NET 363
Introduction to LANs

Subnetting

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IP Subnetting

- **IP Subnetting** is the process by which an organization takes an IP address block assigned to them by an ISP and divides it into smaller subnets that are used for internal routing within the organization's network.
- Any large IP Subnet can be split into **2^n smaller subnets** networks by **borrowing n bits** from the Host bits, and **adding them to the prefix length**.
  - Example: Original Subnet is **22.5.4.0/24** (contains 256 IP addresses). To split this into 4 equal-sized subnets of 64 IPs each, you can borrow 2 bits and add them to prefix length (now /26)
  - New subnets are: **22.5.4.0/26, 22.5.4.64/26, 22.5.4.128/26 and 22.5.4.192/26** (4 subnets of 64 IPs each).

Network Segmentation
Reasons for Subnetting

Large networks need to be segmented into smaller sub-networks, creating smaller groups of devices and services in order to:

- Control traffic by containing broadcast traffic within subnetwork
- Reduce overall network traffic and improve network performance

Subnetting - process of segmenting a network into multiple smaller network spaces called subnetworks or **Subnets.**

Communication Between Subnets

- A router is necessary for devices on different networks and subnets to communicate.
- Each router interface must have an IPv4 host address that belongs to the network or subnet that the router interface is connected to.
- Devices on a network and subnet use the router interface attached to their LAN as their default gateway.

Subnetted IP Structure

- Each **IP address** has 3 parts:
  - A **<u>Network Prefix</u>** part – this is the address prefix originally assigned to an organization or site.
  - An **<u>Subnet</u>** part that is used by internal routers within the organization to deliver packets to a particular smaller Subnet within the internal network.
  - An **<u>IP Host</u>** part that identifies a particular individual device.

Address Example: 130.88.55.12

Network		Subnet	Host
130	**88**	**55**	**12**

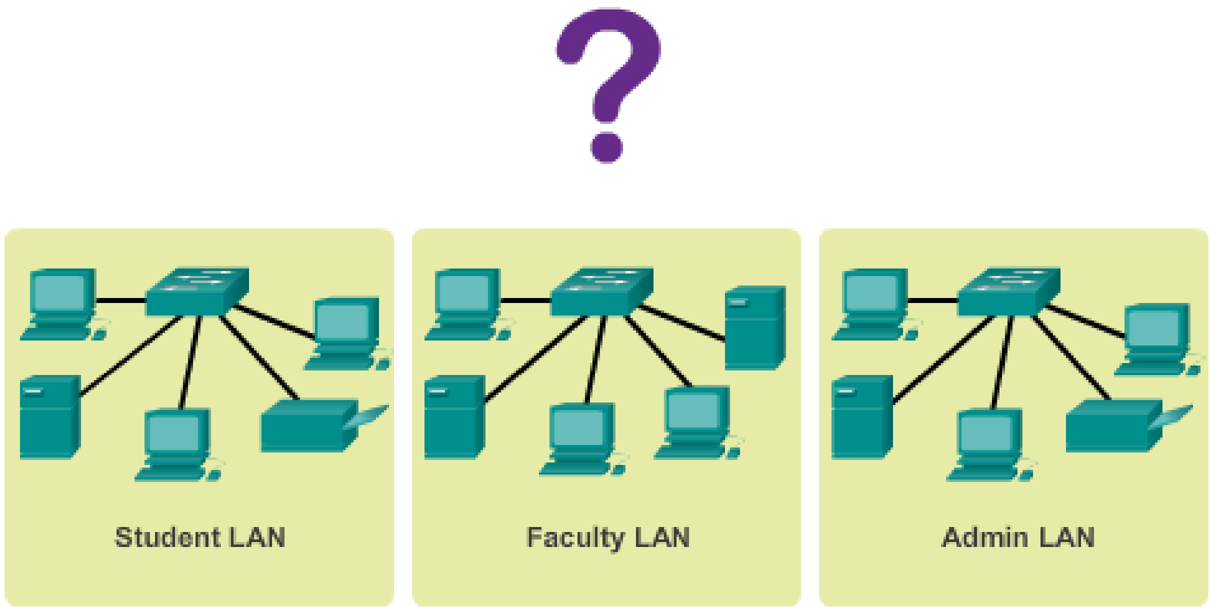
Network = 130.88.0.0/16 (in backbone router tables)

Subnet = 130.88.55.0/24 (in local router tables)

Host = 12 (used by last router to ARP)

