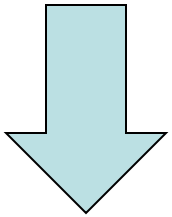
171.10.15.0

128	64	32	16	8	4	2	1
1	0	1	0	1	0	1	1

Binary to Decimal Conversion



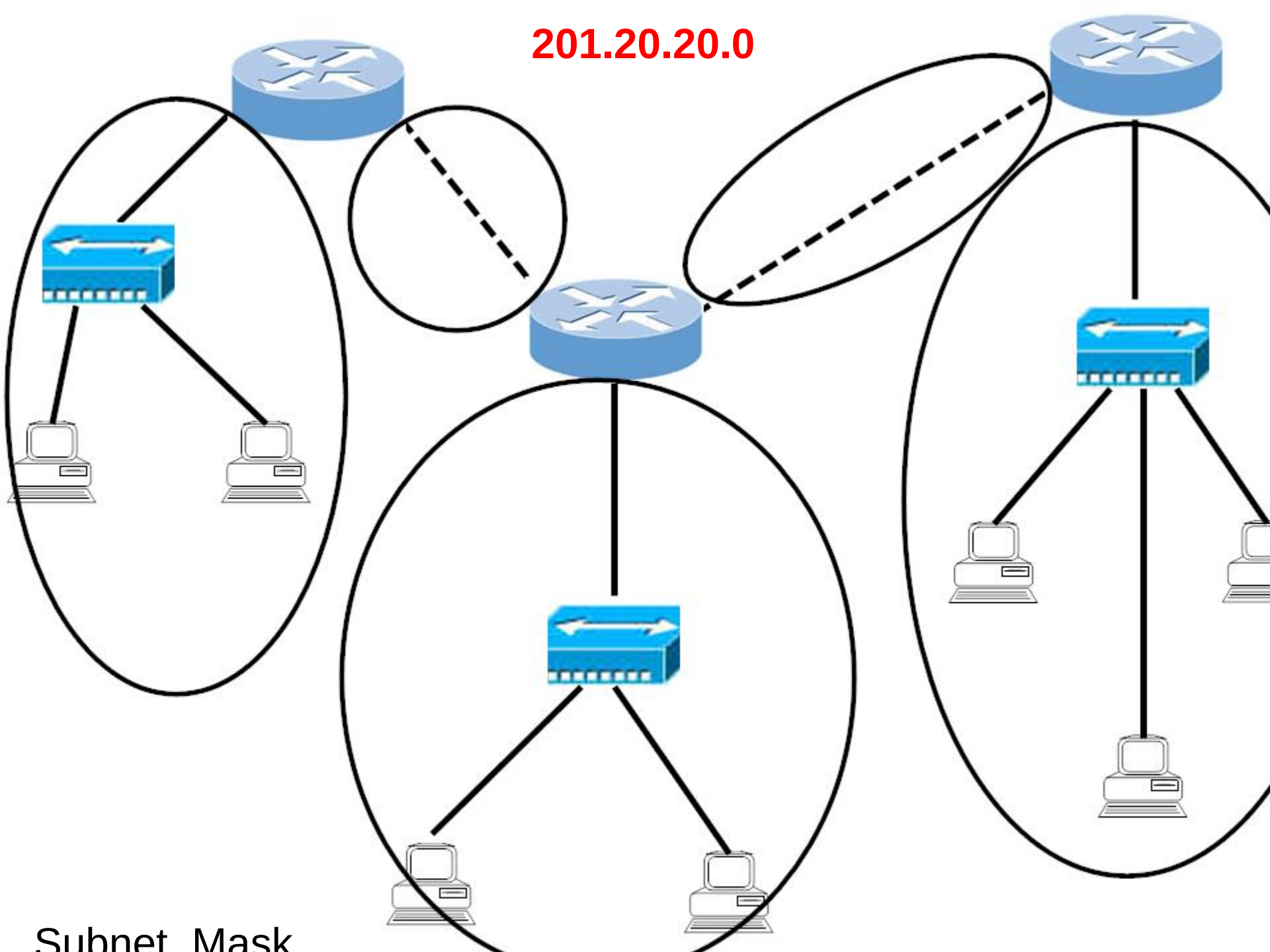
192.10.15.0



128	64	32	16	8	4	2	1
1	1	0	0	0	0	0	0

IP First Octet Address Ranges

High Order Bits	Octet in Decimal	Address Class
0	0 - 127	A
10	128 - 191	B
110	192 - 223	C

