Chapter 6

Variable Length Subnet Masking (VLSM)

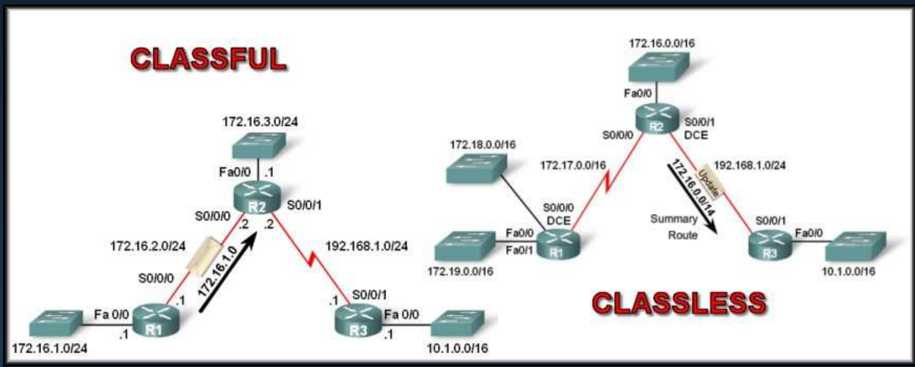
Classless Inter-Domain Routing (CIDR)

Note for Instructors

- These presentations are the result of a collaboration among the instructors at St. Clair College in Windsor, Ontario.
- Thanks must go out to Rick Graziani of Cabrillo College. His material and additional information was used as a reference in their creation.
- If anyone finds any errors or omissions, please let me know at:
    - tdame@stclaircollege.ca.

VLSM and CIDR

Classful and Classless Addressing

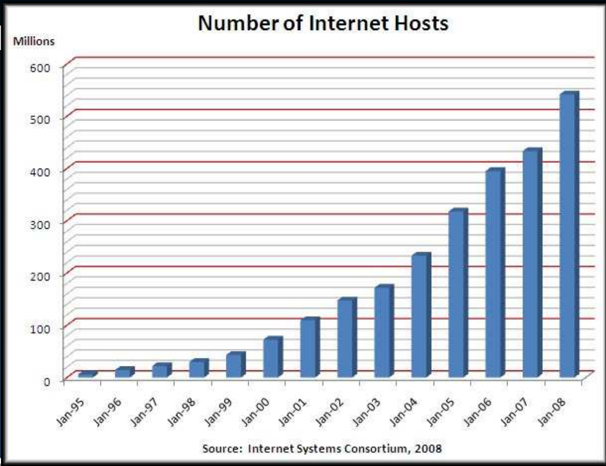


Classful and Classless Routing Protocols

	Interior Gateway Protocols				Exterior Gateway Protocols
	Distance Vector Routing Protocols		Link State Routing Protocols		Path Vector
Classful	RIP	IGRP			EGP
Classless	RIPv2	EIGRP	OSPFv2	IS-IS	BGPv4
IPv6	RIPng	EIGRP for IPv6	OSPFv3	IS-IS for IPv6	BGPv4 for IPv6

- One of the ways to characterize routing protocols is either as classful or classless.
- As networks evolved and began to use classless addressing, classless routing protocols had to be modified or developed to include the subnet mask in the routing update.

Classful IP Addressing



- ARPANET – 1969
- By 1989, it was transformed into what we now call the Internet.
- 1989 – 159,000
- By 2000, it grew to over 72 million hosts.
- As of January 2008, there were over 541 million hosts on the Internet.
- Without VLSM and CIDR, the IPv4 address space would have been exhausted long ago.

High-Order Bits

Class	High Order Bits	Start	End
Class A	0	0.0.0.0	127.255.255.255
Class B	10	128.0.0.0	191.255.255.255
Class C	110	192.0.0.0	223.255.255.255
Multicast	1110	224.0.0.0	239.255.255.255
Experimental	1111	240.0.0.0	255.255.255.255

- In the original specification of IPv4 (RFC 791), released in 1981, the authors established the classes to provide three different sizes of networks for large, medium, and small organizations.
- As a result, Class A, B, and C addresses were defined with a specific format for the high-order bits.

