Evaluation of QoS over IEEE 802.11 Wireless Network in the Implementation of Internet Protocols Mobility Supporting

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***Abstract*—Now-a-days, the internet is an essential part of our digital lives. With the growing number of users, the ultimate goal is to enable all users to stay connected to the internet at anytime and anywhere, regardless of their mobility. Any delay or jitter in the system can cause a deterioration in the performance of multimedia services, such as video streaming, or cause websites to partially load. The current Internet Protocol version 4 (IPv4) cannot handle all the IP addressing requirements, while the next generation Internet Protocol version 6 (IPv6) has been developed to solve some of these problems by improving the quality of service and providing many other features. The primary contribution of this paper is to investigate the evaluation of Quality of Service (QoS) functionality, including end-to-end delay, throughput, jitter, and packet loss, in WLAN mobility environments for MIPv4 to MIPv6 using the OMNeT++ simulator.**

Keywords—QoS; MIPv4; MIPv6; handover; mobility; priority

I. INTRODUCTION

In recent years, communication networks have become the main engine of the world, especially mobile communications, which have spread everywhere. Wireless networks that provide access to the internet are the solution for users who need to move around while exchanging multimedia services such as video, voice, or data. The IEEE 802.11 standard [1], which includes the medium access control (MAC) and physical layer (PHY), has been improved since its initial approval by the IEEE in 1997. The improvements are defined as amendments to the initial standard, such as IEEE 802.11e and IEEE 802.11r, which mainly concern the MAC layer. IEEE 802.11e added QoS mechanics, while IEEE 802.11r improved mobility between the cells of wireless networks (handover) [2] and allowed nodes to switch more quickly between access points (APs).

The Mobile Internet Protocol (MIP) [3] is an IETF communication protocol that allows users to stay connected when moving from one cellular network to another without interrupting the connection. The two versions of MIP, Mobile IPv4 (RFC 3344) and Mobile IPv6 (RFC 3775) [4], are designed to facilitate node mobility and maintain connections when changing locations. MIPv4 is a popular mobile internet protocol based on the IPv4 protocol, which has the responsibility of traffic routing on the internet. However, it cannot handle the IP addressing margin for all users and also has some limitations in terms of quality of service, MIPv6 has been developed to provide mobility support for IPv6, and improves some of this limitations. In order to ensure node mobility, applications and flows, quality of service is particularly important for traffic, and it can give priority to different flow services (such as video, voice, data, etc.) based on a certain level of performance. QoS metrics [5] measure performance in four different aspects: throughput, delay, jitter, and packet loss.

The main objective of this article is to assess the impact of internet protocol mobility support, from Mobile IPv4 to Mobile IPv6, on QoS performance in mobility environments based on 802.11g wireless networks using the OMNeT++ simulator [6]. The QoS functionalities are analyzed and compared, the packets are classified into four traffic classes (background, best effort, video, and voice) with different priority levels of the EDCA mechanism according to the nominal bit rate.

The rest of this paper is organized as follows. Section (2) describes related works on QoS performance on mobile internet protocols. Section (3) introduces QoS in IEEE802.11. Section (4) provides the different QoS Parameters. The simulation results include Simulation Environment, Simulation Scenario, results, analysis, and simulation comparison are talked in section (5), finally we conclude in section (6) and future work in section (7).

II. RELATED WORKS

Several studies have been conducted to evaluate the quality of service (QoS) performance of different network protocols, including Internet Protocol version 6 (IPv6) and Mobile Internet Protocol version 6 (MIPv6). In this paragraph, we discuss three studies that evaluate the QoS performance of video and audio applications in IPv6 and MIPv6 using simulation tools such as OPNET. The studies analyze various QoS metrics such as delay variation, end-to-end delay, packet loss, and handover latency to investigate the effectiveness of different network standards and protocols. The results of these studies provide valuable insights into the strengths and weaknesses of different protocols in terms of QoS performance.

E.S. Ikeremo and M.C. Kelly T. Pepple [7] discuss the evaluation of QoS performance metrics of video streaming in IPv6, including delay variation, end-to-end delay, and packet loss. The simulation analyzes the effect of frame rates, type of service, and bandwidth parameters on the QoS metrics using the OPNET environment.

