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Research Article

Study and Evaluation of Quality of Services in Mobile Internet Protocol v6 Using IEEE802.11e

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Mobile Internet Protocol v6 (MIPv6) is a protocol that allows a mobile node (MN) to transparently maintain connections while moving from one subnet to another. Using the route optimization (RO) method in MIPv6 gives optimized routing and helps avoid triangular routing. In real-time applications such as video conference applications, quality of service (QoS) issues will increase especially in the handover process between subnets. This study investigates the performance of MIPv6 handover in IEEE802.11e standard in wireless environments. The investigation considers that handover for the MN moves between 2 home agents (HA). The system model's fundamental performance limits are measured by packet delay variation, HA binding delay, and wireless local area network (WLAN) media access delay analysis metrics in video conference applications. According to the results of real-time simulations, network performance during the handover process can be effectively improved as the packet lost during handover decreased significantly from 43% in IEEE802.11b distributed coordination function (DCF) to 36% in IEEE802.11e hybrid coordination function (HCF). Furthermore, experimental results prove that IEEE802.11e connects to new HA roughly 20% quicker than IEEE802.11b, and IEEE802.11b has 100 times more time delay than IEEE802.11e. In addition to this, the WLAN media access delay of IEEE802.11b often reaches 0.00011 s as compared to 0.000005 s of IEEE802.11e. Thus, it is evident that the performance of IEEE802.11e in terms of packet delay variation, HA binding delay, and WLAN media access delay is better than IEEE802.11b. Likewise, it is noted that network speed during the handover process in IEEE802.11e can be considerably improved in a MIPv6 scenario.

1. Introduction

Nowadays, a new digital communication technology appeared, and the needs of users in terms of mobility have increased, so wireless networks represent solutions for user mobility and access to information, regardless of geographical place. IEEE802.11 WLAN standard is being accepted widely and rapidly for many different environments today [1]. The main two important requirements are commonly shared by most new devices: QoS support for prioritizing real-time services over non-real-time and power-saving functionality to achieve an operating time meeting users' expectations [2]. IEEE802.11 focuses on the medium access control (MAC) and physical layer (PHY), but the PHY in this standard is direct sequence spread spectrum (DSSS), frequency hopping spread spectrum (FHSS), and infrared (IR). To provide QoS supported in WLAN, IEEE802.11e [3] has been added and tested in many types of research and studies.

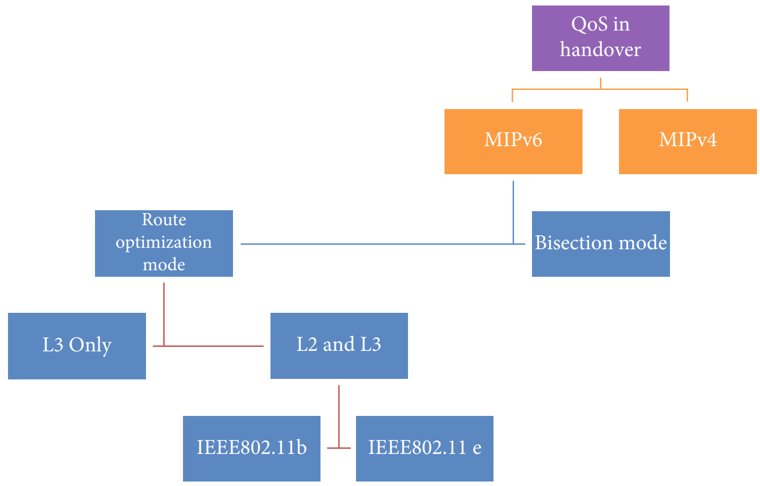

Figure 1: Research methodology.

Several studies have been conducted in this field; some of them focused on handover in MIPv4, not MIPv6 like [4] that explained that latency in IEEE802.11 and found that this latency is significant enough to affect the QoS for many applications especially a large variation in the latency with from one handoff to another. [5, 6] studied WLAN end-to-end delay values measured with QoS in an **I**nternet **P**rotocol v4 (IPv4) environment, and both found an improvement in QoS when both applied IEEE802.16e on WLANs. Besides these, for short-range data communications, researchers have developed various other visible light communication technologies such as [7, 8] and analysed the QoS by optimizing it [9].

From MIPv6, many studies have been done, and we can divide them into two important parts: one for MIPv6 itself especially in the handover process such as [10] that made a comparison in performance of MIPv6 in these two cases during the handover process in real-time application during this movement based on L3 only using IEEE802.11b, and the evaluation results were working in the RO case that can achieve low handover latency and low packet delay comparing with bidirectional tunnel mode, so for that reason, RO method has been used in our study, not bidirectional tunnel mode. Another part in MIPv6 [11] studied the 802.11e and 802.16e standards as well as their QoS mechanisms in vertical handover in a general mode not in RO mode. This study also illustrated that two portable MNs have a good performance during the QoS deployment in the 802.11e and 802.16e networks. In the following paragraphs, we evaluate the performance of the MIPv6 protocol in the handover process in RO mode with 802.11e standard using the real-time application.

Contributions of the study are important as according to the researcher's knowledge none of the previous studies has focused on the influence of handover in IEEE802.11e between stationary node (CN) and MN in real handover MIPv6 scenarios taking the Internet parameters in their studies. Figure 1 explains the methodology of our research. We studied in our research handover in MIPv6 using RO mode for layer 2 and layer 3 to compare the performance of IEEE802.11b and IEEE802.11e together to improve QoS using video conference applications in the real Internet scenario.

