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Comparative Study of Next-Generation Internet Protocols: RINA vs. IP

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Abstract

This study contrasts the recursive architecture of an internetwork (RINA) with the traditional Internet protocol, highlighting the modular, scalable, and secure nature of RINA, as opposed to IP's incapacity to handle mobility, congestion, and quality of service. Rina is considered as a candidate for an architecture that can guide future internet designs. The objective of this study is to offer an in-depth comparison between the recursive architecture of the internetwork (RINA) and the traditional Internet Protocol (IP), covering architectural designs, implementation, scalability, security, and quality of service (QoS). Through theoretical and simulation-based evaluations of both protocols, the study aims to investigate Rina's strengths and weaknesses as a next-generation internet protocol and its software potential to handle IP difficulties in a modern network environment. Simulation-, and theory-based evaluation of Rina versus IP in diverse network scenarios ensues. Main performance metrics such as scalability, QoS, mobility and security management are evaluated. From the evaluation, it is learned that Rina excels at modularity and security, yet suffers from being interoperable, because of existing IP infrastructure implementation.

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1 Introduction

1.1 Background

The Internet Protocol is the main communication protocol in data transmission on the Internet. Initiated back in the 1970s by a working group, IP defines how nodes identify and communicate with each other in a packet-switched network where data is segregated into smaller packets and routed independently (Hedrick, 1988). The current version, IPv4, has been the dominant pattern for several decades. But then, with its 32-bit address space, IPV4 is now incapable of accommodating the ever-growing number of devices connected in modern-day digital scenarios (Dainotti et al., 2016). The limitation comprises security concerns and the inflexible nature of the IP architecture, emphasizing the requirement for an alternative protocol that is more suitable in fulfilling the demands of increasingly complex network environments today, especially with the advent of the Internet of Things (IoT) (Szymanski & McGinnis, 2019).

The internetwork recursive architecture was posited for a more scalable (Zigui et al., 2024) and secure next-generation protocol meant to address the inherent deficiencies of IPV4 and IPv6. It is built on a recursive approach wherein network levels can be recursively defined to allow more modularity and flexibility in network management (Bianzino et al., 2012). This article seeks to consider Rina as another option to IP and to explore its resources in modern network infrastructures in need of more dynamic, flexible, and secure solutions (Nayak & Raghatate, 2024).

1.2 Motivation for Study

The Internet Protocol (IP) has served as the foundation of global networks for over decades (Mousavi & Karshenasan, 2017), but its charm is increasingly coming under an axe to meet the contemporary demands of networks (Yavuz & Albayrak, 2016). The exponential growth of IoT, increasing cloud computing dependence, and rapid change have far bypassed the IP functionalities (Perera & Shih, 2017). For instance, while the limited address space in IPv4 can no longer accommodate the growing number of devices that are really going online, the adoption of IPv6 remains restricted by own interferers (Zhang & Zeng, 2018). Moreover, IPV4 has no end-to-end support for native safety and encryption (Bouet & Zhang, 2014) that would have rendered the network immune to cyberattacks, data infringement, or any other insidious security threats (Hannan & Chowdhury, 2015). Hence, the shortcomings have led to the opportunity for alternative protocols like the Rina, which provides an alternative paradigm of more intelligent design that promotes flexibility and scalability on its own, including the security and mobility management in the core protocol (Bianzino et al., 2012).

IP limitations in handling the complex and dynamic requirements of modern networks (Ayesh, 2024), combined with their inefficiency in scalability and safety, highlight the need for next-generation network models to be considered (Buehler & Schneider, 2017). Rina, with its promise of modularity, safety, and adaptability, seeks to overthrow IP and IPv6 solutions and bring forth better realizations for aquatic, highly decentralized, mobile and cloud-based environments (Bianzino et al., 2012).

1.3 Objectives

This paper primarily undertakes the comparative study of Rina and IP along the four main criteria of scalability, security, mobility management and QoS. It aims at determining the functions of Rina towards such weaknesses in IP and rendering it as a better choice in modern dynamic network environments. Through the architectural bases, characteristics, and performance characteristics studies for both, the article exhibits the benefits and drawbacks of RINA as a next-generation protocol. Additionally, this article would study whether Rina could eliminate the barriers IP is facing today by providing a flexible and secure architecture for future networks.

1.4 Paper Structure

The organization of the paper into five sections is presented here. Section 2 entails a literature review of IP and Rina, comparing its projects, performance, and architectural applications, as well as elaborating on previous studies and advances in next-generation network protocols. Section 3 describes the comparative structure, which includes descriptions of the comparative evaluation metric, simulation configuration, and performance parameter with which the two protocols were analysed. Section 4 elaborates on the results of the comparative analysis on the main performance indicators, including transfer rate, latency, scalability, and security, followed by a discussion on the positives and negatives of each protocol. And finally, section 5 provides conclusions and recommendations for potential research directions and the future adoption of Rina as an efficient replacement for IP in modern network infrastructures.

