IR.1101 RÉSEAUX/NETWORKS

REPORT

[PROJECT 1]
Comparative Analysis of Distance-Vector and Link-State Routing Protocols Based on RIP and OSPF

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1. Introduction

Dynamic routing protocols are essential in modern networking, allowing routers to exchange information dynamically, thereby enabling networks to adapt seamlessly to changes. This adaptability ensures continuous, efficient routing, simplifies network management, and significantly reduces administrative burdens. Compared to static routing, dynamic protocols offer enhanced scalability and functionality, revolutionizing network design.

Since the introduction of the Exterior Gateway Protocol (EGP) by Eric C. Rosen in 1982, the field of dynamic routing has seen substantial advancements. These developments have led to the creation of various sophisticated protocols, each designed to optimize network efficiency and robustness.[1]

Among these, Distance-Vector and Link-State protocols stand out due to their widespread use and distinct operational mechanisms. This report specifically focuses on the Routing Information Protocol (RIP) and Open Shortest Path First (OSPF). By monitoring network changes and distributing this information across routers, the choice of an appropriate routing protocol becomes a pivotal decision in network design and management[2].

This project focuses on the exploration of dynamic routing protocols, specifically analysing and experimenting with Distance-vector (RIP) and link-state (OSPF) protocols.

2. Routing Protocol

2.1 Distance-Vector Routing Protocol

Distance vector routing protocols disseminate updates among neighbouring routers, defined as routers connected by a shared link and configured with the same routing protocol. These routers are only cognizant of their own interface network addresses and those of remote networks accessible via their neighbours. However, they do not have knowledge of the overall network topology.

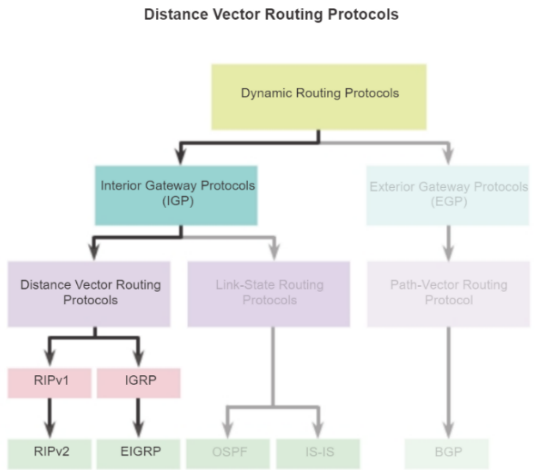


Figure 1 Distance Vector Routing Protocols[3]

The characteristics of Distance Vectors routing protocol are given below:

- Distance Vector routing protocol defines its routing table where all neighbours are directly connected with the table at a steady period.
- New information should put in each routing table instantly when the routes become unreachable.
- Distance Vector routing protocols are easy and effective in smaller networks and thus require little management.
- Distance Vector routing is mainly based on hop counts vector.
- The Distance Vector algorithm is iterative.

2.1.1 Exploration of Routing Information Protocol (RIP)

The Routing Information Protocol (RIP) is a distance-vector routing protocol that fundamentally operates on the principles of distance and direction, utilizing hop count as its primary metric. It was designed for smaller IP networks. [4]

RIP, utilizing the Bellman-Ford algorithm, gauges route reliability through an Administrative Distance, with lower values indicating higher reliability. The primary metric for RIP is hop count, with a maximum of 15 hops, the 16-hop count is considered unreachable.

Routing Information Protocol is class-full routing protocol.

- RIPv1 uses classful routing, all subnets in a network class must have the same size. There is also no support for router authentication, making RIP vulnerable to various attacks.

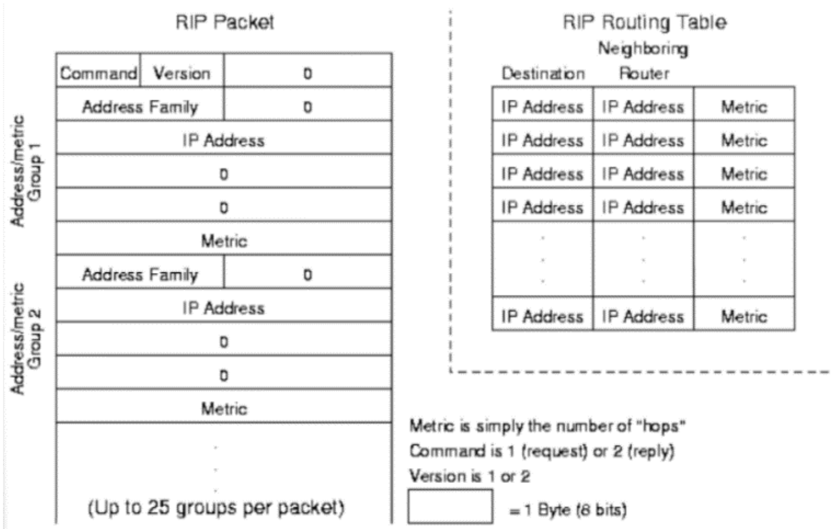


Figure 2 RIP-Ver1 Packet Format[5]

- RIPv2 included the ability to carry subnet information, thus supporting Classless Inter-Domain Routing (CIDR). The hop count limit of 15 remained. Route tags were added in to allows a distinction between routes learned from the RIP protocol and routes learned from other protocols.