The rest of the paper is organized as follows: Section 2 provides a brief explanation of movement in MIPv6, introduces the 802.11e network, and outlines a practical study scenario. Section 4 provides the test result obtained by a new model of MIPv6 with IEEE802.11b and IEEE802.11e. Finally, the paper ends with a conclusion in Section 5.

2. Materials and Methods

2.1. MIPv6 Protocol. MIPv6 [12–14] enables MNs to migrate active connections of the transport layer and application sessions from one IPv6 address to another. The idea of a HA is utilized in the MIPv6 specification [15], which routes the MN to a fixed permanent address termed the home address (HoA). When roaming, the MN creates a bidirectional tunnel [15] with its HA by employing local care-of address (CoA). The HA maintains a binding between an MN's HoA and its CoA, and packets destined for the MN's HoA are forwarded to the MN's new IPv6 address through a bidirectional tunnel. As a result, the MN becomes available in the new location and can communicate because of this movement. Packets for MN pass between the HA and the mobile node through a bidirectional tunnel. The difficulties caused by encapsulation and tunnelling of packets through the HA include inefficient routes and high overhead. The performance of real-time applications diminishes when the end-to-end latency grows due to poor routing. Furthermore, the header overhead caused by encapsulation causes bandwidth inefficiencies, and fragmentation may ensue. In [10, 16], a simulation analysis was performed to compare the latency and overhead produced by MIPv6's bidirectional tunnelling and RO. The results showed that bidirectional tunnelling has greater end-to-end latency than RO. To solve this gap, MIPv6 developed RO [12], which allows two nodes to interact directly without passing packets via the HA. The primary idea behind RO is to allow packets to bypass the HA

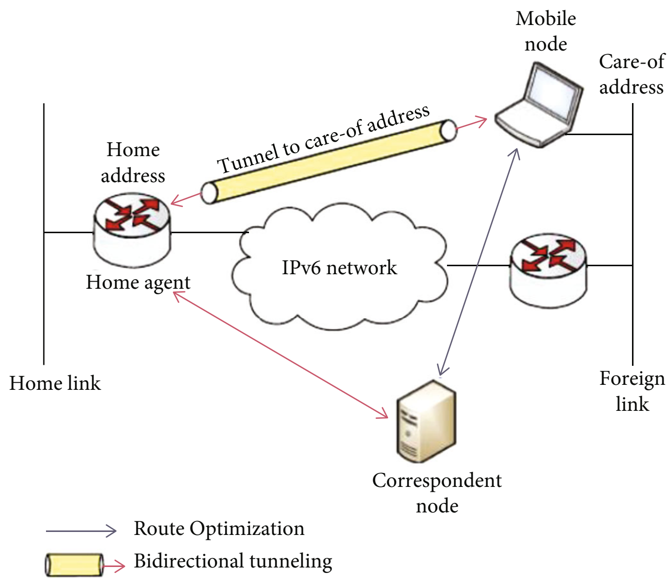

Figure 2: Mobile Internet Protocol v6 bidirectional tunnelling and route optimization [16].

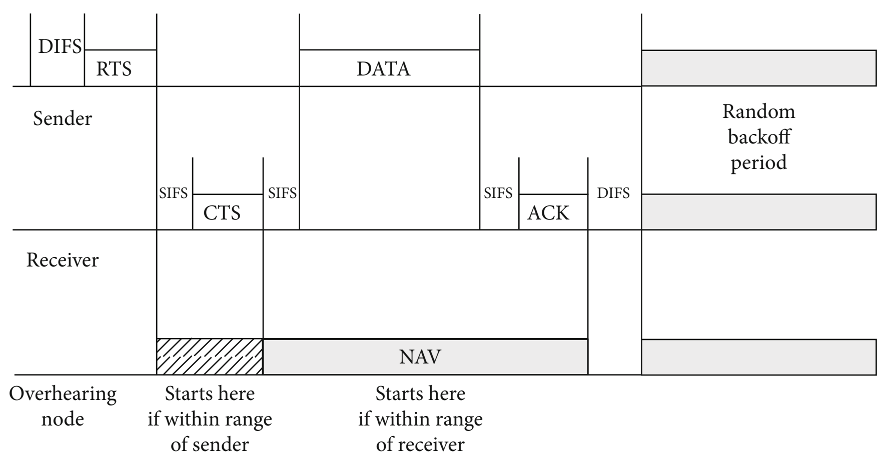

Figure 3: 802.11 distributed coordination function algorithm [15].

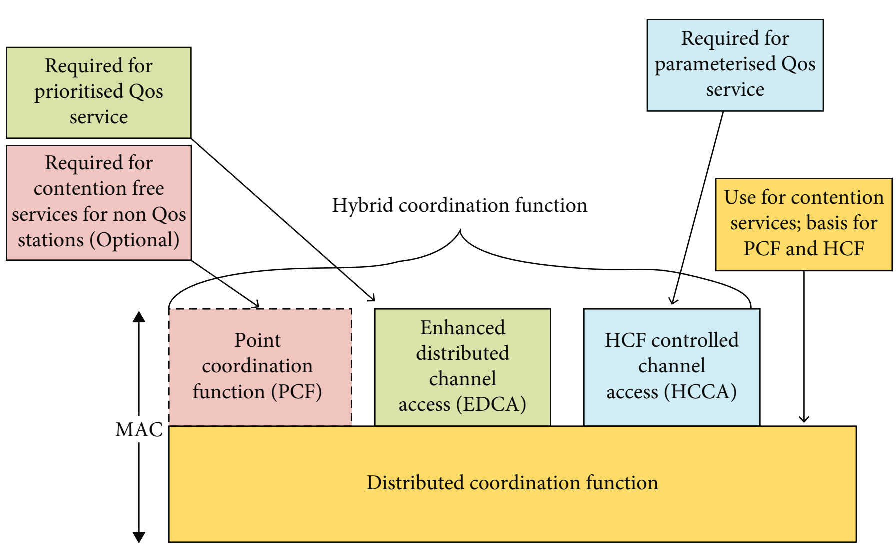

Figure 4: IEEE802.11e medium access control architecture (modified from [23]).

