

# Comparative Analysis of IPv4 and IPv6 to Improve Quality of Service on a University Wireless Network

## Análisis Comparativo de IPv4 e IPv6 para Mejorar la Calidad del Servicio en una Red Inalámbrica Universitaria

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### Abstract

**Introduction:** The exhaustion of IPv4 addresses has created an imperative need to globally adopt IPv6 as the primary protocol to ensure the continuity and expansion of the Internet. This transition from IPv4 to IPv6 implies the coexistence of both protocols in dual-stack networks, which represents a significant technical challenge that impacts the quality of service.

**Objective:** To analyze the comparative performance of IPv4 and IPv6 protocols in a dual-stack network implemented at the Universidad de la Costa, to evaluate their impact on the quality of service, and propose recommendations for an efficient transition to IPv6.

**Method:** An experimental study was conducted in the wireless network of the Universidad de la Costa. Performance metrics, including connection speed, traffic performance, and error rate, were evaluated for both protocols. The analysis was complemented with the observation of specific network events, such as TCP connection establishment and TLS packet handling, using traffic capture and analysis tools.

**Results:** The results show that IPv4 and IPv6 have similar average speeds, with a slight advantage for IPv4. However, IPv6 had a lower error rate (2.92%) compared to IPv4 (3.69%), indicating more efficient transmission. Greater variability was observed in IPv6, particularly during the processing of specific network tasks. Both protocols demonstrated reliable overall performance, albeit with key differences in service stability and consistency.

**Conclusions:** The transition to IPv6 offers significant advantages in terms of address availability and data transmission efficiency, but also presents challenges associated with the stability of specific network parameters. Successful implementation in academic environments requires sound technological governance, including clear policies, constant monitoring, and staff training. This study offers valuable guidance for institutions facing similar challenges in their IPv6 adoption processes.

**Keywords:** IPv4, IPv6, QoS, IPv6 Adoption, Dual-stack

### Resumen

**Introducción:** El agotamiento de las direcciones IPv4 ha generado la necesidad imperante de adoptar de manera global IPv6 como protocolo base para garantizar la continuidad y expansión de Internet. Esta transición de IPv4 a IPv6 implica la coexistencia de ambos protocolos en redes dual-stack, lo cual representa un desafío técnico significativo que impacte en la calidad de servicio.

**Objetivo:** Analizar el desempeño comparativo de los protocolos IPv4 e IPv6 en una red dual-stack implementada en la Universidad de la Costa, con el fin de evaluar su impacto sobre la calidad de servicio y proponer recomendaciones para una transición eficiente hacia IPv6.

**Método:** Se realizó un estudio experimental en la red inalámbrica de la Universidad de la Costa. Se evaluaron métricas de rendimiento como velocidad de conexión, rendimiento del tráfico y tasa de errores en ambos protocolos. El análisis se complementó con la observación de eventos específicos de red, como el establecimiento de conexiones TCP y la gestión de paquetes TLS, utilizando herramientas de captura y análisis de tráfico.

**Resultados:** Los resultados muestran que IPv4 e IPv6 tienen velocidades promedio similares, con una ligera ventaja para IPv4. Sin embargo, IPv6 presentó una menor tasa de errores (2.92%) frente a IPv4 (3.69%), lo que indica una transmisión más eficiente. Se observó mayor variabilidad en IPv6, particularmente durante el manejo de ciertos procesos de red. Ambos protocolos demostraron un desempeño general confiable, aunque con diferencias clave en la estabilidad y consistencia del servicio.

**Conclusiones:** La transición a IPv6 ofrece ventajas significativas en términos de disponibilidad de direcciones y eficiencia en la transmisión de datos, pero también plantea retos relacionados con la estabilidad de parámetros específicos de la red. Una implementación exitosa en entornos académicos requiere una gobernanza tecnológica sólida, que incluya políticas claras, supervisión constante y formación del personal. Este estudio ofrece una valiosa orientación para las instituciones que se enfrentan a retos similares en sus procesos de adopción de IPv6.

**Palabras clave:** IPv4, IPv6, QoS, Adopción de IPv6, Dual-stack



## INTRODUCTION

In today's hyperconnected environment, the transition from IPv4 to IPv6 has become a technical imperative driven by the exhaustion of IPv4 address space, resulting in a significant scarcity of public IPv4 addresses [1]. The increasing demand for internet-connected devices has further intensified this issue, making IPv6 adoption essential for sustaining global internet growth [2]. Dual-stack networks, where both IPv4 and IPv6 operate concurrently, have emerged as a transitional architecture to facilitate compatibility during this migration phase [3]. The implementation of dual-stack not only ensures backward compatibility but also supports the deployment of modern internet services that rely on IPv6's enhanced capabilities [4].