Subnetting an IPv4 Network

IP Subnetting is FUNdamental



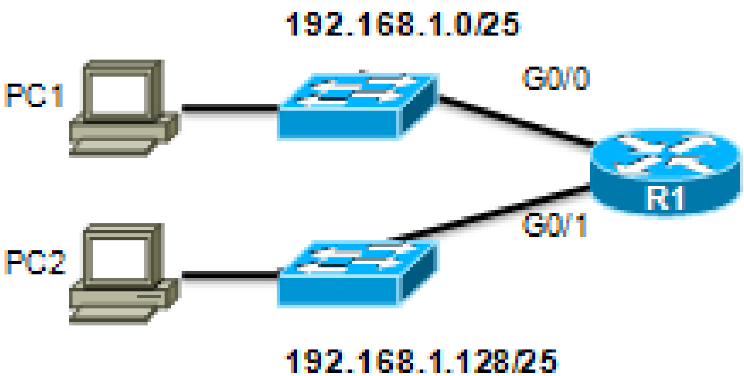
Planning requires decisions on each subnet in terms of size, the number of hosts per subnet, and how host addresses will be assigned.

Subnetting an IPv4 Network

Subnets in Use

Subnet 0

Network 192.168.1.**0-127**/**25**



Subnet 1

Network 192.168.1.**128-255**/**25**

Address Range for 192.168.1.0/25 Subnet

Network Address				
192.	168.	1.	0 000 0000	= 192.168.1.0
First Host Address				
192.	168.	1.	0 000 0001	= 192.168.1.1
Last Host Address				
192.	168.	1.	0 111 1110	= 192.168.1.126
Broadcast Address				
192.	168.	1.	0 111 1111	= 192.168.1.127

Address Range for 192.168.1.128/25 Subnet

Network Address				
192.	168.	1.	1 000 0000	= 192.168.1.128
First Host Address				
192.	168.	1.	1 000 0001	= 192.168.1.129
Last Host Address				
192.	168.	1.	1 111 1110	= 192.168.1.254
Broadcast Address				
192.	168.	1.	1 111 1111	= 192.168.1.255

Subnetting an IPv4 Network

Subnetting Formulas

- Calculate Number of Subnets

Subnets = 2^n
(where n = bits borrowed)

`192. 168. 1. 0 000 0000`

1 bit was borrowed

2^1 = 2 subnets

- Calculate Number of Hosts

Hosts = 2^n
(where n = host bits remaining)

`192. 168. 1. 0 000 0000`

7 bits remain in host field

2^7 = 128 hosts per subnet

Creating 4 Subnets

- Borrowing 2 bits to create 4 subnets. **2^2 = 4 subnets**

Borrowing 2 Bits

Original	192.	168.	1.	00	00 0000
Mask	255.	255.	255.	00	00 0000

Borrowing 2 bits creates 4 subnets:

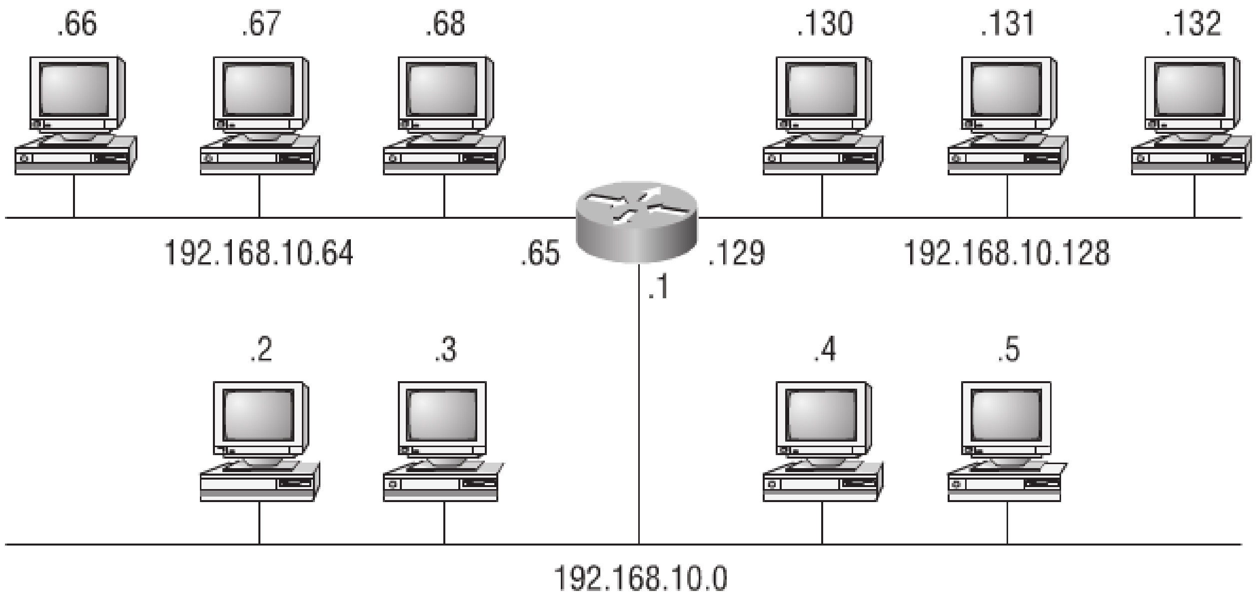
Net 0	192.	168.	1.	00	00 0000	192.168.1.0/26
Net 1	192.	168.	1.	01	00 0000	192.168.1.64/26
Net 2	192.	168.	1.	10	00 0000	192.168.1.128/26
Net 3	192.	168.	1.	11	00 0000	192.168.192/26