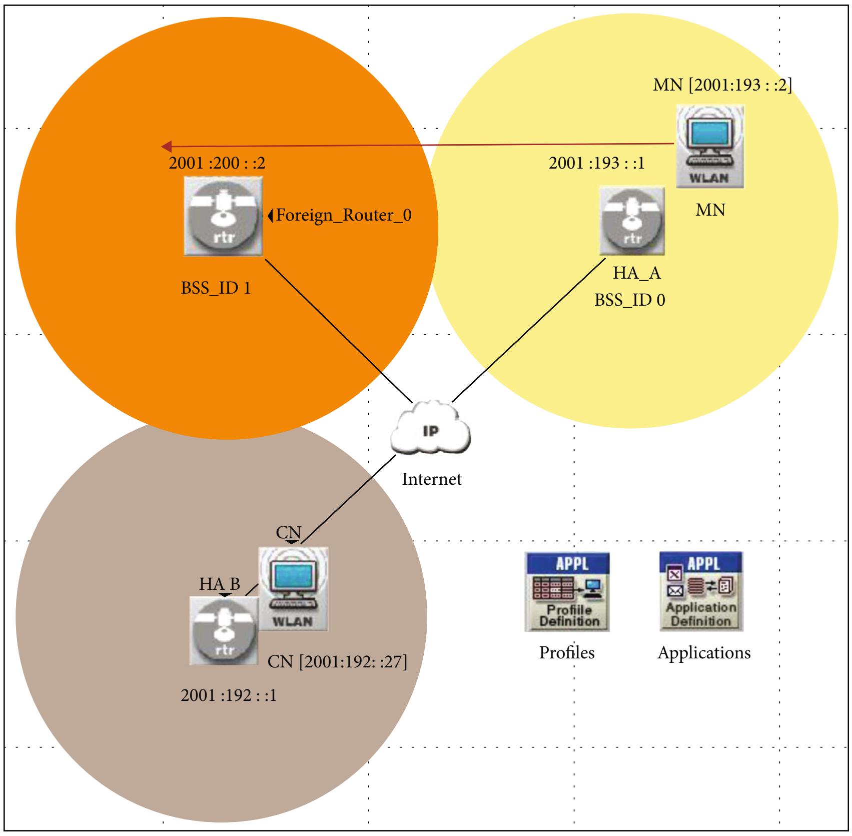

Figure 5: Practical study scenarios.

Attribute	Value
Wireless LAN	
Wireless LAN MAC Address	Auto Assigned
Wireless LAN Parameters	(...)
BSS Identifier	1
Access Point Functionality	Enabled
Physical Characteristics	Direct Sequence
Data Rate (bps)	11 Mbps
Channel Settings	Auto Assigned
Transmit Power (W)	0.005
Packet Reception-Power Threshold...	-95
Rts Threshold (bytes)	None
Fragmentation Threshold (bytes)	None
CTS-to-self Option	Enabled
Short Retry Limit	7
Long Retry Limit	4
AP Beacon Interval (secs)	0.02
Max Receive Lifetime (secs)	0.5
Buffer Size (bits)	256000
Roaming Capability	Disabled
Large Packet Processing	Drop
PCF Parameters	Disabled
HCF Parameters	Not Supported
High Throughput Parameters	Default 802.11n Settings

Figure 6: Parameters of access points.

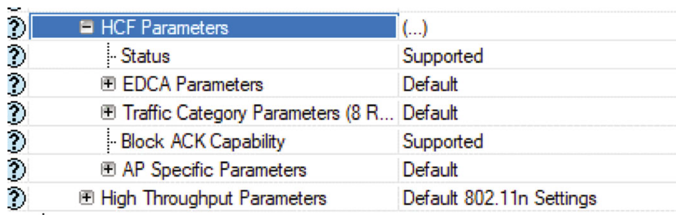

FIGURE 7: Hybrid coordination function wireless configuration for IEEE802.11e.

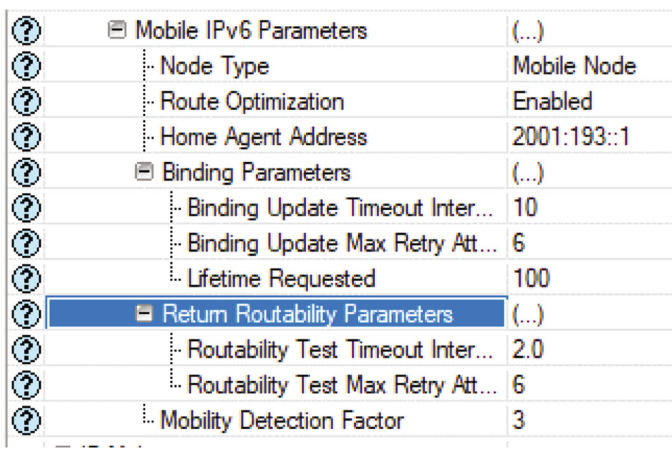

FIGURE 8: MIPv6 client configuration.

TABLE 1: Video conference parameters.

Parameter	Value
Traffic	Video conferencing
Type of service	Best effort

and reach the MN directly. Figure 2 depicts the fundamental functioning of bidirectional tunnelling and RO in MIPv6.