From a strategic perspective, the transition to IPv6 is not merely an upgrade, it is a necessity to guarantee uninterrupted network functionality and global interoperability in the long term [5]. IPv6 provides an exponentially larger address space compared to IPv4, effectively addressing the limitations of its predecessor and enabling the continuous expansion of digital services [6]. Furthermore, IPv6 incorporates features such as simplified header structure, improved multicast routing, and better support for mobile devices, which contribute to performance and scalability improvements [7].

Within this framework, QoS becomes a critical factor, extending beyond simple bandwidth considerations to include parameters such as latency, jitter, and packet loss. QoS in IPv6 is pivotal for ensuring reliability, especially in real-time and mission-critical applications [8]. Therefore, the evolution toward IPv6 must be accompanied by robust QoS strategies to maintain the performance and stability of network services.

The primary objective of this research project is to analyze the traffic efficiency of IPv4 and IPv6 protocols in the wireless network infrastructure of Universidad de la Costa. The transition from IPv4 to IPv6 has become a technical necessity due to the near-total depletion of the IPv4 address space [9]. While the implementation of IPv6 offers expanded addressing capabilities and enhanced routing efficiency, its widespread adoption introduces significant operational and compatibility challenges, especially in dual-stack environments where IPv4 and IPv6 must coexist [10].

Effectively managing this coexistence is crucial to ensure seamless connectivity, minimize latency, and maintain a high QoS, which are critical factors for the overall user experience [11]. IPv6 introduces advanced features such as improved multicast routes, stateless address autoconfiguration (SLAAC), and better support for mobile devices, all of which contribute to potential QoS improvements. However, these advantages are counterbalanced by the complexity of transition mechanisms and limited legacy support in some networking equipment [12].

The research question guiding this project is: How can specific QoS strategies and policies be designed and implemented in a dual-stack (IPv4/IPv6) wireless network to enhance connectivity and user experience? A detailed analysis of the theoretical foundations and current literature on IPv6 deployment, transition techniques such as tunneling and dual-stack, and comparative QoS metrics for both protocols will provide the foundation for this inquiry [13], [14].

Accordingly, a methodological framework is proposed to evaluate and compare the performance of IPv4 and IPv6 within the wireless environment of Universidad de la Costa. This includes empirical testing of channel performance, throughput, and packet loss under controlled scenarios. The goal is to identify performance gaps and infrastructure limitations, offering strategic recommendations for optimizing the network's QoS and facilitating a more efficient transition to IPv6 [15].

## RELATED WORKS

Recent scientific works have focused on the performance comparison of IPv4 and IPv6 protocols in wireless university networks and their impact on improving QoS. The following section introduces the main contributions in this research area. [Table I](#) shows a brief introduction to the main works.

Recent empirical studies have highlighted the urgent need to evaluate the performance of IPv4 and IPv6 in wireless environments, particularly in educational institutions. In [16], QoS metrics for Mobile IPv6 handovers using IEEE 802.11e were examined, demonstrating that IPv6 significantly improves throughput and reduces handover delays in video conferencing applications. These findings underscore the potential performance benefits of IPv6 for latency-sensitive academic networks.

TABLE I. OVERVIEW OF KEY RESEARCH CONTRIBUTIONS

Cite	Study	Main Topic	Key Findings
[16]	QoS in mobile handover.	QoS in mobile handover with IPv6 in IEEE 802.11e.	IPv6 significantly improves performance (higher throughput, lower delay) in university videoconferencing.
[17]	Mobility simulation with IPv6.	MIPv6 vs. Mobile IPv4 under Real Traffic: MIPv6.	Improves packet loss, jitters, and delay in WLANs, improving real-time services
[18]	Comparison of queuing mechanisms (FIFO, WFQ, CBWFQ).	IPv4 vs. IPv6 Performance in IPv6 Traffic Management.	IPv6 exhibits more stable QoS under weighted/priority queuing, making it particularly useful for diverse university scenarios.
[19]	Review of QoS deployments in university wireless networks.	Deployment of DiffServ in dual-stack environments.	IPv6 offers equivalent performance to IPv4 with DiffServ, reinforcing its viability in university access networks.
[20]	Mobility Protocols and Header Design in IPv6.	Impact on real-time traffic and performance stability.	IPv6 reduces fragmentation overhead and improves multicast traffic delivery, reducing latency.
[21]	Comparative study on bandwidth estimation tools (av_bw).	Comparison of wired and heterogeneous scenarios with wireless link.	Analysis reveals notable differences in latency and bandwidth measurement between IPv4 and IPv6 in mixed environments.
[22-23]	IPv6 deployment in higher education.	IPv6 deployment in higher education.	Dual-stack deployment achieved over 80% IPv6 traffic, utilizing user-centric strategies.

