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Simulation-Based Performance Evaluation of Layer 3 Routing Protocols: RIP, EIGRP, and OSPF

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Abstract
The choice of routing protocols greatly influences the functioning of today's IP networks. This paper is an empirical, simulation-based study of three Interior Gateway Protocols (IGP) that are run in Cisco Packet Tracer: Routing Information Protocol (RIP), Enhanced Interior Gateway Routing Protocol (EIGRP), and Open Shortest Path First (OSPF). Four important performance metrics — Packet Loss Ratio (PLR), Packet Delivery Ratio (PDR), end-to-end throughput and convergence time — were quantified using ten standardised test scenarios per protocol. Results of the experiments show that EIGRP provides the best throughput (65.54 Mbps) and convergence (1.2–2.5 s), while OSPF provides good reliability and is vendor-neutral and scalable. The weakest performances are found in RIP with regard to all the dimensions measured. These outcomes are relevant to the selection of protocols in enterprise and campus network deployments and can serve as evidence.

Keywords: RIP; EIGRP; OSPF; Interior Gateway Protocol; Packet Loss; Throughput; Packet Delivery Ratio; Convergence Time; Cisco Packet Tracer; Network Simulation.

I. Introduction

Data communication networks are the backbone for most industries today, including financial trading systems and remote delivery of healthcare. The backbone of this infrastructure is the OSI reference model network layer, where routing protocols are used to determine the network path through a set of interconnected devices. The wrong protocol can directly lead to high latency, high packet loss and slow link failure recovery, which impacts the user experience and lowers application availability [1].

IGPs can broadly be divided into three families of algorithms. Distance-vector protocols, such as RIP, keep short routing summaries and send updates to neighbouring routers on a regular basis. Link-state protocols like OSPF attempt to build a detailed topological map of all of the routers in the routing domain so that each one can calculate optimal paths on its own using Dijkstra's Shortest Path First (SPF) algorithm. Hybrid protocols, in which EIGRP is the primary example, have selective features of both types of methods, such that they provide for rapid convergence without the flooding overhead that is typical of pure link-state designs [2][3].

While previous studies have done some comparisons of such protocols in lab settings [4][5][6], far fewer published studies use more than fifteen test instances for any protocol and most limit their studies to one platform. This investigation addresses those gaps by performing 10 different test scenarios for each of the protocols in a controlled Packet Tracer environment, and obtaining statistically meaningful average values for each of the four selected metrics.

The rest of this paper outlines the experimental methodology and topology (Section II), quantitative results and analysis (Section III), practical deployment implications (Section IV), and conclusions and directions for future research (Section V).

II. Methodology

The topology of the evaluation consisted of ten routers connected to each other through managed switches, to end hosts spread out in five sub-networks. The physical configuration was identical for all three protocol configurations with the exception that the routing protocol parameters were changed on each router between experimental runs.

All switches were assigned to a single VLAN, and all IPs and subnet masks were configured to be the same before any protocol settings were configured, to eliminate confounding variables.
The number of sender–receiver pairs was chosen as 10 for each protocol to cover intra-segment and inter-segment communication paths, and so cover the routing tables of different depth and convergence complexity. A 4-packet sequence of ICMP packets was sent for each test case and the results were recorded from the Packet Tracer simulation log. A set of four performance metrics is formally defined below.

A. Performance Metrics

Packet Loss Ratio (PLR)
Quantifies the proportion of transmitted packets that fail to reach their destination:
PLR (%) = [(Packets Sent − Packets Received) / Packets Sent] × 100
Packet Delivery Ratio (PDR)
The complement of PLR, expressing the fraction of successfully delivered packets:
PDR (%) = (Packets Received / Packets Sent) × 100
Throughput
Derived from the TCP window-size formula using a 64 KB window (524,288 bits) and measured round-trip latency:
Throughput (bps) = Window Size (bits) / Latency (seconds)
Convergence Time
The elapsed duration from the initiation of routing updates until all routers in the topology maintain consistent, loop-free forwarding tables, measured via timestamped entries in the Packet Tracer simulation timeline.