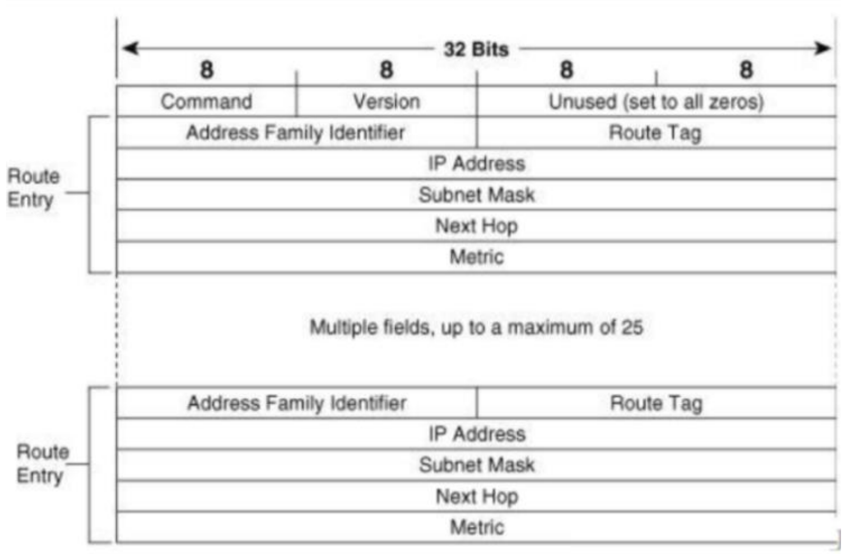


Figure 3 RIP-Ver2 Packet Format[6]

- RIP next generation (RIPng) is the extension of RIPv2 for IPv6 support.

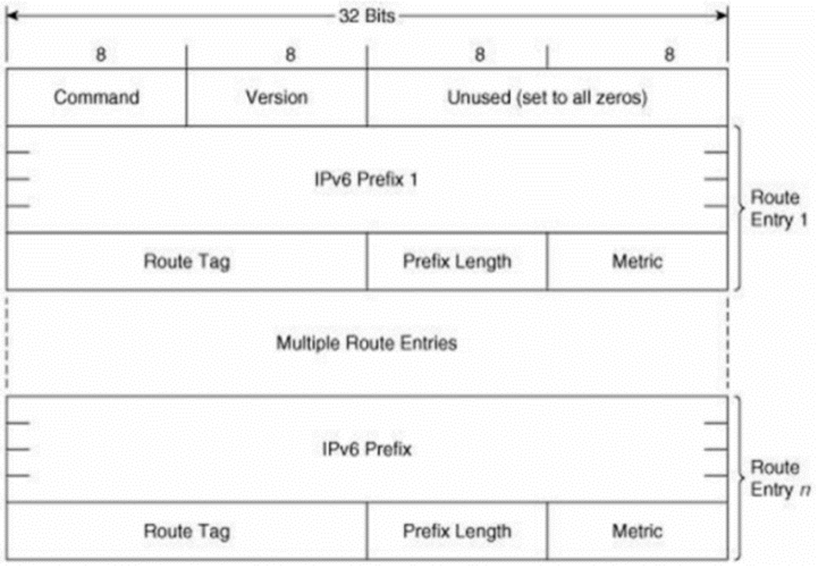


Figure 4 RIPng Packet Format[6]

2.2 Link-State Routing Protocol

Link-state routing emerged as a solution to the limitations of distance vector routing, offering functionalities such as rapid response to network changes using triggered updates, swift adaptation to network alterations, and self-healing for non-functional routes. It conserves bandwidth by dispatching updates solely on change occurrence and communicates link status changes through Link State Advertisements (LSAs).

