

Analysis of Quality of Experience (Q&E) and Network Security in Multimedia Streaming Traffic between IPv4 and IPv6

Ricardo Andrés Medina ¹

1. Universidad Santo Tomás; ricardo.medina@ustabuca.edu.co; <https://orcid.org/0000-0002-0576-8460>

Abstract: The ongoing technological changes that University Bucaramanga's Campus constantly faces as a higher education institution affects directly its development, therefore, it requires developing, creating and improving its technological tools in order to get a higher quality and education standards; this can be done by increasing the ICT appropriation by the academic community, along with the innovation and use of technology, which demands a better infrastructure and upgraded devices that allow a suitable scalability [1].

The process includes the implementation of IPv6 protocol as part of the actualization of the existing digital posters system in Bucaramanga and Floridablanca University Campus and which at the same time, enables to conduct a research study around the issue.

This research study seeks to carry out a multimedia internet traffic comparative between IPv4 and IPv6 protocols, through a laboratory-controlled environment, including video compression mechanisms H.264 and H.265 [2] at different video quality formats under three proposed bitrates from queuing packets configured on the router in order to analyze content adaptation in a dynamic way by means of a DASH protocol and identify IPv6 traffic vulnerabilities with controlled network attacks applications.

Finally, to solve these variables results in a positive experience for the users who consume multimedia content from digital posters and support the network performance. The analysis of the results obtained is presented along with the multimedia traffic comparative between internet protocols previously mentioned, IPv6 security analysis and quality service parameters, just as quality experience techniques used for this research study.

Keywords: project management; Streaming Media; Quality of Experience; IP Networks; Firewalls (computing); DASH Protocol.

Análisis de la Calidad de la Experiencia (Q&E) y Seguridad en Redes en tráfico de Streaming Multimedia entre IPv6 e IPv4

Resumen: Los constantes cambios en términos tecnológicos a los que la Universidad Santo Tomás Seccional Bucaramanga se ve enfrentada como institución educativa y que repercuten en desarrollar, crear y mejorar los medios tecnológicos que brinda la institución en pro de ofrecer los mejores estándares de educación de calidad mediante el incremento en la apropiación de las TIC por parte de la comunidad académica, innovación y uso de tecnologías que implican una problemática en infraestructura y actualización de equipos que permitan una escalabilidad adecuada [1]. En este proceso se incorpora la implementación del protocolo de internet versión 6, IPv6, como parte de la actualización del sistema de carteleras digitales existente en los campus de Bucaramanga y Floridablanca y que permite un trabajo de investigación en torno a esta temática. Este trabajo de investigación busca realizar la comparativa de tráfico multimedia entre los protocolos IPv4 e Ipv6, por medio de un entorno controlado de laboratorio, incorporando mecanismos de compresión de video H.264 y H.265 [2] a diferentes formatos de calidad de video bajo tres tasas de bit propuestas a partir del encolamiento de paquetes configurado en el router a fin de analizar la adaptación del contenido de manera dinámica mediante el protocolo DASH e identificar vulnerabilidades al tráfico Ipv6 mediante la aplicación de ataques a la red de manera controlada. Finalmente, resolver estas variables se traduce en una calidad de experiencia positiva para los usuarios que consumen el contenido de las cartelas digitales y favorecen el desempeño de la red. Se presenta el análisis de los resultados obtenidos para la comparativa de tráfico multimedia entre los protocolos de internet mencionados,

el análisis de seguridad de IPv6 y los parámetros de calidad de servicio y las técnicas de calidad de la experiencia utilizados para el desarrollo de la investigación.

Palabras clave: gestión de proyectos; Streaming Media; Quality of Experience; IP Networks; Firewalls (computing); DASH Protocol.

Introduction

The present article is developed within the framework of a technological update at the Santo Tomás University, Bucaramanga section, using Internet Protocol version 6, IPv6, on its network configuration system. It is based on the analysis of four key themes in the technology deployment environment, because of social appropriation of knowledge stemming from the final master's thesis focused on analyzing IPv4 versus IPv6 traffic behavior for multimedia content, including IPv6 security topics [3].