In [8], the authors study the evaluation of QoS in Mobile Internet Protocol v6 using IEEE 802.11e and IEEE 802.11b standards by OPNET simulator. The paper based on the Route Optimization to investigate the QoS metrics such as packet delay variation, HA binding delay, and latency in the MIPv6 handover with video conference applications in real time. The results indicate that the IEEE 802.11e amendment is more effective than IEEE 802.11b during the handover process.

Zakari et al. [9] present a comparative performance study of IPv4 and IPv6 protocols based on the results of QoS metrics of video and audio applications. The study shows that IPv6 performs better than IPv4 in both scenarios.

III. QOS IN IEEE 802.11

IEEE 802.11e is an amendment to the IEEE 802.11 standard that was approved in 2005. It introduces Quality of Service (QoS) enhancements to the Medium Access Control (MAC) protocol sub-layer of the data link layer of the OSI model. 802.11e improves WLANs by enabling the transport of voice and video with QoS. The packets can belong to different traffic classes that have different transmission priorities. Packets with high priority are more likely to be transmitted before lower priority packets, which reduces delay and jitter for responsive applications.

When QoS is implemented in 802.11, the MAC uses different technical functions [10]. One of these techniques is Enhanced Distributed Channel Access (EDCA), which provides different processing for different classes of packets and channel capacities. EDCA is part of the Hybrid Coordination Function (HCF) and defines four categories of channel access (or priorities), as shown in the table below, from the lowest to the highest priority categories. The Table I represent the different Access categories priority for EDCA function:

TABLE I. ACCESS CATEGORIES PRIORITY IN EDCA FUNCTION

Level	Priority	Access Category
Lowest	1	Background
to	2	
	0	Best Effort
	3	
	4	Video
	5	
	6	Voice
Highest	7	

IV. QOS PARAMETERS

IPv6 is the most recent version of Internet Protocol [11], this new IP address was involved to fulfill the need for more Internet addresses, and to treat some requirements and limits of IPv4. The quality of service is the important requirement in this new version of the protocol, it has been supported and improved. The evaluation of QoS performance can be measured based on different parameters [12], such as:

A. Network Throughput

Throughput is the maximum transmission capacity of a volume of data between two points on a communication line in a given time. QoS optimizes the network by managing network bandwidth and prioritizing applications according to the resources they need. The mathematical formula for throughput is:

$$\text{Throughput} = \frac{\text{Packets Received of data}}{\text{delivery time}} \quad (1)$$

B. End-to-End Delay

End-to-end delay is the time it takes for a packet to travel from the source to the destination. It should ideally be as close to zero as possible. It can also be defined as the time difference between the instance of sending and receiving of the packet between two nodes. The mathematical formula for end-to-end delay is:

$$\text{Delay} = \frac{\sum \text{link packet delays}}{\sum \text{packets received}} \quad (2)$$

Where the sum of link packets delays is:

$$d_{transmission} + d_{propagation} + d_{queueing} + d_{processing} \quad (3)$$

$$d_{trans} = \frac{packet\ lenghth}{transmission\ rate} \quad (4)$$

$$d_{prop} = \frac{distance\ btw\ nodes}{propagation\ rate} \quad (5)$$

d_{queue} dependes on congestion and d_{proces} is a few microsecs.

C. Network Jitters

Jitter, also known as Packet Delay Variation (PDV), is a phenomenon that occurs due to network congestion or queuing, or when data packets are delayed or lost. If jitter is too high, it can lead to a deterioration in the quality of voice or audio communication. In OMNeT++, packet jitter is measured as the difference between the packet delays of successive packets, which is called the Instantaneous Packet Delay Variation. The mathematical formula for jitter is:

$$\text{Jitter} = \frac{\sum_{\mathrm{i}}^{\mathrm{n}} \mathrm{D_i}}{\sum \text{packets received}} \quad (6)$$

Where, the sum of delay variation D is:

$$(D_2 - D_1) + \cdots + (D_n - D_{n-1}) \quad (7)$$

D. Packets Loss

Packet loss is defined as the number of data packets that are dropped between two nodes during network traffic. The mathematical formula for packet loss is:

$$\text{PacketLoss} = \frac{\text{Packets Sent} - \text{Packets Dropped}}{\text{Packets Sent}} \times 100\% \qquad (8)$$

V. SIMULATION RESULTS

This part, describe the simulation paradigm that was studied in OMNeT++, the simulation scenarios that were chosen, and the results obtained from the experiments.

