UNIT 2: Addressing & Routing Design

IPv4 & IPv6 Design, Sub-netting Techniques, Routing Protocols Overview, OSPF & EIGRP Concepts, Route Summarization.

IPv4 & IPv6 Design

What is IP Address?

An **IP Address (Internet Protocol Address)** is a unique address used to identify devices in a network.

Example:

- Computer
- Mobile phone
- Printer
- Server

Two main versions:

1. **IPv4** (Internet Protocol Version 4)
2. **IPv6** (Internet Protocol Version 6)

1. IPv4 Design

Introduction

IPv4 is the fourth version of Internet Protocol and the most widely used protocol.

Features

- 32-bit address
- Written in decimal format
- Divided into 4 octets
- Supports about **4.3 billion addresses**

Example
192.168.1.1

IPv4 Structure

IPv4 uses **32 bits**.

Example:

11000000.10101000.00000001.00000001

Decimal form:

192.168.1.1

IPv4 Address Classes

Class	Range	Default Subnet Mask	Usage
A	1 – 126	255.0.0.0	Large networks
B	128 – 191	255.255.0.0	Medium networks
C	192 – 223	255.255.255.0	Small networks
D	224 – 239	Multicast	Group communication
E	240 – 255	Experimental	Research

IPv4 Advantages

- Simple design
- Easy implementation
- Supported by almost all devices

IPv4 Disadvantages

- Limited addresses
- Requires NAT
- Less security
- Broadcast traffic causes congestion

2. IPv6 Design

Introduction

IPv6 was developed to solve IPv4 address shortage.

Features

- 128-bit address
- Huge number of addresses
- Better security
- Faster routing

Example
2001:0db8:85a3:0000:0000:8a2e:0370:7334

Short form:

2001:db8:85a3::8a2e:370:7334

IPv6 Structure

IPv6 uses **128 bits**.

It is divided into 8 groups.

Example:

2001:0db8:0000:0000:0000:ff00:0042:8329

IPv6 Advantages

- Very large address space
- Built-in security (IPSec)
- No NAT required
- Better performance
- Auto configuration support

IPv6 Disadvantages

- Complex implementation
- Expensive upgrade
- Not fully supported in old devices

IPv4 vs IPv6 Comparison

Feature	IPv4	IPv6
Address Size	32-bit	128-bit
Address Format	Decimal	Hexadecimal
Number of Addresses	4.3 Billion	Almost Unlimited
Security	Optional	Built-in
NAT	Required	Not Required
Configuration	Manual/DHCP	Auto Configuration
Header Size	Variable	Fixed

Simple Network Design Example

IPv4 Network

PC1 ---- Switch ---- Router ---- Internet
192.168.1.0/24

IPv6 Network

PC1 ---- Switch ---- Router ---- Internet
2001:db8:1::/64

Subnetting Techniques

What is Subnetting?

Subnetting is the process of dividing one large network into smaller networks called **subnets**.

It improves:

- Network performance
- Security
- Traffic management
- Efficient IP address usage

Why Subnetting is Needed?

Without subnetting:

- Large broadcast traffic
- Network congestion
- Wastage of IP addresses
- Difficult network management

With subnetting:

- Better organization
- Faster communication
- Improved security

Basic Terms

Term	Meaning
IP Address	Unique address of device
Network ID	Identifies network
Host ID	Identifies device
Subnet Mask	Separates network and host part
CIDR	Classless Inter-Domain Routing

Subnet Mask

Subnet mask identifies:

- Network portion
- Host portion

Example:

255.255.255.0

Binary:

11111111.11111111.11111111.00000000

Types of Subnetting Techniques

1. Fixed Length Subnet Mask (FLSM)

All subnets use:

- Same subnet mask
- Same number of hosts

Example

Given network:

192.168.1.0/24

Need: 4 subnets

Borrow 2 bits:

22=42^2=422=4

New subnet mask:

/26

FLSM Subnets

Subnet	Network Address	Host Range	Broadcast
1	192.168.1.0/26	1 – 62	63
2	192.168.1.64/26	65 – 126	127
3	192.168.1.128/26	129 – 190	191
4	192.168.1.192/26	193 – 254	255

2. Variable Length Subnet Mask (VLSM)

Different subnet sizes use:

- Different subnet masks

Efficient IP usage.