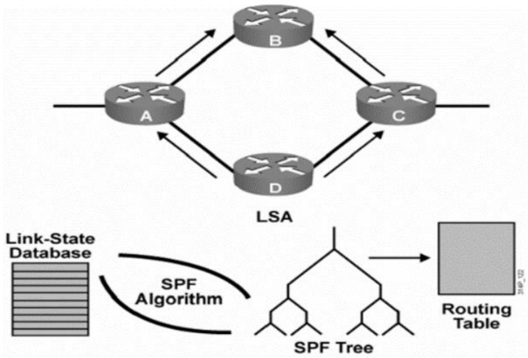


Figure 5 Link State Routing[5]

Link state protocol has the following characteristics[8]:

- Each router possesses the identical database.
- Provides hierarchical structure.
- Include and maintain several paths in the topology table for the destination.
- Efficient and fast convergence without any loop.
- Have much more precise metrics.

Link-state routing protocols are tailored for expansive, enterprise-scale networks. Their complexity requires more intricate configuration, maintenance, and troubleshooting efforts compared to distance vector routing protocols. Despite these challenges, link-state protocols address and resolve numerous limitations inherent to distance vector protocols.

2.2.1 Exploration of Open Shortest Path First (OSPF)

In the dynamic realm of network communications, the Open Shortest Path First (OSPF) protocol stands as a cornerstone in modern routing technologies. Developed as a key interior gateway protocol (IGP), OSPF is instrumental in maintaining efficient and reliable data transmission within large-scale IP networks. Its emergence marked a significant evolution from traditional distance-vector routing protocols, introducing a more robust and scalable approach to address the complexities of growing network infrastructures.

Within the context of OSPF, the term ‘link’ corresponds to a router’s interface, and its ‘state’ represents various characteristics of that interface, including its IP address, subnet mask, and the type of network to which it is connected, this state also details the interface's connectivity with neighbouring routers. [3]

OSPF employs the Dijkstra algorithm to determine the most cost-effective paths to all known destinations[9]:

- **Link State Advertisement Generation**: Upon detecting routing changes, routers generate Link State Advertisements (LSAs) detailing their link states.
- **LSA Exchange and Flooding**: Routers exchange these LSAs with all others through a flooding process, ensuring each maintains an updated link state database.
- **Shortest Path Tree Calculation**: Routers construct a shortest path tree to all

destinations using the Dijkstra algorithm, effectively pinpointing the least cost paths.

- **Recalculation on Changes**: Whenever changes occur in the OSPF network, the Dijkstra algorithm recalculates to find new least cost paths.
- **Algorithm Utilization**: Each router applies the Dijkstra algorithm as the root of the tree, continually updating the shortest and least costly paths to various destinations.

Collectively, all the individual link states together make up the link-state database. OSPF uses this database to find the best routes across the network.

2.3 Comparative Analysis

The comparative analysis between Distance-Vector and Link-State routing protocols elucidates distinct operational characteristics, advantages, and limitations inherent to each protocol type. This section is organized into a table format, providing a clear and concise juxtaposition of the two protocols across various attributes.

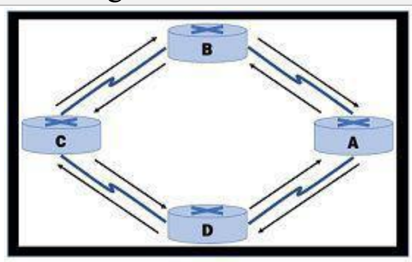
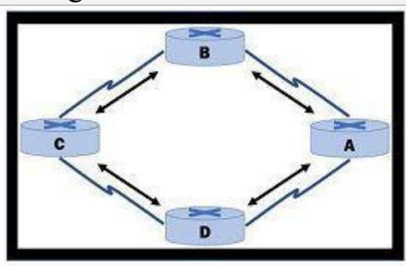
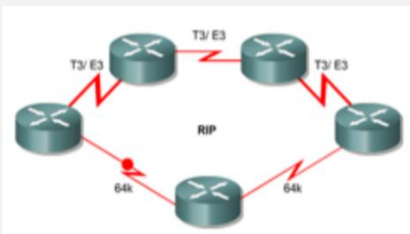
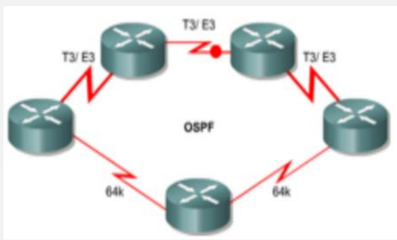
	Distance-Vector	**Link-State**
Metric	Utilizes hop count	Uses the shortest path algorithm
Perspective	View the network from neighbour’s view	Maintains a comprehensive network view
Updates	Sends updates periodically	Has event triggered updates.
Convergence	Slow convergence	Faster convergence
Loops	Susceptible to routing loops	Better at preventing routing loops
Configuration	Easier to configure and manage	More complex in configuration
Resources	Requires less memory and CPU	Needs more memory and CPU
Bandwidth	Consumes a lot of Bandwidth	More efficient in bandwidth usage
Sharing	Exchanges full routing tables with neighbours	Exchanges link-state updates among routers
Distance vector vs. Link state	 **Distance Vector Routing**	 **Link State Routing**
RIP vs. OSPF		

Table 1 Distance vector vs. Link state Routing Algorithm[10][11]

The section concludes with graphical representations illustrating the concept of Distance Vector routing versus Link State routing, followed by a specific comparison of RIP and OSPF. The images depict typical network topologies and the respective flow of routing information between nodes for each protocol.