A. Simulation Environment

In this section, we describe the environment for our simulation experiments, which was implemented using the OMNeT++ 5.6.4 simulator. Our simulation represents a wireless network based on the IEEE 802.11e, IEEE 802.11g, and IEEE 802.11r standards. It includes wireless hosts moving throughout the network area, separated to trigger handover and communicate via access points. The wireless host equipment used in the simulation is a compatible node with support for the IPv6 protocol, as well as handover mechanisms and the Mobile IPv6 protocol. The access points used support multiple wireless radios and multiple Ethernet ports. Table II outlines the simulation parameters, and Table III lists the applications used during the simulation.

TABLE II. NETWORK SIMULATION PARAMETERS

Parameters	Value
Network Simulator	OMNeT++ (V 5.6.2)
Framework	INET
Simulation Area	600×400
Simulation Time	10 s
Channel	Wireless (IEEE802.11)
Standard	IEEE802.11 e/g/r
Speed of node	10 mps
Mobility Model	Linear Mobility
Application layer	TCP, UDP
Network interface model	PHY/WIFI's MAC
Internet Protocol	IPv4, IPv6
Frequency	2.412 GHz
Bandwidth	20 MHz
Data Rate	54Mbit/s
AP Beacon Interval	100 ms
Performance streams	End-to-end delay, packet delay variation, throughput, Packet Loss

TABLE III. NETWORK SIMULATION APPLICATION PARAMETERS

Access Category	Packet Length	Packets Access Priority	Nominal Bitrate
Background	900 B	1	24 Mbps
Best Effort	900 B	0	28 Mbps
Video	600 B	5	5 Mbps
Audio	125 B	6	100 kbps

B. Simulation Scenario

The simulation in Fig. 1 demonstrates handover between two access points (APs) in an 802.11g wireless LAN. A wireless node (sender) moves linearly through the network at a speed of 10 m/s, while the wireless node (receiver) remains stationary. Both nodes are configured to use a PHY rate of 54 Mbit/s. The two access points are separated by a distance of 400 meters. When the host moves within the network area, it uses an active scanning method to attach to the nearest AP, choosing the one with the highest signal strength before exchanging data. Two simulation scenarios were created, one with the wireless node implemented with IPv4 protocol mobility support, and the other with the node implemented to support mobility in IPv6. In both simulation scenarios, the source node sends UDP data to the destination node in wireless mode via four UDP streams, each corresponding to a different access category (background, best effort, video, and audio). QoS functionality is enabled, and parameters such as end-to-end delay, jitter, throughput, and packet loss are measured and analyzed to examine how mobile protocols affect the performance of each other for different access categories during horizontal handover. Packets with the highest priority must have lower delay times and higher throughput. The figures below show the network design implemented in the OMNeT++ simulator and the flow chart of the simulation scenario.

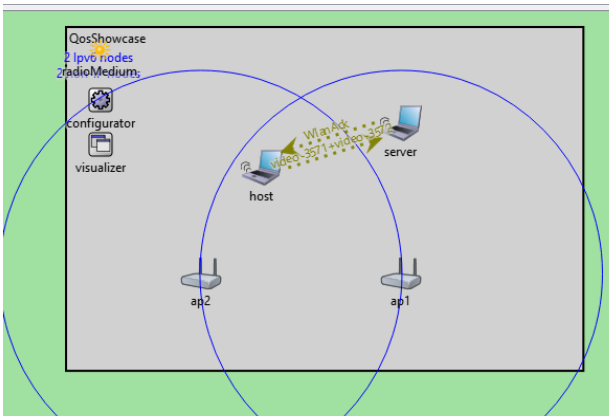

Fig. 1. Network topology design in OMNeT++

The overall flow chart of our proposed scenario is shown as Fig. 2.

