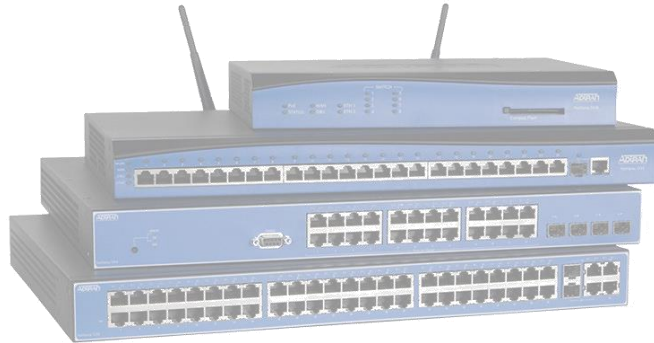


Internet Protocol Addressing

Lecture 3



April 2023

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IP Addresses

- An IP address is an address used to uniquely identify a device on an IP network.
- Two versions of IP addresses:
 - IPv4 and IPv6 (Our focus is on IP version 4)
- IPv4 consists of 32 binary bits which can be divisible into a network portion and host portion with the help of a subnet mask.
- 32 binary bits are broken into four octets (1 octet = 8 bits)
 - In dotted decimal format (for example, 192.168.1.100)



Class A

- Range: 1.0.0.0 – 127.255.255.255
- **Network ID** has 8 bits (1st Octet)
- **Host Portion** has 24 bits (2nd to 4th Octet)

Class B

- Range: 128.0.0.0 – 191.255.255.255
- Network ID has 16 bits (1st and 2nd Octets)
- Host Portion has 16 bits (3rd and 4th Octets)

IPv4 Addresses - Classes



Class C

- Range: 192.0.0.0 – 223.255.255.255
- Network ID has 24 bits (1st to 3rd Octets)
- Host Portion has 8 bits (4th Octets)

Class D

- (224.0.0.0 – 239.255.255.255), For Multicast addresses not to be assigned to hosts.

Class E

- (240.0.0.0 – 254.255.255.255), Experimental and reserved for future use

IP Address Classes

| Address Class | RANGE | Default Subnet Mask |
|---------------|-----------------------------------------|----------------------------------|
| A | 1.0.0.0 to 126.255.255.255 | 255.0.0.0 |
| B | 128.0.0.0 to 191.255.255.255 | 255.255.0.0 |
| C | 192.0.0.0 to 223.255.255.255 | 255.255.255.0 |
| D | 224.0.0.0 to 239.255.255.255 | Reserved for Multicasting |
| E | 240.0.0.0 to 254.255.255.255 | Experimental |

Note: Class A addresses 127.0.0.0 to 127.255.255.255 cannot be used and this range is reserved for loopback testing





Classes A to C addresses are used for Internet routing.

- Class A: The first octet is the network portion. Octets 2, 3, and 4 are for subnets/hosts
- Class B: The first two octets are the network portion. Octets 3 and 4 are for subnets/hosts
- Class C: The first three octets are the network portion. Octet 4 is for subnets/hosts