In controlled simulations utilizing IPv6 mobility support, researchers observed measurable improvements in packet loss, jitter, throughput, and delay across various traffic classes. The study concluded that mobility-enabled IPv6 (MIPv6) supports real-time services more effectively than mobile IPv4, particularly in IEEE 802.11 WLAN environments [17]. Such enhanced QoS through IPv6 is critical to meeting the demands of modern university users.

Comparisons of traffic management strategies between IPv4 and IPv6, utilizing queuing mechanisms such as FIFO, WFQ, and CBWFQ, reveal significant trends: IPv4 may deliver comparable bandwidth under basic queuing, but IPv6 provides greater stability and consistent QoS under weight and priority queuing conditions [18]. These results suggest that IPv6, when paired with advanced QoS scheduling, can outperform IPv4 in diverse real-world scenarios.

While most QoS deployments currently focus on backbone networks, recent reviews suggest the need to evaluate IPv6 QoS mechanisms in wireless access networks, such as those found in universities [19]. In gigabit-scale dual-stack environments, IPv6 traffic demonstrated performance nearly equivalent to IPv4 across service classes, confirming the efficacy of established Differentiated Services (DiffServ) models in IPv6 systems.

Network mobility and routing protocol design also influence QoS comparatives. Implementing optimized algorithms for IPv6 reduces fragmentation and header processing overhead compared to IPv4, thereby enhancing the stability of real-time traffic delivery and throughput. Studies affirm that IPv6's simplified header structure and native multicast routing support contribute to lower latency and improved service reliability [16], [20].

Recent studies conducted at higher education institutions, such as Virginia Tech and Imperial College London, have documented comprehensive deployment frameworks for IPv6 adoption, showing how campuses achieved over 80% IPv6 traffic usage through dual-stack implementation and user-centric strategies [16]. Another relevant case is Fukuoka University in Japan, which reported a gradual, successful campus-wide IPv6 rollout, demonstrating effective planning, infrastructure adaptation, and minimal user-reported issues by 2024 [17].

Recent studies have highlighted the challenges and solutions related to wireless communication and IPv6 deployment in academic and urban contexts. For instance, Barrios-Ulloa analyzed the performance of radio wave propagation models in urban wireless environments, demonstrating how environmental factors influence signal behavior [21]. Similarly, Salcedo emphasized the role of bandwidth in determining both quality of service and QoE in networked systems [22]. Additionally, Pinto-Mejía et al. investigated security vulnerabilities in free public Wi-Fi networks, specifically in the city of Barranquilla, underscoring the importance of robust security practices in open-access environments [23].

The above highlights several aspects that distinguish this work from previous studies. First, it evaluates four av\_bw estimation tools within a purely wired network scenario. Second, it extends the evaluation to a heterogeneous network environment, featuring a wireless link that acts as a backbone between two wired segments. Finally, the study presents a comparative analysis of both scenarios, focusing on latency and av\_bw measurements.

## METHODOLOGY

The work was carried out in several tasks. The first task was comparing the technical features of IPv4 and IPv6. Then, the network testbed was designed and configured to evaluate the protocol's performance. Finally, the experiments were designed and executed.

### A. Comparing the technical features of IPv4 and IPv6

IPv4 mandates the use of addresses across all network layers, whereas IPv6 allows for more flexible configurations, depending on the Virtual Cloud Network (VCN) and subnet settings. This configurability in IPv6 can enhance address management and scalability. In terms of supported traffic types, IPv4 supports full traffic routing across all gateways, whereas IPv6 restricts traffic to specific gateway types, such as Internet Gateways and Dynamic Routing Gateways (DRGs). However, it fully supports east-west traffic within a region (see Table II).