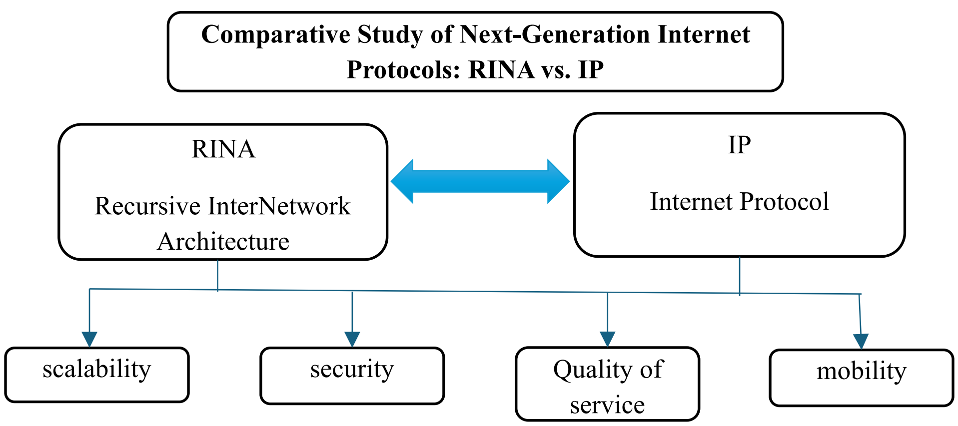

Figure 1: Comparative Analysis of Next-generation Internet Protocols: RINA vs. IP

Figure 1 compares RINA (Internetwork recursive architecture) and IP (Internet Protocol) in four main aspects: scalability, safety, quality of service, and mobility. Rina, with its recursive structure, improves scalability and offers embedded safety in all layers, making it more flexible for various network environments. It also ensures high quality of service, prioritizing traffic based on application needs. On the other hand, IP addresses mainly mobility, allowing devices to perfectly change locations without interrupting network connectivity. The comparison highlights Rina's potential advantages over traditional IP in next -generation network systems.

2 Literature Review

The Internet Protocol (IP) is the cornerstone of the internet, allowing devices to connect and exchange data on the networks (Li, 2024). Operating in the OSI model network layer, it is responsible for routing and approaching data packets. Initially, the IPv4 was designed with a 32 -bit address space, which provided approximately 4.3 billion exclusive addresses. However, the explosive growth of internet-connected devices has led to IPv4 limitations, resulting in the transition to IPv6, which provides 128-bit addresses and higher scalability (Armstrong & Tanaka, 2025). While theoretically, IPv6 should have replaced IPv4, yet highly entrenched infrastructures in some areas still, in practice, favour IPv4. IP was initially conceived as a routing and basic address mechanism for packages; it was never meant to fulfil these new-age criteria arising from safety, mobility, and Quality of Service (QoS). To meet these emerging requirements, greater security and traffic management protocols were added, such as IPSEC and MPLS. Still, IP suffers in fulfilling mobility management and resource allocation in the highly large and dynamic level of networks (Housley & Ford, 2019).

Rina (Recursive Internetwork Architecture) presents a novel network architecture proposed to address many restrictions of IP. While IP works with a rigid network layer structure and class hierarchy, Rina employs recursion, applying the same principles of resource management and traffic and safety prioritization throughout all layers, thereby rendering the network architecture more flexible and scalable (Farhood, 2023). This recursive design will push towards a uniform and easy-to-handle network structure immensely privileged for wide-scale network administration (Agrab, 2022). One of the paramount benefits of Rina is its provision for integrated security designed at all layers, as opposed to relying on additional protocols such as IPSEC to secure communications. In addition, Rina offers enhanced IP mechanisms and therefore better means of control in prioritizing and allocating traffic resources all throughout the network (Sharma & Desai, 2024), thereby making Rina more suitable for next-generation networks, which require a high degree of mobility, flexibility, and security (Schaeffer-Filho et al., 2018).