The first theme involves the analysis of the existing Video Streaming platform used to disseminate institutional information via digital billboards on the Bucaramanga and Floridablanca campuses. This platform is deployed across the campuses connected through the administrative IP network; it is configured with IPv4 protocol and utilizes Raspberry Pi devices [1] and Samsung monitors for Digital Signage¹. Content published on these digital billboards includes institutional videos about High-Quality Accreditation processes, Multi-Campus Comprehensive Plan, and institutional content related to undergraduate and graduate academic program offerings, as well as continuing education. Additionally, academic events taking place within and/or outside the various university campuses are advertised.

This streaming platform serves as a reference point for addressing the second theme and possibly for future work, as it opens the door, for example, to incorporating adaptive video protocols and video on demand into the existing platform. The second theme pertains to IPv6 protocol [4] and its adoption to support multimedia streaming services under certain security parameters [5] and to analyze its performance compared to IPv4 protocol.

To address any work on a video streaming platform in a dual-stack environment, where both IPv4 and IPv6 internet protocols coexist, it is essential to tackle two other key themes: Quality of Experience and Security in IPv6 networks, representing the third and fourth themes of the project, respectively.

Quality of Experience demands an analysis of IPv4 versus IPv6 traffic to study the behavior of the IP header [6] in video streaming services. The significant differences found will form the fundamental basis for this study, as it will lead to practical application. Initially, this analysis is conducted within a controlled laboratory environment with network equipment that, being an academic environment, likely does not handle large amounts of traffic. This leads to transitioning to an experimental practical level within the IP networks, where the digital billboard service is currently deployed.

Subsequently, a second phase of network behavior analysis is conducted. At this point, it is necessary to address network security issues, as the general network security levels at the University are applied to IPv4 networks and in a basic form to IPv6. This leaves room for potential vulnerabilities [7] in the IPv6 network since, being an experimental field, firsthand knowledge of how the University's network may be affected across its various areas is lacking. Therefore, it is imperative to conduct corresponding analyses through controlled network attacks, such as MITM (Man In The Middle) [8] on IPv6 networks with Neighbor Advertisement Spoofing [9], SLAAC (Stateless Address Autoconfiguration) [10] attack, Fake DHCPv6 (Dynamic Host Configuration Protocol version 6), DoS (Denial of Service) [11] on IPv6 networks with SLAAC DoS [12], in order to study potential security gaps that may be detected and avoid inconveniences from a network security standpoint.

¹ [22] Digital Signage Colombia, "Digital Signage Colombia", Colombia, (2020).

Finally, considering supporting the achievement of the objectives of the Santo Tomás University (USTA), Bucaramanga section's Development Plans, which focus on directing and coordinating research and social projection of the USTA with national and global visibility and impact, this project contributes to impactful research production among the university population, improving the classification of research groups.

Methodology

For the development of the present research and based on the themes it encompasses (analysis of multimedia content quality of experience, adaptive dynamic protocol, network security, and IPv4 and IPv6 internet protocols), a mixed research methodology is employed, combining case study (digital billboards) and experimental research through guided tests in a controlled laboratory environment.

The information analysis method is carried out quantitatively through the editing and modification of the multimedia content to be addressed, the establishment of network scenarios provided for the implementation of internet protocols (dual stack²), controlled network attack environments on the IPv6 network, as well as the test methods provided for the analysis of quality of experience. On the other hand, from a qualitative perspective, subjective measurement metrics are applied to compile information through the average opinion scoring technique and the required analysis applied to the results obtained based on the comparison of IPv4 versus IPv6 multimedia traffic. Based on the proposed research methodology and information analysis method, the information gathering methodology is of a mixed nature [13], drawn from the case study, survey, and experimental results.

Additionally, the controlled laboratory environment involves the use of a Mikrotik 750GL router for network management and monitoring, from the creation of IPv6 and IPv4 environments with their respective addressing and subnets through which the multimedia content is transmitted. Regarding multimedia content, it is generated from an mp4 container video file, which is segmented and edited according to predefined parameters to generate an MPD format for the DASH protocol [14]. This content is served through the Dual Stack local network via the proposed subnets in both internet protocols, applying quality of service policies aimed at packet queuing to emulate network latencies given by intrinsic and/or extrinsic parameters, resulting in simulated bandwidth limitations to force content bit rate adaptation [15]. Finally, 3-bit rates are proposed for 3 Quality formats in the transmission of multimedia streaming packets.