Example of VLSM

Given Network:

192.168.10.0/24

Requirements:

- HR → 100 hosts
- Sales → 50 hosts
- Admin → 25 hosts

Step 1: Largest Network First

HR Department

Need 100 hosts:

27−2=1262^7-2=12627−2=126

Use:

/25

Range:

192.168.10.0 – 192.168.10.127

Sales Department

Need 50 hosts:

26−2=622^6-2=6226−2=62

Use:

/26

Range:

192.168.10.128 – 192.168.10.191

Admin Department

Need 25 hosts:

25−2=302^5-2=3025−2=30

Use:

/27

Range:

192.168.10.192 – 192.168.10.223

Subnetting Benefits

- Better security
- Reduced traffic
- Improved performance
- Efficient bandwidth usage
- Easier troubleshooting

IPv6 Subnetting

IPv6 uses prefixes instead of traditional subnet masks.

Example:

2001:db8:1::/64

Common subnet sizes:

- /64
- /48
- /56

Difference Between FLSM and VLSM

Feature	FLSM	VLSM
Subnet Size	Same	Different
Flexibility	Low	High
IP Usage	Less efficient	Efficient
Complexity	Simple	Complex

Routing Protocols Overview

What is Routing?

Routing is the process of transferring data packets from one network to another network using a **router**.

Routers select the best path for data communication.

What is a Routing Protocol?

A **Routing Protocol** is a set of rules used by routers to:

- Share network information
- Discover routes
- Select best paths
- Update routing tables

Functions of Routing Protocols

- Path determination
- Route maintenance
- Network discovery
- Loop prevention
- Fast communication

Types of Routing

1. Static Routing

Routes are manually configured by administrator.

Advantages

- Simple
- Secure
- No routing overhead

Disadvantages

- Difficult in large networks
- No automatic updates

2. Dynamic Routing

Routers automatically learn routes using routing protocols.

Advantages

- Automatic updates
- Scalable
- Better fault tolerance

Disadvantages

- Complex
- Uses CPU and bandwidth

Classification of Routing Protocols

Interior Gateway Protocol (IGP)

Used inside one organization/network.

Examples:

- RIP
- OSPF
- EIGRP

Exterior Gateway Protocol (EGP)

Used between different organizations.

Example:

- BGP

Main Routing Protocols

1. RIP (Routing Information Protocol)

Features

- Distance Vector protocol
- Uses hop count
- Maximum 15 hops
- Slow convergence

Metric

Metric=Hop Count\text{Metric} = \text{Hop Count}Metric=Hop Count

Advantages

- Easy configuration
- Simple design

Disadvantages

- Slow
- Limited network size

RIP Network Example

PC --- Router A --- Router B --- Server

RIP counts number of routers between source and destination.

2. OSPF (Open Shortest Path First)

Features

- Link State protocol
- Fast convergence

- Uses Dijkstra algorithm
- Supports large networks

Metric

Cost=Reference BandwidthInterface Bandwidth\text{Cost} = \frac{\text{Reference Bandwidth}}{\text{Interface Bandwidth}}Cost=Interface BandwidthReference Bandwidth

Advantages

- Fast
- Scalable
- Efficient routing

Disadvantages

- Complex configuration
- Higher memory usage

OSPF Design

Area 0 (Backbone Area)
|

| | |
R1 R2 R3

3. EIGRP (Enhanced Interior Gateway Routing Protocol)

Developed by Cisco.

Features

- Hybrid routing protocol
- Fast convergence
- Uses bandwidth and delay metrics

Metric Formula

Metric=(Bandwidth+Delay)×256\text{Metric} = (\text{Bandwidth} + \text{Delay}) \times 256Metric=(Bandwidth+Delay)×256

Advantages

- Very fast
- Efficient bandwidth usage

Disadvantages

- Mostly Cisco-based networks

4. BGP (Border Gateway Protocol)

Used on the Internet between organizations and ISPs.

Features

- Path Vector protocol
- Very scalable
- Policy-based routing

Advantages

- Internet-scale routing
- Reliable

Disadvantages

- Complex configuration
- Slow convergence

BGP Example

ISP 1 ---- ISP 2 ---- ISP 3

OSPF & EIGRP Concepts

Introduction

Both **OSPF** and **EIGRP** are dynamic routing protocols used in computer networks.

They help routers:

- Discover networks
- Exchange routing information
- Select the best path
- Update routing tables automatically

1. OSPF (Open Shortest Path First)

Definition

OSPF is a **Link-State Routing Protocol** used inside an organization.

It uses the **Dijkstra Shortest Path First (SPF)** algorithm to find the shortest path.