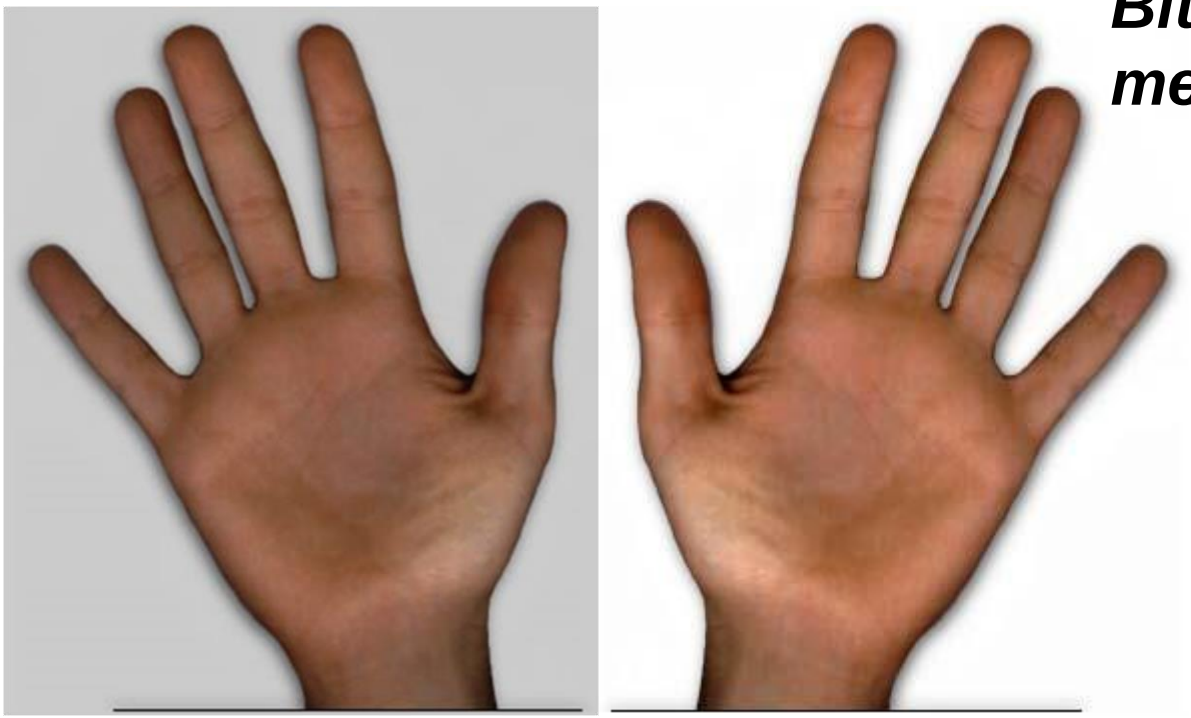


Subnet Mask

11111111.11111111.11111111.000**00000/27**

SUBNET MASK 255.255.255.224

Borrowing 3 Bits will give me 8 subnets

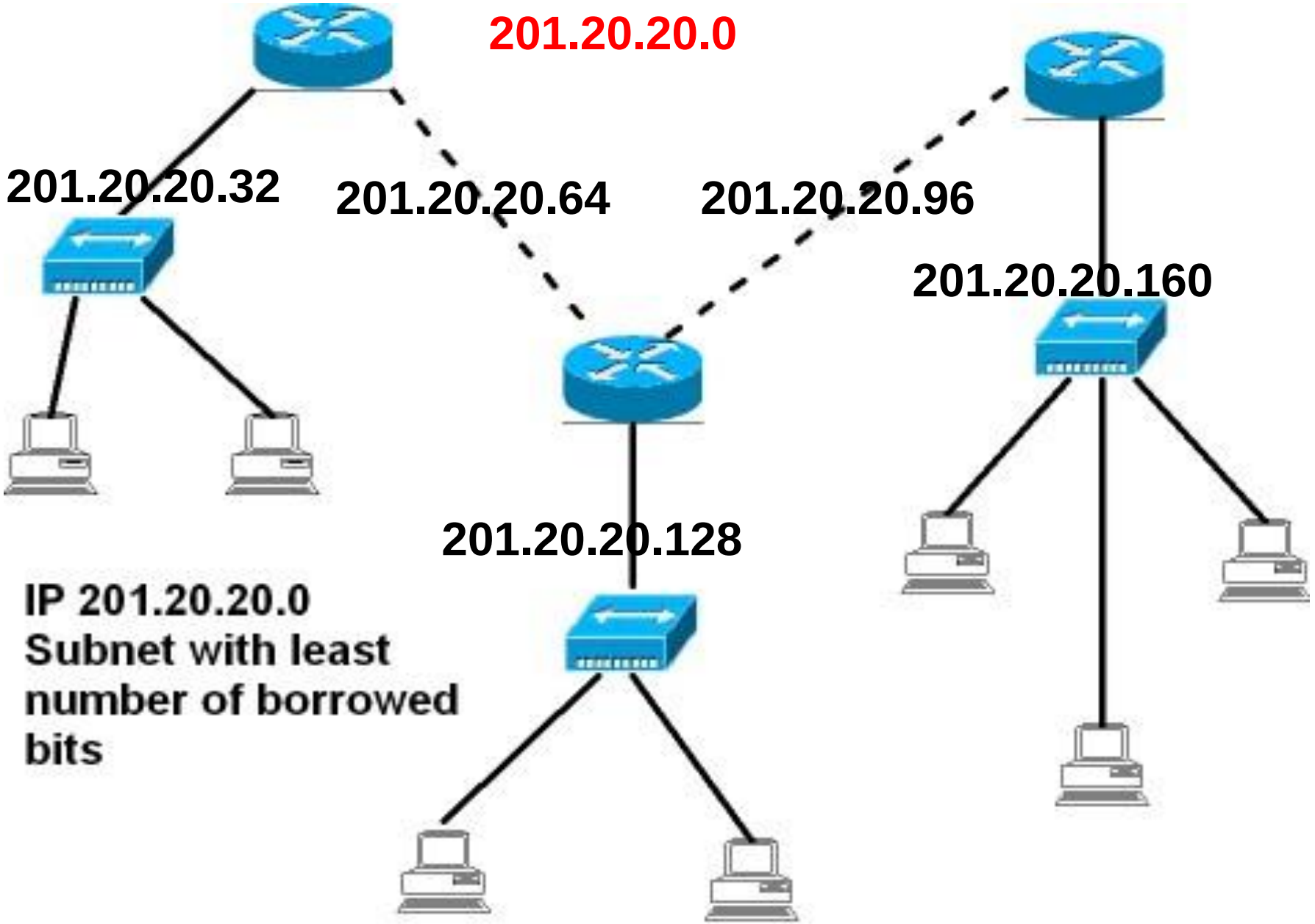


YOU MUST BORROW AT LEAST 2 BITS

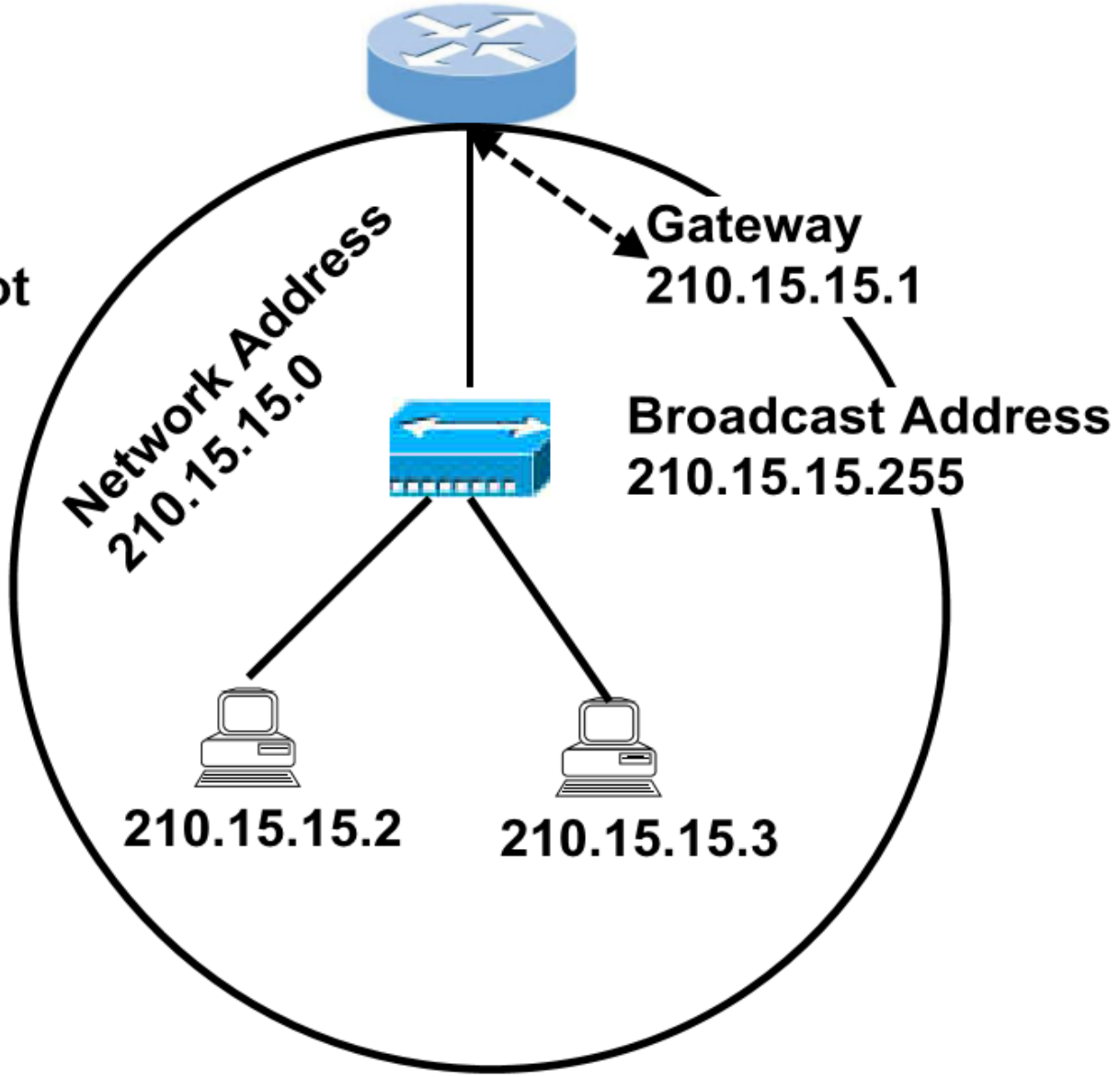
YOU MUST LEAVE AT LEAST 2 BITS

YOU MUST BORROW 2 MORE BITS THAN YOU NEED

SUBNET ADDRESS	HOST ADDR RANGE	BROADCAST ADDR
201.20.20.0	201.20.20.1 ~ 201.20.20.30	201.20.20.31
201.20.20.32	20120.20.33 201.20.20.62	201.20.20.63
201.20.20.64	201.20.20.65 201.20.20.94	201.20.20.95
201.20.20.96	201.20.20.97 201.20.20.126	201.20.20.127
201.20.20.128	201.20.20.129 201.20.20.158	201.20.20.159
201.20.20.160	201.20.20.161 201.20.20.190	201.20.20.191
201.20.20.192	201.20.20.193 201.20.20.222	201.20.20.223
201.20.20.224	201.20.20.225 20120.20.254	201.20.20.255


201.20.20.0
201.20.20.32
201.20.20.64
201.20.20.96
201.20.20.160
201.20.20.128
IP 201.20.20.0
Subnet with least number of borrowed bits
Subnet Mask 255.255.255.224

Within each network the first and last addresses cannot be assigned to hosts. These are the network address and the broadcast address, respectively.



CLASS B SUBNETTING

You have an address of 185.15.0.0
You need 250 networks
You need 250 hosts

11111111.11111111.00000000.00000000/24

SUBNET 0	SUBNET 1	SUBNET 2
185.15.0.0	185.15.1.0	185.15.2.0
185.15.0.1	185.15.1.1	185.15.2.1
185.15.0.2	185.15.1.2	185.15.2.2
185.15.0.3	185.15.1.3	185.15.2.3
185.15.0.1	185.15.1.4	185.15.2.1
185.15.0.5	185.15.1.5	185.15.2.5
185.15.0.~ 255	185.15.1.~ 255	185.15.2.~ 255

The last address will be 185.15.255.255

Class B Subnets

185.15.0.0 (Class B Address)
10100000.00001111.00000000.00000000

We need 60 subnets
Borrow 6
10100000.00001111.11111100.00000000
Count 2 4 8 16 32 64
64 Subnets

Subnet Mask Add the Bits you borrowed
128+64+32+16+8+4=252
255.255.252.0

Remaining Host Bits = 10
Count 10 bits 2 4 8 16 32 64 128 256 512 1024
1024 addresses on each subnet

Class B Subnets

Problem

- **You have 1024 addresses on each subnet**