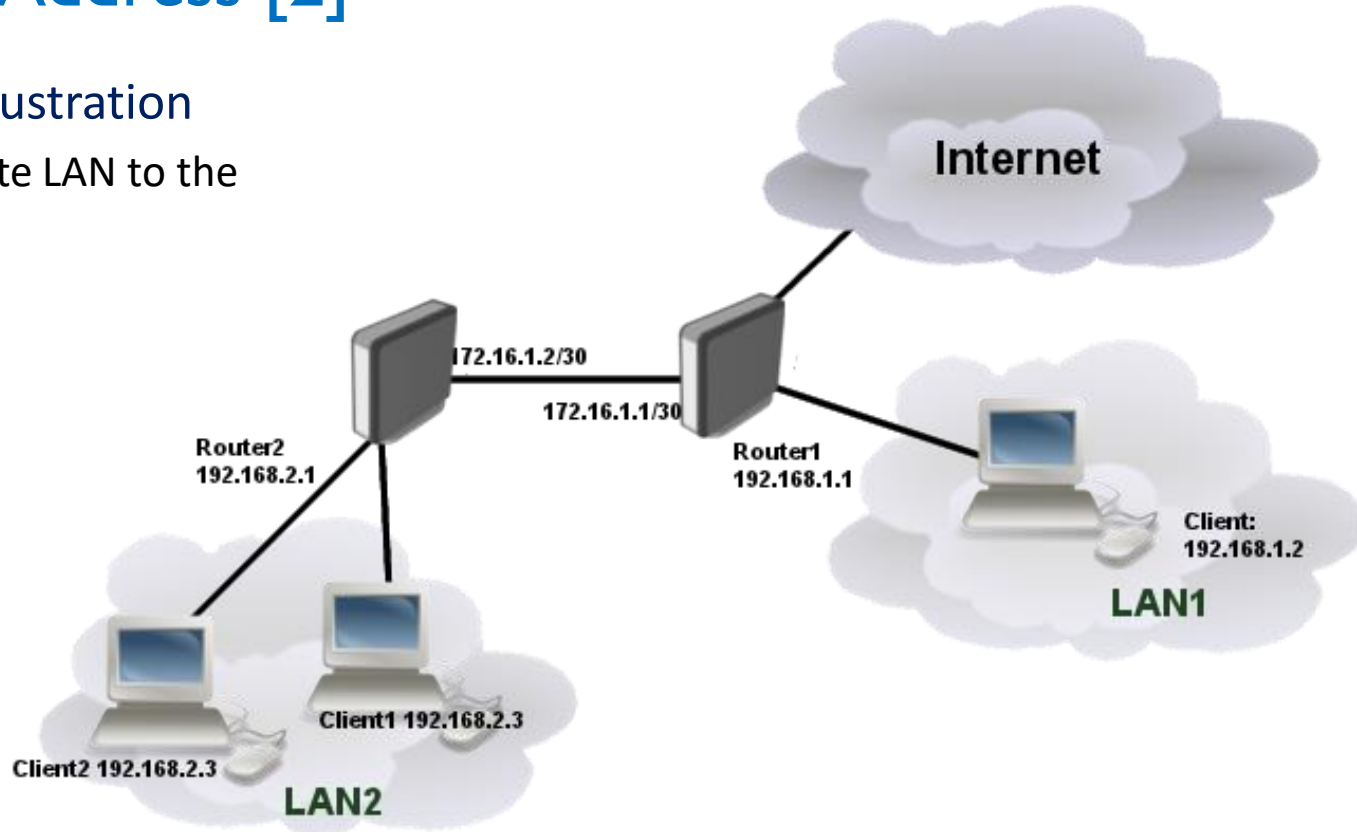
Private vs Public Address

- IP addresses can be categorized as Private and Public
- Public Addresses are routable on the Internet
- Private IP addresses are reserved for use on private networks such as LAN and cannot be routed on the Internet
 - If a LAN uses private IP addresses, **network address translation (NAT)** to a public IP address, is required, on your gateway router.



Private vs Public Address [2]

- Gateway router illustration
 - connects a private LAN to the Internet



Private IP Addresses

- Each IP address class has a **reserved IP address range**
- Class A
 - 10.0.0.0 – 10.255.255.255 (local communication on a private network)
 - 127.0.0.0 – 127.255.255.255 (loopback testing)
- Class B
 - 172.16.0.0 – 172.31.255.255 (local communication on a private network)
- Class C
 - 192.168.0.0 – 192.168.255.255 (local communication on a private network)



Network Masks



- Distinguishes which portion of the address identifies the network and which portion of the address identifies the host.
- Default network masks:
 - Class A: 255.0.0.0
 - Class B: 255.255.0.0
 - Class C: 255.255.255.0

Note: 'host' refers to the network devices such as users' PCs, routers, printers etc