IPv4 Classful Addressing Structure

	1st Octet	2nd Octet	3rd Octet	4th Octet	Subnet Mask
Class A	Network	Host	Host	Host	255.0.0.0 or /8
Class B	Network	Network	Host	Host	255.255.0.0 or /16
Class C	Network	Network	Network	Host	255.255.255.0 or /24

Number of Networks and Hosts per Network for Each Class

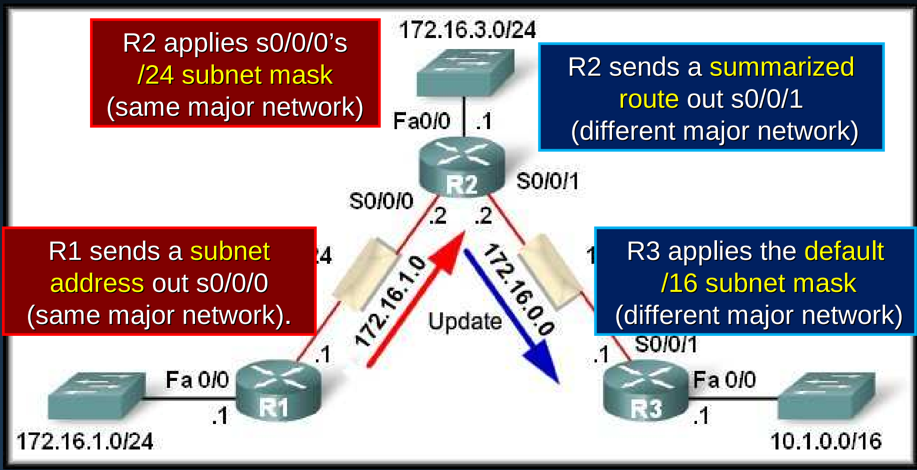
Address class	First Octet Range	Number of Possible Networks	Number of Host per Network
Class A	0 to 127	128 (2 are reserved)	16,777,214
Class B	128 to 191	16,384	65,534
Class C	192 to 223	2,097,152	254

- Subnet masks were determined based on class.
- The only choices were networks with very large number of hosts, large number of hosts, or few number of hosts.

Classful Routing Protocol

- Using classful IP addresses:
  - Subnet mask of a network address could be determined by the value of the first octet.
- The router receiving the routing update could determine the subnet mask simply by examining the value of the first octet.
- RIPv1:
  - Only needed to propagate the network address of known routes and did not need to include the subnet mask in the routing update.
- The subnet mask was directly related to the network address.