- **The largest number you can assign to a host is 255**
- **How do you number the rest of the hosts?**

You have an address of 185.15.0.0
You need at least 60 subnets
You need at least 1000 hosts

11111111.11111111.11111100.00000000/22

Subnet 0
185.15.0.0 to 255
185.15.1.0 to 255
185.15.2.0 to 255
185.15.3.0 to 255

Subnet 1
185.15.4.0 to 255
185.15.5.0 to 255
185.15.6.0 to 255
185.15.7.0 to 255

Subnet 2
185.15.8.0 to 255
185.15.9.0 to 255
185.15.10.0 to 255
185.15.11.0 to 255

Subnet 3
185.15.12.0 to 255
185.15.13.0 to 255
185.15.14.0 to 255
185.15.15.0 to 255

The last address will be 185.15.255.255

You have an address of 185.15.0.0
You need at least 30 subnets
You need at least 2000 hosts

11111111.11111111.11111000.00000000/21

Subnet 0	Subnet 1	Subnet 2
185.15.0.0 to 255	185.15.8.0 to 255	185.15.16.0 to 255
185.15.1.0 to 255	185.15.9.0 to 255	185.15.17.0 to 255
185.15.2.0 to 255	185.15.10.0 to 255	185.15.18.0 to 255
185.15.3.0 to 255	185.15.11.0 to 255	185.15.190 to 255
185.15.4.0 to 255	185.15.12.0 to 255	185.15.20.0 to 255
185.15.5.0 to 255	185.15.130 to 255	185.15.21.0 to 255
185.15.6.0 to 255	185.15.14.0 to 255	185.15.22.0 to 255
185.15.7.0 to 255	185.15.15.0 to 255	185.15.23.0 to 255

The last address will be 185.15.255.255

You have an address of 185.15.0.0
You need at least 10 subnets
You need at least 4000 hosts

11111111.11111111.11110000.00000000**/20**

Subnet 0
185.15.0.0 to 255
185.15.1.0 to 255
185.15.2.0 to 255
185.15.3.0 to 255
185.15.4.0 to 255
185.15.5.0 to 255
185.15.6.0 to 255
185.15.7.0 to 255

Subnet 0
185.15.8.0 to 255
185.15.9.0 to 255
185.15.10.0 to 255
185.15.11.0 to 255
185.15.12.0 to 255
185.15.130 to 255
185.15.14.0 to 255
185.15.15.0 to 255

The last address will be 185.15.255.255

You have an address of 185.15.0.0
You need at least 10 subnets
You need at least 4000 hosts

11111111.11111111.11110000.00000000/20

Subnet 1
185.15.16.0 to 255
185.15.17.0 to 255
185.15.18.0 to 255
185.15.19.0 to 255
185.15.20.0 to 255
185.15.21.0 to 255
185.15.22.0 to 255
185.15.23.0 to 255