Subnetting

- Creates multiple logical networks that exist within a single Class A, B, or C network.
 - Divides your IP address ranges into smaller ranges for efficient assignment of IP addresses
- Every node on a network must have a unique network ID (a unique IP address), and every node must be a member of the same network (utilizing the same Class)





Benefits of Subnetting

- Reduced network traffic
- Simplified management
- Optimized network performance
- Facilitated spanning of large geographical distances

IP Subnet-Zero



- Long ago it was not allowed to use the first and last subnets (because they were all zeros or ones (in red below))

Example for: 50.0.0.0/10 network

- Possible subnets are
 - 50.**00**00 0000.x.x (**first subnet**) i.e. sub-network
 - 50.**01**00 0000.x.x
 - 50.**10**00 0000.x.x
 - 50.**11**00 0000.x.x (**last subnet**)
- Results in wastage of IP address space
 - ie. IP addresses 50.0.x.x to 50.63.x.x would be unusable
 - and IP addresses 50.192.x.x to 50.255.x.x would be unusable

IP Subnet-Zero



- Enable IP Subnet-Zero in your routing devices if it is not a default
 - This command allows you to use the first and last subnet in your network design.

For Example

- With Class C
 - The IP subnet-zero command allows you to use subnets 0, 64, 128, and 192



How to create subnets

- Determine the number of required network IDs:
 - One for each subnet
 - One for each wide area network *connection*
- Determine the number of required host IDs per subnet:
 - One for each *TCP/IP host*
 - One for each *router interface*
- Based on the above requirements, create the following:
 - One subnet mask for your *entire network*
 - A unique subnet ID for each *physical section*
 - A range of host IDs for each subnet

Practice Example



Class C 255.255.255.128 /25

- Note: the number after the slash indicates the number of bits used for the network ID and the number of bits used for the host IP addresses
- Use 2^n to get the number of subnets where n is the number of network-bits in your subnet mask
 - E.g. For 255.255.255.128, you subnet in the 4th Octet
 - | | | | | | | | . | | | | | | | | . | | | | | | | | . | 00000000
 - Number of network-bits in the last octet = 1
 - $2^1 = 2 =$ Number of subnets

Practice Example [2]



Class C 255.255.255.128 /25

- How many subnets? Since 128 is 1 bit on (10000000), the answer would be $2^1 = 2$.
- What are the valid subnets?
- Use $256 - 128 = 128$.
 - Remember, to start at zero and count in our block size, so our subnets are 0 and 128.



Practice Example [3]

Class C: 255.255.255.128 /25

– Use $2^n - 2$ to get the number of hosts in your subnet where n is the number of off bits (not set, i.e. the zero-bits) in your subnet mask

• E.g. For 255.255.255.128 you use off bits in the 4th Octet

– | | | | | | | | . | | | | | | | | . | | | | | | | | . | 0000000

• **Number of bit in last octet = 7**

• $2^7 - 2 = 126$ Number of hosts

• i.e. 126 hosts per subnet

Practice Example [4]



Class C: 255.255.255.128 /25

- Broadcast address:
 - The number right before the value of the next subnet is the broadcast address., so the broadcast (in this example) is 127.
 - The last IP address in any subnet is the broadcast address
- What are the valid hosts? These are the numbers between the subnet (0) and the broadcast address (127)

Practice Example 2



255.255.255.224 /27

- How many subnets? 224 is **11100000**, so our equation would be $2^3 = 8$.
 - ie 3 bits are reserved for the network ID, 8 sub-networks are possible
- How many hosts? 224 is **11100000**, so our equation would be $2^5 - 2 = 30$.
 - ie 5 bits are reserved for the host ID, 30 hosts can be in each subnet
 - (minus 1 address reserved for the subnet)
 - (and minus 1 address reserved for the broadcast address)

The broadcast address can be used to send messages to all devices on the network (or subnetwork).
A message sent to a *broadcast address* may be received by all network-attached hosts.