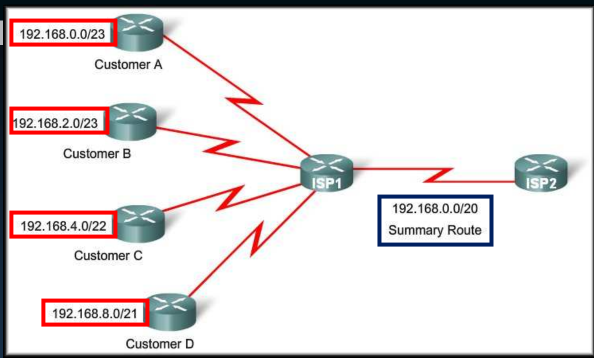
Classful Routing Protocol



Classless IP Addressing

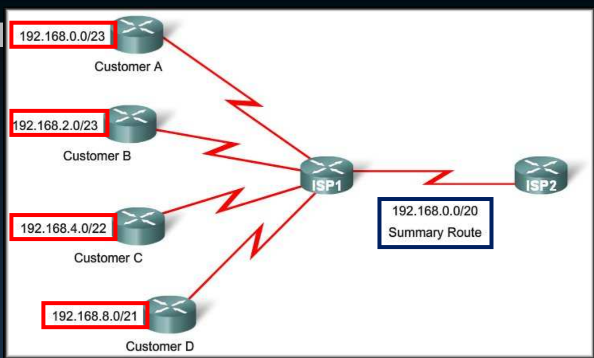
- Moving Toward Classless Addressing:
  - By 1992, members of the IETF had serious concerns about the exponential growth of the Internet.
    - Limited scalability of Internet routing tables.
    - Eventual exhaustion of 32-bit IPv4 address space.
  - In 1993, the IETF introduced Classless Inter-Domain Routing (CIDR).
    - More efficient use of IPv4 address space.
    - Prefix aggregation, which reduced the size of routing tables.

Classless IP Addressing



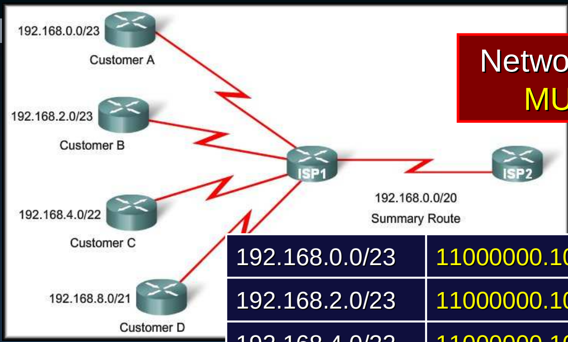
- To CIDR-compliant routers, address class is meaningless.
  - The network portion of the address is determined by the network subnet mask, also known as the network prefix, or prefix length (/8, /19, etc.).
- The network address is no longer determined by the class of the address.

CIDR and Route Summarization



- The capability for routes to be summarized as a single route helped reduce the size of Internet routing tables.
- A Supernet summarizes multiple network addresses with a mask that is less than (or a summary of) the classful mask.

CIDR and Route Summarization

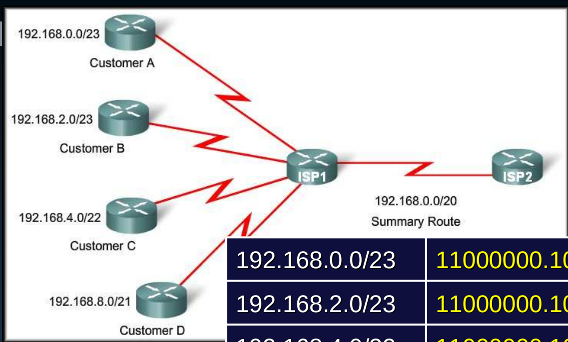


Networks to be summarized MUST be contiguous.

	192.168.0.0/23	11000000.10101000.00000000.00000000
	192.168.2.0/23	11000000.10101000.00000010.00000000
	192.168.4.0/22	11000000.10101000.00000100.00000000
	192.168.8.0/21	11000000.10101000.00001000.00000000
Summary	192.168.0.0/20	11000000.10101000.00000000.00000000

- Networks are converted to binary.
- The summary route is comprised of the least number of bits that are common to all subnets.

