Complete Subnetting Study Notes - Classful Addressing

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1. Introduction to Subnetting {#introduction}

Definition

Subnetting is the process of dividing a big network into smaller networks (subnets).

Context

- Discussed under **classful addressing**
- IP addresses are divided into classes: A, B, C, D, E
- One of the most important topics in computer networks
- Students often get confused about the concept and implementation

Key Concept

- Take a large network and logically divide it into multiple smaller networks
- This division is done internally within an organization

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2. Why Subnetting is Done - Purpose and Benefits {#purpose}

Problem with Large Networks

Example: Class A Network

- **Class A** can support 2^{24} hosts (approximately 16 million hosts)
- Managing such a large number of hosts is extremely difficult

- Single administrator cannot effectively manage millions of hosts

Real-World Analogy: University Example

Consider a **big university** with different departments:

- **Examination Department**
- **Placement Department**
- **Co-curricular Activities Department**
- **Academics Department**
- **Library System**

Without Subnetting (Single Administrator)

- One administrator manages all departments
- Very difficult to maintain and manage
- Inefficient resource allocation

With Subnetting (Logical Division)

- **Subnet 1**: Examination Department only
- **Subnet 2**: Placement Department only
- **Subnet 3**: Academics Department only
- **Subnet 4**: Co-curricular Activities Department only

Each subnet has its own **network administrator** responsible for their respective subnet.

Primary Benefits

1. Easy Maintenance and Management

- Separate network administrators for each subnet
- Each admin manages their own subnet independently
- Easier to troubleshoot and maintain

2. Reduced Wastage

- Class A networks have millions of possible hosts
- Most organizations don't need that many hosts
- Subnetting reduces IP address wastage

3. Enhanced Security

In large organizations:

- Need to authorize each host individually
- Users need passwords and IP addresses
- Difficult to manage security for millions of hosts

With subnetting:

- Each department has separate security policies
- Enhanced security through logical separation
- Easier to implement access controls

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3. How Subnetting Works - Implementation {#implementation}

Basic Principle

Subnetting is implemented by **reserving host bits** to create subnet identifiers.

Key Rules

1. **Network bits must remain unchanged**
   - Never disturb the network portion of the IP address
   - Changing network bits changes the entire network destination
2. **Reserve host bits for subnetting**
   - Take bits from the host portion
   - Use these bits to identify different subnets

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4. Detailed Example: Class C Subnetting {#detailed-example}

Given Network

Network Address: `200.10.20.0`

Step 1: Verify Class C

- First octet: **200**
- Class C range: **192-223**
- ✓ Confirmed as Class C network

Step 2: Analyze Original Network

- **Total IP addresses**: 256 (0-255)
- **Network ID**: `200.10.20.0` (first address)
- **Broadcast address**: `200.10.20.255` (last address)
- **Usable host addresses**: 254 (total - 2)
- **Usable range**: `200.10.20.1` to `200.10.20.254`

Step 3: Divide into 2 Subnets

Binary Analysis

Last octet breakdown:

```
Positions: 1  2  3  4  5  6  7  8
           |  |  |  |  |  |  |  |
           MSB                LSB
```

Subnet Division Process

1. **Reserve 1 bit** (MSB) for subnet identification
2. **Remaining 7 bits** for host identification within each subnet

Subnet 1 (S1)

- **Reserved bit**: 0 (fixed)
- **Host bits**: 0000000 to 1111111
- **Range calculation**:

  ```
  Start: 0 0000000 = 0
  End:   0 1111111 = 127
  ```

- **Subnet range**: `200.10.20.0` to `200.10.20.127`

Subnet 2 (S2)

- **Reserved bit**: 1 (fixed)
- **Host bits**: 0000000 to 1111111
- **Range calculation**:

```
Start: 1 0000000 = 128
End:   1 1111111 = 255
```

- **Subnet range**: `200.10.20.128` to `200.10.20.255`

Step 4: Complete Subnet Analysis

Subnet 1 (S1)

- **Subnet ID**: `200.10.20.0`
- **Range**: `200.10.20.0` to `200.10.20.127`
- **Broadcast address**: `200.10.20.127`
- **Total addresses**: 128
- **Usable addresses**: 126 (128 - 2)
- **Usable range**: `200.10.20.1` to `200.10.20.126`

Subnet 2 (S2)

- **Subnet ID**: `200.10.20.128`
- **Range**: `200.10.20.128` to `200.10.20.255`
- **Broadcast address**: `200.10.20.255`
- **Total addresses**: 128
- **Usable addresses**: 126 (128 - 2)
- **Usable range**: `200.10.20.129` to `200.10.20.254`

Step 5: Impact Analysis

- **Before subnetting**: 254 usable addresses
- **After subnetting**: 252 usable addresses (126 + 126)
- **Loss**: 2 addresses (due to additional subnet IDs and broadcast addresses)

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5. Subnet Mask Calculation {#subnet-mask}

Understanding the Need

External routers need to know about internal subnetting to route packets correctly.