TABLE II. IPV4 AND IPV6 TECHNICAL FEATURES

Cite	Feature	IPv4	IPv6
[24]	Supported Address Types	IPv4 addresses are always required, regardless of whether IPv6 is enabled.	IPv6 addresses are optional at the VCN level, optional per subnet within a VCN where IPv6 is enabled, and optional per VNIC within an IPv6-enabled subnet.
[25]	Supported Traffic Types	IPv4 traffic is supported across all gateway types and between instances within the VCN (also known as east-west traffic).	IPv6 traffic is supported only through specific gateways: the Internet gateway, the local peering gateway, and the dynamic routing gateway (DRG). Both inbound and outbound IPv6 connections are supported by the VCN, whether connecting to the internet or on-premises networks. Intra-region traffic (within and across Virtual Cloud Networks - VCNs) is also fully supported.
[26]	VCN Size	From /16 to /30.	Oracle-assigned GUA: /56 only; BYOIPv6: /64 or larger; ULA: /64 or larger.
[27]	Subnet Size	From /16 to /30, with three reserved addresses per subnet (first two and last).	Fixed at /64, with eight reserved addresses (first four and last four).
[28]	Public and Private IP Address Space	Private: CIDRs may come from RFC 1918 ranges or publicly routable ranges (treated as private). Public: no exclusive public IPv4 space; Oracle dynamically assigns public addresses.	The VCN may receive a /56 GUA prefix from Oracle or import a BYOIPv6 prefix. These can be internet-routable if assigned to public subnet resources. ULAs are also supported but are never internet-routable.
[29]	IP Address Assignment	Each VNIC is assigned a private IP address (user-defined or Oracle-assigned). Optionally, a public IP address can be assigned if the subnet is public. Public and private IPs are distinct API objects.	IPv6 addresses can be assigned from multiple prefixes to a VNIC if available in the subnet. The Ipv6 API object includes address logic and subnet-based public/private designation.

[30]	Internet Access	Internet access is controlled by adding/removing public IPs from private ones on VNICs in public subnets.	Internet access is toggled at the subnet level. There is no separate public IP object; access is controlled via the public/private flag in the subnet configuration.
[31]	Primary and Secondary IP Tags	Each VNIC has one primary and up to 32 secondary IPv4 private addresses.	IPv6 addresses do not distinguish between primary or secondary; up to 32 IPv6 addresses may be assigned per VNIC.
[32]	Hostnames	Hostnames can be assigned to IPv4 addresses.	Hostname assignment is not supported for IPv6 addresses.
[33]	Route Rule Limits	IPv4 and IPv6 route rules may coexist in the same table.	IPv6 route rules can target only the internet gateway, local peering gateway, or DRG, with a maximum of 50 rules per table.
[34]	Security Rule Limits	IPv4 and IPv6 rules may reside in the same security group or list.	IPv6 security rules must use IPv6 prefix ranges; service prefix labels are not allowed. Limits: 50 ingress and 50 egress per list; 16 total rules per network security group.
[35]	Reserved Public IP Addresses	Supported.	Not supported.
[36]	Regional vs. Availability Domain (AD) Specific	Primary private IPv4 addresses are AD-specific. Secondary addresses may be AD-specific or regional, depending on configuration. Public IPs may be regional or AD-specific, depending on their type (ephemeral or reserved).	IPv6 addresses are always regional.

Regarding subnet design, IPv4 subnets range from /16 to /30, while IPv6 enforces a fixed /64 size, reflecting its vastly larger address space. IPv6 also reserves more addresses for network management, which supports enhanced routing protocols but may slightly reduce usable space. Public and private IP management also differ: IPv6 allows the assignment of Global Unicast Addresses (GUAs) and Unique Local Addresses (ULAs), offering improved segmentation and control for internal versus external traffic.

IPv6 introduces a new object model for IP assignment, separating it from the traditional public-private linkages found in IPv4. Additionally, while both protocols allow control over public/private subnet classification for Internet access, IPv6 uses a simplified on/off toggle model, which may streamline administrative tasks.

IPv6 also limits some features present in IPv4, such as hostname assignment and reserved public IPs, potentially requiring additional DNS configurations. Security and routing tables, while shared between both protocols, have stricter limits for IPv6, which could influence scalability in large deployments.

Finally, IPv6 addresses are regional rather than AD specific, which aligns better with distributed cloud-native designs and may improve redundancy and fault tolerance in university-scale wireless infrastructures. These differences justify continued analysis of the impacts of IPv6 deployment in educational environments.

## B. Network Infrastructure

The experiment was executed on specialized network infrastructure (see Fig. 1), which shows a network test diagram commonly used to compare the performance of the IPv4 and IPv6 protocols. The diagram aims to illustrate a network testing environment where the performance of IPv4 vs. IPv6 can be evaluated under real-world conditions by measuring factors such as Bandwidth, Latency, Packet loss, and Connection stability. This is done by sending traffic from the client to the iPerf server across the Internet, alternating between the IPv4 and IPv6 protocols to observe the differences.