Subnet 1
185.15.24.0 to 255
185.15.25.0 to 255
185.15.26.0 to 255
185.15.27.0 to 255
185.15.28.0 to 255
185.15.29.0 to 255
185.15.30.0 to 255
185.15.31.0 to 255

The last address will be 185.15.255.255

You have an address of 185.15.0.0
You need at least 10 subnets
You need at least 4000 hosts

11111111.11111111.11110000.00000000/20

Subnet 2	
185.15.32.0	to 255
185.15.33.0	to 255
185.15.34.0	to 255
185.15.35.0	to 255
185.15.36.0	to 255
185.15.37.0	to 255
185.15.38.0	to 255
185.15.39.0	to 255

Subnet 2	
185.15.40.0	to 255
185.15.41.0	to 255
185.15.42.0	to 255
185.15.43.0	to 255
185.15.44.0	to 255
185.15.45.0	to 255
185.15.46.0	to 255
185.15.47.0	to 255

The last address will be 185.15.255.255

You have an address of 185.15.0.0
You need 250 networks
You need 250 hosts

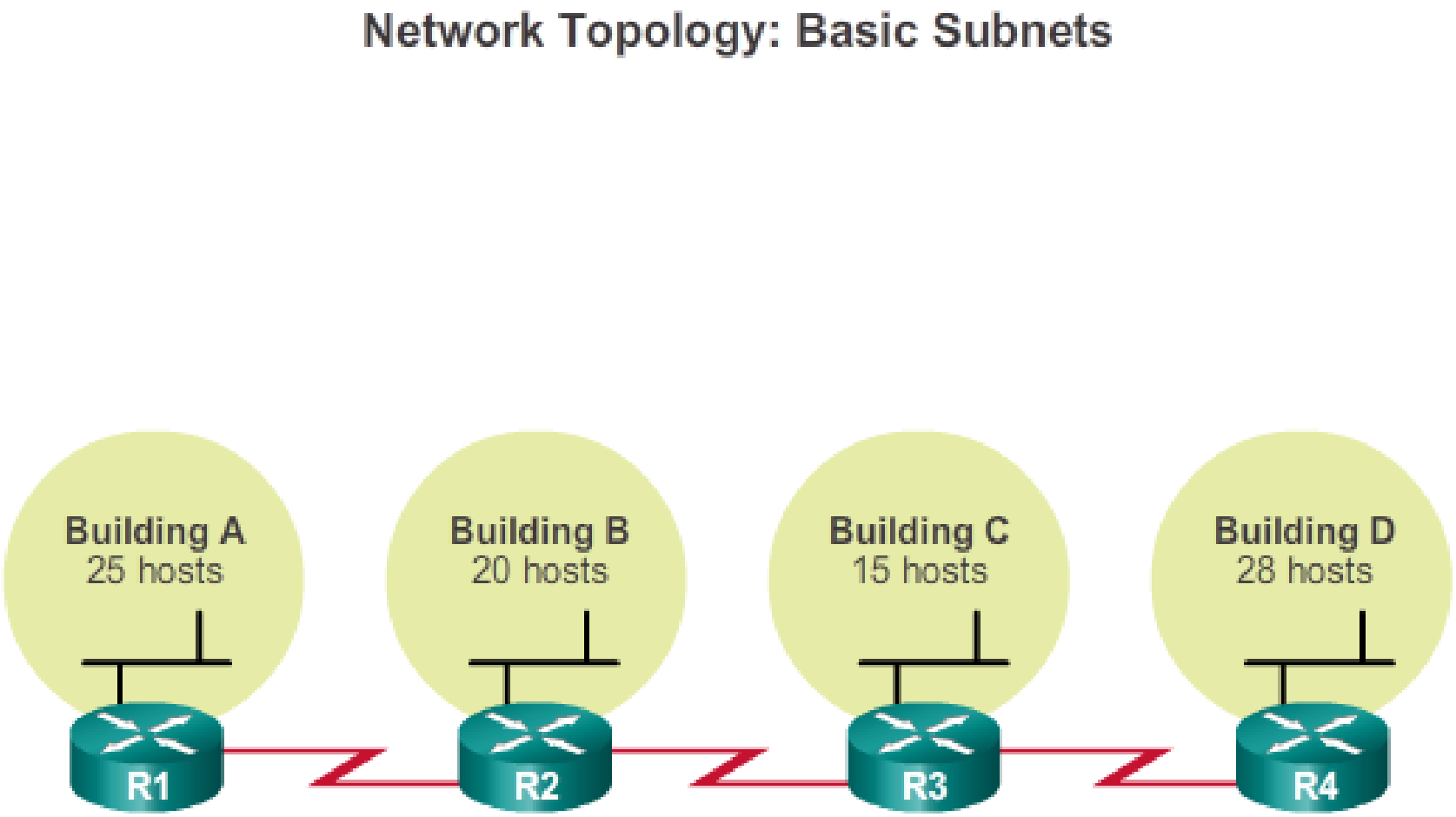
11111111.11111111.00000000.00000000/24

SUBNET 0	SUBNET 1	SUBNET 2
185.15.0.0	185.15.1.0	185.15.2.0
185.15.0.1	185.15.1.1	185.15.2.1
185.15.0.2	185.15.1.2	185.15.2.2
185.15.0.3	185.15.1.3	185.15.2.3
185.15.0.1	185.15.1.4	185.15.2.1
185.15.0.5	185.15.1.5	185.15.2.5
185.15.0.~ 255	185.15.1.~ 255	185.15.2.~ 255

