Routing Protocols - Complete Study Notes

1. Introduction to Network Layer

Primary Function: Forwarding

The network layer's major functionality is **forwarding packets** - putting packets on their correct path through the network.

Definition of Forwarding: The process of directing a packet to its appropriate outgoing interface based on the destination address.

Router Functionality

Routers are network devices that connect multiple networks and make forwarding decisions.

Example Scenario:

> Router R1 connected to multiple networks:
> R1 —— N1 (Network 192.168.1.0/24)
> R1 —— N2 (Network 192.168.2.0/24)
> R1 —— N3 (Network 192.168.3.0/24)
> R1 —— N4 (Network 192.168.4.0/24)

When a packet arrives at R1:

1. Router receives the packet
2. Opens packet header to examine destination IP
3. Determines appropriate outgoing interface
4. Forwards packet on the optimal path

Optimal Path Selection

The "right path" should be the **optimal path** considering:

- **Shortest path** (minimum hops)
- **Lesser delay** (latency)
- **Lower cost** (bandwidth, administrative cost)
- **Faster delivery** (throughput)

2. Routing Tables

Definition

A routing table is a **collection of entries** containing network topology information that helps routers make forwarding decisions.

Contents of Routing Tables

- Network destinations and their reachability
- Next-hop information
- Interface information
- Cost/metric values
- Network status (active/inactive links)
- Path information between nodes

Example Routing Table:

Destination Network	Next Hop	Interface	Metric
192.168.1.0/24	Direct	eth0	0
192.168.2.0/24	10.0.0.2	eth1	1
192.168.3.0/24	10.0.0.3	eth2	2
0.0.0.0/0 (default)	10.0.0.1	eth1	1

Two-way Communication

Routing tables enable **bidirectional communication** by maintaining information about:

- Which connections are working
- Which connections are not working
- Path costs between networks
- Inter-node connectivity status

3. Types of Routing Tables

3.1 Static Routing Tables

Characteristics:

- Created and maintained **manually**
- Network administrator manually inserts data
- Suitable for **small networks**
- Fixed routes that don't change automatically

Example Scenario - Small Office Network:

Office Network (20 devices):
- Router A connects to Internet
- Router B connects LAN1 (Accounting: 192.168.1.0/24)
- Router C connects LAN2 (Sales: 192.168.2.0/24)

Static Route Configuration:
Router A: 192.168.1.0/24 via Router B
Router A: 192.168.2.0/24 via Router C
Router B: 0.0.0.0/0 via Router A
Router C: 0.0.0.0/0 via Router A

Advantages: Simple, predictable, secure **Disadvantages:** Not scalable, no automatic updates, manual maintenance

3.2 Dynamic Routing Tables

Characteristics:

- **Automatically created and updated**
- Routers exchange information automatically
- Suitable for **large networks like the Internet**
- Adapts to network changes in real-time

Example Scenario - ISP Network:

ISP Network with 1000+ routers:
- Routes change frequently due to link failures
- New networks added/removed regularly
- Traffic patterns change throughout the day
- Manual configuration impossible

4. Routing Protocols

Definition

Routing protocols are **sets of instructions and rules** that help routers:

- Share network topology data
- Update routing tables automatically
- Discover optimal paths
- Adapt to network changes

Purpose

Enable routers to:

1. **Share data** about network topology
2. **Update routing tables** periodically
3. **Calculate optimal paths** for packet forwarding
4. **Ensure packets reach destinations** efficiently

5. Categories of Routing Protocols

5.1 Domain-Based Classification

The Internet is divided into **Autonomous Systems (AS)** for management purposes.

Autonomous Systems (AS)

Definition: A collection of networks under a single administrative authority.

Real-World Examples:

- **AS 15169:** Google's autonomous system
- **AS 32934:** Facebook's autonomous system
- **AS 7018:** AT&T's autonomous system
- **AS 3356:** Level3's autonomous system

Geographic Example:

```
Delhi AS (AS 9498):
- All networks in Delhi region
- Managed by Delhi ISP authority
- Includes universities, offices, residential areas

Mumbai AS (AS 9829):
- All networks in Mumbai region
- Managed by Mumbai ISP authority
- Includes financial district, residential areas
```

5.2 Intra-Domain Routing

Definition: Routing **within** a single autonomous system.

Example Scenario:

Within Delhi AS:
Source: Hauz Khas Network (192.168.10.0/24)
Destination: Green Park Network (192.168.20.0/24)

Both networks are in the same AS, so intra-domain routing protocols handle the communication.

Information Shared:

- Link costs within the AS
- Network reachability
- Link status (up/down)
- Path availability
- Internal topology changes

5.3 Inter-Domain Routing

Definition: Routing **between** different autonomous systems.

Example Scenario:

Communication between:
Delhi AS (AS 9498) ↔ Mumbai AS (AS 9829)

User in Delhi wants to access:
- Mumbai bank server
- Mumbai e-commerce site
- Mumbai cloud service

Inter-domain protocols handle routing between these ASes.