All 4 subnets use the same mask:

Mask	255.	255.	255.	11	00 0000	Mask: 255.255.255.192

Implementing Subnets

FIGURE 4.2 Implementing a Class C /26 logical network




```
Router#show ip route
[output cut]
C 192.168.10.0 is directly connected to Ethernet 0
C 192.168.10.64 is directly connected to Ethernet 1
C 192.168.10.128 is directly connected to Ethernet 2
```

IP Subnetting Details

- "Straight IP Subnetting" breaks an <u>initial IP subnet</u> of 2^X addresses (X host bits; prefix length = (32-X)) into 2^n equal-sized smaller IP subnets of size 2^{X-n} by borrowing n bits from the Host bits.
  - The n "borrowed bits" are now the <u>Subnet bits</u>
  - This increases the prefix length by <u>n</u>.
  - After subnetting
    - Number of smaller subnets created = 2^n
    - Prefix length of each smaller subnet = /(32-X+n)
    - Size of each smaller subnet = $2^{(X-n)}$

Subnetting Example Based on Subnet Requirements

- BrewCo was allocated IP address block 201.16.72.0/24 by their ISP. They have 6 departments and want to use 8 subnets internally. What Subnet Mask should they use?

  Initial subnet = 201.16.72.0 / 24
  Initial prefix, subnet mask = /24 or 255.255.255.0
  Size of initial subnet = $2^{(32-24)} = 2^8 = 256$ IP addresses
  Number of new subnets = $8 = 2^3$
  New prefix length = 24 + 3 = <u>/ 27</u>
  New subnet mask = <u>255.255.255.224</u>
  Size of each new subnet = $2^{(32-24-3)} = 2^5 =$ <u>32</u>
  Result: Original block of 256 addresses is split into 8 subnets of 32 IP addresses each.

Listing New Subnets

- Original subnet = **<u>201.16.72.0/24</u>**.
- Using mask 255.255.255.224, the <u>8 new subnets</u> are:

Subnet 201.16.72.0 /27

Valid host range = 201.16.72.1 – 201.16.72.30

Subnet broadcast address = 201.16.72.31

Subnet 201.16.72.32 /27

Valid host range = 201.16.72.33 – 201.16.72.62

Subnet broadcast address = 201.16.72.63

Subnet 201.16.72.64 /27

Valid host range = 201.16.72.65 – 201.16.72.94

Subnet broadcast address = 201.16.72.63

(… leaving four subnets out here …)

Subnet 201.16.72.224 /27

Valid host range = 201.16.72.225 – 201.16.72.254

Subnet broadcast address = 201.16.72.255

Subnetting Example Based on Host Requirements

- JoyCo Corp. has been allocated IP network 130.88.0.0/16 and is split into departments that may have up to 1000 computers each.
  - How many equal-sized subnets can they create with at least 1000 valid host addresses in each?
  - What subnet mask should they use?
  - What are the resulting Subnet IDs?
  - What are the first and last assignable IP address in each of these new subnets?