B. Protocol Configurations

1) RIP — Routing Information Protocol
RIP is a classful, distance-vector IGP, based on the algorithm devised by Bellman and Ford. The most important restriction on operation is a maximum path length of 15 hops, beyond which a route is declared unreachable. The routing state is synchronised periodically every 30 seconds, holds down for 180 seconds, and expires after 240 seconds of no changes to the route. These timers converge very slowly after a topology change, but are easy to configure using conservative defaults. RIPv2 adds support for classless inter-domain routing (CIDR) and MD5 authentication [7] to the base standard.
Configuration synopsis: router rip → version 2 → network <NID> → no auto-summary.
2) EIGRP — Enhanced Interior Gateway Routing Protocol
EIGRP uses the Diffusing Update Algorithm (DUAL) to ensure that there are no loops in the chosen path and that it fails over quickly. EIGRP does not send periodic updates but rather sends routing information only when a routing event occurs, thereby minimizing unnecessary control-plane traffic. It maintains three data structures: a neighbour adjacency table, a full topology table containing details about all known paths, and a routing table containing only the best (successor) and next-best (feasible-successor) routes. The composite path metric combines bandwidth, delay, reliability, load, and MTU. The control-message sequence is: Hello, Update, Query, Reply, Acknowledgement [8].
Configuration synopsis: router eigrp <AS> → network <NID> → no auto-summary.
3) OSPF — Open Shortest Path First
OSPF is a standards-based, link-state IGP in accordance with RFC 2328. Each OSPF router builds its own Link-State Advertisement (LSA) and floods the LSAs within its area, after which it runs the SPF algorithm on the Link-State Database (LSDB) to construct a shortest-path tree. OSPF has no maximum hop limit, so it is appropriate for large enterprise networks. The protocol is hierarchical, with Area 0 (the backbone) connecting to all other areas. For each broadcast segment, a Designated Router (DR) and Backup Designated Router (BDR) are elected to minimize LSA flooding overhead [9].
Configuration synopsis: router ospf <process-id> → network <NID> <wildcard-mask> area <area-id>.

III. Experimental Results and Performance Analysis

A. Packet Loss Ratio
RIP — Packet Loss Ratio

Table 1. Packet Loss Ratio — RIP Protocol (10 Test Cases)

No.	Sender	Receiver	Pkts Sent	Pkts Rcvd	Loss (%)
1	PC0	PC1	4	3	25
2	PC0	PC6	4	4	0
3	PC0	PC21	4	4	0
4	PC21	PC44	4	3	25
5	PC21	PC52	4	3	25
6	PC1	PC10	4	4	0
7	PC5	PC15	4	3	25
8	PC10	PC20	4	3	25
9	PC20	PC30	4	3	25
10	PC35	PC45	4	3	25

Aggregate for RIP: Packets sent = 40; Packets received = 32; PLR = [(40 − 32) / 40] × 100 = 20.0%. The elevated loss rate reflects routing instability during the 30-second periodic update interval, during which stale table entries cause packet misdirection.

EIGRP — Packet Loss Ratio

Table 2. Packet Loss Ratio — EIGRP Protocol (10 Test Cases)

No.	Sender	Receiver	Pkts Sent	Pkts Rcvd	Loss (%)
1	PC0	PC1	4	4	0
2	PC0	PC6	4	4	0
3	PC0	PC21	4	4	0
4	PC0	PC5	4	3	25
5	PC21	PC52	4	3	25
6	PC1	PC10	4	4	0
7	PC5	PC15	4	4	0
8	PC10	PC20	4	4	0
9	PC25	PC35	4	3	25
10	PC35	PC45	4	4	0

Aggregate for EIGRP: Packets sent = 40; Packets received = 36; PLR = [(40 − 36) / 40] × 100 = 10.0%. DUAL's proactive maintenance of feasible-successor routes substantially reduces the window of routing inconsistency following any topology change.

OSPF — Packet Loss Ratio

Table 3. Packet Loss Ratio — OSPF Protocol (10 Test Cases)

No.	Sender	Receiver	Pkts Sent	Pkts Rcvd	Loss (%)
1	PC0	PC1	4	4	0
2	PC0	PC6	4	3	25
3	PC0	PC21	4	4	0
4	PC0	PC5	4	3	25
5	PC21	PC52	4	4	0
6	PC1	PC10	4	4	0
7	PC5	PC15	4	4	0
8	PC10	PC20	4	4	0
9	PC25	PC35	4	4	0
10	PC35	PC45	4	3	25

Aggregate for OSPF: Packets sent = 40; Packets received = 36; PLR = [(40 − 36) / 40] × 100 = 10.0%. OSPF's rapid LSA propagation and SPF recalculation yield the same aggregate reliability as EIGRP across the tested scenario set.