2.2. IEEE802.11 and IEEE802.11e Standards. The IEEE802.11 [17] is an international standard describing the characteristics of a WLAN; this latter is used to replace the local area network (LAN) or as an extension of the LAN infrastructure. With the IEEE802.11, the DCF [18] is an improved variant of the carrier sense multiple access with collision avoidance (CSMA/CA) [15], which avoids collisions during the transmission by the random slowdown after each frame (backoff). The DCF mode has some problems: it only supports the best effort service, it does not guarantee the delay and the jitter, and it degrades the throughput when the load is high. DCF [15, 18] uses a mandatory technique in IEEE802.11-based WLAN standard to avoid collisions. A MAC sublayer technique that uses CSMA/CA is found in places where CSMA/CA is in use. 802.11 has the following functions: the first action a node will do is wait for a random backoff period. This is a random period with room for several applications [19]. The node can pause its transmission timing if it detects that another node is utilizing the channel. The node will sense the channel after the backoff time to see whether another node is transmitting. It will wait for a short period and then detect the channel again if the channel is clear. To start transmitting a request to send (RTS), if the channel is still free, the channel sends an RTS to the destination. If the destination can receive data, it will reply with a clear-to-send (CTS) message (i.e., if it is not receiving data from another node). 802.11 DCF, which optimizes throughput and prevents packet collisions, is what the 802.11-based DCF does. The source node will send its data when it gets the CTS. The network allocation vector (NAV) is also included with both the RTS and CTS. The destination will return an acknowledgement (ACK) to the sender after the data has been correctly received. Once again, the sender will return to back off and continue the procedure. In Figure 3, you can see the whole procedure in action.

The issues resulting from the point coordination function (PCF) [18, 20] are not only the access to the wireless medium without any restriction but also include some problems: to enable synchronous data transfers, the PCF mechanism utilizes a centralized polling method to create a control network that works along with the DCF mechanism to form an access point (AP) station, while sharing the media with DCF and PCF modes, the media length cannot be predicted, which is required for QoS requirements. IEEE802.11e [21] is an improved version of the IEEE802.11 introducing the QoS at the MAC layer for the voice, data, and video transport traffic through the WLAN because the IEEE802.11 protocol does not support QoS due to the lack of guaranteed latency of delay-sensitive applications (e.g., video and voice). The IEEE802.11e standard proposes some major changes to the

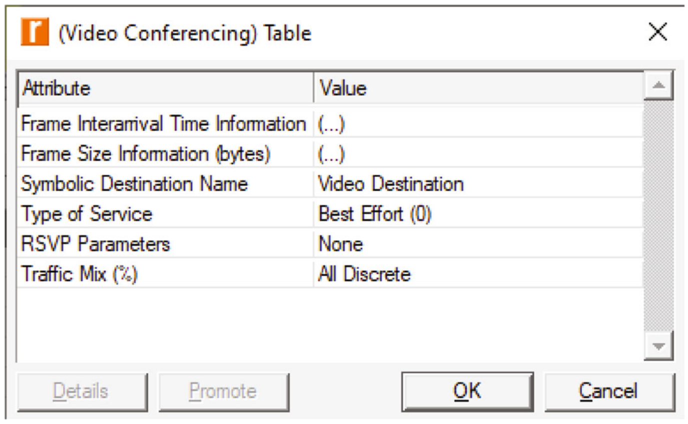

Figure 9: Attributes and their values for video conference.

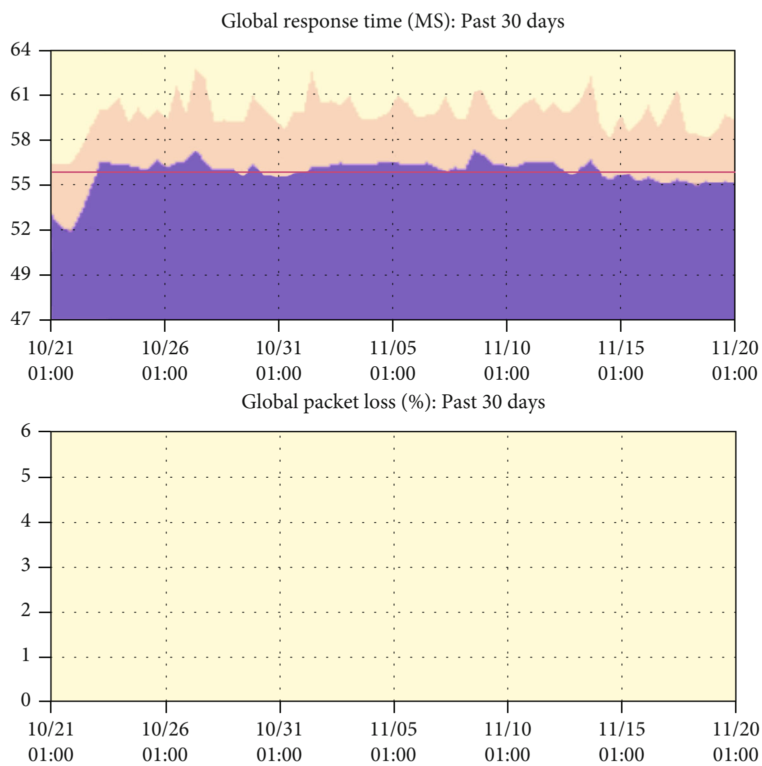

Figure 10: Internet traffic reports [26].

IEEE802.11 standard to incorporate QoS provisioning services. IEEE802.11e introduces a new MAC layer function, called the HCF. The HCF introduces some components and techniques that were missing in the IEEE802.11 standard. HCF brings two new access mechanisms: enhanced distributed channel access (EDCA) [20] which provides a restraint access service (based on CSMA/CA) with traffic differentiation and HCF controlled channel access (HCCA) [22] which provides unconstrained access (by polling) for a service with parameterized QoS. Figure 4 illustrates a synthesis of the 802.11e standard architecture.