JoyCo Example

- Subnet sizes must be powers of 2. The smallest power of 2 that is greater than 1000 is $2^{\mathbf{10}}$ = 1024. This would give them 1024 – 2 = 1022 valid host addresses in each subnet. Thus, each IP address has 10 Host bits.
- The new prefix length will be 32 – 10 = **/22**.
  - So, new Subnet mask is **255.255.252.0**.
- The difference between old prefix length (16) and new prefix length (22) is 22-16 = **6**, so 6 bits are borrowed:
  - Number of new subnets = $2^{\mathbf{6}}$ = 64 subnets
    - We also could have figured this as 65,536 / 1024 = 64

Calculating JoyCo Subnets

- First Subnet ID will be the original network address with the new prefix length.
  - First Subnet ID is **130.88.0.0 / 22**
  - New Subnet Mask = **255.255.252.0**
- Calculate other subnet IDs using Jump Factor:
  - Start with first subnet ID and add 1024 IP addresses to it. This will increase value in 3rd byte by 1024 / 256 = **4**.
  - OR 3rd byte jump factor = **256 – 252** = **4***
- So, 2nd subnet ID is **130.88.4.0 / 22**
- 3rd, 4th and subsequent subnet IDs calculated same way.

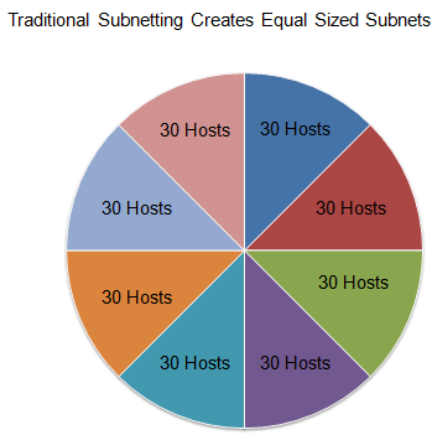
Joyco Subnets

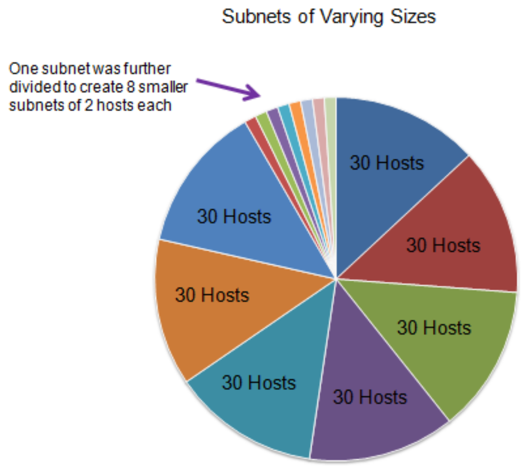
- 1st Subnet: <u>**130.88.0.0 / 22**</u>
  - Valid IPs 130.88.0.1 – 130.88.3.254 (1022 addresses)
  - Subnet broadcast address = 130.88.3.255
- 2nd Subnet: <u>**130.88.4.0 / 22**</u>
  - Valid IPs 130.88.4.1 – 130.88.7.254 (1022 addresses)
  - Subnet broadcast address = 130.88.7.255
- 3rd Subnet: <u>**130.88.8.0 / 22**</u>
  - Valid IPs 130.88.8.1 – 130.88.11.254 (1022 addresses)
  - Subnet broadcast address = 130.88.11.255
- … *(leaving out 60 subnets here*) …
- 64th Subnet: <u>**130.88.252.0 / 22**</u>
  - IPs 130.88.252.1 – 130.88.255.254 (1022 addresses)
  - Subnet broadcast address = 130.88.255.255

Benefits of Variable Length Subnet Masking

Traditional Subnetting Wastes Addresses

- Traditional subnetting - same number of addresses is allocated for each subnet.
- Subnets that require fewer addresses have unused (wasted) addresses. For example, WAN links only need 2 addresses.
- Variable Length Subnet Mask (VLSM) or subnetting a subnet provides more efficient use of addresses.





Benefits of Variable Length Subnet Masking

Variable Length Subnet Masks (VLSM)

- VLSM allows a network space to be divided in unequal parts.
- Subnet mask will vary depending on how many bits have been borrowed for a particular subnet.
- Network is first subnetted, and then the subnets are subnetted again.
- Process repeated as necessary to create subnets of various sizes.