The comparative analysis effectively highlights the operational differences between Distance-Vector and Link-State routing protocols, with a clear inclination towards the advantages of Link-State in terms of convergence, responsiveness, and bandwidth efficiency. However, the simplicity and lower resource requirements of Distance-Vector protocols like RIP may still make them a viable choice for certain network scenarios.

3. Implementation

To gain a comprehensive understanding of dynamic routing protocols, particularly the distinctions between RIP and OSPF, Use Cisco to build the following simulation scenario:

3.1 Small-Scale Network (Suitable for RIP)

Set up a small network comprising several routers and multiple subnets. This environment is ideal for implementing RIP due to its simplicity and the protocol's limitations.

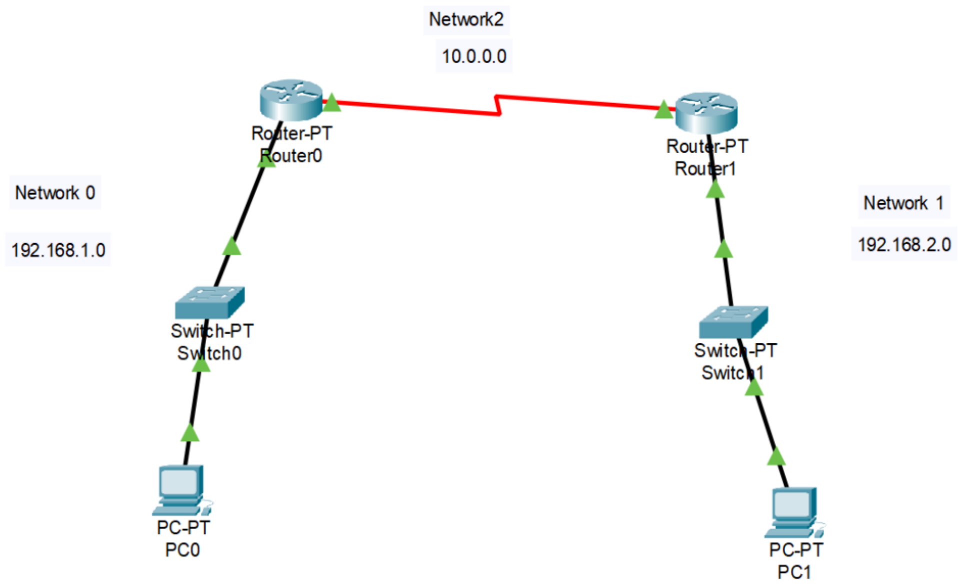


Figure 6 Small-Scale Network

The provided network diagram presents a fundamental configuration comprising two interconnected routers, Router0 and Router1, bridged by a network designated as Network2 with an assigned IP range of 10.0.0.0. Both routers are interfaced with distinct local networks and switches.

In the evaluation for the implementation of the Routing Information Protocol (RIP), the following points were considered:

- RIP Version Consistency: It has been verified that both routers operate under a uniform RIP version to ensure cross-compatibility.
- **Periodic Routing Updates:** The routers are configured to disseminate their comprehensive routing tables to neighbouring routers at standardized intervals, nominally every 30 seconds, through interfaces participating in the RIP-enabled network.
- **Hop Count Metric:** RIP's routing metric, the hop count, is employed for route determination. The hop count between the two PCs is quantified as 2.
- **RIP Configuration:** The configuration necessitates activation of RIP on both routers with explicit declaration of the networks for advertisement. Router0 will advertise the networks 192.168.1.0 and 10.0.0.0, while Router1 will advertise 192.168.2.0 and 10.0.0.0.

- **Timers for Protocol Management:** The protocol is governed by a set of timers—update, invalid, hold down, and flush—to modulate its operational behaviour.
- **Multicast Address Allocation:** When utilizing RIP v2, it is imperative to direct broadcasts to the multicast address 224.0.0.9, specific to RIP v2, as opposed to the generic broadcast domain.

To enhance the network's performance using the Routing Information Protocol (RIP), it is essential to configure each router to broadcast the networks directly connected to it and update its routing table based on the RIP announcements received from the other router.