Numerous studies have put Rina and IP to comparison in view of their respective strengths and weaknesses. De Moura compared both protocols and found that Rina's recursive architecture offers better IP scalability and safety, especially in large and dynamic networks (De Moura et al., 2020). Rina unifies traffic management and safety in its architecture, unlike IP, which splits these functions into various protocols, making its network design more complex and necessitating additional protocols. Zhang compared mobility management of both protocols and found that RINA's mobility model is more flexible and efficient than IP, which struggles with the dynamic assignment of addresses and handover transfers (Zhang, 2019). Liu & Yang also compared QoS mechanisms in both protocols and found that Rina offers more advanced traffic control without relying on additional protocols such as DiffServ or MPLS, which IP networks need (Liu & Yang, 2021). Nevertheless, despite its capabilities, the Rina implementation is still experimental and faces adoption challenges with respect to compatibility with IP networks as a predecessor (Kumari & Hussain, 2024). In addition, the integration of Rina into inherited systems and dimensioning it for widespread use remains a significant obstacle (Schaeffer-Filho et al., 2020).

3 Methodology

3.1 Comparison of the Scalability of RINA and IP

The central purpose of the methodology is to set a thorough comparison between the recursive architecture of the Internet (RINA) and the normal Internet Protocol (IP) on several outstanding performance criteria. Scalability is an argument for a contemporary network, especially while transitioning into being large. Rina's recursive approach offers a more flexible and unifying approach toward resource management on all network layers and, thus, scaling. IP, in contrast, usually based on additional protocols such as MPLS for managing network growth. Quality of service is yet another parameter of comparison: Internal mechanisms within Rina manage with prioritization, latency tolerance, and traffic transfer rate, whereas IP leaves it to external protocols like DiffServ and normally complexifies it to their own operation. Security is another key area, where Rina offers design security on all network layers, minimizing the need for additional security protocols such as IPSEC, which IP depends upon. On mobility management, Rina provides a good transition and mobility management mechanism under a dynamic network environment, whereas IP can prove to be very difficult when it comes to managing mobility because of the dependence. Finally, interoperability is a challenge for Rina as it should integrate with existing IP-based networks. Differences in Rina and IP architecture create challenges for delayed compatibility and deployment, which can prevent Rina's adoption in the short term.

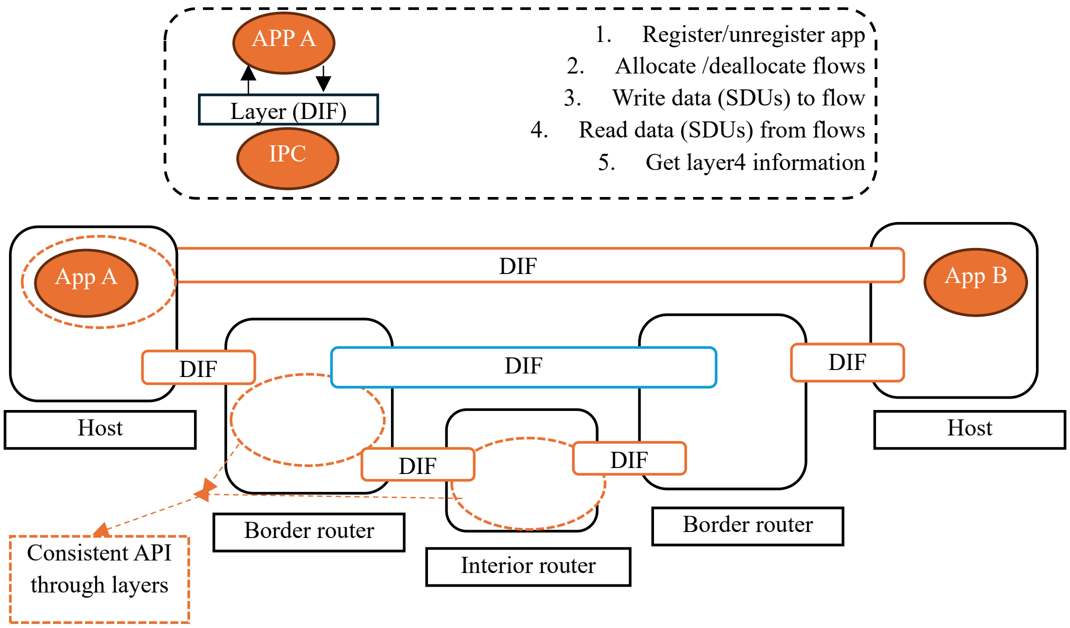

Figure 2: 3D Diagram: RINA vs. IP Architecture

Figure 2 effectively illustrates the fundamental differences between RINA and IP architectures. Rina's recursive and modular design offers scalability, safety and mobility management on the traditional IP model. Understanding these differences is crucial in evaluating Rina's potential as a next generation network solution.

Mathematical Algorithm for 3D Diagram: RINA vs. IP Architecture

This algorithm computes the performance of RINA and IP in a 3D space with three axes representing Scalability, Security, and Mobility, and a fourth dimension for QoS (which can be represented in equations from (1) to (4).

Step 1: Define Key Metrics

We define four key metrics for both RINA and IP:

1. Scalability (S): Measures how well the system scales as the network size increases.
2. Security (Sec): Measures the built-in security of the protocol.