Fig. 1. Connection Topology

Below is an explanation of each component:

### 1. WiFi Client (IPv4/IPv6)

- Represents a device (such as a laptop or PC) connected via WiFi and configured to operate with both IPv4 and IPv6 protocols.
- This device generates the network traffic used for performance testing.

### 2. ISP Router (Internet Service Provider)

- A device that connects the user's local network to the Internet.
- Supports routing of both IPv4 and IPv6 traffic externally.
- Its primary role is to forward the client's packets to the iPerf server through the Internet.

### 3. Internet

- The transport medium between the client and the server, through which all traffic flows.
- It may include multiple intermediate nodes (routers, switches, etc.) across the global network.

### 4. iPerf Server (IPv4/IPv6)

- A server configured to receive and measure network traffic using the iPerf tool, which is a standard for performance testing.
- It is enabled to accept both IPv4 and IPv6 connections, allowing a direct performance comparison between the two protocols.

TABLE III. CONNECTION DATA

Version	IP Origen	IP Destino	Protocol	Puerto
IPv4	192.168.20.51	89.84.1.194	TCP	9200
IPv6	2801:144:5:10::200	2001:860:de01:1101::2	TCP	9200

Table III presents the connection parameters used for evaluating network performance. Both entries show TCP traffic directed to port 9200. The first row corresponds to a connection using IPv4, where a private IP (192.168.20.51) communicates with a public IP (89.84.1.194). The second row reflects a parallel IPv6 connection, from 2801:144:5:10::200 to 2001:860:de01:1101::2. This symmetrical setup ensures comparability between the two protocol versions under identical conditions.

## EXPERIMENTS AND RESULTS

### A. Channel Throughput in IPv4 and IPv6

#### 1. IPv4

Fig. 2 shows relatively stable performance with minor fluctuations in both transfer rate and bandwidth. The data suggests that the connection being tested maintains good throughput, with occasional drops possibly due to congestion, latency, or protocol-specific behavior.

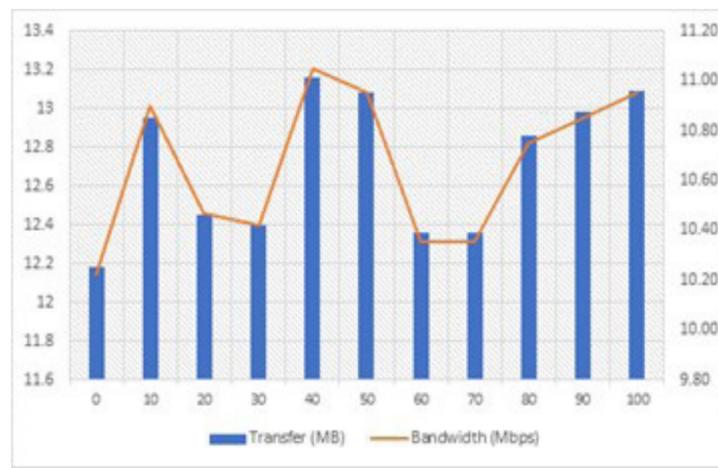


Fig. 2. iPerf3 Test in Channel Performance using IPv4

During a 120-second test, 153 MB were sent at 10.7 Mbps and 149 MB were received at 10.4 Mbps, indicating stable bidirectional network performance. In essence, the connection maintained relatively stable throughput in both directions during the test period (see Table IV).

TABLE IV. TOTAL DATA TRANSFER IN IPV4

#	Interval	Transfer	Bandwidth	
1	0.00-120.00 sec	153 MBytes	10.7 Mb/s	Enviados
2	0.00-120.00 sec	149 MBytes	10.4 Mb/s	Recibidos