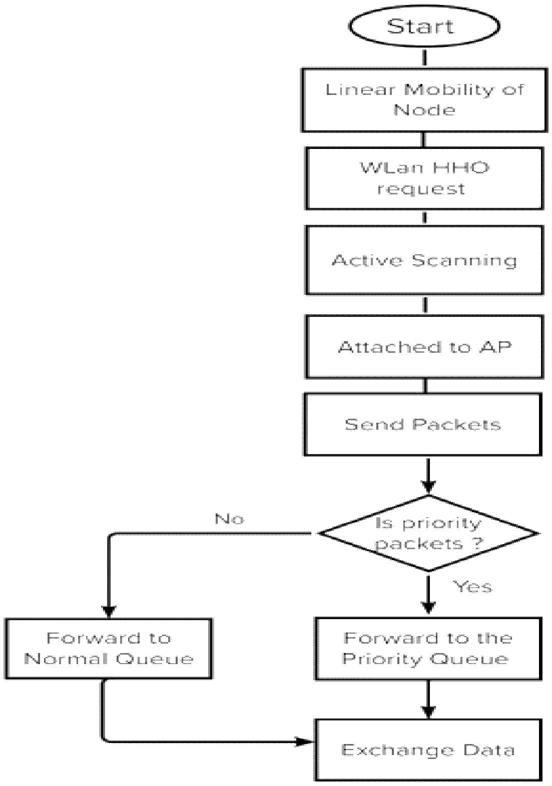

Fig. 2. Flow chart of simulation scenario proposed

C. *Results and Analysis*

1) Scenario 1: It was implemented with IPv4 mobility support to evaluate the QoS functionality between the two nodes during handover of the two access points in a wireless network.

In Fig. 3, we observed that the throughput values matched their nominal bitrate for high priority traffic (video and audio), 5Mbps for video and 100kbps for audio, in contrast to the lower priority traffic (background and best effort), which had lower throughput values. This explains the instability in the graphs.

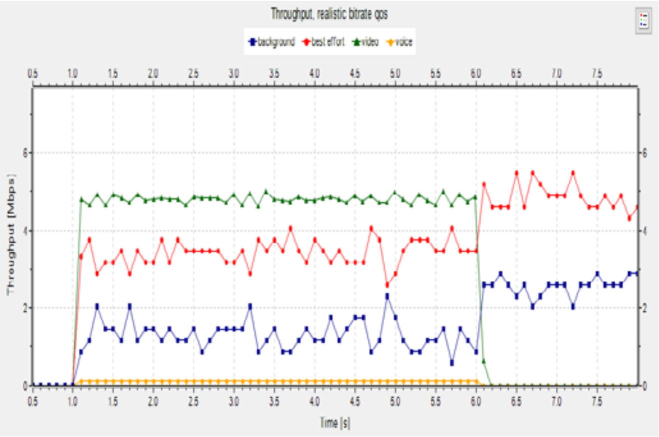

Fig. 3. Throughput variations in scenario 1

The Fig. 4 presents the jitter values for the video and audio access categories remained relatively low (especially for video) compared to the more dispersed scatter points observed for the background and best effort categories, which can reach up to 0.06s. Jitter values began to decrease when the video and audio traffic stopped.

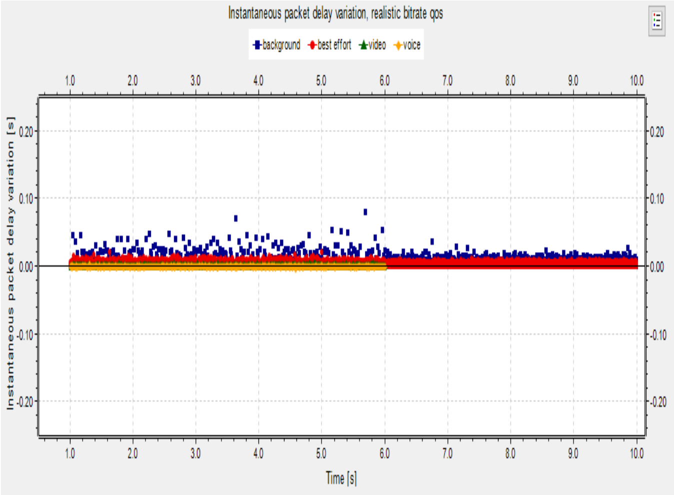

Fig. 4. Jitter variations in scenario 1

This scatter plot in Fig. 5 analyzes the delay of each of the four access categories studied. The video and audio categories were more likely to be sent first, which explains the lower values of packet delay observed in these categories. The best effort category was prioritized over background because its packets were sent periodically, which takes more time.