B. Packet Delivery Ratio

Table 4. Packet Delivery Ratio Summary

Protocol	Pkts Sent	Pkts Received	PDR (%)
RIP	40	32	80
EIGRP	40	36	90
OSPF	40	36	90

EIGRP and OSPF have a PDR of 90%, ten percentage points higher than that of RIP. This is a practical benefit of using an event-driven (EIGRP) and LSA-based (OSPF) update mechanism compared to the timer-driven broadcast approach used by RIP, especially in networks with a large number of topology changes.

C. Throughput Analysis

Throughput was estimated using a 64 KB TCP window (524,288 bits) divided by the observed round-trip latency of each protocol:

Table 5. Throughput Comparison Across Protocols

Protocol	Window (bits)	Latency (ms)	Throughput (bps)	Throughput (Mbps)
RIP	524,288	17	30,840,470	30.84
EIGRP	524,288	8	65,536,000	65.54
OSPF	524,288	11	47,662,545	47.66

EIGRP's event-driven update model eliminates the periodic update broadcasts seen in RIP and lowers latency compared to the LSA flooding seen in OSPF. The net effect is a 2.1× throughput gain over RIP, and a substantial gain over OSPF, which can make a difference in bandwidth-limited or latency-sensitive environments.

D. Convergence Time

Table 6. Convergence Time Comparison

Protocol	Range (sec)	Convergence Mechanism
RIP	17 – 24	Periodic 30-second broadcast; slow failover
EIGRP	1.2 – 2.5	DUAL pre-computes backup paths; sub-second redirects
OSPF	7.7 – 8.5	LSA flooding followed by SPF recalculation

EIGRP is roughly 10 times faster than RIP because DUAL pre-computes feasible successors; when the primary route fails, traffic is redirected within milliseconds instead of waiting for the next 30-second broadcast cycle. OSPF converges moderately, since SPF recalculation is triggered upon receipt of an LSA, resulting in convergence in about 8 seconds. The dependency on timers makes RIP unsuitable for environments that need fast failover.

IV. Discussion

The results across all four metrics are coherent and combine into a clear performance hierarchy. RIP's architectural simplicity comes at a price: its limited hop count restricts it to small networks, and its reliance on timer-based synchronization creates a period of routing inconsistency following any link event. This limitation is directly reflected in the 20% aggregate packet loss rate recorded in this study — twice that of the other two protocols.

OSPF overcomes the scalability limits of RIP and provides significantly better convergence for multi-area enterprise networks that need to operate interoperably across a heterogeneous mix of hardware platforms. Being an open standard is an important factor in multi-vendor infrastructure. Throughput of OSPF is measured at 47.66 Mbps in the present experiments, with convergence time around 8 seconds — much better than RIP [10].

When measured in terms of throughput, convergence time, and packet delivery ratio (equal to OSPF), EIGRP performs best quantitatively in 3 of the 4 measured dimensions. Its DUAL algorithm offers sub-second failover in most cases, while the composite metric structure allows fine-grained traffic engineering. Cisco's partial open-sourcing of EIGRP (RFC 7868) has greatly reduced past concerns about vendor lock-in and made EIGRP more useful in mixed-vendor networks.

EIGRP is the recommended protocol for deployment when the primary considerations are throughput maximization and fast convergence and the network topology is largely Cisco-based. If vendor neutrality or a large-scale hierarchical design through area segmentation is desired, OSPF is the natural default. RIP should only be used in legacy migrations or instructional laboratory scenarios where operational simplicity is the primary concern.

V. Conclusion

In this study, the authors compared three routing protocols using 10 standardised test scenarios for each protocol, set up in an identical Packet Tracer topology, and simulated them. Packet Loss Ratio, Packet Delivery Ratio, throughput, and convergence time were all quantitatively assessed and yielded consistent results: with regard to packet delivery reliability, EIGRP performed the same as OSPF, and RIP lagged in all aspects measured; with regard to throughput and convergence time, EIGRP was the clear winner in both cases compared to the alternatives. The results give evidence-based design direction for protocol selection in enterprise and campus networks.

Future work may expand the scope of the comparison to include IS-IS and BGP, apply variable and bursty traffic loads to test convergence under realistic conditions, and deploy the evaluation onto real hardware to validate the simulation results against real-world behaviour.

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