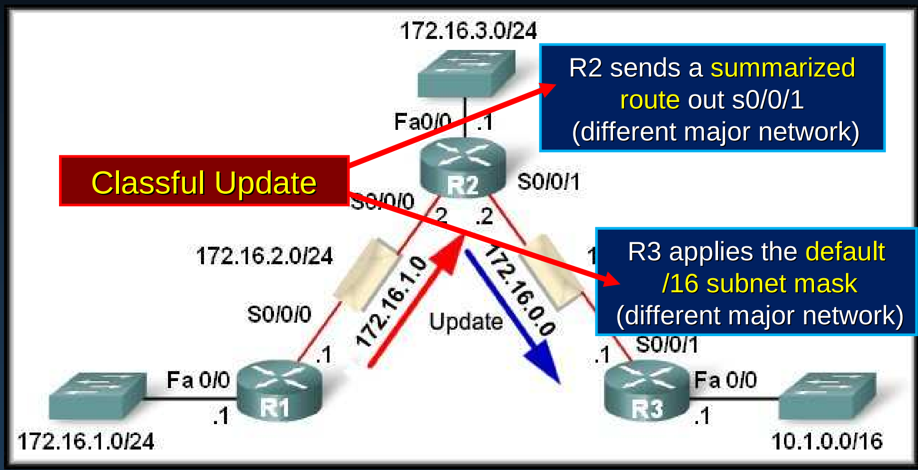
CIDR and Route Summarization



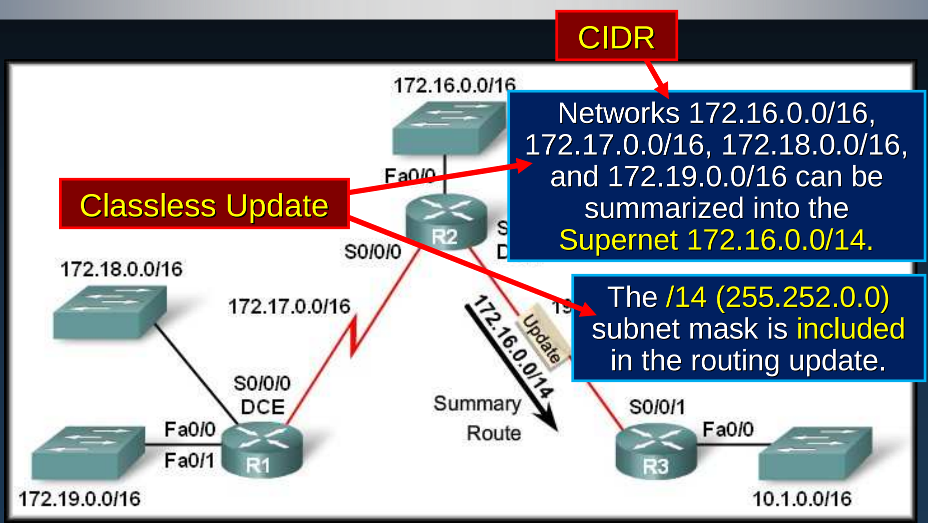
	192.168.0.0/23	11000000.10101000.00000000.00000000
	192.168.2.0/23	11000000.10101000.00000010.00000000
	192.168.4.0/22	11000000.10101000.00000100.00000000
	192.168.8.0/21	11000000.10101000.00001000.00000000
Summary	192.168.0.0/20	11000000.10101000.00000000.00000000

- Requires a classless routing protocol (RIPv2, EIGRP, OSPF).
- The subnet mask of the network MUST be included with the routing update.

Classless Routing Protocol

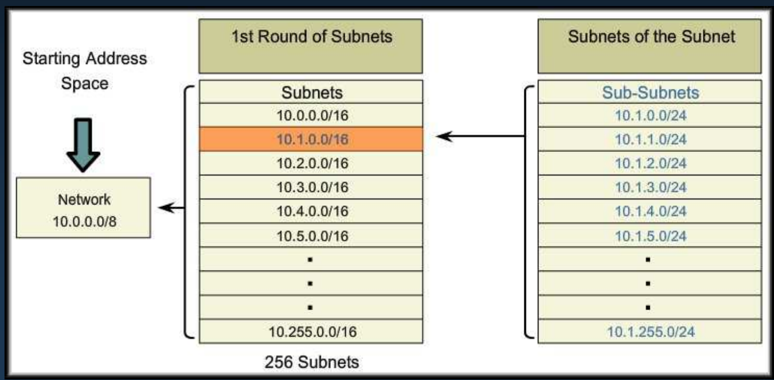


Classless Routing Protocol

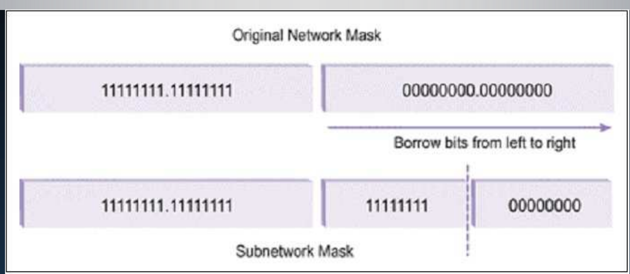


VLSM and CIDR

Variable Length Subnet Masking (VLSM)