Features of OSPF

- Open standard protocol

- Fast convergence
- Supports large networks
- Hierarchical design
- Uses areas
- Supports VLSM and CIDR

OSPF Working Process

1. Neighbor discovery
2. Exchange link-state information
3. Build topology database
4. Run SPF algorithm
5. Create routing table

OSPF Packet Types

Packet Type	**Purpose**
Hello	Discover neighbors
DBD	Database description
LSR	Link-state request
LSU	Link-state update
LSAck	Acknowledgment

OSPF Areas

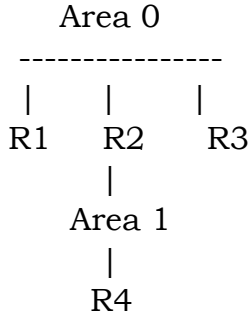
OSPF divides networks into areas.

Backbone Area

Area 0

All other areas connect to Area 0.

OSPF Design Example



OSPF Neighbor States

State	Meaning
Down	No communication
Init	Hello received
2-Way	Bidirectional communication
ExStart	Database exchange begins
Exchange	Routing info exchange
Full	Fully connected

Advantages of OSPF

- Fast convergence
- Scalable
- Efficient routing
- Loop-free design

Disadvantages of OSPF

- Complex configuration
- Higher CPU and memory usage

2. EIGRP (Enhanced Interior Gateway Routing Protocol)

Developed by Cisco.

Definition

EIGRP is a **Hybrid Routing Protocol** combining:

- Distance Vector features
- Link-State features

Features of EIGRP

- Fast convergence
- Supports VLSM
- Uses DUAL algorithm
- Low bandwidth usage
- Partial updates only

EIGRP Working

1. Neighbor discovery
2. Exchange routing information

3. Build topology table
4. Select best route
5. Update routing table

EIGRP Tables

Table	**Purpose**
Neighbor Table	Stores neighbors
Topology Table	Stores routes
Routing Table	Best routes

EIGRP Metric

EIGRP uses:

- Bandwidth
- Delay
- Reliability
- Load
- MTU

Advantages Comparison

OSPF

- Vendor independent
- Large network support

EIGRP

- Faster convergence
- Lower bandwidth usage

Disadvantages Comparison

OSPF

- Complex setup

EIGRP

- Limited vendor support

Route Summarization

Route Summarization is the process of combining multiple network routes into a single summarized route.

It reduces:

- Routing table size
- CPU usage
- Memory usage
- Routing updates

Another name:

- **Route Aggregation**
- **Supernetting**

Why Route Summarization is Important?

Without summarization:

- Large routing tables
- More bandwidth consumption
- Slow routing updates

With summarization:

- Smaller routing tables
- Faster routing
- Better performance
- Improved scalability

Basic Idea

Instead of advertising many routes separately:

192.168.1.0/24
192.168.2.0/24
192.168.3.0/24
192.168.4.0/24

We combine them into one summarized route.

Example of Route Summarization

Networks:

192.168.0.0/24
192.168.1.0/24
192.168.2.0/24
192.168.3.0/24

Summarized route:

192.168.0.0/22

Binary Understanding

Convert to Binary

Network	**Binary**
192.168.0.0	11000000.10101000.00000000
192.168.1.0	11000000.10101000.00000001
192.168.2.0	11000000.10101000.00000010
192.168.3.0	11000000.10101000.00000011

Common bits determine summary prefix.

Formula for Number of Networks

2n2^n2n

Where:

- n = borrowed bits

CIDR Notation

Example:

10.0.0.0/8

- /8 → Network prefix length

Steps in Route Summarization

1. Write network addresses
2. Convert to binary
3. Find common bits
4. Count common prefix
5. Create summarized route

Route Summarization

Example

Networks:

172.16.0.0/24
172.16.1.0/24
172.16.2.0/24
172.16.3.0/24

Summary:

172.16.0.0/22

Summarization in Routing Protocols

RIP

Supports manual summarization.

OSPF

Supports summarization:

- Between areas
- At ABR (Area Border Router)

OSPF Design

Area 1 ---- ABR ---- Area 0

ABR performs summarization.

EIGRP

Supports:

- Automatic summarization
- Manual summarization

Developed by Cisco.

BGP Summarization

BGP uses aggregation to reduce Internet routing table size.

IPv6 Route Summarization

IPv6 also supports summarization.

Example:

2001:db8:1::/48

Real World Example

Large companies summarize routes:

- Reduces router workload
- Improves WAN performance

ISPs use summarization for Internet scalability.