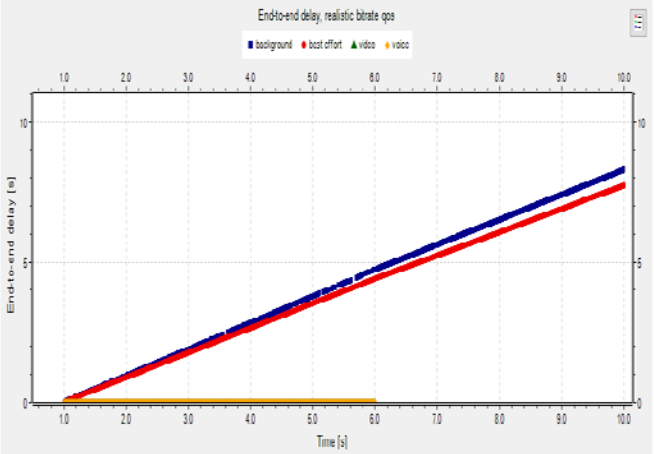

Fig. 5. End-to-end delay variations in scenario 1

In Scenario 1, the QoS parameters were measured for various access categories .The results were summarized in Table IV that provides values for parameters such as end-to-end delay, jitter, throughput, and packet loss, and allows us to compare the performance of different categories in terms of QoS. Overall, the results suggest that high-priority traffic, such as video and audio, had a lower jitter and delay compared to low-priority traffic, such as background and best effort.

TABLE IV. SIMULATION RESULTS OF QOS IN IPV4 MOBILITY SUPPORT

Access Category	Throughput (Mbps)	End-to-End Delay (s)	Jitter (ms)	Packet Loss (%)
Background	1.68	5	440	14
Best Effort	3.63	4.26	73	25
Video	2.38	0.0012	1.1	0
Audio	0.05	0.0008	0.6	0

2) Scenario 2: The objective of this scenario 2 was to evaluate the QoS performance in handover during the implementation of ipv6 mobility support in wireless network. Based to the graph obtained in Fig. 6, the throughput of video reaches a maximum bitrate of 16 Mbps, then it settles stable at 5 Mbps during the last simulation. On the other hand, the throughput of audio takes a maximum value of 6 Mbps. The priority is given to the packets of these two access categories; this explains the straightness of the curve. The line charts of the other lower access categories (background and best effort) show an improvement and a stability in the values of productivity. As long as a high priority packet continues to send, the throughput for the background and best effort categories is lower. It increases just when the traffic for the high priority categories stops.

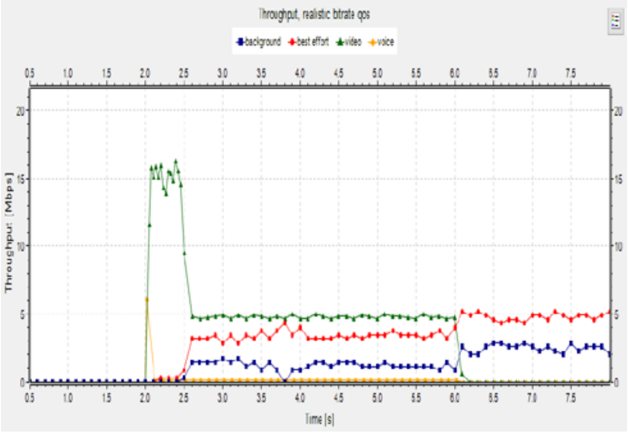

Fig. 6. Throughput variations in scenario 2

The scatter plot in Fig. 7 represents the jitter results for Scenario 2. The jitter starts at two seconds from the beginning of node mobility. The scatter graph for video and audio show horizontal data points, with values almost at zero. In contrast, the best effort and background categories showed more dispersion because the priority of these access categories is low and the packets are not sent consecutively.