Once RIP is configured on the routers, it is crucial to verify the correct propagation and updating of the routing information. Monitoring the exchange of routing information via RIP will yield valuable insights into its operational efficiency and potential limitations.

Advantages

- RIP is user-friendly and easy to configure, making it accessible for network administrators without the need for complex setup procedures.
- It operates efficiently by not requiring updates with each topology change, thus conserving network resources.
- RIP is designed to be compatible with a wide range of devices and networks, ensuring support for nearly all routers.

Disadvantages

- RIP relies solely on hop count for routing decisions, disregarding other critical performance metrics such as bandwidth and latency, which could lead to less-than-optimal path selections.

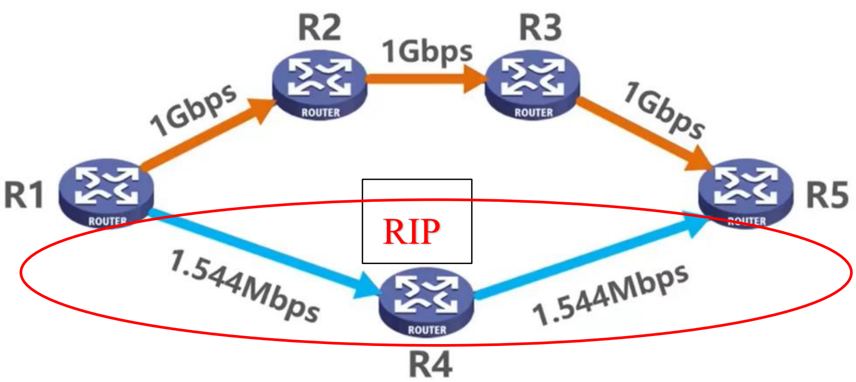


Figure 7 Path of RIP

- The protocol is suitable for smaller networks only, as it supports a maximum of 15 hops. Beyond this, the network is deemed unreachable, limiting its use in larger network topologies.

- The convergence rate of RIP is notably slow, leading to potential delays in routing updates when a network change occurs, which can impact performance and reliability.

Results and analysis

The network's performance under RIP exhibits the expected stability and efficiency for a network of this scale. RIP's ease of configuration and compatibility across devices are evident, providing a user-friendly environment for network administration. However, the limitations of RIP are also apparent, particularly its reliance on hop count without considering bandwidth or latency, potentially leading to suboptimal path selection. The maximum hop count of 15 limits its applicability to small networks, and the slower convergence rate can affect performance in dynamic topologies.

Applicability

The depicted network is a small-scale, low-complexity topology optimized for Routing Information Protocol (RIP), ideal for scenarios that prioritize administrative simplicity and resource efficiency. It is best suited for stable, smaller networks due to RIP's hop count limitations and minimal routing metrics, which favor ease of management over advanced functionality. The network's design implies limited scalability, making it less suitable for larger or more dynamically changing environments where more complex routing protocols would be necessary.

3.2 Large Enterprise Network (Suitable for OSPF)

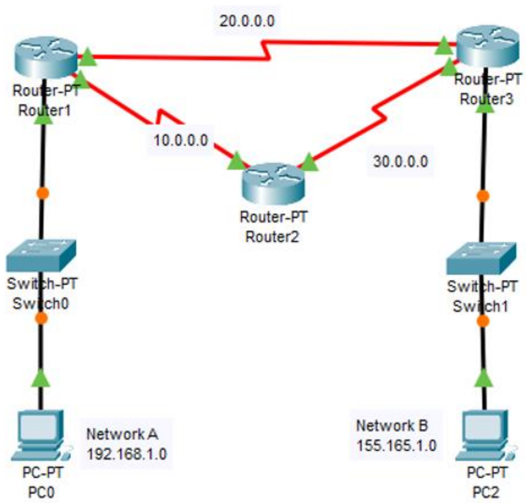


Figure 8 Single-Area OSPF Network Configuration

The simple single-area OSPF network consists of a triangular structure formed by three routers, each connected by a point-to-point subnet. Router2 is situated between Router1 and Router3, serving as a transit point that allows communication between the two internal networks.

In the context of deploying Open Shortest Path First (OSPF) within this network framework, several key elements were assessed:

- **Distinct Router Identifiers:** It is imperative that each router is assigned a unique OSPF Router ID, customarily selected based on the highest IP address present on the router or through manual assignment.
- **Distinct IP Address Segmentation:** It is essential to ensure that each network segment is distinctly identified by a unique IP address range, with Network A utilizing 192.168.1.0 and Network B utilizing 155.165.1.0.
- **OSPF Protocol Configuration:** OSPF necessitates specific network statements on each router, encapsulating the router's directly connected networks, thereby facilitating the propagation of these networks among the routers.
- **Link-State Advertisements (LSAs):** Routers within the OSPF domain generate and exchange LSAs, enabling the construction of a comprehensive network topology map, from which routers independently ascertain the most efficient routing paths.
- **Rapid Convergence:** OSPF is distinguished by its swift convergence capabilities, attributed to the expeditious dissemination of LSAs and the protocol's responsive update mechanisms.
- **Load Balancing and Redundancy:** OSPF inherently supports multiple paths of identical cost to a given destination, thereby facilitating equitable traffic distribution across these paths.
- **Authentication Measures:** OSPF incorporates mechanisms for the authentication of routing updates, reinforcing the security of the routing domain.