Practice Example 2 [2]



255.255.255.224 /27

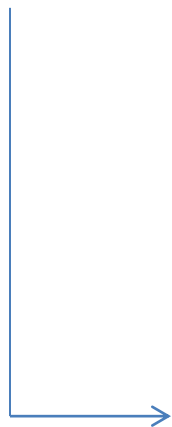
- What are the valid subnets?
- Use $256 - 224 = 32$.
 - We start at zero and count to the subnet mask value in blocks (increments) of 32: 0, 32, 64, 96, 128, 160, 192, and 224.
- What's the broadcast address for each subnet? Always the number right before the next subnet or last IP of each subnet
- What are the valid hosts? The numbers between the subnet number and the broadcast address.



Practice Example 2 [3]

Class C

255.255.255.224 (/27)



| | Addresses | Hosts | Network Mask | Amount of Class C sub networks |
|-----|-----------|-------|-----------------|--------------------------------|
| /30 | 4 | 2 | 255.255.255.252 | 1 / 64 |
| /29 | 8 | 6 | 255.255.255.248 | 1 / 32 |
| /28 | 16 | 14 | 255.255.255.240 | 1 / 16 |
| /27 | 32 | 30 | 255.255.255.224 | 1 / 8 |
| /26 | 64 | 62 | 255.255.255.192 | 1 / 4 |
| /25 | 128 | 126 | 255.255.255.128 | 1 / 2 |



Practice Example 2 [4]

Class C

255.255.255.224 (/27)

8 possible subnets

| Network # | IP Range | Broadcast |
|-----------|------------|-----------|
| .0 | .1 - .30 | .31 |
| .32 | .33 - .62 | .63 |
| .64 | .65 - .94 | .95 |
| .96 | .97 - .126 | .127 |

| Network # | IP Range | Broadcast |
|-----------|-------------|-----------|
| .128 | .129 - .158 | .159 |
| .160 | .161 - .190 | .191 |
| .192 | .193 - .222 | .223 |
| .224 | .225 - .254 | .255 |



Practice Example 2 [4]

Class C

255.255.255.224 (/27)

All 8 of the Possible /27 Networks for 192.168.0.*

| Network Address | Usable Host Range | Broadcast Address: |
|-----------------|-------------------------------|--------------------|
| 192.168.0.0 | 192.168.0.1 - 192.168.0.30 | 192.168.0.31 |
| 192.168.0.32 | 192.168.0.33 - 192.168.0.62 | 192.168.0.63 |
| 192.168.0.64 | 192.168.0.65 - 192.168.0.94 | 192.168.0.95 |
| 192.168.0.96 | 192.168.0.97 - 192.168.0.126 | 192.168.0.127 |
| 192.168.0.128 | 192.168.0.129 - 192.168.0.158 | 192.168.0.159 |
| 192.168.0.160 | 192.168.0.161 - 192.168.0.190 | 192.168.0.191 |
| 192.168.0.192 | 192.168.0.193 - 192.168.0.222 | 192.168.0.223 |
| 192.168.0.224 | 192.168.0.225 - 192.168.0.254 | 192.168.0.255 |

Practice Example – Class B

Class B: 255.255.128.0 /17 *(Subnet mask)*
Network 172.16.0.0

255.255.128.0 = 255.255.10000000.00000000

You are subnetting in the 3rd octet

- Number of Subnets? 255.255.10000000.00000000
 - $2^1 = 2$
- Number of Hosts? 255.255.10000000.00000000
 - $2^{15} - 2 = 32,766$ (7 bits in the third octet, and 8 bits in the fourth octet)
- Valid subnets? $256 - 128 = 128.0, 128.$
 - Remember that subnetting is performed in the third octet, so the subnet numbers are really 0.0 and 128.0,





Practice Example – Class B

Class B: 255.255.128.0 /17

| Subnet | 0.0 | 128.0 |
|------------|---------|---------|
| First Host | 0.1 | 128.1 |
| Last Host | 127.254 | 255.254 |
| Broadcast | 127.255 | 255.255 |



