

# Network Design Fundamentals

## Internet Protocol: Subnetting

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# Agenda

- Review
  - IP Addressing
    - Format
    - Classfull
    - Reserved
- Subnetting
  - Terms
  - Binary calculations
  - IP subnet calculation

# Review

- RFC 1466 (IPv4)
- Address format:
  - 4 octets, dotted decimal notation
  - Example: 192.168.005.100
  - Applied to any interface that wants to communicate in an IP network
- Purpose:
  - Addresses logically grouped: Subnet
    - Routers “deal in” subnets

# Classful Boundaries – 1<sup>st</sup> Octet

00000000	0	Class A	/
01111111	127		
10000000	128	Class B	/
10111111	191		
11000000	192	Class C	/
11011111	223		
11100000	224	Class D	
11101111	239		

# RFC 1878 and 1918

- reserved: 0.0.0.0 – 0.255.255.255 /8
- Class A: 1.0.0.0 - 127.255.255.255
  - reserved: 10.0.0.0 - 10.255.255.255 /8 (private)
  - reserved: 127.0.0.0 - 127.255.255.255 /8 (loopback)
- Class B: 128.0.0.0 - 191.255.255.255
  - reserved: 128.0.0.0 - 128.255.255.255 /8
  - reserved: 172.16.0.0 - 172.31.255.255 /12 (private)
- Class C: 192.0.0.0 - 223.255.255.255
  - reserved: 192.168.0.0 - 192.168.255.255 /16 (private)
- Class D: 224.0.0.0 – 239.255.255.255
  - reserved: 224.0.0.0 - 225.255.255.255 (Multicast)
- reserved: 255.255.255.255 (Broadcast) /32

# Subnetting Terms

- Address
- Subnet
- Subnet Mask
- Network field (as determined by the Subnet Mask)
- Host field (as determined by the Subnet Mask)
- Subnet ID: all 0's (in the Host field)
- Broadcast ID: all 1's (in the Host field)
- Unicast (useable address on a subnet)
- Host route

# Binary Calculation

## 2 to the power of X

- 4 Octets (a.k.a. Bytes) in a IPv4 address
  - 8 bits in an octet
  - 32 bits in an address
- 8 Bits in each octet
  - $2^8 = 256$ 
    - Decimal number range:  
0 – 255 (256 numbers counting “0”)
    - Binary range:  
00000000 – 11111111 (256 combinations of 1’s and 0’s)

# Decimal to Binary

**255 = 11111111**

**128 = 10000000**

**64 = 01000000**

**32 = 00100000**

**16 = 00010000**

**8 = 00001000**

**4 = 00000100**

**2 = 00000010**

**1 = 00000001**

**0 = 00000000**

**255 = 11111111**

**252 = 11111100**

**248 = 11111000**

**240 = 11110000**

**224 = 11100000**

**192 = 11000000**

**128 = 10000000**

**0 = 00000000**

# Binary Template

always start counting from 0

$$2^x = \begin{array}{cccccccc} \hline & & & & & & & & \\ \hline 128 & 64 & 32 & 16 & 8 & 4 & 2 & 1 \end{array}$$

$$x = \begin{array}{cccccccc} 7 & 6 & 5 & 4 & 3 & 2 & 1 & 0 \end{array}$$

$$\text{Position} = \begin{array}{cccccccc} 8 & 7 & 6 & 5 & 4 & 3 & 2 & 1 \end{array}$$

# Subnet Mask

- Purpose:
  - Apply the Mask to the IP Address to determine:
    - Network bits
    - Host bits
    - Subnet ID, Broadcast ID & Unicast range
- Format:
  - 4 octets, dotted decimal notation (same as IP address)
  - Contiguous binary 1's starting from the left
- Examples:
  - 255.255.255.0 (typical for LAN segment)
  - 255.255.255.252 (typical for WAN pvc)
  - 255.255.255.1 (incorrect)

# Subnet Mask in Binary

- 255.255.255.0
- 11111111.11111111.11111111.00000000
  
- 255.255.255.252
- 11111111.11111111.11111111.11111100
  
- 255.255.255.1 - incorrect
- 11111111.11111111.11111111.00000001

# Subnet Calculation

- Step 1 – Convert:
  - decimal address & mask format to binary address & mask format
- Step 2 – Apply:
  - binary subnet mask to the binary IP address using the “and” function
- Step 3 – Calculate:
  - Subnet ID
  - Broadcast ID
  - Unicast range (usable subnet addresses)

**DECIMAL**

Step 1

XXX = 0 - 255

XXX.XXX.XXX.XXX



Network bits

Host bits

address

185.213.22.219

subnet mask

255.255.255.0

# Step 1

XXXXXXXX = 00000000 - 11111111

XXXXXXXX.XXXXXXXXXX.XXXXXXXXXX.XXXXXXXXXX

BINARY

Network bits      Host bits

10111001.11010101.00010110.11011011

11111111.11111111.11111111.00000000

# Step 2: IP Subnet Calculation

Subnet MASK

<AND>      IP Address

IP Subnet

<AND> Rules:

1 and 1 = 1

1 and 0 = 0

0 and 1 = 0

0 and 0 = 0

Another way:

1 and X = X

0 and X = 0

# Step 3 – IP Subnet – Example 1

185.213.022.219

255.255.255.000 /24

11111111.11111111.11111111.00000000

\_\_\_\_\_ .11010101.00010110.11011011

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\_\_\_\_\_ Subnet ID

\_\_\_\_\_ Broadcast ID

Subnet ID: \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_

Broadcast ID: \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_

Unicast: \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_ - \_\_\_\_\_

# IP Subnet – Example 2

185.213.022.219

255.255.255.252 /30

11111111.11111111.11111111.11111100  
\_\_\_\_\_.11010101.00010110.11011011

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Subnet ID

Broadcast ID

Subnet ID: \_\_\_\_\_.\_\_\_\_\_.\_\_\_\_\_.\_\_\_\_\_

Broadcast ID: \_\_\_\_\_.\_\_\_\_\_.\_\_\_\_\_.\_\_\_\_\_

Unicast: \_\_\_\_\_.\_\_\_\_\_.\_\_\_\_\_.\_\_\_\_\_ - \_\_\_\_\_

# Useable IP Address Calculations

- 1) 32 bits in address
- 2)  $32 - \text{network bits} = \text{host bits}$
- 3)  $2 \text{ to the power of host bits} = \text{addresses on subnet}$
- 4)  $\text{addresses} - 2 \text{ (Broadcast and Subnet ID)}$   
= usable addresses on subnet

$$255.255.255.240 = /28$$

$$32 - 28 = 4$$

$$2^4 = 16 \text{ Addresses on Subnet}$$

$$16 - 2 = 14 \text{ Unicast addresses on Subnet}$$

# Host Route

- Purpose:
  - Used on Loopback and Dial-up interfaces
- Example:
  - 10.5.109.22 255.255.255.255 (/32)

# IP Subnet example 3

- IP Address: \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_
- Subnet Mask: \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_
  - Network bits \_\_\_\_\_ Host bits \_\_\_\_\_
- Subnet: \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_
- Broadcast: \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_
- Usable Range: \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_
- through \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_ . \_\_\_\_\_