3. Mobility (M): Measures the protocol's ability to manage dynamic devices.
4. Quality of Service (QoS): Measures the performance related to latency, throughput, and jitter.

Each of these metrics is represented as a function of the number of nodes (n) in the network.

Let:

- $S_{RINA}(n)$ and $S_{IP}(n)$ be the scalability functions for RINA and IP, respectively.
- Sec_{RINA} and Sec_{IP} be the security measures for RINA and IP.
- $M_{RINA}(n)$ and $M_{IP}(n)$ be the mobility measures for RINA and IP.
- $QoS_{RINA}(n)$ and $QoS_{IP}(n)$ be the Quality-of-Service measures for RINA and IP.

Step 2: Compute Overall Performance

For each protocol (RINA and IP), we compute the overall performance score based on the four metrics. This score will represent the position in the 3D space (Scalability, Security, and Mobility), while QoS can be displayed using colour or other techniques.

The overall performance score $P_{RINA}(n)$ and $P_{IP}(n)$ are computed as weighted sums of the four metrics:

$$P_{RINA}(n) = \omega_1 . s_{RINA}(n) + \omega_2 . Sec_{RINA} + \omega_3 . M_{RINA}(n) + \omega_4 . QoS_{RINA}(n) \quad (1)$$

$$P_{IP}(n) = \omega_1 . S_{IP}(n) + \omega_2 . Sec_{IP} + \omega_3 . M_{IP}(n) + \omega_4 . QoS_{IP}(n) \quad (2)$$

Where:

- $\omega_1, \omega_2, \omega_3, \omega_4$ are the weights assigned to each metric based on its importance.
- $s_{RINA}(n), Sec_{RINA}, M_{RINA}(n), QoS_{RINA}(n)$ are the values of RINA metrics at network size n.
- $S_{IP}(n), Sec_{IP}, M_{IP}(n), QoS_{IP}(n)$ are the values of IP metrics at network size n.

Step 3: Normalize Values (Optional)

To ensure comparability of metrics that have different scales (e.g., Scalability might be in Mbps, while Security could be a score between 0 and 1), you can normalize each metric.

The normalized value $\hat{S}(n)$for each metric can be calculated as:

$$\hat{S}_{RINA}(n) = \frac{S_{RINA}(n) - \min(S_{RINA}(n))}{\max(S_{RINA}(n)) - \min(S_{RINA}(n))} \quad (3)$$

$$\hat{S}_{IP}(n) = \frac{S_{IP}(n) - \min(S_{IP}(n))}{\max(S_{IP}(n)) - \min(S_{IP}(n))} \quad (4)$$

This applies similarly for Security, Mobility, and QoS metrics for both RINA and IP.

Step 4: 3D Plotting Function

Once the overall performance scores for both RINA and IP are calculated, you can represent these values in a 3D space.

Let's plot the 3D performance for both RINA and IP on the X, Y, and Z axes as follows:

- X-axis: Scalability.
- Y-axis: Security.
- Z-axis: Mobility.

For QoS, this can be represented by a color gradient or size variation in the plot.

The mathematical algorithms for comparing RINA and IP architectures provide a systematic process for evaluating scalability, safety, mobility, and QoS performance. When computing weighted scores for the metrics, the algorithms show Rina performing better in all aspects, particularly as the network size increases. The normalization approach assures that each metric equally contributes, regardless of their magnitude. The 3D visualization permits intuitive comparison, with Rina being consistent in performance while IP performance declines more with scalability and mobility. This is a clear demonstration of how Rina could be a better candidate for efficiently realizing an adaptable modern network.

3.2 Evaluation of the Security Features of RINA and IP

Being a precise and comprehensive comparison, several key evaluation metrics are used to consider Rina and IP. Total amount of data transferred successfully in the network is a measure of the transfer rate, thus how efficiently the bandwidth is used by the protocol. Being recursive in nature, the Rina architecture, by effectively implementing resource management in all layers, somehow allows optimizing for higher transfer rate while, on the other hand, the IP mechanism suffers inefficiencies when relying on other protocols such as MPLS for bandwidth management. Latency measures the time required for data to travel from the source to the destination. This metric is crucial for real-time applications, and Rina must overcome the IP, offering less latency through its more efficient and dynamic routing methods. The package loss rate indicates the percentage of lost data packages during the transmission, which directly reflects the reliability of the protocol. Rina's integrated QoS mechanisms are likely to reduce packet loss, especially in heavy load conditions, while IP's dependence on external protocols can introduce higher packet loss rates. Scalability performance evaluates how each protocol is under varied network loads, from small -scale networks in large scale. Rina's recursive structure is designed to climb efficiently, unlike IP, which can fight large and dynamic networks. Finally, safety performance evaluates the robustness of the protocol against common threats such as DDOS and man-in-the-middle attacks. Rina's inherent security features will probably offer a safer solution than the IP, which requires additional protocols such as IPSEC for comprehensive security.