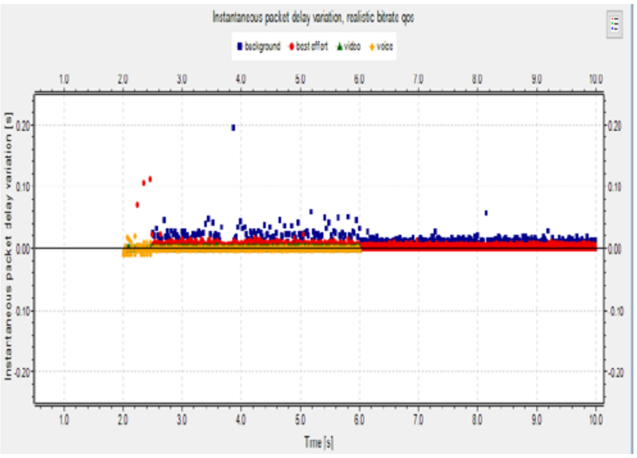

Fig. 7. Jitter variations in scenario 2

In the end-to-end delay graph shown in Fig. 8, the higher priority access categories such as video and voice are characterized by low or almost zero expected delay because they are sent before the lower priority categories like background and best effort.

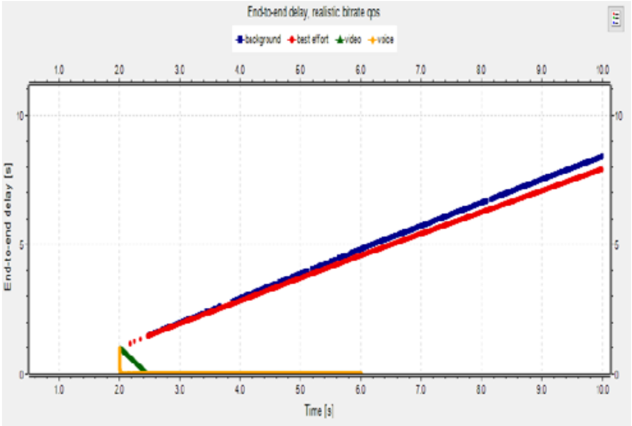

Fig. 8. End-to-end delay variations in scenario 2

Table V provides a summary of the QoS parameter values obtained for the various access categories in Scenario 2, including throughput, end-to-end delay, jitter, and packet loss:

TABLE V. SIMULATION RESULTS OF QOS IN IPV6 MOBILITY SUPPORT

Access category	Throughput (Mbps)	End-to end delay (s)	Jitter (ms)	Packet Loss (%)
Background	1.43	5.57	380	**11**
Best Effort	3.12	5	67	**21**
Video	**3.5**	0.14	1.1	0
Audio	**0.995**	0.1	0.5	0

D. Simulation Comparison

Based on the results obtained, IPv6 mobility support shows relatively better performance than IPv4 mobility in terms of QoS. In particular, it produces higher average throughput values of 3.5 Mbps in video and 0.995 Mbps in audio applications, which are better than the throughput values of Mobile IPv4 as is evident from Fig. 9. The packet delay values were very low in video and audio, which distinguishes the highest priority queue with low packet delay, the background with a high value of delay because the queue priority is low, and the best effort with high throughput and medium packet delay (see Fig. 10). Regarding jitter, as seen in Fig. 11, the study shows that it is close to zero in video and audio in both Mobility IPv4 and Mobility IPv6, but more dispersed in background and best effort. Packet loss was high in background and best effort for both protocols, which explains the high level of jitter in those categories (refer Fig. 12). However, in Mobility IPv6, the packet loss values show better results compared to Mobility IPv4.