## 2. IPv6

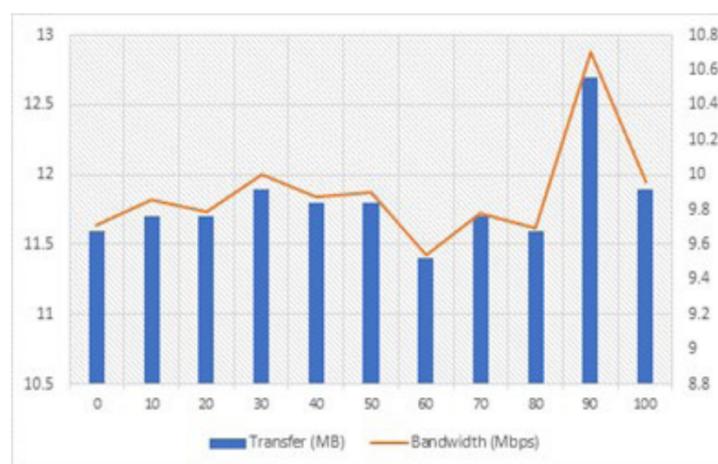


Fig. 3. iPerf3 Test in Channel Performance using IPv6

Fig. 3 shows the relationship between data transfer (in megabytes) and bandwidth (in megabits per second) over a series of test intervals. Overall, transfer values remain relatively stable between 11.5 MB and 12.5 MB across most intervals, while bandwidth fluctuates more noticeably, peaking sharply at the 90-second mark, indicating a temporary increase in network performance.

### B. Evaluación de Rendimiento de Trafico usando Wireshark

The traffic performance evaluation using Wireshark focused on the number of packets and the detection of possible errors in the dual-stack IPv4 and IPv6 network. Wireshark provided a detailed overview of data transmission, enabling the analysis of packet frequency and distribution under both protocols. Special attention was paid to identifying potential errors, such as packet loss or retransmissions, to assess the network's stability and reliability.

COMPARATIVE ANALYSIS OF IPV4 AND IPV6 TO IMPROVE QUALITY OF SERVICE ON A UNIVERSITY WIRELESS NETWORK

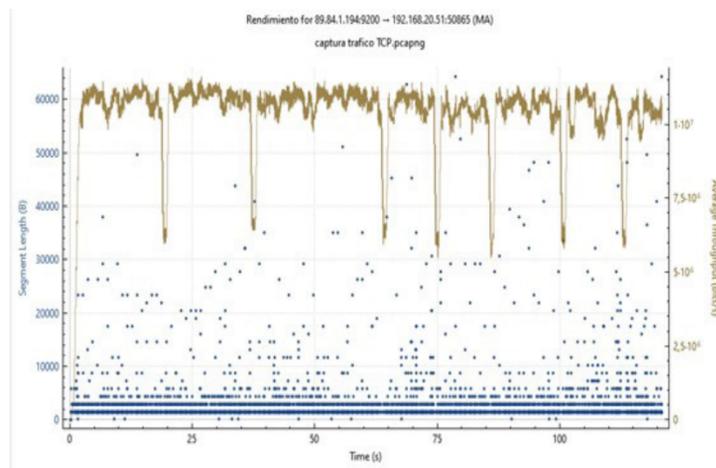


Fig. 4. IPv4 Traffic Performance channel using iPerf3 Tests

Fig. 4 presents the TCP traffic captured between two IP addresses 89.84.1.194:9200 and 192.168.20.51:50865, likely from a Wi-Fi IPv4 transmission. Additionally, it demonstrates the performance of a TCP connection between two IP addresses, where segment lengths vary widely and the average throughput remains relatively stable at around 10 Mbps, with occasional drops likely caused by network fluctuations or protocol adjustments.

TABLE V. IPV4 PERFORMANCE STATISTICS

Bytes	Paquetes totales	Packets A → B	Bytes A → B	Packets B → A	Bytes B → A	Bits/s A → B	Bits/s B → A
164458129	138825	50767	2741467	88058	161716662	181338	10697017

Table V presents the communication statistics between IP addresses 192.168.20.51 and 89.84.1.194, showing a total of 164,458,129 bytes transferred in 138,825 packets, with 50,767 packets and 2,741,467 bytes sent from A to B, and 88,058 packets and 161,716,662 bytes sent from B to A, resulting in transmission rates of approximately 181,338 bits/s from A to B and 10,697,017 bits/s from B to A.