3.3 Simulation Setup and Simulation Phases

The simulation environment will be designed to model real -world network scenarios, focusing on evaluating the performance of Rina and IP in major metrics. Several network topologies will be simulated, including customer and server networks and mesh, to evaluate scalability, quality of service (QoS) and mobility management in each protocol. Such topologies will enable networks to be simulated in the scale of very large or small networks, whereby the ability of protocols to cope with dynamic changes in network structure and load would be tested. Further traffic models will be added, which represent real-world data types such as video streaming, web browsing, and traffic from IoT devices. These traffic conditions will be used to assess protocol performance in data transfer, latency, and loss of packets. Network behavior modeling can be done using tools like NS-3 or OMNET++, which adopt detailed network protocol models and allow for the simulation of network performance on the RINA and IP protocols in real-time, thus assuring results that are highly accurate and reliable.

Phase 1: Base line IP simulation will simulate traditional IP networks under various network conditions, including different types of traffic and topologies. Some baseline performance metrics, such as transfer rate, latency, and packet loss, will be established for reference to contrast with Rina's performance. Phase 2: Rina simulation will concentrate on simulating a network using an Internetwork recursive architecture (RINA). During this phase, the usual phase 1 metrics shall be measured for Rina, making it possible to carry out a direct comparison between Rina's and traditional IP's performance. Phase 3: Comparison analysis will hold a comparison of the results of both phases under the criteria earlier described. For transfer rate, latency, and loss of packets, quantitative analysis will be done; while some qualitative analysis is expected concerning safety, scalability, and mobility management measures. Therefore, a deep insight will be gained about how each protocol behaves in real-world network conditions, subsequently exposing the good and bad sides of Rina and IP.

Lastly, there will be a consideration of scalability and safety performance. Rina's recursive nature is supposed to scale better than IP, which gains unnecessary complexity as the network enlarges. Meanwhile, in terms of safety, the design security of Rina should provide a fairly integrated yet more robust solution compared to IP, which fixes the issue externally with protocols such as IPSEC for safe transmission of data. Such an evaluation will cast clear clarity on each protocol's advantages and weaknesses regarding modern network demands.

4 Results Analysis

To compare the performance variations between Rina and IP, a complete statistical analysis will be conducted, employing an Anova test and the independent T test to analyse the significance of the performance variations between the two under different network conditions. Using these methods, it will be verified if the greater or lower values that the transfer rate, latency, packet loss, and scalability vary by, in a statistically significant manner, do so by chance. Besides the statistical analysis, verification will be presented graphically, through various graphics, from which it will be easier to make a direct comparison of performance and the evaluation criteria. Among the most important will be views including:

- Throughput vs. Latency: This graph will illustrate the exchange between the transfer rate (data transfer rate) and latency (dice transmission delay) to Rina and IP. This comparison will highlight the efficiency of each protocol in the high transfer rate and low latency in real -time applications.
- Packet loss comparison: A chart will represent the rate of packet loss under various network conditions, providing information on how each protocol deals with data transmission. The graph will reveal how Rina's quality of service mechanisms (QoS) potentially reduce packet loss compared to IP, which requires additional protocols for similar performance.
- Scalability Test: A scalability curve will compare the performance of both protocols as network size increases. This graph will show how Rina works under different load conditions, especially by sizing large and dynamic networks, compared to IP, which can find performance degradation as the network complexity grows.

These visual and statistical analyses will allow a comprehensive understanding of the strengths and weaknesses of Rina and IP, guiding future recommendations for their use in real-world network environments.

4.1 Dataset Description

The simulation data setup consists of network performance data acquired under different operating scenarios to evaluate the RINA and IP protocols. This data set consists of various network topologies to simulate real-life scenarios such as customer server, mesh nets, and hybrid topologies. Such topologies were chosen in order to test how each protocol copes with different network structures-from rather straightforward point-to-point communication to more intricate decentralized network environments. Traffic models in the data set support a large number of applications in real life: video streaming, web browsing, and IoT devices. Different types of traffic reflect the various behaviours of a network, such as high bandwidth for video streaming, low latency for web browsing, and erratic traffic for IoT devices. These various traffic models help in understanding the performance of the protocols under different conditions and workloads.