Practice Example – Class B

Class B: 255.255.128.0 /17

All 2 of the Possible /17 Networks for 172.16.*.*

| Network Address | Usable Host Range | Broadcast Address: |
|-----------------|-------------------------------|--------------------|
| 172.16.0.0 | 172.16.0.1 - 172.16.127.254 | 172.16.127.255 |
| 172.16.128.0 | 172.16.128.1 - 172.16.255.254 | 172.16.255.255 |

Practice Example 2 – Class B



Class B 255.255.240.0 /20

- Subnets? 255.255.||||0000.00000000
 - $2^4 = 16$.
- Hosts? 255.255.||||0000.00000000
 - $2^{12} - 2 = 4094$.
- Valid subnets? $256 - 240 = 16$
 - Therefore valid subnets: **0, 16, 32, 48, etc.**, up to **240** in the 3rd octet.

*Exercise

- Given the IP Address 172.16.0.0 and subnet mask **255.255.240.0**
- Broadcast addresses (for each of the first 5 subnets)?
- Valid host ranges (for each of the first 5 subnets out of 16 subnets)?



Practice Example 2 – Class B

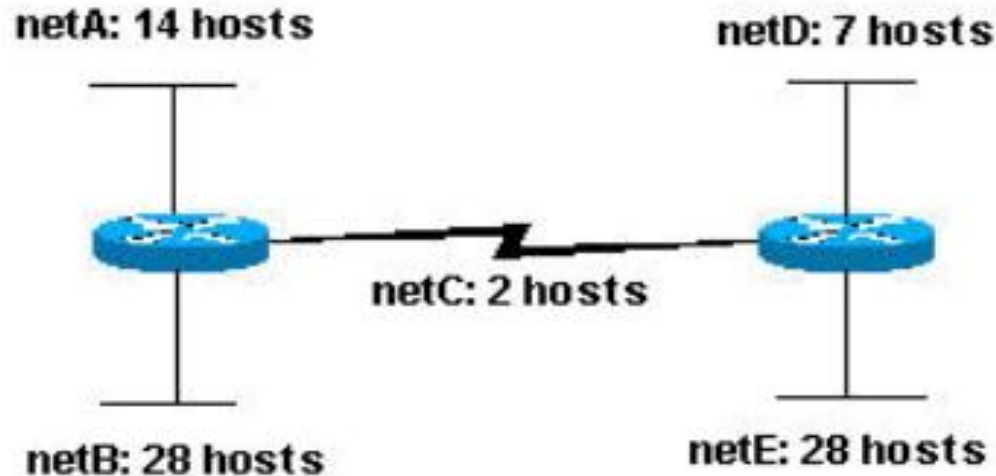
Class B: 255.255.240.0 /20

| | <i>subnet 1</i> | <i>subnet 2</i> | | <i>subnet 16</i> |
|---------------|-----------------|-----------------|--------------|------------------|
| Subnet | 0.0 | 16.0 | | 240.0 |
| First Host | 0.1 | 16.1 | | 240.1 |
| Last Host | 15.254 | 31.254 | | 255.254 |
| Broadcast | 15.255 | 31.255 | | 255.255 |



Variable Length Subnet Mask(VLSM)

VLSM allows you to have subnets of different ranges in a given IP address space



Sample Example 1:

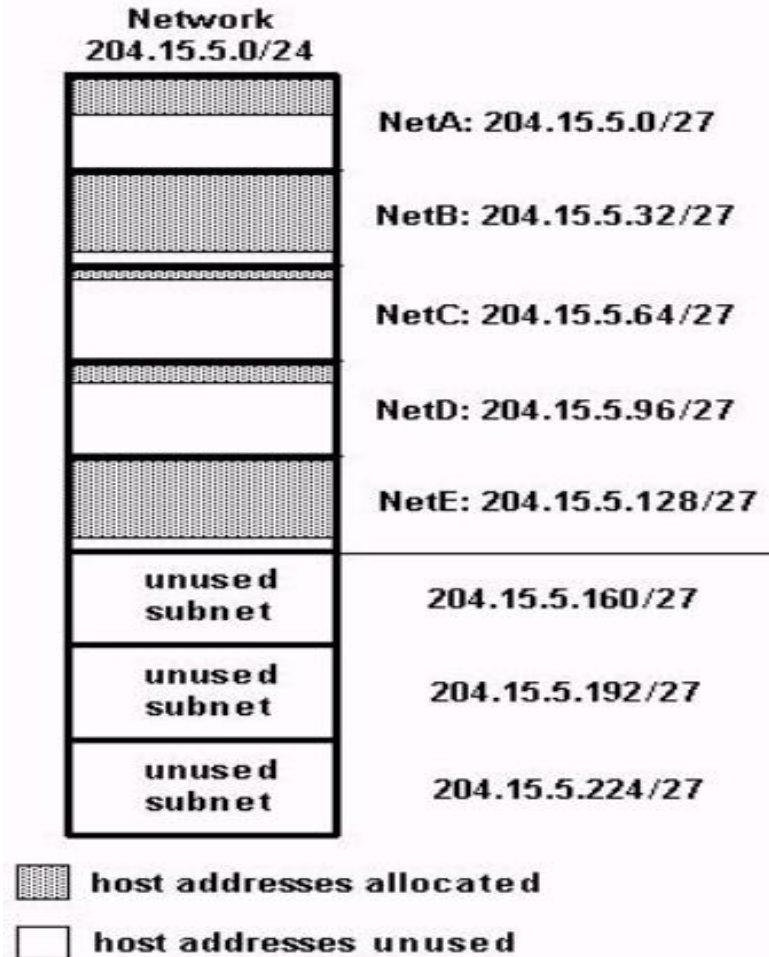
Variable Length Subnet Mask(VLSM)



- 5 subnets needed (*from the previous example*)
- Can be assigned as follows without VLSM:
 - netA: 204.15.5.0/27 host address range 1 to 30
 - netB: 204.15.5.32/27 host address range 33 to 62
 - netC: 204.15.5.64/27 host address range 65 to 94
 - netD: 204.15.5.96/27 host address range 97 to 126
 - netE: 204.15.5.128/27 host address range 129 to 158



Variable Length Subnet Mask(VLSM)





Variable Length Subnet Mask(VLSM)

- Given the same network and requirements as in Sample Example 1, develop a subnetting scheme using VLSM, given that :
 - netA: must support 14 hosts
 - netB: must support 28 hosts
 - netC: must support 2 hosts
 - netD: must support 7 hosts
 - netE: must support 28 hosts



Variable Length Subnet Mask(VLSM)

1) Determine what mask allows the required number of hosts.

- netA: requires a /28 (255.255.255.240) mask to support 14 hosts
- netB: requires a /27 (255.255.255.224) mask to support 28 hosts
- netC: requires a /30 (255.255.255.252) mask to support 2 hosts
- netD: requires a /28 (255.255.255.240) mask to support 7 hosts
- netE: requires a /27 (255.255.255.224) mask to support 28 hosts

Variable Length Subnet Mask(VLSM)



- The easiest way to assign the subnets is to assign the largest first. For example, you can assign in this manner:
 - netB: 204.15.5.0/27 host address range 1 to 30
 - netE: 204.15.5.32/27 host address range 33 to 62
 - netA: 204.15.5.64/28 host address range 65 to 78
 - netD: 204.15.5.80/28 host address range 81 to 94
 - netC: 204.15.5.96/30 host address range 97 to 98

Variable Length Subnet Mask(VLSM)



- netB: 204.15.5.0/27 host address range 1 to 30
- netE: 204.15.5.32/27 host address range 33 to 62
- netA: 204.15.5.64/28 host address range 65 to 78
- netD: 204.15.5.80/28 host address range 81 to 94
- netC: 204.15.5.96/30 host address range 97 to 98

Note: the number difference between each subnet will not be a consistent 32, since VLSMs are being used.

Using VLSM will remove the unused host address (which would occur if VLSM was not used)

Variable Length Subnet Mask(VLSM)