Tabla 1. Correlation of phases of the methodology with the respective specific objectives to be met

Number	Phase	Specific Objective
1	Characterization of multimedia network traffic	Develop a diagnosis on the behavior of adaptive multimedia streaming traffic IPv4 and IPv6.
2	Implementation of adaptive dynamic protocol DASH	
3	Analysis of traffic of multimedia content	
4	Network security analysis in the transmission of multimedia content on IPv6 networks	Analyze security parameters in IPv6.
5	Evaluation of Quality of Experience (QoE) for streaming service over IPv6.	Evaluate the quality of experience of video streaming over IPv6.

Source: author.

Results

² [23] Dell, P, "On the dual-stacking transition to IPv6: A forlorn hope?", USA, 2018.

The following chapter presents the results obtained at each stage of the research development based on the methodology proposed in the previous section. Once each phase is completed, the most representative contributions to the research are shown, which, in general, form the backbone of the integration of the findings, leading to their analysis and respective conclusions.

For an initial exercise, a manifest file is generated with two video segments produced from an original file ("Tears of Steel") [16], each lasting 30 seconds, and each of these segments with three different qualities (360p, 720p, and 1080p). The client creates a new request in the Shaka Player. To successfully reach the server through the Shaka Player [17], the request must be made via the secure HTTP protocol (HTTPS) [18], as this web tool is loaded through the latter. If the server serves the resources with HTTP when requested, a mixed content error will occur from the client's browser, blocking the requested content and indicating that it should be served with HTTPS using an SSL certificate [19], as shown in the following figure.

Figure 1. Mixed content error message. The request is blocked for the client until the content is served with HTTPS.