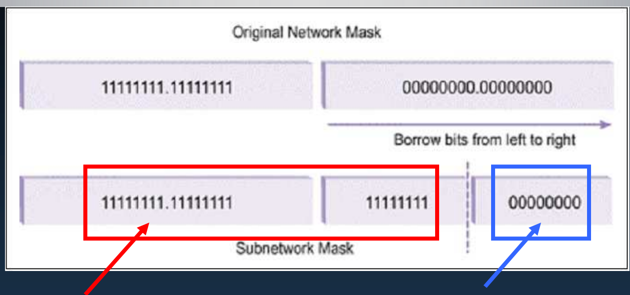


Review - Creating a Subnet



- 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.

Review - 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.

Review - 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

Review - 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: $2^{number\_of\_borrowed\_host\_bits}$
  - <u>Usable</u> Hosts Per Subnet:

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

Review - Creating a Subnet – The Rules

- To determine the number of hosts:
  - Hosts: $2^{number\_of\_remianing\_host\_bits}$
  - <u>Usable</u> Hosts Per Subnet:

    $2^{number\_of\_remaining\_host\_bits} - 2$
- To determine the number of subnets:
  - Subnets: $2^{number\_of\_borrowed\_host\_bits}$
  - *<u>NOTE:</u> It is now possible to use the zero subnet. Previous to allowing its use, subnetting resulted in the loss of the first and last subnets (host bits all 0's and all 1's). That is no longer the case.*

Review - 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.

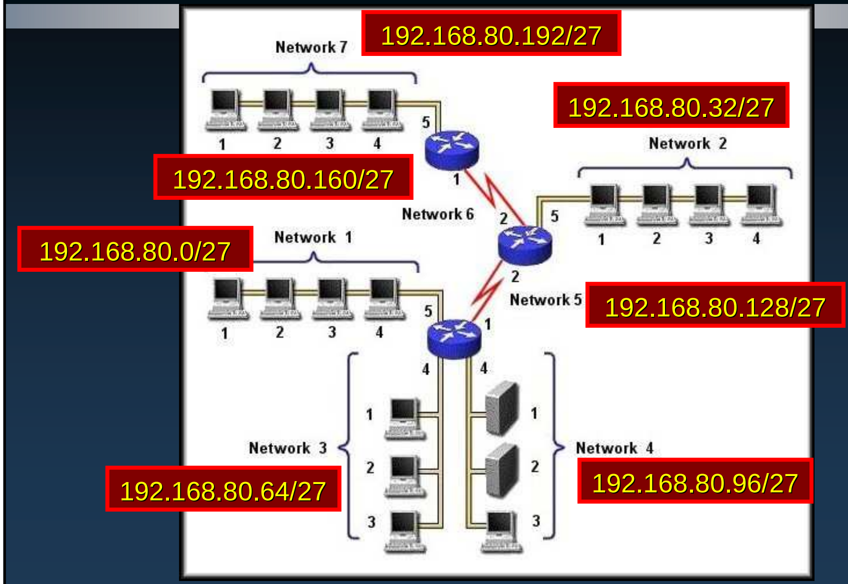
- The calculation $2^{number\_of\_host\_bits}$ yields the "magic" number.
- We have 5 host bits remaining so…..
  - 2^5 = 32 - our "magic" number.