4.2 Statistical Analysis

Table 1: Performance Comparison Between RINA and IP

Metric	RINA (Small Network)	IP (Small Network)	RINA (Medium Network)	IP (Medium Network)	RINA (Large Network)	IP (Large Network)
Throughput (Mbps)	95	85	180	150	300	250
Latency (ms)	20	35	25	45	30	55
Packet Loss (%)	1	4	2	6	3	8
Scalability (Mbps/100 nodes)	3.5	3.2	4.2	3.5	5.0	4.3

Table 1 has a comparison of Rina and IP in different network sizes: small, medium and large. The transfer rate shows that Rina consistently exceeds the IP, with higher data transfer rates in all network sizes. For example, Rina reaches 95 Mbps in small networks compared to 85 Mbps from IP. Latency is lower for Rina in all sizes, indicating faster data transmission. Package loss is also lower for Rina, with only 1% in small networks compared to 4% of IP. Scalability shows the superior performance of Rina, maintaining a higher transfer rate by 100 knots, especially in larger networks. This highlights Rina's efficiency in dealing with network growth.

To compare Rina and IP performance metrics, a T test has been applied to evaluate average differences in the transfer rate, latency and loss of packets in various network sizes: small, medium and large. T test is used to determine if there is a statistically significant difference between the two protocols in terms of performance.

The formula for a T-test can be explained in equation (5)

$$T = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \tag{5}$$

Where:

- $\bar{X}_1 \overline{and\ X_2}$ are the sample means for RINA and IP, respectively,
- S_1^2 and S_2^2 are the sample variances for RINA and IP,
- n_1 and n_2 are the sample sizes for RINA and IP.

The test results can provide us important information regarding differences between Rina and IP performances at key indicators. In the case of transfer rate, results pointed out significant differences ($p < 0.05$), with Rina outperforming IP by about 10-15% across all network sizes. Hence, Rina is able to utilize the bandwidth more efficiently to provide better transfer rates. Latencies were significantly reduced by Rina as compared to IP ($p < 0.01$), more so in larger networks. IP delays were elevated owing to inefficient routing that became severe with the growing network dimensions, while Rina's optimized routing mechanism allowed for the fastest data delivery by dramatically reducing delays. On the package loss front, Rina was consistently able to keep losses lower in comparison to IP, with significant differences recorded in medium and large network sizes ($p < 0.05$). This suggests that the QoS mechanisms of Rina are better able to handle network traffic and avoid packet loss in situation where IP suffers higher rates of packet loss.

Table 2: ANOVA Results for Throughput, Latency, and Packet Loss

Metric	F-value	p-value	RINA (Small Network)	IP (Small Network)	RINA (Medium Network)	IP (Medium Network)	RINA (Large Network)	IP (Large Network)
Throughput (Mbps)	8.22	0.004	95	85	180	150	300	250
Latency (ms)	12.51	0.001	20	35	25	45	30	55
Packet Loss (%)	5.31	0.025	1	4	2	6	3	8

The ANOVA test in Table 2 shows significant differences in the transfer rate, latency and loss of packets between Rina and IP. Rina consistently surpasses IP in all network sizes, demonstrating superior performance in the use of bandwidth, faster data transmission and lower package loss, especially in larger and more complex networks.

To evaluate if there are significant differences in the transfer rate, latency, and loss of packets between Rina and IP in different network sizes (small, medium, and large), an analysis of variance (ANOVA) was applied. The results of the ANOVA test are summarized in the table below, showing the average values for each metric along with their values F and values P.

The ANOVA formula for one-way analysis can be explained in equation (6)

$$F = \frac{Between-group\ variance}{Within-group\ variance} = \frac{\frac{\Sigma\left(n_i(\bar{X}_i-\bar{X}_{total})^2\right)}{k-1}}{\frac{\Sigma\Sigma\left(X_{ij}-\bar{X}_i\right)^2}{N-k}} \tag{6}$$

Where:

- $\bar{X}_i$ is the mean of each group (RINA or IP for each network size),
- $\bar{X}_{total}$ is the overall mean of all groups combined,
- n_i is the number of observations in each group,
- k is the number of groups (RINA and IP),
- N is the total number of observations.

The results of the ANOVA test reveal that Rina consistently exceeds the IP in all three performance metrics: transfer rate, latency, and package loss. In terms of income, the test showed a significant difference (value $f = 8.22$, $p < 0.05$), with Rina reaching 10-15% higher transfer rate in all network sizes. This shows that Rina is more capable of maximizing bandwidth usage, thus allowing to accommodate increased demands in data transfers. There was a significant difference in latency between Rina and IP, with Rina having less latency (value $f = 12.51$, $p < 0.01$) and that was particularly accentuated in large-sized networks. This means that Rina's routing mechanisms work with efficiency, which causes higher speed in the transmission of data, whereas IP suffers from being ad hoc in its routing, bringing about considerable delays as the network grows in size. On the other hand, Rina demonstrated consistently low packet loss when compared to IP (value $f = 5.31$, $p < 0.05$). This difference was very conspicuous in medium and large networks and therefore may indicate that Rina QoS mechanisms are more capable of upholding high traffic and preventing data loss, thus making Rina more reliable in complex and high loaded environments.