2.3. Practical Study Scenarios. The OPNET simulator offers a graphical interface for several network models for network and distribution system performance assessment. The models are made up of many tools, each of which focuses on a particular element of the modelling task [24]. OPNET organizes the modelled system into layers, each with its purpose. Each layer contains numerous sublayers that perform many minor jobs. OPNET is made up of three domains: process domain, domain nodes, and network domain [25]. In our study, we investigated several parameters from the MN perspective, such as packet delay variation, HA binding delay, and WLAN

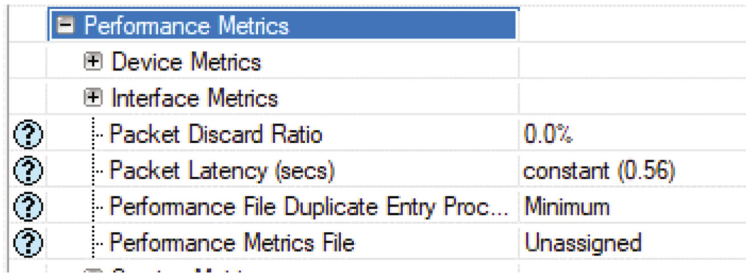

Figure 11: Video conference parameters.

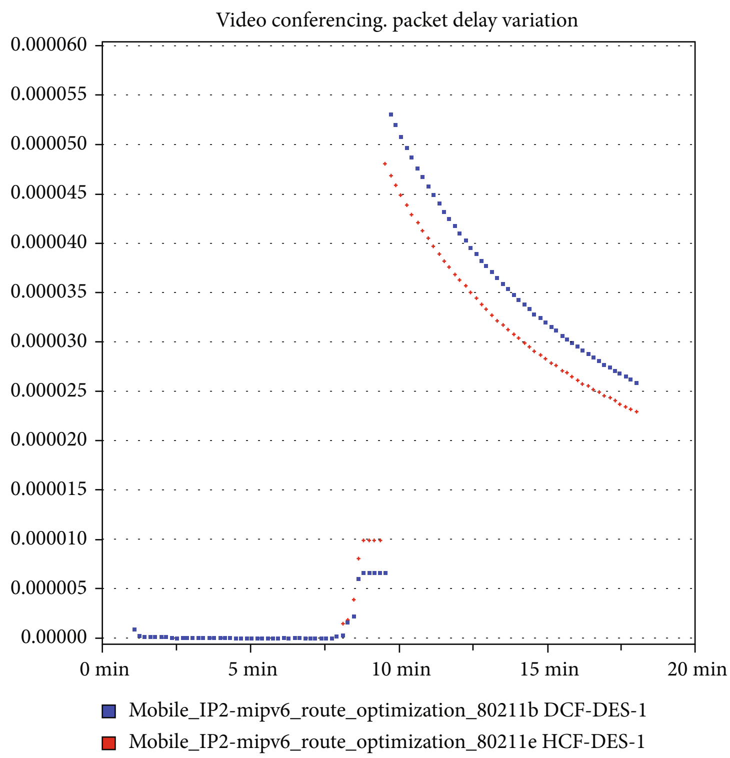

Figure 12: Packet delay variation.

media access delay for MN as well as HA_*A* and HA_*B*. Figure 5 illustrates the network architecture using MIPv6. In this topology, there are two nodes, one of which is CN and the other of which is mobile (MN) which travels from one AP to another. In these 2 scenarios, we examined as follows: (1) 802.11b DCF and (2) 802.11e HCF, in terms of QoS. For both, we investigated a video conference application, which involves videoconferencing, in actual Internet settings.

3. The Simulation Parameters

3.1. Parameters for WLAN. The settings for IEEE802.11b and IEEE802.11e include enabling the AP functionality with direct sequence PHY and having an 11 Mbps data rate and transmission power of 0.005 W at a beacon interval of 0.002 seconds. The detailed settings for IEEE802.11b and IEEE802.11e's all APs are suggested in Figure 6.

Furthermore, additional parameters are included for the previous AP to utilize the HCF protocol in the event of the IEEE802.11e standard, such as EDCA parameters, traffic category, AP-specific parameters, and high throughput parameters, as shown in Figure 7.

Using the RO technique, the configuration of a MIPv6 client is shown in Figure 8.

3.2. Parameters for Applications. The parameters of the applications and the assessment criteria are given in Table 1 and Figure 9.

3.3. Parameters for IP Cloud. Figure 10 shows the last load on the Internet from [26] between 10-9-2021 and 20-9-2021; then, these numbers are applied inside the OPNET software with zero packet discard ratio and constant (0.56 seconds) packet latency, as shown in Figure 11.

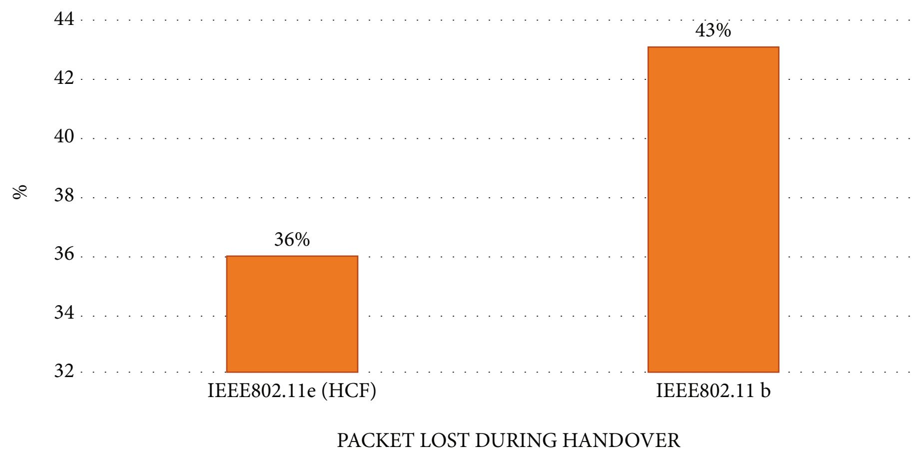

Figure 13: Packet delay variation ratio using video conference application.

