Subnetting Notes

What is Subnetting?

Subnetting is the process of dividing a large network into smaller, more manageable sub-networks (subnets) by borrowing bits from the host portion of an IP address to create additional network portions.

Understanding IP Addresses and Octets

What is an IP Address?

An IP address is a 32-bit binary number that uniquely identifies a device on a network. It's represented in dotted decimal notation for human readability.

Binary to Decimal Conversion

- **Binary**: 11000000.10101000.00000001.00001010
- **Decimal**: 192.168.1.10

What are Octets?

An **octet** is a group of 8 bits. Since an IP address is 32 bits, it consists of 4 octets:

- **Octet 1**: Bits 1-8 (leftmost)
- **Octet 2**: Bits 9-16
- **Octet 3**: Bits 17-24
- **Octet 4**: Bits 25-32 (rightmost)

Why xxxxxxxx.xxxxxxxx.xxxxxxxx.xxxxxxxx Format?

The IP address format uses dots to separate octets because:

- **Readability**: Easier for humans to read and remember
- **Standardization**: Universal format across all networking systems
- **Logical Structure**: Each octet represents a different hierarchical level
- **Calculation**: Makes subnetting calculations more manageable

Octet Value Ranges

Each octet can represent values from 0 to 255:

- **Binary**: 00000000 to 11111111
- **Decimal**: 0 to 255
- **Total combinations per octet**: 256 (2^8)

Key Concepts

IP Address Structure

- **Network Portion**: Identifies the network
- **Host Portion**: Identifies the specific device within the network
- **Subnet Mask**: Determines the boundary between network and host portions

Classful vs Classless Addressing

Classful Addressing (Legacy)

- **Class A**: 1.0.0.0 - 126.255.255.255 (Default /8)
  - First octet: 1-126
  - Networks: 126 (2^7 - 2)
  - Hosts per network: 16,777,214 (2^24 - 2)
  - Used for very large networks
- **Class B**: 128.0.0.0 - 191.255.255.255 (Default /16)
  - First octet: 128-191
  - Networks: 16,384 (2^14)
  - Hosts per network: 65,534 (2^16 - 2)
  - Used for medium-sized networks
- **Class C**: 192.0.0.0 - 223.255.255.255 (Default /24)
  - First octet: 192-223
  - Networks: 2,097,152 (2^21)
  - Hosts per network: 254 (2^8 - 2)
  - Used for small networks
- **Class D**: 224.0.0.0 - 239.255.255.255 (Multicast)
- **Class E**: 240.0.0.0 - 255.255.255.255 (Reserved/Experimental)

Classful Subnetting Examples

Class A Subnetting (10.0.0.0/8)

- Original: 10.0.0.0/8 (16,777,214 hosts)
- Subnet to /16: Creates 256 subnets with 65,534 hosts each
- Subnet to /24: Creates 65,536 subnets with 254 hosts each

Class B Subnetting (172.16.0.0/16)

- Original: 172.16.0.0/16 (65,534 hosts)
- Subnet to /24: Creates 256 subnets with 254 hosts each
- Subnet to /25: Creates 512 subnets with 126 hosts each

Class C Subnetting (192.168.1.0/24)

- Original: 192.168.1.0/24 (254 hosts)
- Subnet to /25: Creates 2 subnets with 126 hosts each
- Subnet to /26: Creates 4 subnets with 62 hosts each
- Subnet to /27: Creates 8 subnets with 30 hosts each

Classless Addressing (CIDR - Modern)

- Subnet mask can be configured independently of IP address class
- More flexible and efficient use of IP addresses
- Uses CIDR notation (e.g., /24, /16, /8)

Why Do We Subnet?

1. Network Organization

- Logically separate departments, floors, or functions
- Example: HR subnet, IT subnet, Guest subnet

2. Improved Security

- Control traffic flow between segments
- Implement firewalls and access control lists
- Limit security breach impact (blast radius)

3. Reduced Network Congestion

- Smaller broadcast domains
- Less broadcast traffic in each segment
- Better overall network performance

4. Efficient IP Address Usage

- Avoid IP address waste
- Allocate appropriate address spaces based on needs
- Better resource management

5. Better Network Management

- Easier troubleshooting and monitoring
- Simplified network administration
- Clearer network topology

