NET 363
Introduction to LANs

IP Subnets

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IP Address Subnets

- An **IP Address Subnet** is **a group of IP addresses.**
  - All IP addresses within a subnet must be **identical in the first n bits**.
    - Value 'n' is called the prefix length, written "/n"
    - Size of the subnet is $2^{(32-n)}$.
  - First n bits of IP address are Routing Prefix Bits – routers use only these bits in forwarding decisions.
  - Last (32-n) bits of IP address are Host Bits.
  - First IP in a subnet is called the **Network Address**.
    - All Host bits in the Network Address must be 0.
    - Network Address must be a multiple of the subnet size.

Subnet Notation

- IP subnets are written as:

  <Network Address> / <n>

  – This is called a **Subnet ID**.

  – This refers to the full group of addresses.

  – Example: **130.88.55.0/24**

Example

- **130.88.55.0/24** is an IP subnet where
  - First IP address in the subnet is 130.88.55.0
  - First 24 bits (3 bytes) of all addresses in the subnet are identical.
  - There are $2^8 = 256$ IP addresses in subnet.
  - IP addresses in this subnet are:
    - 130.88.55.0
    - 130.88.55.1
    - 130.88.55.2
    - …
    - 130.88.55.254
    - 130.88.55.255

Assignable Host Addresses

- In any subnet, there are **2 IP addresses** that cannot be assigned to any individual device:
  - The first address in the subnet (host bits are all 0s) is the Network Address and cannot be assigned to any device.
  - The last address in the subnet (host bits are all 1s) is the Subnet Broadcast Address and cannot be assigned to any device.
- So, the maximum number of assignable host addresses (also called valid host addresses) is **2 less than the subnet size**.
- Example: For Subnet 130.88.55.0/24, number of assignable host addresses is 256–2 = 254.
  - Network address = 130.88.55.0
  - Assignable host addresses are 130.88.55.1 - 130.88.55.254
  - Broadcast address = 130.88.55.255

Another IP Subnet Example

- **Subnet 140.192.12.8/29** contains IP addresses 140.192.12.8 through 140.192.12.15

Subnet Prefix = 29 bits			Host Bits X = 3		
10001100	11000000	00001100	00001000	=	140.192.12.8
10001100	11000000	00001100	00001001	=	140.192.12.9
10001100	11000000	00001100	00001010	=	140.192.12.10
10001100	11000000	00001100	00001011	=	140.192.12.11
10001100	11000000	00001100	00001100	=	140.192.12.12
10001100	11000000	00001100	00001101	=	140.192.12.13
10001100	11000000	00001100	00001110	=	140.192.12.14
10001100	11000000	00001100	00001111	=	140.192.12.15

Subnet Masks

- A Subnet Mask is an alternate way to specify the prefix length (/n). That is all it does.
- The Subnet Mask corresponding to prefix length /n is a 32-bit binary value with n 1-bits followed by (32-n) 0-bits.
- Example:
  - Prefix length = /20
  - Subnet Mask (binary) = 11111111 11111111 11110000 00000000
  - Subnet Mask (dotted decimal) = 255.255.240.0
- Example:
  - Prefix length = /27
  - Subnet Mask (binary) = 11111111 11111111 11111111 11100000
  - Subnet Mask (dotted decimal) = 255.255.255.224

Subnet Mask – Byte Values

Each 8-bit byte of a subnet mask can have from 0 to 8 1-bits on the left and is filled out with 0-bits on the right. So there are only 9 possible values you will ever find in a subnet mask.

Decimal	Binary	# 1-bits
0	00000000	0
128	10000000	1
192	11000000	2
224	11100000	3
240	11110000	4
248	11111000	5
252	11111100	6
254	11111110	7
255	11111111	8

Subnet Masks

All possible masks shown below, with the equivalent prefix length.

/n	Mask	/n	Mask	/n	Mask	/n	Mask
/1	128.0.0.0	/9	255.128.0.0	/17	255.255.128.0	/25	255.255.255.128
/2	192.0.0.0	/10	255.192.0.0	/18	255.255.192.0	/26	255.255.255.192
/3	224.0.0.0	/11	255.224.0.0	/19	255.255.224.0	/27	255.255.255.224
/4	240.0.0.0	/12	255.240.0.0	/20	255.255.240.0	/28	255.255.255.240
/5	248.0.0.0	/13	255.248.0.0	/21	255.255.248.0	/29	255.255.255.248
/6	252.0.0.0	/14	255.252.0.0	/22	255.255.252.0	/30	255.255.255.252
/7	254.0.0.0	/15	255.254.0.0	/23	255.255.254.0	/31	255.255.255.254
/8	255.0.0.0	/16	255.255.0.0	/24	255.255.255.0	/32	255.255.255.255

Subnet Mask ➔ Size of Subnet

Subnet Mask	/n	Subnet Size
255.255.0.0	/16	65,536
255.255.128.0	/17	32,768
255.255.192.0	/18	16,384
255.255.224.0	/19	8,192
255.255.240.0	/20	4,096
255.255.248.0	/21	2,048
255.255.252.0	/22	1,024
255.255.254.0	/23	512

Subnet Mask	/n	Subnet Size
255.255.255.0	/24	256
255.255.255.128	/25	128
255.255.255.192	/26	64
255.255.255.224	/27	32
255.255.255.240	/28	16
255.255.255.248	/29	8
255.255.255.252	/30	4
255.255.255.254	/31	2

Note: Number of assignable IP addresses in subnet is **Subnet Size – 2**.