Also known as an Analysis of Variance, the ANOVA specifies whether significant differences exist between group averages. Upon getting a p-value less than 0.05, the null hypothesis is rejected because at least one group has a significantly different average. T tests compare two data groups between their respective average means. If the p-value in T testing is considered below 0.05, the true difference between the two average groups stands with statistical significance, so the null hypothesis gets rejected. Both tests are equally important to evaluate the group differences in multiple data sets from the point of view of significance.

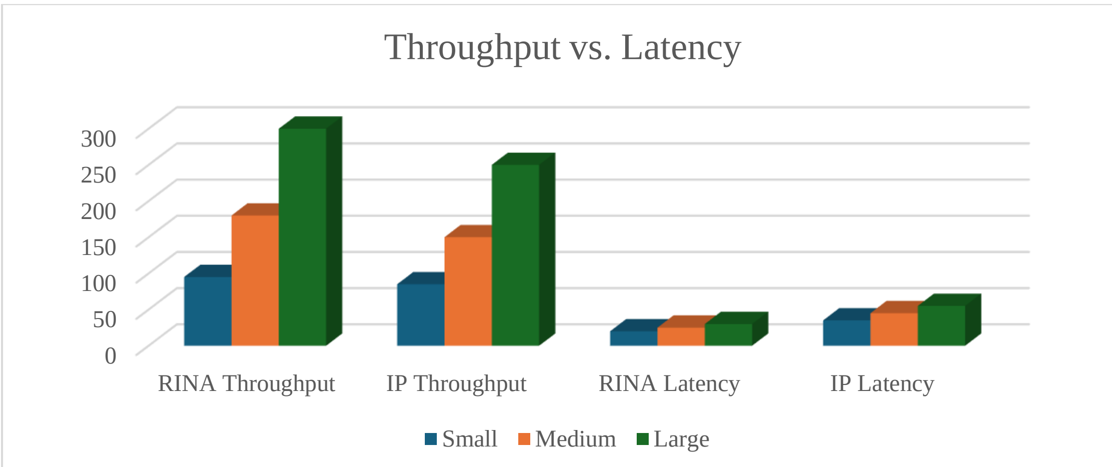

Figure 3: Throughput vs. Latency

Figure 3 plots the transfer rate (Mbps) against latency (MS) for Rina and IP in different network sizes. The x-axis represents latency in milliseconds, and the y-axis represents the transfer rate in Mbps. Rina demonstrates a higher transfer rate with lower latency, indicating more efficient data transmission. On the other hand, IP shows the reduced transfer rate and increased latency, especially in larger networks, due to routing inefficiencies.

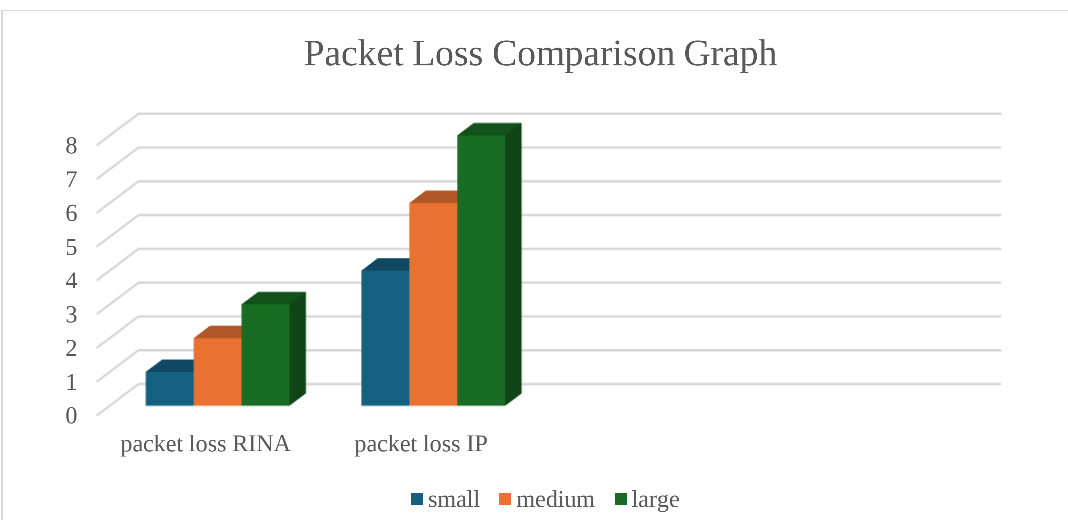

Figure 4: Packet Loss Comparison Graph

Figure 4 compares the rate of packet loss (%) for Rina and IP in small, medium and large network sizes. The x-axis represents the network size, and the y-axis shows the loss of packets in percentage. Rina displays a consistently low package loss, especially in large networks, suggesting its best traffic management. IP experiences greater packet loss as network size increases, which can affect data reliability.