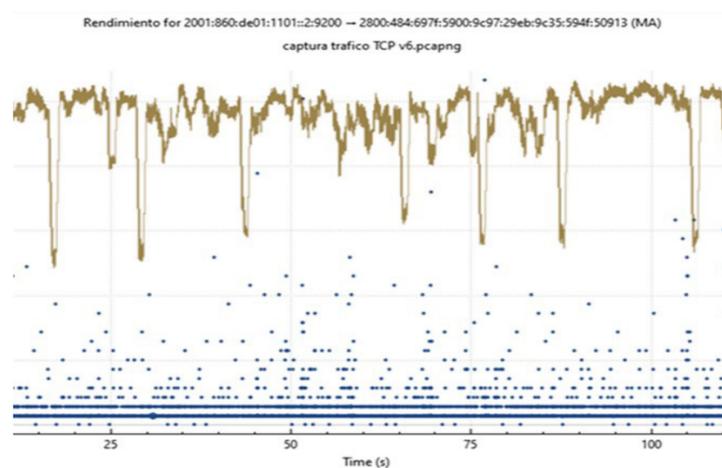


Fig. 5. IPv6 Traffic Performance channel using iPerf3 Tests

TCP traffic performance over IPv6 between the IP addresses 2001:860:de01:1101::2:9200 and 2800:484:697f:5900:9c97:29eb:9c35:594f:50913, where the brown line represents the average throughput (in bits per second) and the blue dots show the segment lengths over time. However, throughput remains stable, primarily with periodic drops, indicating fluctuations in data transmission efficiency during the capture period (see Fig. 5).

TABLE VI. IPV6 PERFORMANCE STATISTICS

Paquetes	Bytes	Paquetes totales	Packets A → B	Bytes A → B	Packets B → A	Bytes B → A	Bits/s A → B	Bits/s B → A
136551	158754595	136551	49989	3699235	86562	155055360	244498	10248299

The connection between the IPv6 addresses 2800:484:697f:5900:9c97:29eb:9c35:594f (Direction A) and 2001:860:de01:1101::2 (Direction B) involved a total of 136,551 packets and 158,754,595 bytes, where 49,989 packets and 3,699,235 bytes were sent from A to B,

and 86,562 packets and 155,055,360 bytes from B to A, with average transmission rates of 244,498 bits/s ( $A \rightarrow B$ ) and 10,248,299 bits/s ( $B \rightarrow A$ ), see Table VI.

Fig. 6 shows the TCP traffic capture over time using Wireshark, where the brown line represents the number of TCP packets processed per second, remaining primarily between 1100 and 1300 packets/s, while the red bars indicate TCP errors that occur intermittently with a notable spike around 145 seconds suggesting possible network instability; additionally, the iPerf3 IPv4 traffic test recorded 5133 erroneous packets out of a total of 138,825 packets.

Fig. 7 shows the input/output behavior during a TCP IPv6 traffic capture using Wireshark, where the brown line represents the number of filtered packets per second relatively stable between 1000 and 1300 with occasional dips and the red bars indicate intermittent TCP errors, particularly after the 50 second mark, suggesting degraded network performance; additionally, the iPerf3 IPv6 traffic test recorded 3982 erroneous packets out of a total of 136,551 packets.

### C. TCP Traffic Error in IPv4 and IPv6

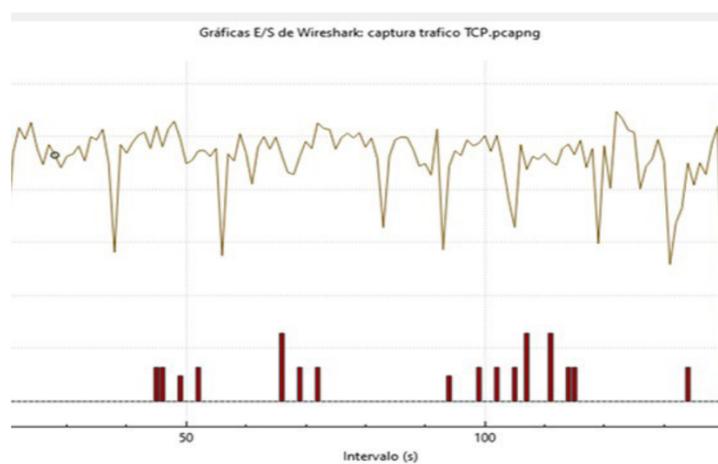


Fig. 6. IPv4 Traffic Errors using iPerf3 Test

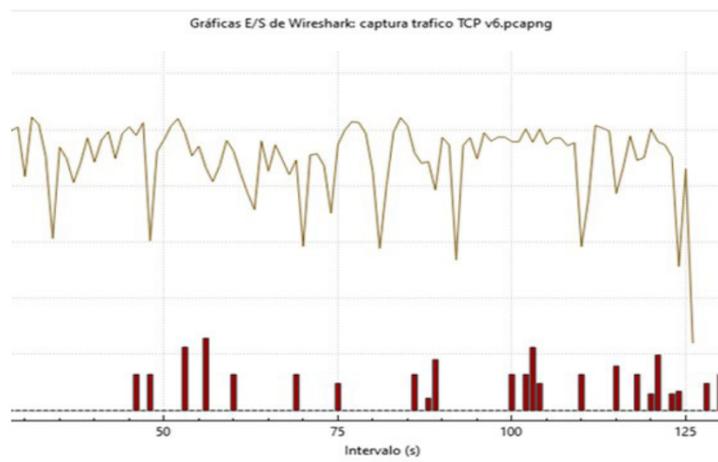


Fig. 7. IPv6 Traffic Errors using iPerf3 Test

### D. Analysis of IPv4 and IPv6 performance in terms of connection speed

A detailed analysis of IPv4 and IPv6 performance was conducted on the dual-stack network at the University of the Coast, with a specific focus on connection speed. The tests were carried out using the iperf3 and Wireshark tools to measure data transfer and bandwidth.