Common Subnet Masks

CIDR	Subnet Mask	Network Bits	Host Bits	Max Hosts
/8	255.0.0.0	8	24	16,777,214
/16	255.255.0.0	16	16	65,534
/24	255.255.255.0	24	8	254
/25	255.255.255.128	25	7	126
/26	255.255.255.192	26	6	62
/27	255.255.255.224	27	5	30
/28	255.255.255.240	28	4	14
/29	255.255.255.248	29	3	6
/30	255.255.255.252	30	2	2

IP Address Calculation Methods

Total IP Addresses in a Network

Formula: 2^(host bits)

- /24 network: 2^8 = 256 total addresses
- /16 network: 2^16 = 65,536 total addresses
- /8 network: 2^24 = 16,777,216 total addresses

Usable Host Addresses

Formula: 2^(host bits) - 2

- Subtract 2 for network address and broadcast address
- /24 network: 2^8 - 2 = 254 usable addresses
- /16 network: 2^16 - 2 = 65,534 usable addresses

Number of Subnets

Formula: 2^(borrowed bits)

- If you borrow 4 bits for subnetting: 2^4 = 16 subnets
- If you borrow 8 bits for subnetting: 2^8 = 256 subnets

Subnet Increment/Block Size

Formula: 256 - subnet mask value

- /25 (255.255.255.128): 256 - 128 = 128 (block size)
- /26 (255.255.255.192): 256 - 192 = 64 (block size)
- /27 (255.255.255.224): 256 - 224 = 32 (block size)

Detailed Calculation Examples

Example 1: Class C Subnetting (192.168.1.0/24 to /26)

Original Network: 192.168.1.0/24

- Subnet Mask: 255.255.255.0
- Host bits: 8
- Total addresses: 2^8 = 256
- Usable hosts: 254

After Subnetting to /26:

- New Subnet Mask: 255.255.255.192
- Borrowed bits: 2 (from 24 to 26)
- Number of subnets: 2^2 = 4
- Host bits remaining: 6
- Hosts per subnet: 2^6 - 2 = 62
- Block size: 256 - 192 = 64

Subnet Breakdown:

1. 192.168.1.0/26 (192.168.1.1 - 192.168.1.62)
2. 192.168.1.64/26 (192.168.1.65 - 192.168.1.126)
3. 192.168.1.128/26 (192.168.1.129 - 192.168.1.190)
4. 192.168.1.192/26 (192.168.1.193 - 192.168.1.254)

Example 2: Class B Subnetting (172.16.0.0/16 to /20)

Original Network: 172.16.0.0/16

- Subnet Mask: 255.255.0.0
- Host bits: 16
- Total addresses: 2^16 = 65,536

- Usable hosts: 65,534

After Subnetting to /20:

- New Subnet Mask: 255.255.240.0
- Borrowed bits: 4 (from 16 to 20)
- Number of subnets: 2^4 = 16
- Host bits remaining: 12
- Hosts per subnet: 2^12 - 2 = 4,094
- Block size: 256 - 240 = 16

Subnet Breakdown (first few):

1. 172.16.0.0/20 (172.16.0.1 - 172.16.15.254)
2. 172.16.16.0/20 (172.16.16.1 - 172.16.31.254)
3. 172.16.32.0/20 (172.16.32.1 - 172.16.47.254)
4. 172.16.48.0/20 (172.16.48.1 - 172.16.63.254)

Example 3: Class A Subnetting (10.0.0.0/8 to /12)

Original Network: 10.0.0.0/8

- Subnet Mask: 255.0.0.0
- Host bits: 24
- Total addresses: 2^24 = 16,777,216
- Usable hosts: 16,777,214

After Subnetting to /12:

- New Subnet Mask: 255.240.0.0
- Borrowed bits: 4 (from 8 to 12)
- Number of subnets: 2^4 = 16
- Host bits remaining: 20
- Hosts per subnet: 2^20 - 2 = 1,048,574
- Block size: 256 - 240 = 16

Subnet Breakdown (first few):

1. 10.0.0.0/12 (10.0.0.1 - 10.15.255.254)
2. 10.16.0.0/12 (10.16.0.1 - 10.31.255.254)
3. 10.32.0.0/12 (10.32.0.1 - 10.47.255.254)

Binary Representation and Calculations

Converting Decimal to Binary

Example: 192.168.1.10

- 192 = 11000000
- 168 = 10101000
- 1 = 00000001
- 10 = 00001010
- **Full Binary**: 11000000.10101000.00000001.00001010

Subnet Mask in Binary

Example: 255.255.255.192 (/26)

- 255 = 11111111
- 255 = 11111111
- 255 = 11111111
- 192 = 11000000
- **Network bits**: 26 ones, **Host bits**: 6 zeros