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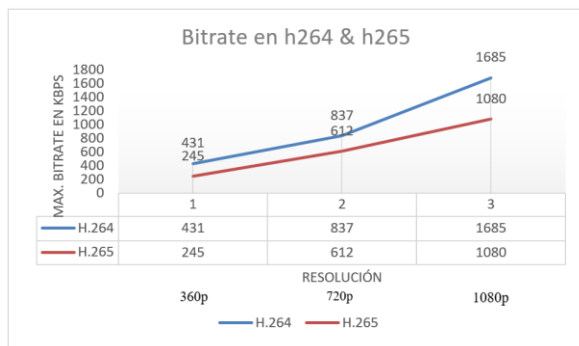
2 ▶ Mixed Content: The page at 'https://shaka-playe http_fetch_plugin.js:112
r-demo.appspot.com/demo/#audiolang=en-US;textlang=en-US;...ttp://192.168.0.1
7/dash/t2_60s.mpd;panel=CUSTOM%20CONTENT;build=uncompiled' was loaded over
HTTPS, but requested an insecure resource 'http://192.168.0.17/dash/t2_60
s.mpd'. This request has been blocked; the content must be served over
HTTPS.
  
```

Source: Author

- **Traffic characterization and multimedia content acquisition**

The goal is to generate three different qualities for the original file. The following statement will proceed to create the segments: `ffmpeg -i [input file] -an -c:v libx264 -x264opts keyint=24:min-keyint=24:no-scenecut -b:v [bit rate] -maxrate [maximum bit rate] -bufsize [buffer size] -vf scale=-1:[video scale] [name output file]`.

Figure 2. Performance of bitrate in h.264 and h.265 codecs.

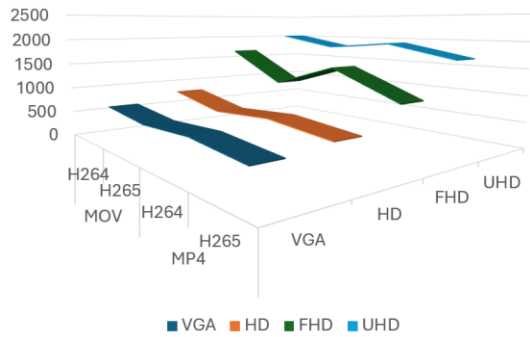


Source: Author

When encoding the video, the difference in size reduces significantly as its bit rate decreases. However, to perceive the real difference in video transmission, it's necessary to have a screen that supports such resolution. While the file size decreases, so does its bitrate, and this can certainly affect the quality of experience.

Figure 3. Definition of video content Bitrate values based on three variables: codec, container, and resolution.

Characterization of the video content bit rate

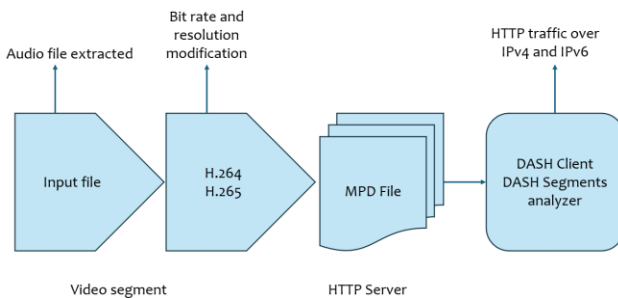


Source: Author.

Implementation of adaptive dynamic protocol DASH

The MPD file generation is carried out from FFMPEG³ using the following statement: `MP4Box -dash 4000 -rap -frag-rap -profile onDemand -out video_out.mpd video_in360p.mp4 video_in720p.mp4 video_in1080p.mp4 audio_in.mp4`, in which the output file .mpd is determined based on the compilation of the three generated video segments .mp4, as well as the audio file .mp4. With this, a first approach to creating a client-server topology is developed and it can proceed to the analysis and comparison of adaptive DASH multimedia traffic behavior between IPv4 and IPv6.

Figure 4. Overall scheme of the DASH architecture applied to the project.



Source: Author

Analysis of traffic of multimedia content

With the content ready to be requested from the Apache server [20], we proceed to configure a dual-stack network environment in which both IPv4 and IPv6 internet protocols coexist for the purpose of comparing and analyzing streaming traffic behavior in each of them. Objective parameters such as delay, jitter, and PSNR are measured.

The network environment is generated using a Mikrotik RouterBoard 750GL⁴, which allows connectivity through both IPv4 and IPv6 protocols. With the service running from a laboratory setting, specifically in the Telecommunications Laboratory of Santo Tomás University, 8 devices have been configured within a network

³ [25] FFMpeg “AVStream Struct Reference”, USA, 2023.

⁴ [24] Mikrotik “Official web site”, Latvia, 2024.

domain for IPv4 and for IPv6, managed from the router. These clients request content from the server initially in IPv4 and then in IPv6 to read the traffic using Wireshark and MikroTik Traffic Analyzer tools.

Table 2. Relationship of Jitter (variation of delay in milliseconds) [21] in the transmission of multimedia traffic over IPv4 and IPv6 with preconfigured QoS parameters (traffic queues applied to different resolution formats).

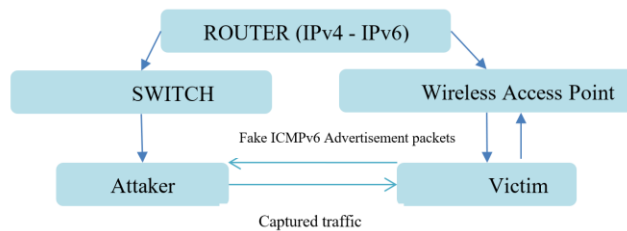
Quality	360P		720P		1080P		2160P		Internet protocol
	Traffic queques								
Q1 (256Kbps)	3,0651	2,3491	3,7133	3,4089	8,8080	6,5722	8,1082	7,8812	IPv4
	3,1227	2,1598	3,6956	3,3578	8,9758	6,8521	7,7512	7,6250	IPv6
Q2 (512Kbps)	2,4470	1,8723	5,4771	3,0441	7,4002	4,6881	6,2966	5,3565	IPv4
	2,3459	1,9875	5,3155	2,9120	6,9856	4,7852	6,3120	5,1549	IPv6
Q3 (1000Kbps)	1,6487	1,6053	4,9067	3,3884	7,3398	4,5395	7,9800	5,6799	IPv4
	1,5985	1,8512	4,5695	3,2458	7,3115	4,5060	7,8564	5,6145	IPv6