#### 1. IPv4 Performance

The results obtained from the iperf3 tests revealed that, within the 0.00 to 120.00 second interval, a total of 153 MB were sent at an average speed of 10.7 Mbps, while 149 MB were received at an average speed of 10.4 Mbps. Wireshark provided additional information, showing that the address 192.168.20.51 sent 138,825 packets, of which 5,133 had errors, representing approximately 3.69% of the total (Table V).

#### 2. IPv6 Performance

During the same time interval, tests with iperf3 on IPv6 showed that 145 MB were sent at an average speed of 10.1 Mbits/sec, and 141 MB were received at an average speed of 9.88 Mbits/

sec. According to the information provided by Wireshark, the IPv6 address 2801:144:5:10::200 sent 136,551 packets, of which 3,982 had errors, constituting approximately 2.92% of the total (Table VI).

### 3. Comparative Analysis

The results suggest that IPv4 and IPv6 have similar performance in terms of connection speed. Both protocols have similar average speeds, with IPv4 slightly higher. IPv4 shows a slightly higher error rate (3.69%) compared to IPv6 (2.92%). However, both error rates are relatively low, indicating generally reliable data transmission in both versions of the protocol. The comparative analysis highlights that, although IPv4 and IPv6 show similarities in connection speed, the implementation of IPv6 appears to be slightly more efficient in terms of packet errors.

## CONCLUSIONS

The detailed analysis of IPv4 and IPv6 performance on a dual-stack academic network reveals several significant trends. In terms of connection speed, both protocols deliver comparable results, with IPv4 showing slightly better transfer rates. However, IPv6 demonstrates superior efficiency in terms of packet errors, highlighting its ability to provide more reliable data transmission.

This study presents a detailed comparative evaluation of IPv4 and IPv6 network performance, utilizing iPerf3 and Wireshark, with a focus on throughput, error rates, and connection stability. The results show that IPv4 achieved slightly higher average transmission speeds (10.7 Mbps sent and 10.4 Mbps received) than IPv6 (10.1 Mbps sent and 9.88 Mbps received), consistent with prior findings on mature IPv4 infrastructure [37]. However, IPv6 demonstrated a lower error rate (2.92%) compared to IPv4 (3.69%), indicating enhanced reliability in dual-stack environments [38]. Through Wireshark's visual traffic analysis, the TCP packet flow remained relatively stable for both protocols; however, IPv4 presented a spike in error packets around 145 seconds, suggesting transient congestion [40].

The iPerf3 test confirmed stable bandwidth behavior over time for IPv6, with minor fluctuations reflecting dynamic routing or buffer latency, in line with prior simulation-based studies [39]. Packet-level visualization further revealed that IPv6 maintains consistent throughput despite occasional dips, reinforcing the protocol's suitability for modern networks [38]. Overall, the experimental results support the ongoing transition to IPv6, highlighting its comparable performance and slightly superior stability [37], [38].

Finally, challenges to improving academic telecommunications infrastructure using IPv6 are ensuring full compatibility and seamless integration with existing IPv4-based systems, which still dominate many institutional networks. Transitioning to IPv6 also demands significant investments in training, hardware upgrades, and security adjustments, as network administrators must adapt to new addressing schemes, routing protocols, and monitoring tools. Furthermore, optimizing IPv6 performance to match or exceed that of IPv4, particularly in terms of error handling and latency, requires ongoing performance evaluation and fine-tuning in complex academic environments with high user density and diverse traffic patterns.

## AUTHOR CONTRIBUTION

The authors' contributions to this article are as follows:

Rodolfo Cañas: Results analysis, testbed design, data analysis, visualization, writing, and editing.

Carlos Henriquez: Research, data analysis, visualization, writing, and editing.

Javier Silva: Research, data analysis, visualization.

The authors participated in reviewing the results and approved the final version of the article.

## CONFLICT OF INTERESTS

The authors declare that they have no interests or financial relationships that could have influenced this work.

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