Finding Network Address

Method: Perform bitwise AND between IP and subnet mask

- IP: 192.168.1.75 (11000000.10101000.00000001.01001011)
- Mask: 255.255.255.192 (11111111.11111111.11111111.11000000)
- **Network**: 192.168.1.64 (11000000.10101000.00000001.01000000)

Subnetting Examples

Basic Examples

- Network: 192.168.1.0/24
- Subnet Mask: 255.255.255.0
- Usable Range: 192.168.1.1 - 192.168.1.254
- Broadcast: 192.168.1.255

Example 2: /16 Network with /24 Subnets

Concept: Taking a /16 network and dividing it into /24 subnets

Starting Network: 192.168.0.0/16

- Subnet Mask: 255.255.0.0
- Total address space: 192.168.0.0 to 192.168.255.255
- Total addresses: 65,536

Creating /24 Subnets:

- Each /24 subnet uses 8 additional bits (from 16 to 24)
- Number of /24 subnets: 2^8 = 256
- Hosts per /24 subnet: 2^8 - 2 = 254

Subnet List:

```
192.168.0.0/24   (192.168.0.1 - 192.168.0.254)
192.168.1.0/24   (192.168.1.1 - 192.168.1.254)
192.168.2.0/24   (192.168.2.1 - 192.168.2.254)
...
192.168.255.0/24 (192.168.255.1 - 192.168.255.254)
```

Practical Use:

- Organization gets 192.168.0.0/16 allocation
- IT Department: 192.168.1.0/24
- HR Department: 192.168.2.0/24
- Finance: 192.168.3.0/24
- Guest Network: 192.168.100.0/24
- Network: 192.168.0.0/16
- Can be divided into 256 /24 subnets:
  - 192.168.0.0/24
  - 192.168.1.0/24
  - 192.168.2.0/24
  - ... up to 192.168.255.0/24

Example 3: Variable Length Subnet Masking (VLSM)

Network: 192.168.1.0/24 divided into:

- Subnet 1: 192.168.1.0/26 (62 hosts) - for main office
- Subnet 2: 192.168.1.64/27 (30 hosts) - for branch office
- Subnet 3: 192.168.1.96/28 (14 hosts) - for servers
- Subnet 4: 192.168.1.112/30 (2 hosts) - for point-to-point links

Important Network vs Subnet Distinction

Network Level

- Defined by the overall address space allocation
- Example: 192.168.0.0/16 is a network

Subnet Level

- Actual configured segments within the network
- Example: 192.168.1.0/24 and 192.168.5.0/24 are subnets within the 192.168.0.0/16 network

Key Point

- 192.168.1.10/16 and 192.168.5.20/16 are on the same **network**
- But they are on different **subnets** (192.168.1.0/24 vs 192.168.5.0/24)
- Communication depends on the actual subnet mask configured on devices

Subnetting Process

Step 1: Determine Requirements

- Number of subnets needed
- Number of hosts per subnet
- Future growth considerations

Step 2: Choose Subnet Mask

- Calculate bits needed for required subnets
- Calculate bits needed for required hosts
- Ensure total bits don't exceed available host bits

Step 3: Calculate Subnet Addresses

- Determine network addresses for each subnet
- Identify usable host ranges
- Identify broadcast addresses

Step 4: Document and Implement

- Create subnet allocation table
- Configure devices with appropriate subnet masks
- Update routing tables and documentation

Best Practices

Planning

- Always plan for future growth
- Use consistent subnet sizing where possible
- Document all subnet allocations

Security

- Implement proper inter-subnet routing controls
- Use VLANs to match IP subnets
- Regular security audits of subnet configurations

Management

- Use descriptive naming conventions
- Maintain accurate network documentation
- Monitor subnet utilization

Common Mistakes to Avoid

1. **Overlapping subnets** - Ensure subnet ranges don't overlap
2. **Insufficient host addresses** - Plan for growth and overhead
3. **Incorrect subnet mask configuration** - Verify masks match network design
4. **Forgetting network and broadcast addresses** - These are not usable for hosts
5. **Ignoring VLSM benefits** - Use variable-length subnets for efficiency

Quick Reference Formulas

- **Number of subnets**: 2^(borrowed bits)
- **Number of hosts per subnet**: 2^(host bits) - 2
- **Subnet increment**: 256 - subnet mask value in relevant octet
- **Network address**: First address in subnet range
- **Broadcast address**: Last address in subnet range
- **Usable host range**: Network address + 1 to Broadcast address - 1