Codec	H-264	H-265	H-264	H-265	H-264	H-265	H-264	H-265	

Source: Author.

Note: the variation in transmission time for the video qualities used regarding the application of a specific codec is observed, thus: decrease in bitrate for each of the queues in H.265 compared to H.264 and decrease in bitrate through IPv6 transmission compared to IPv4.

Network security analysis in the transmission of multimedia content on IPv6 networks.

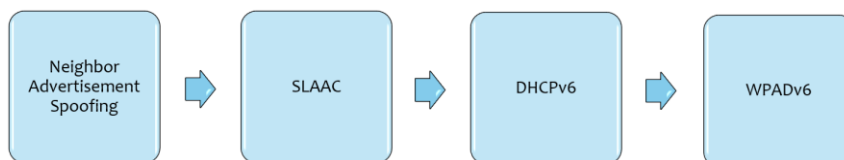
Figura 5. Simplified network diagram set up for executing the Neighbor Advertisement Spoofing attack.



Source: Author

Using Evil Foca software, the attacker scans the network to find IPv6 network neighbors to choose a victim. Four types of MITM attacks are performed by configuring the attacker's equipment as a fake gateway of the network (Gateway) and the target device.

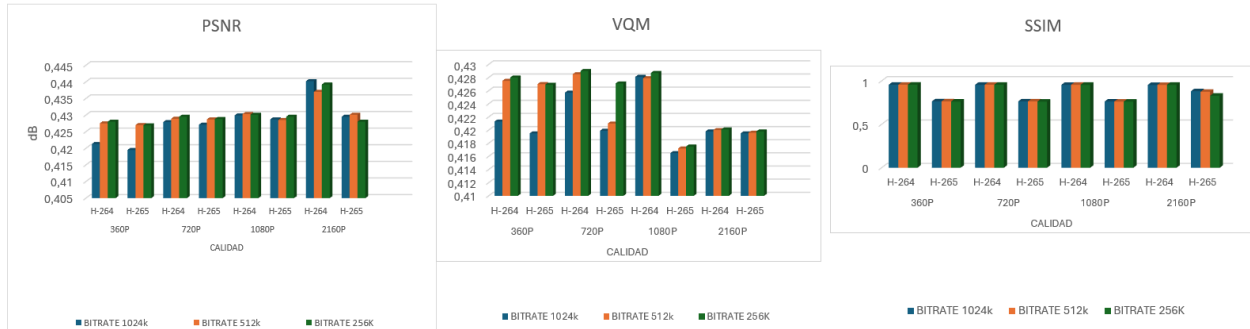
Figura 6. MITM attacks deployed trough IPv6 network.



Source: Author.

Evaluation of Quality of Experience (QoE) for streaming service over IPv6.

Figura 7. Comparison of PSNR, VMQ and SSIM parameters for the established bit rates and quality formats.



Source: Author.

To conduct the quality-of-service measurement, it's necessary to revisit the results obtained in achieving the first objective, where it is demonstrated whether there is a real difference in the behavior of multimedia streaming traffic under controlled network conditions, as well as in the real network scenario. Additionally, new variables need to be applied to the activity, such as including content with 4K resolution (2160p) (3840*2160) encoded in both H.264 and H.265, to push the system to a stress point where it becomes possible to observe what the new challenges would be in terms of hardware and software infrastructure scalability to accommodate emerging streaming technologies that incorporate improvements in image quality.

Conclusions

The present research work has outlined four main thematic axes that are progressively integrated throughout the document through the implementation of the laboratories, and for which conclusions are presented for each of the results obtained in each phase.

This research aimed to evaluate the Quality of Experience (QoE) of video streaming over IPv6 compared to IPv4 through the study of traffic in the transmission of multimedia content, the measurement of Quality of Service (QoS), and network security analysis for a technological update of the digital billboard system at the Santo Tomás University, Bucaramanga section. However, within the context of the Covid-19 pandemic, difficulties arose in terms of implementing the laboratories, necessitating a reconsideration of application installation scenarios and the laboratory environment. Two of the main justifications presented in this research work are cohesive in two fields of study: the bandwidth occupation of multimedia content and the adoption of the IPv6 internet protocol. These two aspects lead to the analysis of other collateral elements that should not be overlooked in network infrastructures.

From the perspective of multimedia content, it is essential to discuss the quality of service of the infrastructure that enables the serving of this type of content, especially if users are located within the same network infrastructure. This entails a series of configuration parameters in terms of traffic prioritization, incorporation of network equipment that supports traffic demand, physical infrastructure, and network segmentation for video with traffic differentiation policies through broadcast domain segmentation via VLAN, traffic marking, packet marking, traffic queue configuration, among others.

On the other hand, the incorporation of the IPv6 protocol directly leads to analyzing the security policies implemented for this protocol that allow mitigating the different threats present in the network and through which security incidents can occur, as shown in the sections of phase 4, corresponding to security in IPv6 traffic.

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