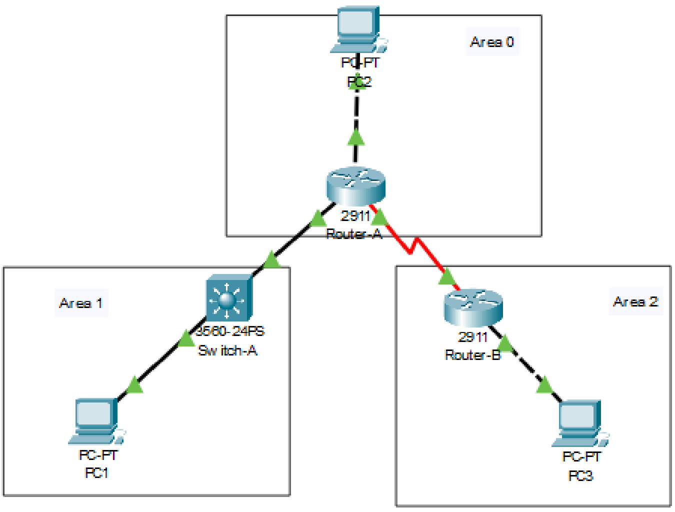


Figure 9 Enterprise Multi-Area OSPF Network Topology

The second diagram presents a multi-area OSPF setup, with a backbone router connecting to different OSPF areas, which is ideal for large enterprise networks to reduce routing table size and network traffic.

The OSPF configuration under examination reveals several critical aspects pertinent to its design and operation:

- **Backbone of Area 0:** Router R2 is situated within Area 0, serving as the OSPF backbone, a pivotal element in the network's topology. Connectivity to Area 0 is established by Router-A and Router-B, ensuring that all other areas are appropriately linked to the network's core.
- **Routing Between Areas:** Functioning as Area Border Routers (ABRs), Router-A is instrumental in managing the routing interchange between Area 0 and the adjoining non-backbone areas, namely Area 1 and Area 2.
- **Router Configuration:** OSPF protocols have been configured on each router, with acknowledgment to their specific operational areas. Specifically, Router-A interfaces with all the areas, and Router-B interfaces with Area 0 and Area 2.
- **Link-State Advertisement (LSA) Generation:** To facilitate network-wide information dissemination, Router-A and Router-B are configured to generate Type 3 Summary LSAs, advertising network availability from Area 1 to Area 0, and from Area 2 to Area 0, respectively, and in reverse.
- **Path Selection Protocol:** OSPF is tasked with calculating the most expedient path to each network, based on the cost metrics associated with each connecting link.
- **Traffic Load Balancing:** In scenarios where multiple inter-area links exist with equivalent costs, OSPF is equipped to distribute traffic evenly across such links, enhancing the network's operational efficiency.
- **Operational Expectations:** With Router-A at the helm of the OSPF architecture, the network is anticipated to manage routing processes with high efficiency, fostering seamless communication across all areas. Each PC within the network will maintain the capability to interact with others spanning different OSPF areas, with routing directives and path decisions being managed by the routers in accordance with OSPF algorithms.

Advantages

- OSPF provides a mechanism for more granular network segmentation into areas which can be seen in the second diagram. This improves scalability and network organization by containing route calculations within an area, reducing the overall routing overhead. RIP lacks this capability.
- OSPF ensures faster convergence due to its efficient handling of topology changes, which is vital for the high-availability requirements of large networks. In contrast, RIP's convergence time is significantly slower, which can lead to temporary routing loops and longer downtimes.
- OSPF's cost metric, based on link speed and other factors, allows for more

sophisticated route selection compared to RIP's simple hop count metric. This allows OSPF to support high-speed links more effectively, which is evident in the connections between the routers in both diagrams.

Disadvantages

The complexity of OSPF, including its configuration and management, is greater than that of RIP, which can be an overhead for network administrators. RIP's simplicity makes it easier to configure and manage for smaller, less complex networks.

- OSPF requires more resources such as memory and CPU power on network devices due to its complex calculations and maintenance of multiple tables. RIP, with its simpler mechanism, is less resource intensive.