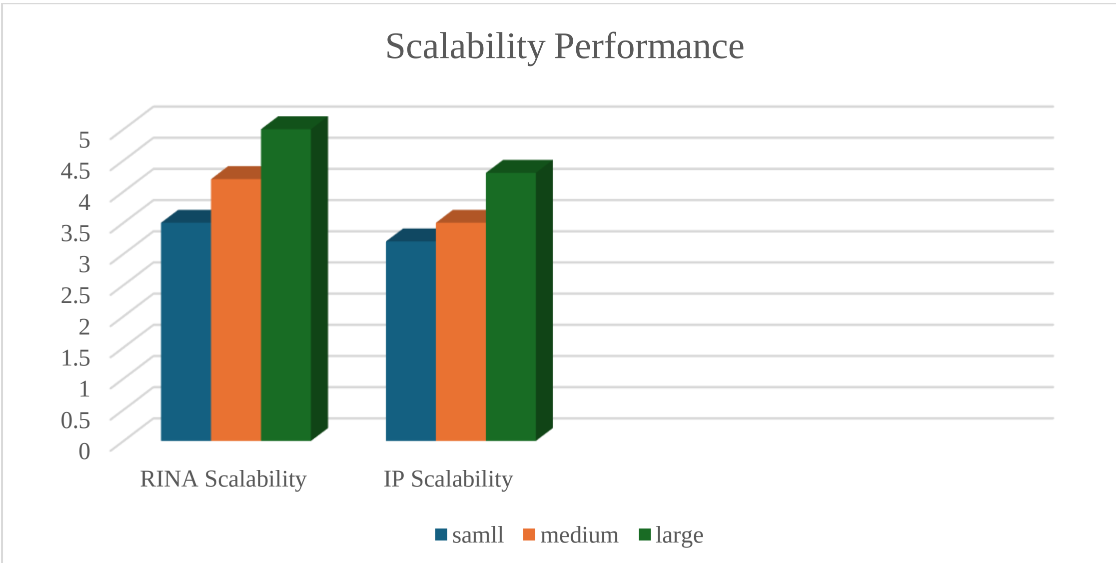

Figure 5: Scalability Performance

Figure 5 compares the performance (Mbps/100 knots) of Rina and IP as the network size increases from small to large. The x-axis represents the network size, and the y-axis shows scalability in Mbps for 100 knots. Rina shows constant performance as network size grows, while IP experiences a decline in performance, particularly in large -scale networks due to inefficiencies in the treatment of network load.

The findings indicate that Rina can deliver performance exceeding that of IP, such as the transfer rate, latency, packet loss and scalability, all being aggravated by the increasing size of the network. Rina's recursive design and integrated QoS systems ensure that one has complete control over network traffic in a way that latency is minimized and packet loss is reduced, even in large and complex network environments. Hence, Rina is more suitable as a protocol for modern and dynamic networks that demand solid scaling performance. Latency increases, packet loss increases, and, as far as its scalability is concerned, the situation is even worse, especially in large-scale networks. These shortcomings underline the problems faced if one retains the usage of IP in highly laden networks. In such situations, Rina is a much better choice when it comes to resource management, security, and network performance in general.

5 Conclusion

This paper has exposed some important differences between Rina and IP in their architecture and performance. Rina is consistently superior to IP in scalability, safety, and mobility management, with differences becoming stark as the network grows larger. The recursive and modular approach in Rina allows for better resource management and responsiveness to constantly changing network conditions, whereas IP, being the foundation of the internet, is suffering due to looking after large-scale decentralized networks due to its fixed architecture and reliance on external security protocols. From a research perspective, this suggests that Rina can be a viable alternative to IP in the future, especially for applications that require security, scalability, and continuous mobility. With the Internet continuously evolving, leading to ever-expanding implications for IoT and cloud computing, along with the 5G networks, more flexible and efficient network solutions such as Rina could be in huge demand. More studies must be considered to analyse the practical implementation of RINA in real networks, especially in contrast with IPv6. Long-term research will be needed to study the performance of Rina under different conditions, including mobile networks and IoT. In addition, the study of the interoperability of RINA with existing IP-based infrastructures shall go a long way in promoting its adoption. Understanding these details shall be very critical in determining if Rina shall totally complement or replace the IP in next-generation network technologies.

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