Simulation of Routing Protocols (RIP, OSPF, BGP, IS-IS)

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1. Introduction

The objective of this assignment was to simulate the fundamental working of four key routing protocols, each representing a different class of routing algorithm:

- **RIP (Routing Information Protocol):** A classic **Distance-Vector** protocol.
- **OSPF (Open Shortest Path First):** A **Link-State** protocol.
- **IS-IS (Intermediate System to Intermediate System):** A **Link-State** protocol.
- **BGP (Border Gateway Protocol):** The internet's standard **Path-Vector** protocol.

These protocols are the foundation of packet routing in modern networks. The simulations were implemented in Python, using the networkx library for graph representation. The core logic for each protocol's algorithm—Bellman-Ford for RIP, Dijkstra's for OSPF and IS-IS, and a shortest-path-vector algorithm for BGP—was implemented to practically observe theoretical concepts like path selection, convergence behavior, and algorithmic differences. This report summarizes the network topologies used, analyzes the final routing tables, and provides a comparative analysis of the protocols' behavior.

2. Network Topologies

To test the protocols, distinct network topologies were created to highlight their specific characteristics.

- RIP Topology: A 4-node graph (A, B, C, D) was used. The links, each with a hop cost of 1, were: (A, B), (A, C), (B, C), (B, D), and (C, D).
  [Placeholder for RIP network topology diagram]
- OSPF Topology: A 6-node graph (A, B, C, D, E, F) was created with asymmetrically weighted links representing cost: (A, B, 5), (A, C, 2), (B, D, 1), (B, E, 6), (C, D, 4), (C, F, 8), (D, E, 3), (E, F, 2).
  [Placeholder for OSPF network topology diagram]
- BGP Topology: A 5-node graph representing Autonomous Systems (ASes) was used: (AS1, AS2), (AS1, AS3), (AS2, AS4), (AS3, AS4), (AS4, AS5).
  [Placeholder for BGP network topology diagram]
- IS-IS Topology: A 5-node graph (R1, R2, R3, R4, R5) was used with weighted links: (R1, R2, 10), (R1, R3, 10), (R2, R4, 20), (R3, R4, 5), (R3, R5, 10), (R4, R5, 5).
  [Placeholder for IS-IS network topology diagram]

3. Simulation Results and Routing Tables

3.1. RIP (Routing Information Protocol)

The RIP simulation used the Bellman-Ford algorithm, with all link costs as 1 (hop count). The simulation converged in 3 iterations.

Sample Converged Routing Tables (RIP):

```
--- RIP Routing Table for A ---
Destination  | Next Hop   | Cost
----------------------------------
A            | A          | 0
B            | B          | 1
C            | C          | 1
D            | B          | 2

--- RIP Routing Table for D ---
Destination  | Next Hop   | Cost
----------------------------------
A            | C          | 2
B            | B          | 1
C            | C          | 1
D            | -          | 0
```

(Data from rip.png)

Analysis: The results clearly show RIP's hop-count metric and "routing by rumor" nature. For Router A to reach D, two paths exist with a cost of 2 hops (A-B-D and A-C-D). The simulation converged on Next Hop: B for this route. This iterative, neighbor-dependent update process is the hallmark of distance-vector protocols and is prone to slow convergence (count-to-infinity) in larger networks.

3.2. OSPF (Open Shortest Path First)

The OSPF simulation used Dijkstra's algorithm. Each router was assumed to have a complete link-state database (LSDB) after LSA flooding and then independently calculated its shortest path tree.

Sample Converged Routing Tables (OSPF):

```
--- OSPF Routing Table for A ---
Destination  | Next Hop   | Cost
----------------------------------
A            | -          | 0
B            | B          | 5
C            | C          | 2
D            | C          | 6
```

E | C | 9
F | C | 10

--- OSPF Routing Table for D ---
Destination | Next Hop | Cost

A | B | 6
B | B | 1
C | C | 4
D | - | 0
E | E | 3
F | E | 5

(Data from ospf_part1.png and ospf_part2.png)

Analysis: OSPF's strength is evident in its optimal path calculation. For Router A to reach E, the table shows Next Hop: C and Cost: 9. This corresponds to the full path A->C->D->E (cost 2 + 4 + 3 = 9). The algorithm correctly identified this path as superior to the shorter, 3-hop path A->B->E (cost 5 + 6 = 11), which RIP would have preferred. This "full map" approach is more accurate and converges faster.