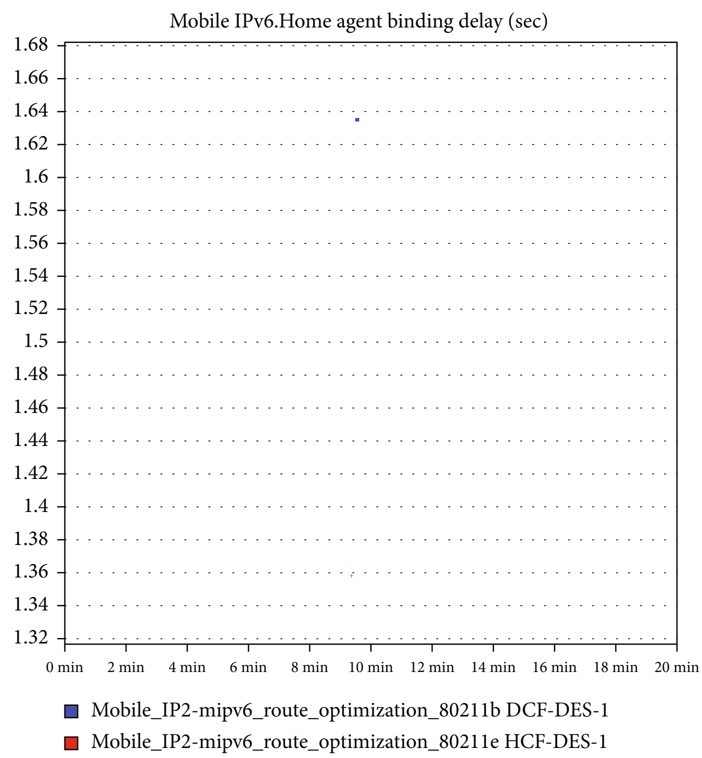

Figure 14: Home agent binding delay.

4. Results and Discussion

In this section, various parameters for different nodes have been measured to get desired results.

4.1. MN View

4.1.1. Packet Delay Variation. Packet delay variation is a variance among end-to-end delays for video packets received by this node as shown in Figure 12. The packet delay variations are the same in both IEEE802.11b and IEEE802.11e till 8 min; however, between the 8 and 9 min, IEEE802.11e has more delay variation, but eventually, after 10 min, it is much lower than IEEE802.11b.

We notice that packet delay variation for IEEE802.11e HCF is less and faster than IEEE802.11b DCF during the handover process between *HA_A* and *HA_B*. As expected, the packet lost during handover decreased dramatically from 43% to 36% as depicted in Figure 13.

4.1.2. Home Agent Binding Delay. HA binding delay is the time interval between when the MN sent a binding update (MIPv6 mobility) message to the HA and when the MN

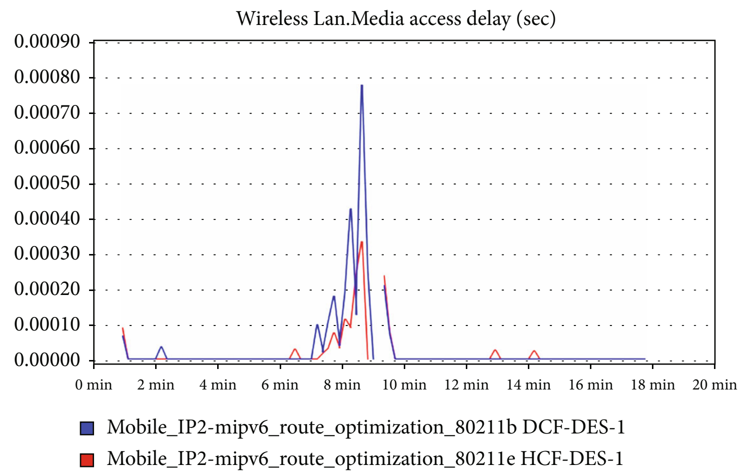

Figure 15: WLAN media access delay in MN.

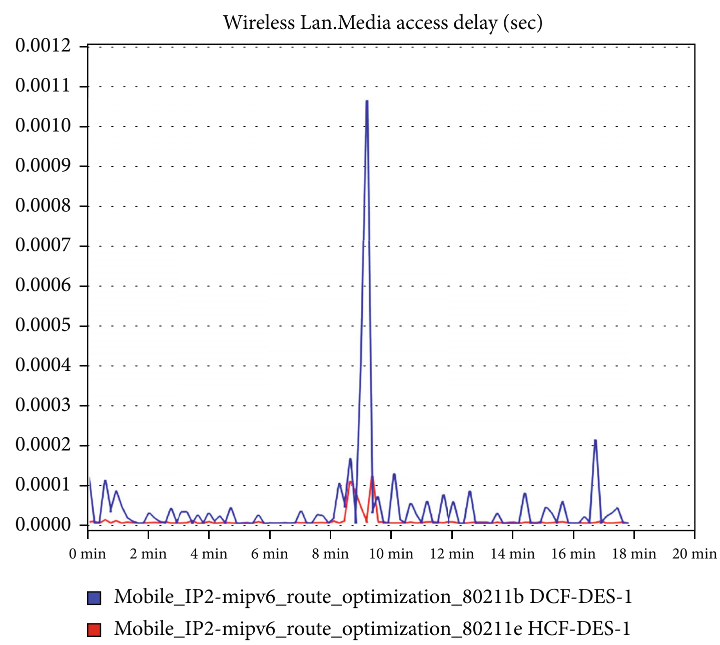

Figure 16: WLAN media access delay in HA_A.