Default vs Subnet Mask

Default Class C Mask

```
255.255.255.0
```

- Binary: `11111111.11111111.11111111.00000000`
- Used by external routers

Subnet Mask Calculation

1. **Start with default mask**: `255.255.255.`
2. **Add reserved bits**: We reserved 1 bit
3. **Binary representation**: `1` followed by `7 zeros`

   ```
   Binary: 10000000
   Decimal: 128
   ```

4. **Final subnet mask**: `255.255.255.128`

General Formula

```
Number of reserved bits = n
Subnet mask last octet = 2^(8-n) * (2^n - 1) + 2^(8-n)
```

For 1 reserved bit: `128` For 2 reserved bits: `192` For 3 reserved bits: `224`

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6. Routing with Subnets {#routing}

Network Infrastructure

External Gateway Router

- **Purpose**: Routes packets from outside world to the organization
- **Mask used**: Default mask (`255.255.255.0`)
- **Knowledge**: Only knows about main network `200.10.20.0`

Internal Router

- **Purpose**: Routes packets between subnets within organization
- **Mask used**: Subnet mask (`255.255.255.128`)
- **Knowledge**: Knows about internal subnet structure

Routing Examples

Example 1: Packet to Address `200.10.20.15`

Step 1: Internal router receives packet

- Destination: `200.10.20.15`
- Subnet mask: `255.255.255.128`

Step 2: Binary masking operation

```
Address:    200.10.20.15
Binary:     11001000.00001010.00010100.00001111
                             ^^^^^^^^
Subnet mask: 255.255.255.128
Binary:     11111111.11111111.11111111.10000000
                             ^^^^^^^^
Result:     11001000.00001010.00010100.00000000
Decimal:    200.10.20.0
```

Step 3: Subnet identification

- Result: `200.10.20.0` = Subnet 1 ID
- **Routing decision**: Forward to Subnet 1

Example 2: Packet to Address `200.10.20.130`

Step 1: Binary masking operation

```
Address:    200.10.20.130
Binary:     11001000.00001010.00010100.10000010
                             ^^^^^^^^
Subnet mask: 255.255.255.128
Binary:     11111111.11111111.11111111.10000000
                             ^^^^^^^^
Result:     11001000.00001010.00010100.10000000
Decimal:    200.10.20.128
```

Step 2: Subnet identification

- Result: `200.10.20.128` = Subnet 2 ID
- **Routing decision**: Forward to Subnet 2

House Analogy

Think of subnetting like a house with multiple rooms:

- **House number** = Network ID (visible from outside)
- **Rooms inside** = Subnets (internal organization)
- **Street address** = External router knowledge
- **Room layout** = Internal router knowledge

Someone outside knows the house number (180), but doesn't know the internal room structure. The internal routing system directs visitors to the correct room.

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7. Advantages and Disadvantages {#pros-cons}

Advantages

1. Easy Maintenance

- Separate administrators for each subnet
- Independent management of different departments
- Localized troubleshooting

2. Enhanced Security

- Logical separation between departments
- Department-specific security policies
- Controlled inter-subnet communication

3. Reduced IP Wastage

- Better utilization of available IP addresses
- Appropriate subnet sizes for different needs

4. Scalability

- Can create multiple subnets as needed
- Flexible network design

Disadvantages

1. Increased Routing Complexity

Traditional routing (3 steps):

1. Find Network ID
2. Find Host within network
3. Find Process (Port) within host

Subnetting routing (4 steps):

1. Find Network ID
2. **Find Subnet within network** ← Additional step
3. Find Host within subnet
4. Find Process (Port) within host

2. Additional Overhead

- More complex routing tables
- Additional processing for subnet identification
- Increased computational requirements

3. IP Address Loss

- Each subnet requires its own network ID and broadcast address
- Reduces total usable IP addresses
- Example: 254 → 252 usable addresses (loss of 2)

Summary

Subnetting is a fundamental networking concept that provides:

✅ **Better network management and organization** ✅ **Enhanced security through logical separation** ✅ **Reduced IP address wastage** ✅ **Scalable network architecture**

❌ **Increased routing complexity** ❌ **Additional computational overhead** ❌ **Slight reduction in usable IP addresses**

The benefits generally outweigh the disadvantages, making subnetting essential for large organizational networks.

Quick Reference

Key Formulas

- **Number of subnets**: 2^n (where n = reserved bits)

- **Hosts per subnet**: 2^(remaining bits) - 2
- **Subnet mask calculation**: Default mask + (2^n × subnet bits)

Common Subnet Masks (Class C)

- 1 subnet bit: `255.255.255.128` (2 subnets, 126 hosts each)
- 2 subnet bits: `255.255.255.192` (4 subnets, 62 hosts each)
- 3 subnet bits: `255.255.255.224` (8 subnets, 30 hosts each)