Review - Subnetting - Class C

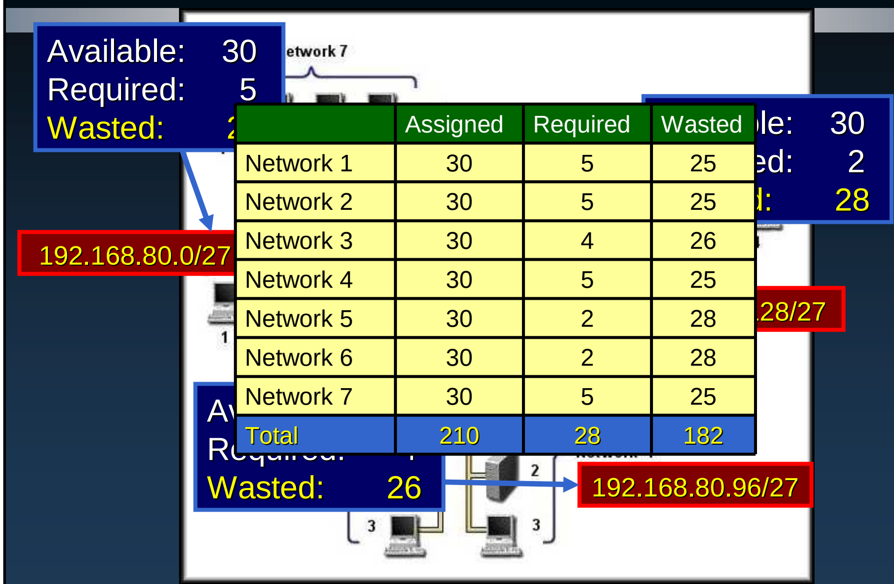
- Network: 192.168.80.0 Subnet Mask: 255.255.255.224
- Network: 27 bits Host: 5 bits Magic Number: 2^5 = 32

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

Dividing Networks Into the Right Size



Dividing Networks Into the Right Size



	Assigned	Required	Wasted
Network 1	30	5	25
Network 2	30	5	25
Network 3	30	4	26
Network 4	30	5	25
Network 5	30	2	28
Network 6	30	2	28
Network 7	30	5	25
Total	210	28	182

Variable Length Subnet Masking (VLSM)

- A serious limitation of using only a *single subnet mask across a given network-prefix* (the number of network or 1 bits in the mask) was that an organization is *locked into a fixed-number of fixed-sized subnets*.
- VLSM enables a network number to be configured with different subnet masks on different interfaces.
  - Subnet an already subnetted network address.
  - Conserves IP addresses.
  - More efficient use of available address space.
- Allows for more hierarchical levels within an addressing plan.

Variable Length Subnet Masking (VLSM)

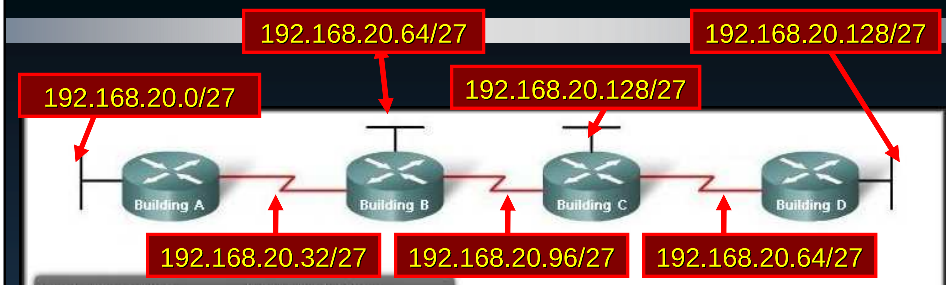
10.0.0.0/8 Subnet using /16

Subnet	1st Host	Last Host	Broadcast
10.0.0.0/16	10.0.0.1	10.0.255.254	10.0.255.255
10.1.0.0/16	10.1.0.1	10.1.255.254	10.1.255.255
10.2.0.0/16			
10.3.0.0/16	10.3.0.1	10.3.255.254	10.3.255.255
Etc.			
10.255.0.0/16	10.255.0.1	10.255.255.254	10.255.255.255