received a binding acknowledgement (MIPv6 mobility) message from the HA in response. As seen in Figure 14, IEEE802.11e transitions from *HA_A* to *HA_B* are faster than IEEE802.11b. MN received the binding acknowledgement message from IEEE802.11e in 1.36 seconds, whereas IEEE802.11b received it in approximately 1.64 seconds, indicating that IEEE802.11e connects to the new HA roughly 20% quicker than IEEE802.11b.

4.1.3. WLAN Media Access Delay. The media access delay is computed as the time between when the frame is entered into the transmission queue, which is the arrival time for higher-layer data packets and the creation time for all other frame types and when it is first transferred to the PHY. According to Figure 15, 802.11e is somewhat faster and has less ripple than IEEE802.11b. Additionally, IEEE802.11e uses fewer queues and transmits packets without delay compared to IEEE802.11b.

4.2. Home Agent View

4.2.1. WLAN Media Access Delay for HA_A. Figure 16 illustrates that the WLAN media access latency for *HA_A* for IEEE802.11b has a significant increase when compared to the stable value for IEEE802.11e. Comparing IEEE802.11b and IEEE802.11e, we can see that IEEE802.11b has a time delay from *HA_A* that is 100 times greater than IEEE802.11e, which implies MN can depart the preceding HA without facing any delay in IEEE802.11e.

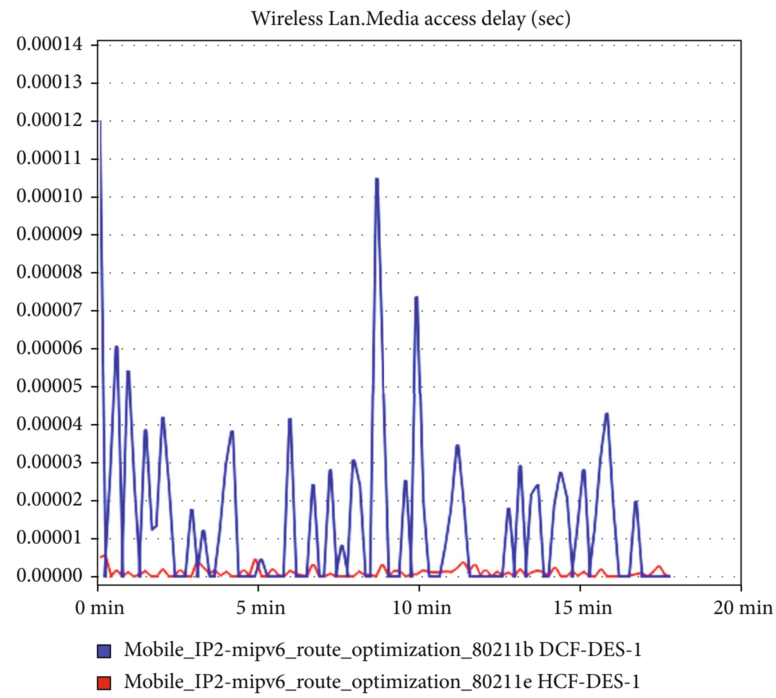

Figure 17: WLAN media access delay in HA_B.

4.2.2. WLAN Media Access Delay for HA_B. According to the results shown in Figure 17, IEEE802.11e has the smallest amount of latency and the shortest queue packet length when compared to IEEE802.11b. The WLAN media access delay of IEEE802.11e remained less than 0.000005 seconds whereas IEEE802.11b fluctuates a lot and often reached 0.00011 seconds; thus, as a result, we can conclude that IEEE802.11e provides better performance than the IEEE802.11b standard.

5. Conclusions

In this paper, the RO method was used to investigate the QoS in the context of the MIPv6 handover. This paper is developed using OPNET Modeler to simulate IEEE802.11b DCF and IEEE802.11e HCF with video conference applications in real-world Internet parameters. This research investigated the performance of the MN and HA perspectives, and the simulation results indicated that 802.11e improves system performance metrics such as packet delay variation, HA binding delay, and WLAN media access latency. The WLAN media access latency for HA_*A* and HA_*B* has also been evaluated, with the results indicating that the IEEE802.11e approach is more effective than IEEE802.11b during the handover process and that IEEE802.11e provides smoother handover than IEEE802.11b.

Data Availability

The study did not produce any new data.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] C. Heegard, J. T. Coffey, S. Gummadi et al., “High performance wireless Ethernet,” *IEEE Communications Magazine*, vol. 39, pp. 64–73, 2001.

[2] X. Perez-Costa and D. Camps-Mur, “IEEE 802.11E QoS and power saving features overview and analysis of combined performance [Accepted from Open Call],” *IEEE Wireless Communications*, vol. 17, no. 4, pp. 88–96, 2010.

[3] H. Wu, X. Wang, Q. Zhang, and X. Shen, “IEEE 802.11e enhanced distributed channel access (EDCA) throughput analysis,” in *2006 IEEE International Conference on Communications*, pp. 223–228, Istanbul, Turkey, 2006.