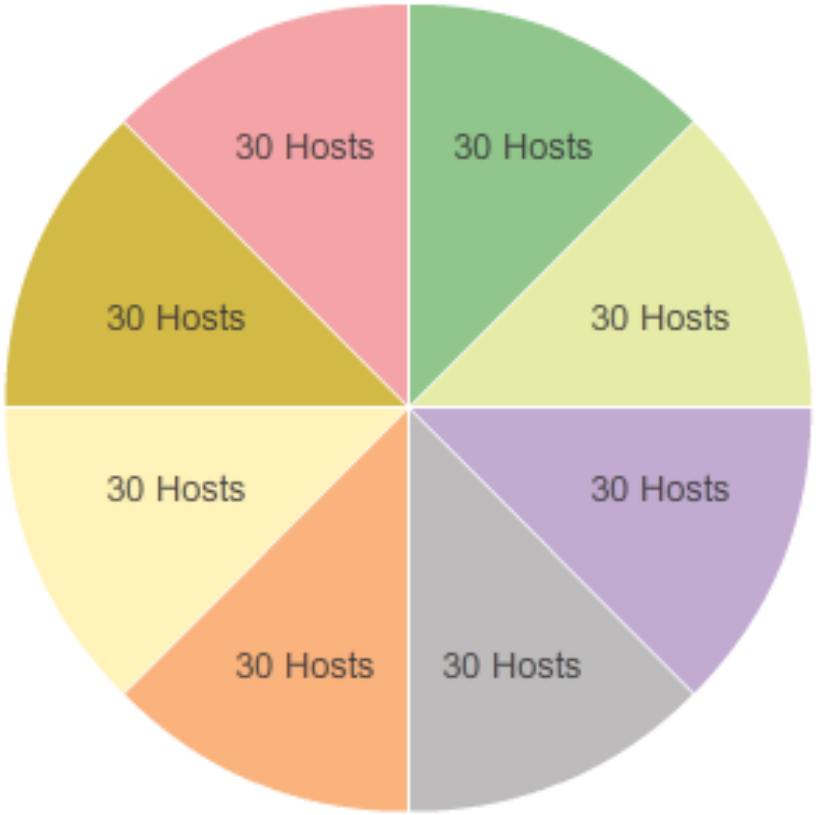
The last address will be 185.15.255.255

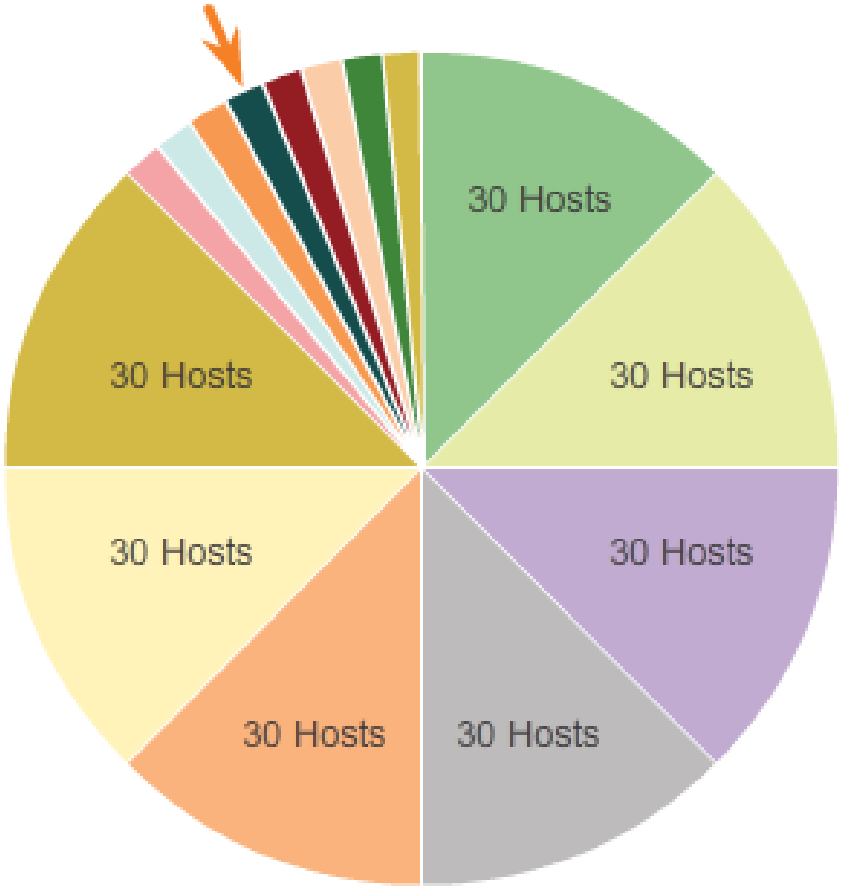
VLSM
Variable Length Subnet Mask

9.1.5.1 Traditional Subnetting Wastes Addresses

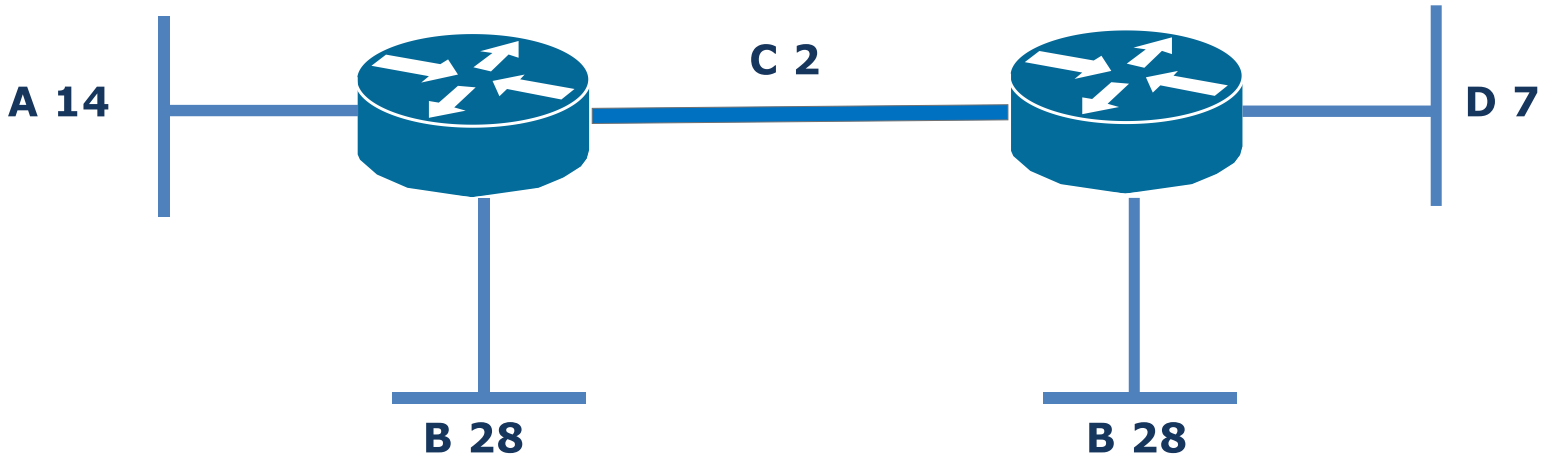


Variable Length Subnet Masks (VLSM)