Benefits of Variable Length Subnet Masking

Basic VLSM

- Company allocated IP address space 192.168.20.0/24
- Company has 4 LANs – up to 30 devices on each.
- Company has 3 Pt-Pt WAN links – 2 routers on each.
- Straight subnetting => split into 8 subnets, 32 IPs on each

VLSM Subnetting Scheme

11000000.10101000.00010100.000 00000 192.168.20.0/24

0	11000000.10101000.00010100.000 00000	192.168.20.0/27	LANs A, B, C, D
1	11000000.10101000.00010100.001 00000	192.168.20.32/27	
2	11000000.10101000.00010100.010 00000	192.168.20.64/27	
3	11000000.10101000.00010100.011 00000	192.168.20.96/27	
4	11000000.10101000.00010100.100 00000	192.168.20.128/27	Unused / Available
5	11000000.10101000.00010100.101 00000	192.168.20.160/27	
6	11000000.10101000.00010100.110 00000	192.168.20.192/27	
7	11000000.10101000.00010100.111 00000	192.168.20.224/27	

3 more bits borrowed from subnet 7:

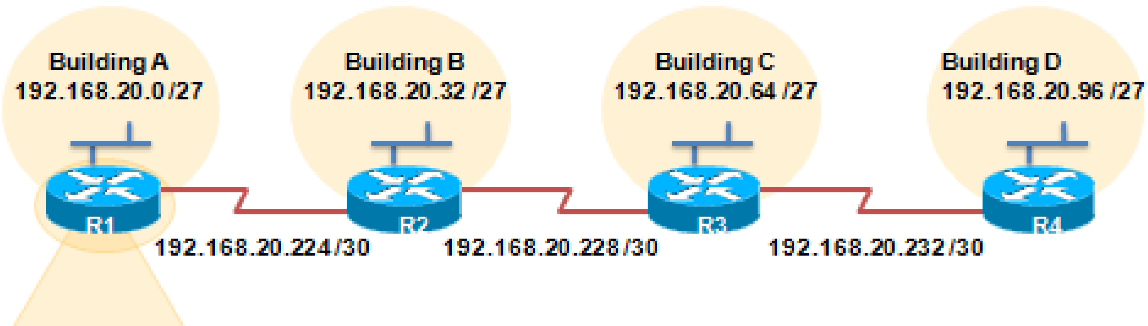
7:0	11000000.10101000.00010100.111000 00	192.168.20.224/30	WANs
7:1	11000000.10101000.00010100.111001 00	192.168.20.228/30	
7:2	11000000.10101000.00010100.111010 00	192.168.20.232/30	
7:3	11000000.10101000.00010100.111011 00	192.168.20.236/30	Unused / Available
7:4	11000000.10101000.00010100.111100 00	192.168.20.240/30	
7:5	11000000.10101000.00010100.111101 00	192.168.20.244/30	
7:6	11000000.10101000.00010100.111110 00	192.168.20.248/30	
7:7	11000000.10101000.00010100.111111 00	192.168.20.252/30	

Benefits of Variable Length Subnet Masking

VLSM in Practice

- Using VLSM subnets, the LAN and WAN segments in example below can be addressed with minimum waste.
- Each LANs will be assigned a subnet with /27 mask.
- Each WAN link will be assigned a subnet with /30 mask.

Network Topology: VLSM Subnets




```
R1(config)#interface gigabitethernet 0/0
R1(config-if)#ip address 192.168.20.1 255.255.255.224
R1(config-if)#exit
R1(config)#interface serial 0/0/0
R1(config-if)#ip address 192.168.20.225 255.255.255.252
R1(config-if)#end
R1#
```

Benefits of Variable Length Subnet Masking

VLSM Chart

VLSM Subnetting of 192.168.20.0 /24

	/27 Network	Hosts
Bldg A	.0	.1 - .30
Bldg B	.32	.33 - .62
Bldg C	.64	.65 - .94
Bldg D	.96	.97 - .126
Unused	.128	.129 - .158
Unused	.160	.161 - .190
Unused	.192	.193 - .222
	.224	.225 - .254

	/30 Network	Hosts
WAN R1–R2	.224	.225 - .226
WAN R2–R3	.228	.229 - .230
WAN R3–R4	.232	.233 - .234
Unused	.236	.237 - .238
Unused	.240	.241 - .242
Unused	.244	.245 - .246
Unused	.248	.249 - .250
Unused	.252	.253 - .254

VLSM Design Example

- BigCo has been allocated IP address block **192.168.10.0 /24** for use on their corporate network. They have these subnet requirements:
  - Reception: 6 IP addresses
  - IT Staff: 12 IP addresses
  - Executive: 10 IP addresses
  - Research: 25 IP addresses
  - Point-to-point link: 2 IP addresses
- Determine a Subnet ID (address range) and subnet mask for each group that meets their address needs while keeping as much address space as possible free for future use.

VLSM Solution Steps

- Solution steps:
  - Sort groups by size, largest to smallest
  - Determine minimum possible subnet size for each group (size must be power of 2).
  - Based on required size, write down subnet mask and prefix length (/n) for each group.
  - Allocate IP addresses, starting with largest group and proceeding down to smallest.