6. Intra-Domain Routing Protocols

6.1 Distance Vector Routing

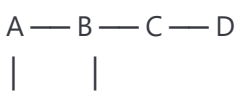
Algorithm: Bellman-Ford Algorithm **Real Protocol:** RIP (Routing Information Protocol)

Key Characteristics:

- Each router maintains distance to all destinations
- Periodic updates to neighbors
- Uses hop count as metric
- Maximum hop count: 15 (16 = infinity)

Example Network:

Network Topology:



Distance Vector Table at Router A:

Destination	Distance	Next Hop
B	1	B
C	2	B
D	3	B
E	1	E
F	2	E

RIP (Routing Information Protocol):

- Version 1: Classful routing
- Version 2: Classless routing (VLSM support)
- Updates every 30 seconds
- UDP port 520

6.2 Link State Routing

Algorithm: Dijkstra's Algorithm
Real Protocol: OSPF (Open Shortest Path First)

Key Characteristics:

- Each router has complete network topology
- Calculates shortest path tree
- Triggered updates on topology changes
- Supports variable length subnet masks (VLSM)

Example Network:

OSPF Network:

```
    [A]—2—[B]—3—[C]
     |     |     |
     4     1     2
     |     |     |
    [D]—1—[E]—2—[F]
```

Router A's Link State Database:
A-B: cost 2, A-D: cost 4
B-C: cost 3, B-E: cost 1
C-F: cost 2, D-E: cost 1, E-F: cost 2

Shortest Path Tree from A:
A→B (cost 2)
A→B→E (cost 3)
A→B→C (cost 5)
A→B→E→D (cost 4)
A→B→E→F (cost 5)

OSPF Features:

- Areas for scalability
- Authentication support
- Load balancing
- Fast convergence

7. Inter-Domain Routing Protocol

Border Gateway Protocol (BGP)

Algorithm: Path Vector **Characteristics:**

- Policy-based routing
- Handles routing between ISPs
- Prevents routing loops using AS path
- Supports complex routing policies

Example Scenario:

BGP Routing Between ISPs:

ISP-A (AS 100) ── ISP-B (AS 200) ── ISP-C (AS 300)
                    |
                ISP-D (AS 400)

BGP Announcement from AS 300:
"Network 192.168.100.0/24 reachable via AS path: 300"

Path received at AS 100:
Via AS 200: 300 → 200 (path length: 2)
Via AS 400: 300 → 400 → 200 (path length: 3)

AS 100 chooses shorter path via AS 200.

8. Communication Types

Unicasting vs Multicasting

All three major routing protocols (RIP, OSPF, BGP) work with **unicasting**.

Unicasting:

- One-to-one communication
- Single sender, single receiver
- Example: Web browsing, email, file transfer

Multicasting:

- One-to-many communication
- Single sender, multiple receivers
- Example: Video conferencing, live streaming
- Uses separate multicast routing protocols (PIM, DVMRP)

Example Scenarios:

Unicast Example:

User A (192.168.1.100) → Web Server (203.123.45.67)
Single data stream from user to specific server

Multicast Example:

```
Video Server → Group of viewers
224.1.1.1 (multicast address)
├── Viewer 1 (192.168.1.100)
├── Viewer 2 (192.168.1.101)
└── Viewer 3 (192.168.1.102)
```

9. Importance for Examinations

Priority for Competitive Exams

For GATE, NET, and University Exams:

1. **Distance Vector Routing** - **Most Important**
   - Bellman-Ford algorithm
   - RIP protocol details
   - Count-to-infinity problem
   - Split horizon solutions
2. **Link State Routing** - **Important**
   - Dijkstra's algorithm
   - OSPF protocol basics
   - SPF tree calculation
3. **Path Vector Routing** - **Basic Understanding**
   - BGP fundamentals
   - AS path concept
   - Policy routing basics

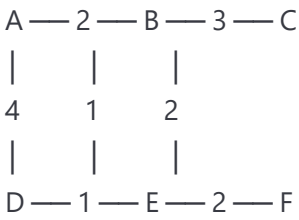
Key Topics to Focus On:

1. **Routing Table Construction**
2. **Distance Vector Algorithm Implementation**
3. **Link State Algorithm Implementation**
4. **Autonomous System Concepts**
5. **Intra vs Inter-domain Routing**
6. **Protocol Comparisons (RIP vs OSPF vs BGP)**

10. Practice Problems

Problem 1: Distance Vector Calculation

Given Network:



Calculate distance vector table at each router.

Problem 2: OSPF Area Design

Design OSPF areas for a company network with:
- 200 routers total
- 4 regional offices
- 1 headquarters
- Requirement: Minimize LSA flooding

Problem 3: BGP Policy Implementation

Three ISPs: ISP-A, ISP-B, ISP-C
ISP-A wants to:
- Accept routes from ISP-B
- Not transit traffic between ISP-B and ISP-C
- Advertise only customer routes to ISP-C

Design BGP policies.

Summary

Routing protocols are essential for dynamic network operation, enabling automatic path discovery and network adaptation. The hierarchical approach (intra-domain and inter-domain) provides scalability, while different algorithms (distance vector, link state, path vector) offer various trade-offs between simplicity, optimality, and convergence speed.

Understanding these concepts is crucial for network design, troubleshooting, and competitive examinations in computer networking.