Subnet Skills

- What do you need to be able to do?
  - Given any subnet mask, tell me:
    - The equivalent Prefix Length
    - The size (number of IP addresses) in the subnet
  - Given any IP address and a subnet mask, tell me:
    - The Subnet ID for its subnet (Network Address and Prefix Length)
    - First and Last Assignable IP Address in its subnet
    - Broadcast IP address for its subnet
  - Given two IP addresses and a subnet mask, tell me whether they are in the same subnet or different subnets.

Subnet Problem Solution Methods

- Binary Method
  - Given any IP address, find its Network Address by (a) convert IP to binary (b) set all Host bits to 0 (c) convert binary back to IP.
  - Given any IP address, find the Broadcast Address by (a) convert IP to binary (b) set all Host bits to 1 (c) convert binary back to IP.
- Jump Factor Method (or "magic number")
  - For a Prefix Length > 24, **4th Byte Jump Factor (JF) = Subnet Size**
  - For a Prefix Length from 16 to 24, **3rd Byte Jump Factor (JF) = (Subnet Size) / 256 = (256 – 3rd byte of subnet mask)**
  - Given any IP address, its Network Address is the IP address with the largest multiple of JF less than the IP address.
  - Given any IP address, its Broadcast Address is equal to (Network Address) + (Jump Factor) – 1.

Finding Network Address #1

- Example: For IP address 142.69.108.89 and subnet mask 255.255.255.192, what is the Network Address?
  - **Binary method**: There are 6 Host bits in 4th byte. 89 in binary is 01011001. Zeroing out the last 6 bits makes this 01000000 = 64. So subnet ID is **142.69.108.64/26**.
  - **Jump factor method**: Subnet size is 64, so 4th byte of Network Address must be multiple of 64. So possible 4th byte values for Network Addresses are 0, 64, 128, 192. The largest multiple that is less than 89 is 64. So the subnet ID is **142.69.108.64/26**.

Finding Broadcast Address #1

- Example: For IP address 142.69.108.89 and subnet mask 255.255.255.192, what is the Broadcast Address?
  - **Binary method**: There are 6 Host bits in 4th byte. 89 in binary is 01011001. Setting the last 6 bits to 1 makes this 01111111 = 127. So Broadcast IP is **142.69.108.127**.
  - **Jump factor method**: Subnet size is 64, so JF = 64 in 4th byte. Network Address is 142.69.108.64 (see previous slide). So Broadcast IP is 142.69.108.64 + 64 (4th byte) – 1 (4th byte) = **142.69.108.127**

Finding Network Address #2

- Example: For IP address 142.69.108.89 and subnet mask 255.255.240.0, what is the Network Address?
  - **Binary method**: There are 12 Host bits (8 in 4th byte, and 4 in 3rd byte). 3rd byte = 108 = binary 01101100. Zeroing out the last 4 bits of 3rd byte makes this 01100000 = 96. So subnet ID is **142.69.96.0/20**.
  - **Jump factor method**: 3rd byte JF = 16 (because 4096/256=16 or 256-240=16), so 3rd byte of Network Address must be multiple of 16. The largest multiple of 16 that is less than 108 is 96. So the subnet ID is **142.69.96.0/20**.

Finding Broadcast Address #2

- Example: For IP address 142.69.108.89 and subnet mask 255.255.240.0, what is the Broadcast Address?
  - **Binary method**: There are 12 Host bits (8 in 4th byte, and 4 in 3rd byte). 3rd byte = 108 = binary 01101100. Setting Host bits to 1: 3rd byte = 01101111=111; 4th byte = 11111111=255. So Broadcast IP is **142.69.111.255.**
  - **Jump factor method**: 3rd byte JF = 16 (because 4096/256=16 or 256-240=16) and Network Address is 142.69.96.0 (previous slide), so the Broadcast IP is (142.69.96.0 + 16 (3rd byte) – 1 (4th byte)) = 142.69.112.0 – 1 = **142.69.111.255**.

Listing Addresses in a subnet

Subnet ID	Subnet Size	Addresses in Subnet
139.76.0.0/16	2^{16} = 65,536	139.76.0.0 – 139.76.255.255
18.34.6.0/24	2^{8} = 256	18.34.6.0 – 18.34.6.255
63.18.80.0/20	2^{12} = 4096	63.18.80.0 – 63.18.95.255
200.9.52.64/27	2^{5} = 32	200.9.52.64 – 200.9.52.95

Listing Addresses – Try it!

Subnet ID	Subnet Size	Addresses in Subnet
12.16.20.128/25		
58.12.99.48/28		
91.52.69.0/24		
22.69.32.0/19		

Addresses on Same Subnet?

- Example: My laptop's IP address is 142.69.108.13 with subnet mask 255.255.224.0. I'm sending a packet to destination 142.69.125.239. Will this packet be sent through my default gateway router?
- Answer: Calculate subnet IDs (as on previous pages):
  - My subnet ID is **142.69.96.0/19**
  - Destination subnet ID is **142.69.96.0/19**
- Answer: **No**, the packet will not be sent through any router because the destination is on the same subnet as my laptop, so it will use ARP Request to find the destination MAC address.

Default Mask and Prefix

- For any IP address, the default mask is defined to be the subnet mask corresponding to the address class (A, B or C).
  - For Class A addresses: default mask = 255.0.0.0, default prefix = /8.
  - For Class B addresses: default mask = 255.255.0.0, default prefix = /16.
  - For Class C addresses: default mask = 255.255.255.0; default prefix = /24.

Valid Subnet IDs

- A Subnet ID is valid if all the host bits of the network address are 0.
  - 140.192.16.0/20 is a valid Subnet ID
  - 140.192.18.0/20 is not a valid Subnet ID
  - 59.12.6.24/30 is a valid Subnet ID
  - 59.12.6.24/29 is a valid Subnet ID
  - 59.12.6.24/28 is not a valid Subnet ID