Results and analysis

The OSPF deployment in the presented network schematics demonstrates OSPF's suitability for complex, large-scale enterprise networks. The multi-area configuration shows OSPF's advantage in segmenting a network into manageable sections, which reduces routing overhead and improves efficiency. OSPF's protocol dynamics, such as faster convergence and more nuanced route calculation, provide clear benefits over RIP's more basic functionality. The analysis concludes that for large enterprise environments with requirements for high availability and scalability, OSPF is the superior choice. However, it comes with the trade-off of increased complexity and resource requirements. This necessitates skilled network management and might be an overkill for simpler or smaller network setups where RIP could suffice.

Applicability

Described above is an expansive enterprise network architected for the Open Shortest Path First (OSPF) protocol, indicative of considerable size and complexity. It is structured for enhanced efficiency through a multi-area OSPF configuration, ensuring faster convergence and sophisticated routing capabilities necessary for high-availability network demands. The network is designed to accommodate administrative complexity due to the nuanced setup and management OSPF requires, which, while resource-intensive, allows for improved scalability and optimization of high-speed data transit. This setup is thus well-suited for large, complex enterprise environments where network performance and expansion are prioritized over simplicity and minimal resource utilization.

3.3 Hybrid Network (Coexistence of RIP and OSPF)

In large enterprises, multiple routing protocols may be used in the same network.

To achieve cooperation and collaborative work among multiple routing protocols, route redistribution can be used between routers to transfer the learned routing protocols to each other. A routing protocol's routes are broadcast through another routing protocol so that all parts of the network can be connected. To achieve redistribution, the router must run multiple routing protocols at the same time, so that each routing protocol can take all or part of the routes of other protocols in the routing table for broadcast.

Design a network that utilizes both RIP and OSPF, considering the transition and coexistence strategies between the protocols.

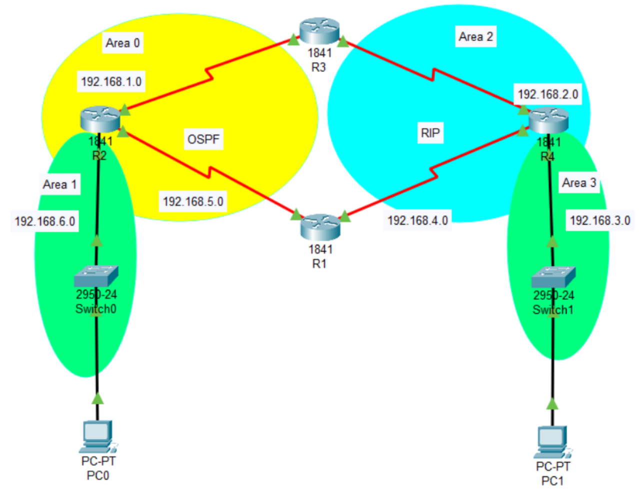


Figure 10 Hybrid OSPF and RIP Network Topology

This network diagram delineates a hybrid routing framework that incorporates both OSPF and RIP protocols, reflecting a nuanced approach tailored to diverse network segment requirements.

- **OSPF Implementation:** The topology includes OSPF-configured Areas 0 and 1. Routers R2 is embedded within these OSPF zones, with R2 connected to Area 1. Router R1 and R3 are positioned to interface between the OSPF and non-OSPF regions, likely serving as an Area Border Router (ABR).
- **RIP Configuration:** Router R4 is equipped with the RIP protocol, interfacing with both an OSPF area (Area 2) and a distinct segment (Area 3). Configure RIP on the network segment connecting routers R1 to R4 and R3 to R4. RIP's inclusion suggests a segment of the network that either prioritizes simplicity or necessitates compatibility with legacy systems.
- **Protocol Interoperability:** Router R1 and R3 play a pivotal role in mediating between the OSPF and RIP realms, demanding meticulous route redistribution configurations to prevent routing discrepancies and maintain optimal path selection.
- **Network Addressing:** Each designated area maintains a unique IP subnet, a critical factor for coherent routing. Router interfaces must be appropriately assigned IP addresses that align with their respective network segments.
- **Resiliency and Path Selection:** The network diagram does not explicitly indicate secondary path options. Consequently, the resilience of the OSPF-RIP interconnectivity hinges on the uninterrupted operation of Router R1.
- **Protocol Coexistence Strategy:** The simultaneous deployment of OSPF and

RIP within the network could be indicative of a phased transition between protocols or a deliberate segmentation strategy, with OSPF managing more complex segments and RIP addressing simpler or outdated portions.