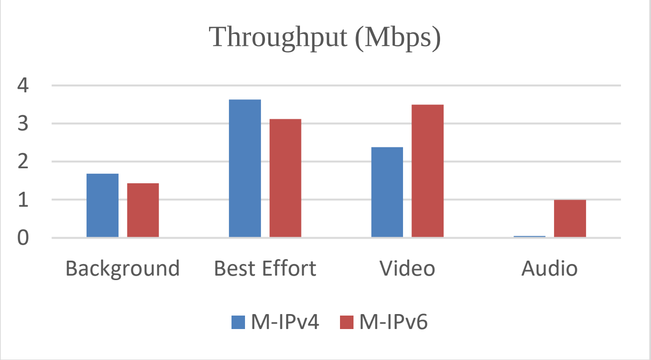

Fig. 9. Throughput comparison

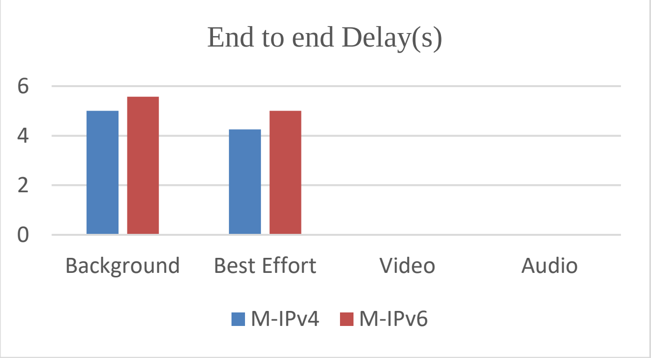

Fig. 10. End to end delay comparison

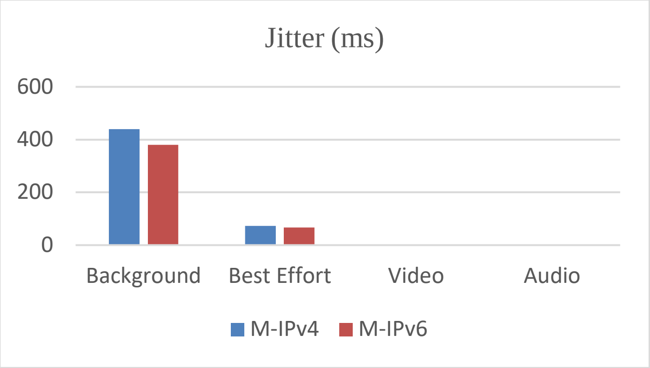

Fig. 11. Jitter comparison

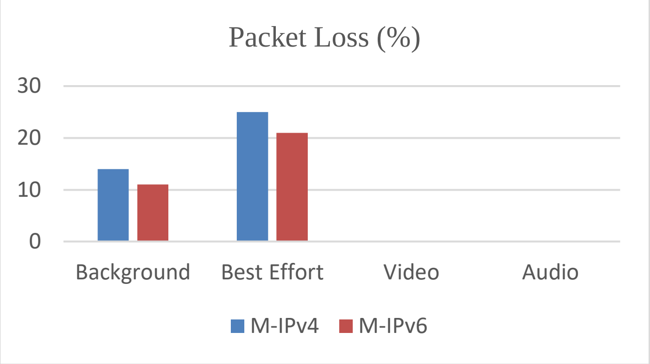

Fig. 12. Packet loss comparison

VI. CONCLUSION

This paper provides a detailed comparison of the QoS performance between different access categories, which is crucial for evaluating the effectiveness of the network protocols and identifying areas for improvement. By analyzing the values presented in the Table IV and V, one can gain a deeper understanding of the strengths and weaknesses of each access category in terms of QoS, allowing for more informed decision making and optimization of network performance. The study concludes IPv6 mobility support facilitates node movement in a wireless network and contributes to the improvement of quality-of-service performance. With QoS, IPv6 has a built-in mechanism for ensuring the quality of services, which makes it possible to prioritize urgent packets and to manage the processing of data packets more efficiently. In the simulation, priority is given to video and audio applications. Based on the results obtained, MIPv6 provides better QoS, with an improvement in throughput, fewer lost packets, and slight delay compared to Mobile IPv4 throughput, which was not stable in the four types of services.

VII. FUTURE WORK

The future work could explore the potential benefits of using QoS mechanisms in MIPv4 and MIPv6 such as Differentiated Services (DiffServ) and Resource Reservation Protocol (RSVP). The results of the study could provide useful insights for the design of mobile networks that aim to provide high QoS levels for multimedia traffic.

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