VLSM
HOSTS ON EACH SUBNET

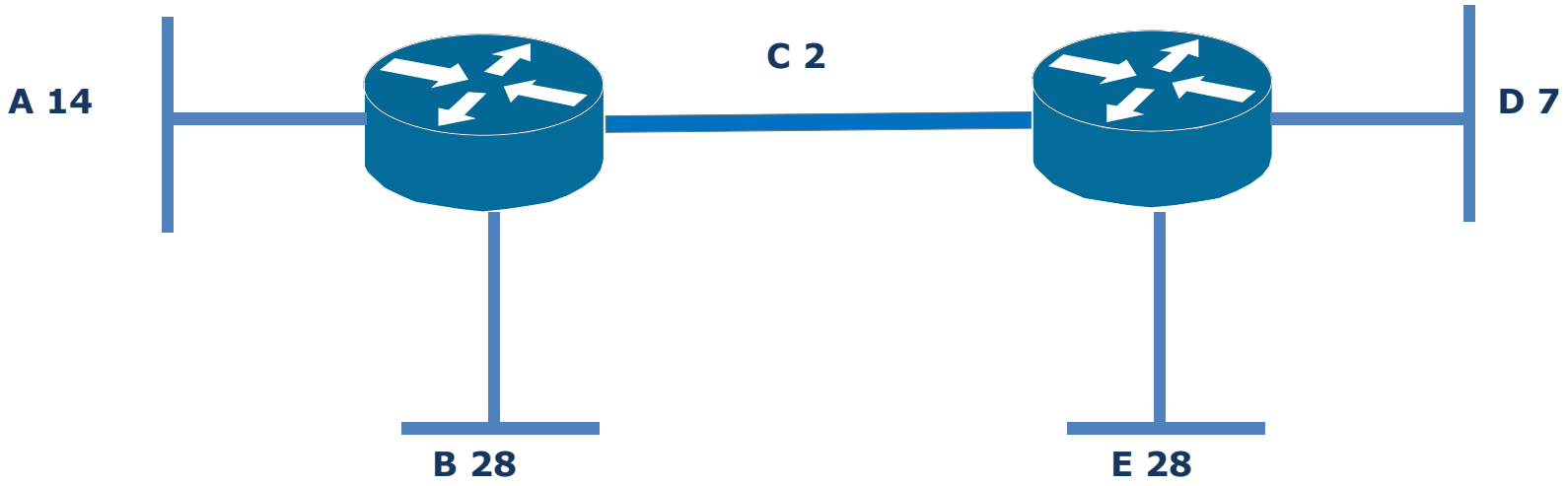


NNNNNNNN.NNNNNNNN.NNNNNNNN.NNNHHHHH

- Using Classful addressing we would borrow 3 bits for the networks which would give us 8 subnets (we only need 5)
- The remaining 5 bits would be turned into host addresses giving us 32 addresses on each subnet
- This is a waist of addresses because we do not need 32 address on each subnet

VLSM

HOSTS ON EACH SUBNET

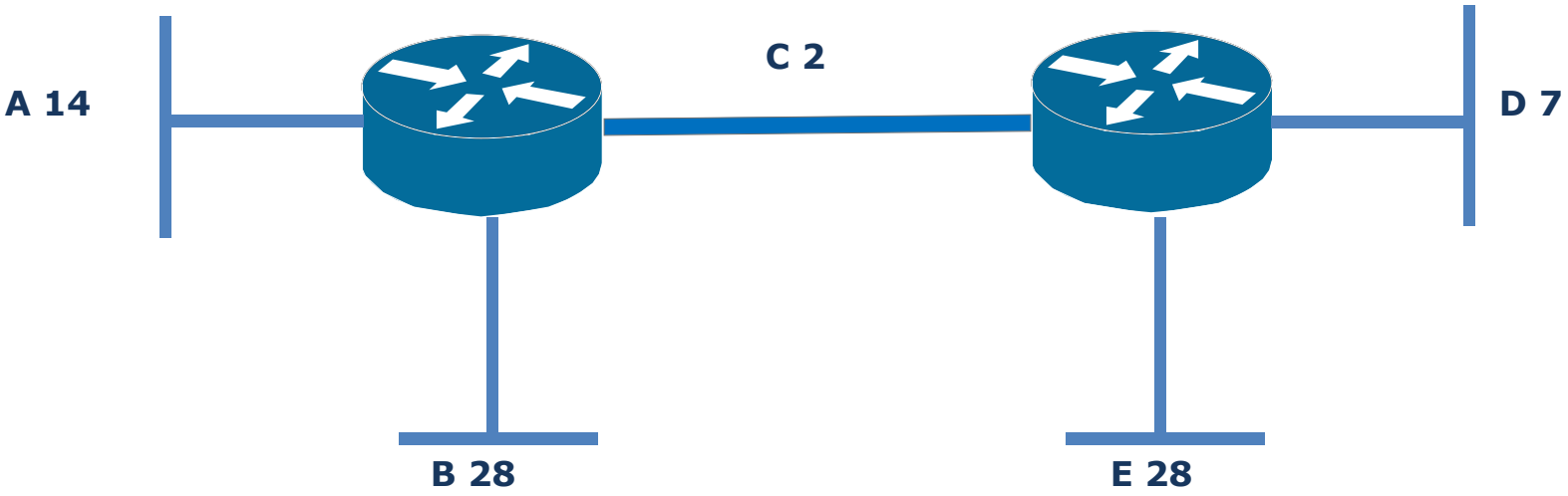


NNNNNNNN.NNNNNNNN.NNNNNNNN.HHHHHHHH

A: must support 14 hosts
B: must support 28 hosts
C: must support 2 hosts
D: must support 7 hosts
E: must support 28 host

VLSM

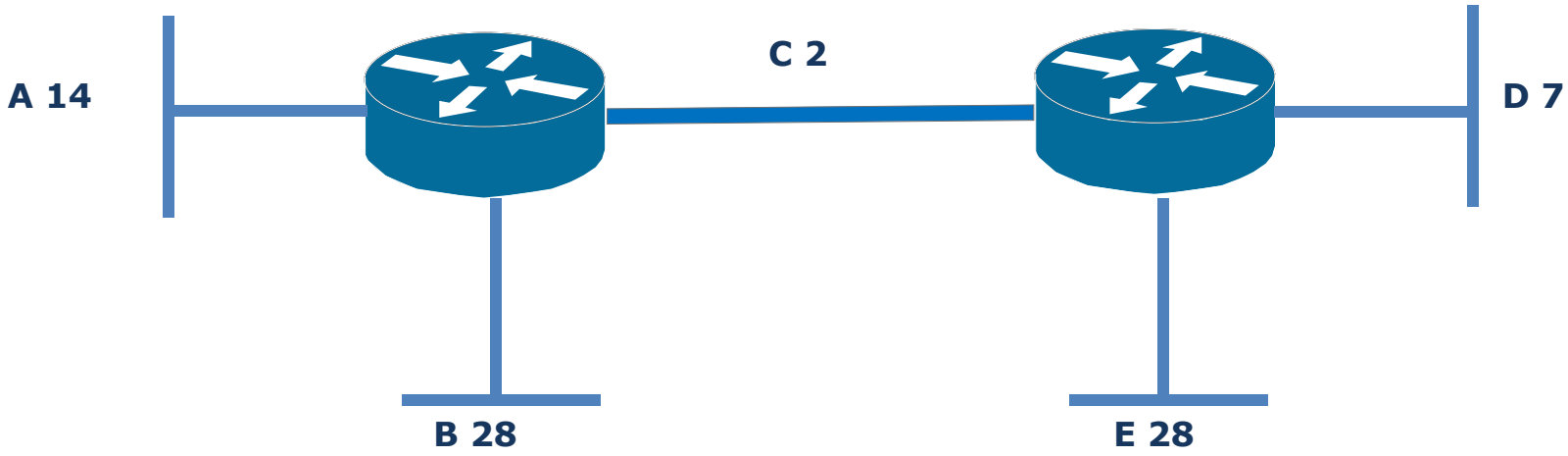
HOSTS ON EACH SUBNET



NNNNNNNN.NNNNNNNN.NNNNNNNN.HHHHHHHH

A: /28 (255.255.255.240) mask to support 14 hosts
B: /27 (255.255.255.224) mask to support 28 hosts
C: /30 (255.255.255.252) mask to support 2 hosts
D*: /28 (255.255.255.240) mask to support 7 hosts
E: /27 (255.255.255.224) mask to support 28 hosts