[4] L. Das Dhomeja, S. Abbasi, A. A. Shaikh, and Y. A. Malkani, “Performance analysis of WLAN standards for video conferencing applications,” *International Journal of Wireless & Mobile Networks*, vol. 3, no. 6, pp. 59–69, 2011.

[5] B. T. Vijay and B. Malarkodi, “Improved QoS in WLAN using IEEE 802.11e,” *Procedia Computer Science*, vol. 89, pp. 17–26, 2016.

[6] H. Kyung, S. Seo, and S. C. Park, “QoS (quality-of-service) improvement bibliographyin IEEE 802.11e enhanced distributed channel access (EDCA),” in *IEEE International Symposium on Communications and Information Technology, 2004. ISCIT 2004*, pp. 302–307, Sapporo, Japan, 2004.

[7] A. Khalid and H. M. Asif, “OCDMA and OSTBC based VLC transceiver design using NI cDAQ,” *Photonic Network Communications*, vol. 35, no. 1, pp. 97–108, 2018.

[8] D. Gupta, H. Alkatrani, M. Ilyas et al., "Polygon number algorithm for peak-to-average ratio reduction of massive 5G systems using modified partial transmit sequence scheme," *Wireless Communications and Mobile Computing*, vol. 2021, Article ID 7498240, 10 pages, 2021.

[9] Z. Tahira, H. M. Asif, A. A. Khan, S. Baig, S. Mumtaz, and S. Al-Rubaye, "Optimization of non-orthogonal multiple access based visible light communication systems," *IEEE Communications Letters*, vol. 23, no. 8, pp. 1365–1368, 2019.

[10] E. Ibrhim and A. Alwer, "Performance analysis of MIPv6 protocol in handover process in different working cases using OPNET Modeler ® 14.0," *Research Journal of Aleppo University, Engineering Science Series*, 2010.

[11] A. Khiat, A. Bahnasse, M. E. L. Khaili, and J. Bakkoury, "Study, evaluation and measurement of 802.11e and 802.16e quality of service mechanisms in the context of a vertical handover case of real time applications," *International Journal of Computer Science and Network Security (IJCSNS)*, vol. 17, no. 2, pp. 119–130, 2017.

[12] D. B. Johnson, J. Arkko, and C. E. Perkins, "Mobility Support in IPv6," no. 6275. RFC Editor, 2011.

[13] D. Le and J. Chang, "Tunnelling-based route optimization for mobile IPv6," in *2010 IEEE International Conference on Wireless Communications, Networking and Information Security*, pp. 509–513, Beijing, China, 2010.

[14] A. Omar Alwer, "Performance evaluation for MIPv6 in pure IPv6 networks vs. 6 to 4 IP mechanism networks using OPNET," *International Journal of Electronics, Mechanical and Mechatronics Engineering*, vol. 6, no. 4, 2016.

[15] A. Balador, S. Jabbehdari, A. Movaghar, and D. Kanellopoulos, "A novel contention window control scheme for IEEE 802.11 WLANs," *IETE Technical Review*, vol. 29, no. 3, p. 202, 2012.

[16] P. A. Shah, H. B. Hasbullah, I. A. Lawal, A. A. Mu'Azu, and L. T. Jung, "A TOTP-based enhanced route optimization procedure for mobile IPv6 to reduce handover delay and signalling overhead," *Scientific World Journal*, vol. 2014, pp. 1–16, 2014.

[17] B. P. Crow, I. Widjaja, J. G. Kim, and P. T. Sakai, "IEEE 802.11 Wireless Local Area Networks," *IEEE Communications Magazine*, vol. 35, no. 9, pp. 116–126, 1997.

[18] H. Wu, S. Cheng, Y. Peng, K. Long, and J. Ma, "IEEE 802.11 distributed coordination function (DCF): analysis and enhancement," in *2002 IEEE International Conference on Communications. Conference Proceedings. ICC 2002 (Cat. No.02CH37333)*, pp. 605–609, New York, NY, USA, 2002.

[19] S. Choi, "Overview of emerging IEEE 802.11 protocols for MAC and above," *SK Telecom Telecommunications Review*, vol. 13, 2003.

[20] Y. Ge, J. C. Hou, and S. Choi, "An analytic study of tuning systems parameters in IEEE 802.11e enhanced distributed channel access," *Computer Networks*, vol. 51, no. 8, pp. 1955–1980, 2007.

[21] S. Mangold, C. Sunghyun, O. Klein, G. Hiertz, and L. Stibor, "IEEE 802.11e wireless LAN for quality of service," in *Proceedings European Wireless (EW 2002)*, pp. 32–39, Florence, Italy, 2002.

[22] C. Cicconetti, L. Lenzini, E. Mingozzi, and G. Stea, "A software architecture for simulating IEEE 802.11e HCCA," in *IPS-MoMe'05: Proceeding from the 3rd Workshop on Internet Performance, Simulation, Monitoring and Measurement*, pp. 97–104, Warsaw, Poland, 2005.

[23] R. Moraes, P. Portugal, F. Vasques, and J. A. Fonseca, "Limitations of the IEEE 802.11e EDCA protocol when supporting real-time communication," in *2008 IEEE International Workshop on Factory Communication Systems*, pp. 119–128, Dresden, Germany, 2008.

[24] A. Hussein, A. Ali, N. Abbas, and M. Hamad, "Open access performance evaluation ofIEEE802. 11g WLANsusing OPNET modeler," *American Journal of Engineering Research*, vol. 11, no. 12, pp. 9–15, 2013.

[25] W. Jiang, "OPNET-based WLAN modeling and its performance testing," *Chemical Engineering Transactions*, vol. 51, pp. 361–366, 2016.

[26] http://www.internettrafficreport.com/30day.htm.