Subnet Using /24

Subnet	1st Host	Last Host	Broadcast
10.2.0.0/24	10.2.0.1	10.2.0.254	10.2.0.255
10.2.1.0/24	10.2.1.1	10.2.1.254	10.2.1.255
10.2.2.0/24	10.2.2.1	10.2.2.254	10.2.2.255
Etc.			
10.2.255.0/24	10.2.255.1	10.2.255.254	10.2.255.255

Variable Length Subnet Masking (VLSM)

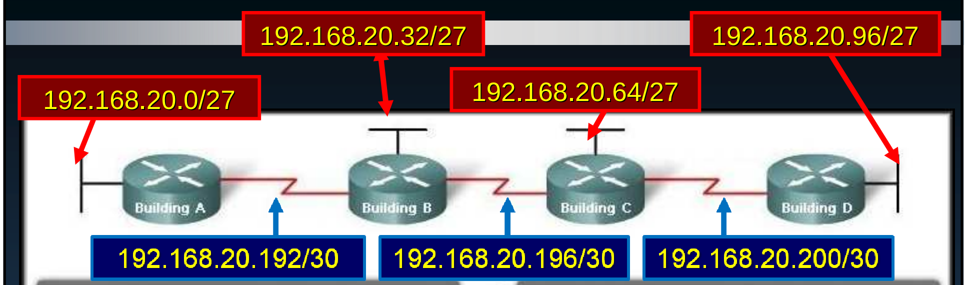


Subnet Number	Subnet Address
Subnet 0	192.168.20.0/27
Subnet 1	192.168.20.32/27
Subnet 2	192.168.20.64/27
Subnet 3	192.168.20.96/27
Subnet 4	192.168.20.128/27
Subnet 5	192.168.20.160/27
Subnet 6	192.168.20.192/27
Subnet 7	192.168.20.224/27

7 Networks with 30 usable addresses for each network

Wasted 28 addresses on each WAN link

Variable Length Subnet Masking (VLSM)



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

Variable Length Subnet Masking (VLSM)

Original Subnet Mask Magic Number = 32	255.255.255.224 1 1 1 0 0 0 0 0
192.168.20.0	0 0 0 0 0 0 0 0
192.168.20.32	0 0 1 0 0 0 0 0
192.168.20.64	0 1 0 0 0 0 0 0
192.168.20.96	0 1 1 0 0 0 0 0
192.168.20.128	1 0 0 0 0 0 0 0
192.168.20.160	1 0 1 0 0 0 0 0
192.168.20.192	**1 1 0 0 0 0 0 0**
192.168.20.224	1 1 1 0 0 0 0 0

255.255.255.252 1 1 1 1 1 1 0 0	Sub-Subnet Mask Magic Number = 4
1 1 0 0 0 0 0 0	192.168.20.192
1 1 0 0 0 1 0 0	192.168.20.196
1 1 0 0 1 0 0 0	192.168.20.200
1 1 0 0 1 1 0 0	192.168.20.204
1 1 0 1 0 0 0 0	192.168.20.208
1 1 0 1 0 1 0 0	192.168.20.212
1 1 0 1 1 0 0 0	192.168.20.216
1 1 0 1 1 1 0 0	192.168.20.220

Variable Length Subnet Masking (VLSM)

"If you know how to subnet, you can do VLSM."

What's the trick?

Always satisfy the requirements of your biggest LAN and then work your way down ….

Variable Length Subnet Masking (VLSM)

- Steps for VLSM:
  1. List the number of hosts required per network beginning with the largest to the smallest.
  2. Convert the subnet mask to binary.
  3. Draw a line where the network portion ends.
  4. Ask yourself the question… *How many bits do I need to support the required number of hosts?*
  5. Move the line to show your new network portion.
  6. Determine your new magic number.
  7. Finish subnetting using the new magic number.

- The starting address is always the first network.
- You cannot go past the *next* network of the *previous level*.

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