3.3. BGP (Border Gateway Protocol)

The BGP simulation used a path-vector algorithm, where each "router" represented an AS. The best path was selected based on the shortest AS path length.

Sample Converged Routing Tables (BGP):

--- BGP RIB for AS1 ---
Prefix | Next Hop | AS Path

AS1 | self | AS1
AS2 | AS2 | AS1 -> AS2
AS3 | AS3 | AS1 -> AS3
AS4 | AS2 | AS1 -> AS2 -> AS4
AS5 | AS2 | AS1 -> AS2 -> AS4 -> AS5

--- BGP RIB for AS5 ---
Prefix | Next Hop | AS Path

AS1 | AS4 | AS5 -> AS4 -> AS2 -> AS1
AS2 | AS4 | AS5 -> AS4 -> AS2
AS3 | AS4 | AS5 -> AS4 -> AS3
AS4 | AS4 | AS5 -> AS4
AS5 | self | AS5

(Data from bgp_part1.png and bgp_part2.png)

Analysis: The BGP simulation highlights the AS Path metric and loop prevention. The path itself (e.g., AS5 -> AS4 -> AS2 -> AS1) is the primary metric, not link costs. This path is also the loop-prevention mechanism: if an AS receives an update containing its own AS number, it discards it. While this simulation used the shortest path, BGP's real power is enforcing routing policies.

3.4. IS-IS (Intermediate System to Intermediate System)

As a link-state protocol, the IS-IS simulation also used Dijkstra's algorithm, similar to OSPF.

Sample Converged Routing Tables (IS-IS):

```
--- IS-IS Routing Table for R1 ---
Destination  | Next Hop   | Cost
-----------------------------------
R1           | -          | 0
R2           | R2         | 10
R3           | R3         | 10
R4           | R3         | 15
R5           | R3         | 20

--- IS-IS Routing Table for R5 ---
Destination  | Next Hop   | Cost
-----------------------------------
R1           | R3         | 20
R2           | R4         | 25
R3           | R3         | 10
R4           | R4         | 5
R5           | -          | 0
```

(Data from isis_part1.png and isis_part2.png)

Analysis: The results are operationally identical to OSPF, demonstrating the effectiveness of the link-state approach. For R1 to reach R5, the path is R1->R3->R5 (cost 10 + 10 = 20), which the algorithm correctly identified as superior to the alternative R1->R2->R4->R5 (cost 10 + 20 + 5 = 35). While OSPF is common in enterprises, IS-IS is widely used in large ISP backbones.

4. Comparative Analysis

Feature	**RIP (Distance Vector)**	**OSPF / IS-IS (Link State)**	**BGP (Path Vector)**
Protocol Class	IGP (Interior Gateway Protocol)	IGP (Interior Gateway Protocol)	EGP (Exterior Gateway Protocol)
Core Algorithm	Bellman-Ford (Distributed)	Dijkstra (Centralized per router)	Path Vector (Policy-based)
Network View	"Routing by Rumor"	"Full Map"	"List of AS Paths"
Metric	Hop Count	Link Cost	AS Path Length &

		(configurable)	Policy
Convergence	**Slow.** (Count-to-infinity)	**Fast.** (Triggered, flooded updates)	**Slow.** (Policy propagation)
Overhead	**High.** (Periodic full table)	**Low.** (Floods changes only)	**Update-driven.**
Scalability	Poor (Max 15 hops).	Excellent (Hierarchical via Areas).	Extremely scalable (internet-scale).

5. Observations and Conclusions

This lab successfully demonstrated the core differences between the three main classes of routing protocols.

1. **RIP (Distance-Vector)**: The simulation showed its simplicity but also its critical weakness. Its reliance on "routing by rumor" and a simple hop-count metric makes it inefficient and slow to react to failures.
2. **OSPF & IS-IS (Link-State)**: These simulations demonstrated the clear superiority of the link-state approach. By giving every router a complete "map," each router can independently and correctly calculate the *true* shortest path using Dijkstra's algorithm, leading to faster convergence and better paths.
3. **BGP (Path-Vector)**: This simulation showed that BGP operates on a different level. It is not concerned with the lowest-cost path *within* a network, but with the best *AS path* between networks, using the path itself as both the metric and a loop-prevention mechanism.

In conclusion, the simulations confirm the theoretical advantages and disadvantages of each protocol. The choice is clearly dependent on the application: RIP for trivial networks, OSPF/IS-IS for scalable and fast interior routing (within an AS), and BGP for exterior, policy-driven routing that forms the backbone of the internet.