VLSM
HOSTS ON EACH SUBNET



NNNNNNNN.NNNNNNNN.NNNNNNNN.HHHHHHHH

B: 204.15.5.0/27 host address range 1 to 30
E: 204.15.5.32/27 host address range 33 to 62
A: 204.15.5.64/28 host address range 65 to 78
D: 204.15.5.80/28 host address range 81 to 94
C: 204.15.5.96/30 host address range 97 to 98

NNNHHHHH
NNNHHHHH
NNNNHHHH
NNNNHHHH
NNNNNNHH

201.15.5.0/27

Subnets breakout

Subnet Name	Needed Hosts per Subnet
a	14
b	2
c	7
d	28
e	28

Change number of subnets

5

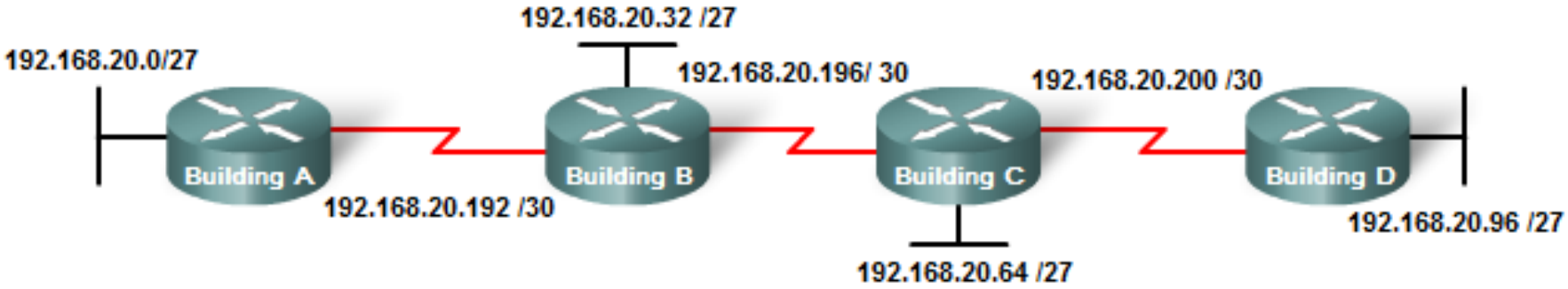
CHANGE SUBNETS

The network 201.15.5.0/27 has 30 hosts. Your subnets need 79 hosts.

Looks like those subnets will not fit into that network, but here is something else that may work for you:

Name	Hosts Needed	Hosts Available	Unused Hosts	Network Address	Slash	Mask	Usable Range	Broadcast
Subnet 428	28	30	2	201.15.5.0	/27	255.255.255.224	201.15.5.1 - 201.15.5.30	201.15.5.31
Subnet 5	28	30	2	201.15.5.32	/27	255.255.255.224	201.15.5.33 - 201.15.5.62	201.15.5.63
Subnet 1201	14	14	0	201.15.5.64	/28	255.255.255.240	201.15.5.65 - 201.15.5.78	201.15.5.79
Subnet 37	7	14	7	201.15.5.80	/28	255.255.255.240	201.15.5.81 - 201.15.5.94	201.15.5.95
Subnet 22	2	2	0	201.15.5.96	/30	255.255.255.252	201.15.5.97 - 201.15.5.98	201.15.5.99

Subnetting a Subnetwork Block

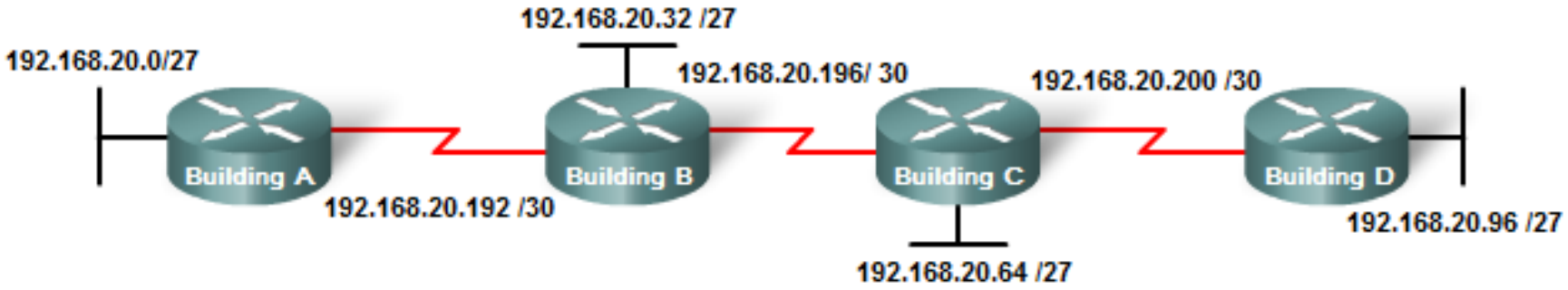


Subnet Number	Subnet Address
Subnet 0	192.168.20.0/27
Subnet 1	192.168.20.32/27
Subnet 2	192.168.20.64/27
Subnet 3	192.168.20.96/27
Subnet 4	192.168.20.128/27
Subnet 5	192.168.20.160/27
Subnet 6	192.168.20.192/27
Subnet 7	192.168.20.224/27