Advantages

- **Interoperability:** Supports legacy systems where RIP is already in place, allowing for a smoother transition to more advanced OSPF without immediate full-scale upgrades.
- **Flexibility:** Enables phased network upgrades, transitioning individual segments to OSPF while maintaining overall network service.
- **Cost-Effectiveness:** May defer costs associated with upgrading hardware that does not support OSPF.

Disadvantages

- **Complexity:** Managing two protocols increases the complexity of the network, necessitating advanced knowledge and careful configuration to prevent issues like routing loops and asynchronous routing tables.
- **Inconsistency in Metrics:** OSPF and RIP use different metrics for determining the best path, which can lead to suboptimal routing decisions when the protocols interact.
- **Administrative Overhead:** Requires careful tuning of redistribution between the protocols to maintain a consistent and loop-free environment.

Results and analysis

In this examination of a hybrid network utilizing OSPF and RIP, the coexistence of the two protocols is necessitated by transitional network strategies and legacy system integration. The network demonstrates the effectiveness of protocol redistribution mechanisms, ensuring continuity and communication across diverse routing domains. This duality, however, introduces complexity and necessitates meticulous management to mitigate the risk of routing loops and maintain consistency across routing tables. The deployment exemplifies a pragmatic approach to modern network architecture, balancing legacy system integration with the progressive adoption of advanced routing protocols.

Applicability

- Hybrid networks are suitable in scenarios where an organization with an existing RIP-based network needs to integrate with OSPF-enabled systems, often due to expansion or modernization efforts.

- They are also applicable when different parts of a network have different performance and complexity requirements, allowing for a tailored approach to routing within each segment.
- Temporary use during a migration phase where a network is transitioning from RIP to OSPF to avoid service disruption.

4. Conclusion

This report has conducted an in-depth analysis of dynamic routing protocols, with a focus on the distinct characteristics and operational differences between Distance-vector (RIP) and Link-state (OSPF) protocols. As networking infrastructures advance, dynamic routing protocols continue to play a crucial role in sustaining communication channels that are efficient, reliable, and capable of scaling.

RIP, with its Distance-vector approach, stands out for its straightforwardness and ease of configuration, which suits smaller, less complex networks. Its reliance on hop count as a routing metric and periodic updates simplifies routing decisions. However, this simplicity comes at the cost of limited scalability, vulnerability to routing loops, and slower convergence times.

In contrast, OSPF is a Link-state protocol tailored for extensive, intricate network landscapes. It leverages Link State Advertisements (LSAs) to form a detailed representation of the network and employs the Dijkstra algorithm for optimal path calculation, leading to quicker convergence. While OSPF provides a more robust solution, adept at handling the dynamic nature of modern networks, it demands greater computational power and involves more complex configuration processes.

Ultimately, the choice between RIP and OSPF should be informed by the network's size, complexity, and specific demands for administrative ease, efficiency, and scalability. Each protocol serves its purpose within its intended scope, and the decision should align with the network's operational objectives and resource availability.

5. References

[1] Catchpoint. “Dynamic Routing Protocols.” [Online]. https://www.catchpoint.com/dynamic-routing-protocols

[2] Medium. “Why does distance vector routing scale better than link state routing.” https://medium.com/@aita.official10/why-does-distance-vector-routing-scale-better-than-link-state-routing-d8571a674154

[3] Cisco Networking Academy. “Module 7: Distance Vector Routing Protocols.” http://cisco.num.edu.mn/CCNA_R&S2/course/module7/7.2.1.1/7.2.1.1.html

[4] Dynamic Routing protocols. https://networking.ringofsaturn.com/IP/Routing.php#_Toc471493321

[5] Khan, Murad; Javaid, Nadeem. (2019, February). “Routing in IP-based Networks.” Thesis. pp.19.[51].

[6] Khan, Murad; Javaid, Nadeem. (2019, February). “Routing in IP-based Networks.” Thesis. pp.20.[51].

[7] Khan, Murad; Javaid, Nadeem. (2019, February). “Routing in IP-based Networks.” Thesis. pp.14.[51].

[8] Khan, Murad; Javaid, Nadeem. (2019, February). “Routing in IP-based Networks.” Thesis. pp.15.[51].

[9] Komal, Navita; Vohra, Rajan; Sawhney, Ravinder Singh. (2013, May). “Assessment of Dynamic Routing Protocols for Increased Number of Workstations.” International Journal of Computer Applications, Volume 70, No. 25. DOI: 10.5120/12225-8483. [Online]. https://www.researchgate.net/publication/237009755

[10] Dipti KC. “Distance Vector vs. Link State Routing Algorithm.” [Online]. https://benchpartner.com/distance-vector-vs-link-state-routing-algorithm

[11] GeeksforGeeks. “Difference between Distance vector routing and Link State routing” https://www.geeksforgeeks.org/difference-between-distance-vector-routing-and-link-state-routing/