Subnet Number	Subnet Address

NNNNNNNN.NNNNNNNN.NNNNNNNN.HHHHHHHH

Subnetting a Subnetwork Block



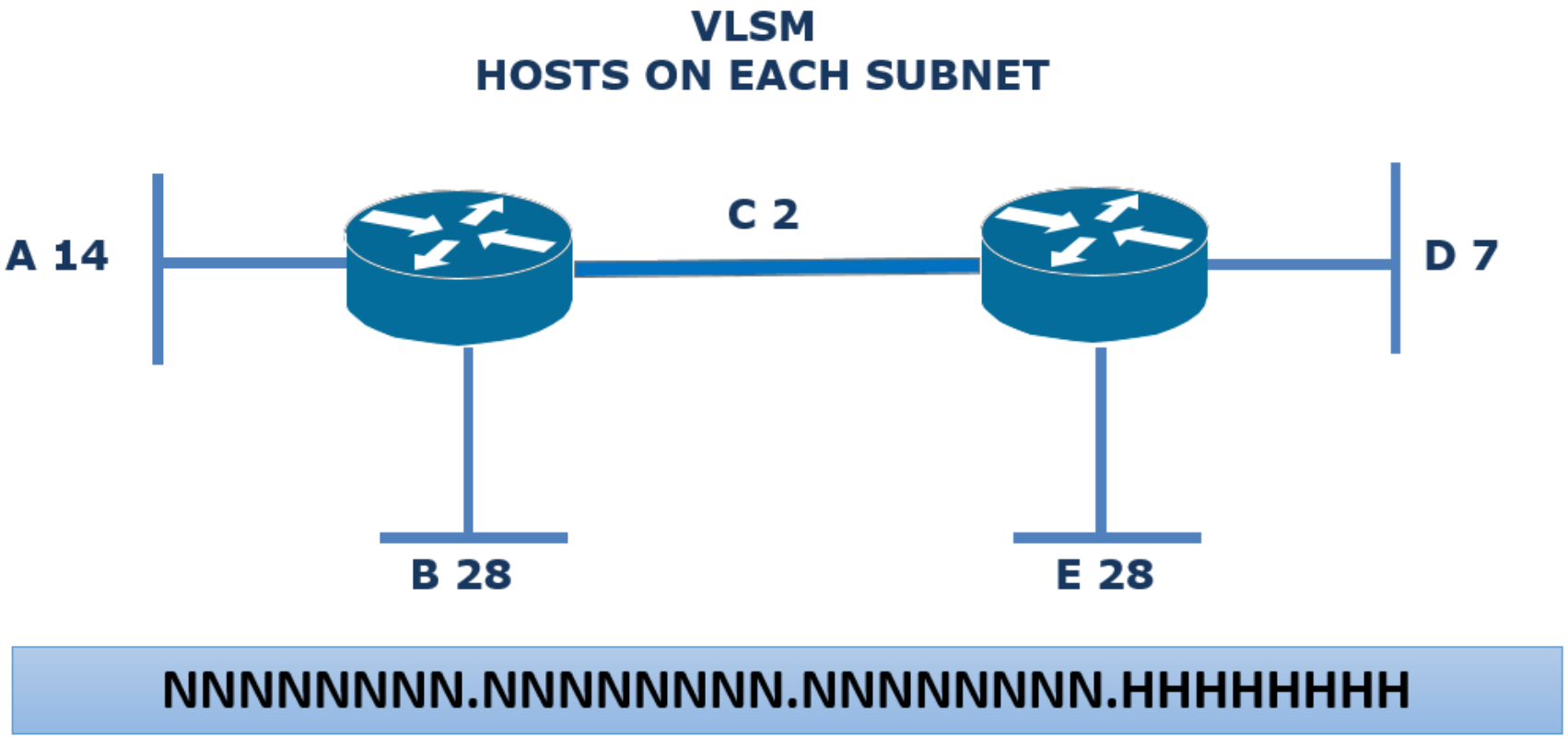
Subnet Number	Subnet Address
Subnet 0	192.168.20.0/27
Subnet 1	192.168.20.32/27
Subnet 2	192.168.20.64/27
Subnet 3	192.168.20.96/27
Subnet 4	192.168.20.128/27
Subnet 5	192.168.20.160/27
Subnet 6	192.168.20.192/27
Subnet 7	192.168.20.224/27

Subnet Number	Subnet Address
Subnet 0	192.168.20.192/30
Subnet 1	192.168.20.196/30
Subnet 2	192.168.20.200/30
Subnet 3	192.168.20.204/30
Subnet 4	192.168.20.208/30
Subnet 5	192.168.20.212/30
Subnet 6	192.168.20.216/30
Subnet 7	192.168.20.220/30

NNNNNNNN.NNNNNNNN.NNNNNNNN.HHHHHHHH

http://vlsmcalc.net/

201.15.5.0



https://subnettingpractice.com/vlsm.html

Major network	201.15.5.0/24	
Subnets	Name	Size
	A	7
	B	14
	C	2
	D	28
	E	28
	Number of subnets: 5 Change	
	Sort results by: size	
Submit		

Subnetting Successful

Major Network: **201.15.5.0/24**
Available IP addresses in major network: **254**
Number of IP addresses needed: **79**
Available IP addresses in allocated subnets: **90**
About **39%** of available major network address space is used
About **88%** of subnetted network address space is used

Subnet Name	Needed Size	Allocated Size	Address	Mask	Dec Mask	Assignable Range	Broadcast
D	28	30	201.15.5.0	/27	255.255.255.224	201.15.5.1 - 201.15.5.30	201.15.5.31
E	28	30	201.15.5.32	/27	255.255.255.224	201.15.5.33 - 201.15.5.62	201.15.5.63
B	14	14	201.15.5.64	/28	255.255.255.240	201.15.5.65 - 201.15.5.78	201.15.5.79
A	7	14	201.15.5.80	/28	255.255.255.240	201.15.5.81 - 201.15.5.94	201.15.5.95
C	2	2	201.15.5.96	/30	255.255.255.252	201.15.5.97 - 201.15.5.98	201.15.5.99

HEXIDECIMAL

Binary and Hexadecimal System

Binary	Hexadecimal	Binary	Hexadecimal
0000	0	1000	8
0001	1	1001	9
0010	2	1010	A
0011	3	1011	B
0100	4	1100	C
0101	5	1101	D
0110	6	1110	E
0111	7	1111	F

Only need 4 Hex positions:

4096 256 16 1

Converting Binary to Hexadecimal

Converting Binary Number to Hexadecimal Number

100100100010111110111110111001001

Converts to:

0001 0010 0100 0101 1111 0111 1101 1100 1001

Converts to:

1 2 4 5 F 7 D C 9

So:

100100100010111110111110111001001 binary

= 1245F7DC9 hexadecimal

Converting Hexadecimal Number to Binary Number

0x2102

Converts to:

2	1	0	2
0010	0001	0000	0010

So:

2102 hexadecimal converts to: 0010 0001 0000 0010 binary

Example:

4F6A =

(4 x $16^{3)}$

+ (F[15] x $16^{2)}$

+ (6 x $16^{1)}$

+ (A[10] x 16^{0})

= 20330 (decimal)

$16^{3} = 4096$
$16^{2} = 256$
$16^{1} = 16$
$16^{0} = 1$

Convert hex 3F4B to a Decimal

(Work right to left)

3*	4096	=12288
F*	256	=3840
4*	16	=64
B*	1	=11
		=16203