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PAPER

Efficient Mobility in Next Generation Heterogeneous Wireless Networks Based on Enhanced Vertical Handoff Approach

Vishnu Kumar Kaliappan[1](✉),
T. Padmapriya[2],
S. V. Manikanthan[3],
S. Ilavarasi[4],
B. Suresh Kumar[5]

[1]Department of Computer Science and Engineering, KPR Institute of Engineering and Technology, Arasur, Coimbatore, Tamil Nadu, India

[2]Melange Publications, Puducherry, India

[3]Melange Academic Research Associates, Puducherry, India

[4]Department of Computer Science and Engineering, Sengunthar Engineering College (autonomous), Tiruchengode, Tamil Nadu, India

[5]Department of Electronics and Communication Engineering, The Kavery Engineering College, Mecheri, Salem, Tamil Nadu, India

vishnukumar.k@kpriet.ac.in

ABSTRACT

The progression of mobile technologies from first generation (1G) to fifth generation (5G) networks has brought about noteworthy advancement. The present network environment is characterized by the coexistence of various mobile networks and technologies, leading to overlapping or non-overlapping coverage areas, creating a next-generation heterogeneous landscape. Handoffs within the same network (i.e., GSM to GSM or vice versa) are known as horizontal or homogeneous handoffs. Conversely, when handoffs entail a transition to a different network type, such as moving from GSM to CDMA or vice versa, they are categorized as vertical or heterogeneous handoffs. Multiple link triggers, such as link down (LD), link going down (LGD), link detected, and link up, are employed to initiate and execute vertical handoff (VHO) when needed. We have determined the thresholds for vehicular speed and link triggers through extensive simulations, explicitly focusing on high-demand traffic types like video. This paper proposed an enhanced VHO approach based on IEEE 802.21, commonly called media independent handover (MIH), to improve Quality of Service (QoS) parameters, specifically mitigating packet loss (PL), and handoff delay and enhancing the user experience.

KEYWORDS

mobile networks, vertical handoff (VHO), media independent handover (MIH), quality of service (QoS), heterogeneous network

1 INTRODUCTION

Heterogeneous networks (HetNet) offer a wide range of services to mobile users everywhere [1]. Fifth-generation (5G) networks, which will offer significantly faster upload and download speeds, greater coverage, and more dependable connections on smartphones and other devices than previously are symbolizing the next wave of mobile internet connectivity [2]. The Internet of Things (IoT) technology has

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advanced significantly as a result of their efforts. One of the key challenges facing the upcoming generation is how to effectively synchronize various networks with distinct disparities in data rates, transmission ranges, supported traffic classes, and access expenses.

The growing frequency of wireless communication networks has created the challenge of staying consistently connected to a network. It is important to streamline the algorithms utilized in wireless communication networks. The issue of call drops remains a worry when traveling to isolated regions, as the number of users depending on networked technology has considerably risen over the past ten years. Different access technologies offer the possibility for wireless high-speed communications [3]. The newest wireless systems are being designed with the concept that a mobile device can link with several wireless networks like cellular and wireless local area networks (WLAN) simultaneously [4].

The primary characteristics of WLANs and worldwide interoperability for microwave access (WiMAX) comprise rapid data transfer, significant bandwidth, and affordability, although they are limited by short range [5]. The universal mobile telecommunications system (UMTS) provides broad coverage and connectivity advantages, yet comes with the drawback of reduced data speeds and higher expenses [6]. To maintain seamless services during movement across different network types, an intelligent vertical handoff decision algorithm is crucial for this universal wireless access. The vertical handoff decision engine functions as a remedy to tackle mobility issues and guarantee consistent data transmission across various network types, especially while traversing multiple networks.

Vertical handover must be implemented in varied wireless networks due to the need for seamless mobility, continuous transition, reliable optimum connection, quality of service (QoS), and quality of experience. Depending on what is available, users can select their chosen network from a range of network lists using the numerous interfaces that many contemporary portable devices have [7].

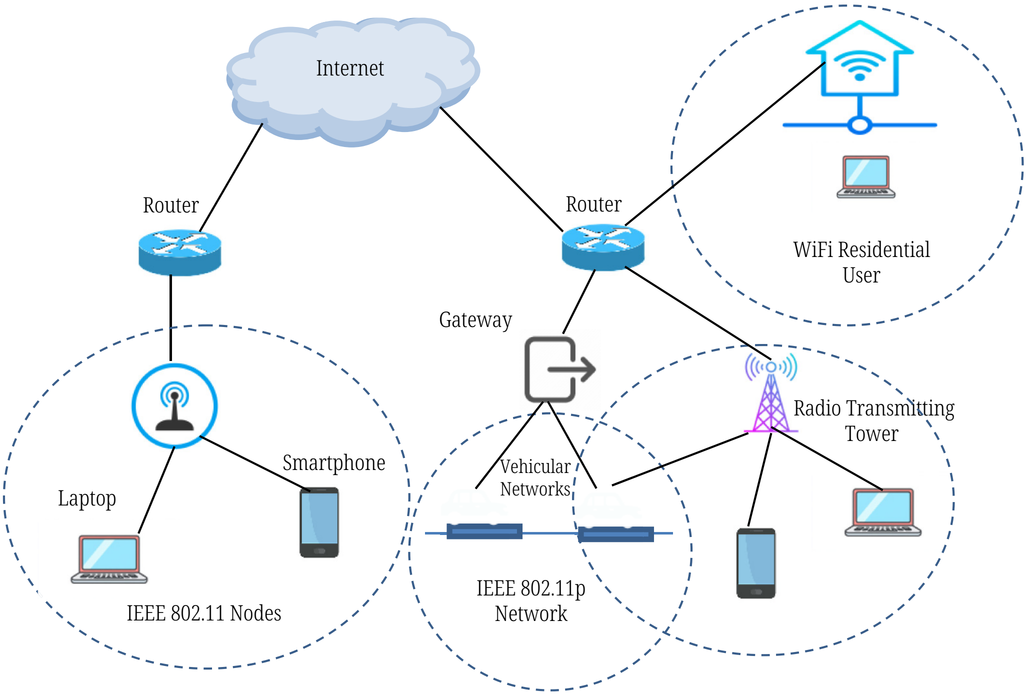

Fig. 1. Heterogeneous network model

In order to enable communication between mobile nodes in HetNet, heterogeneous handover—also known as vertical handover—is crucial [8]. An ecosystem with a variety of networks that vary in terms of data speeds, radio interfaces, coverage, prices, latency, and other aspects is depicted in Figure 1. Due to its influence on the QoS in the heterogeneous system, vertical handoff (VHO) has emerged as a critical issue that requires attention in the current requirement for coexistence. Smooth handover across various wireless networks depends on having a dependable VHO system.

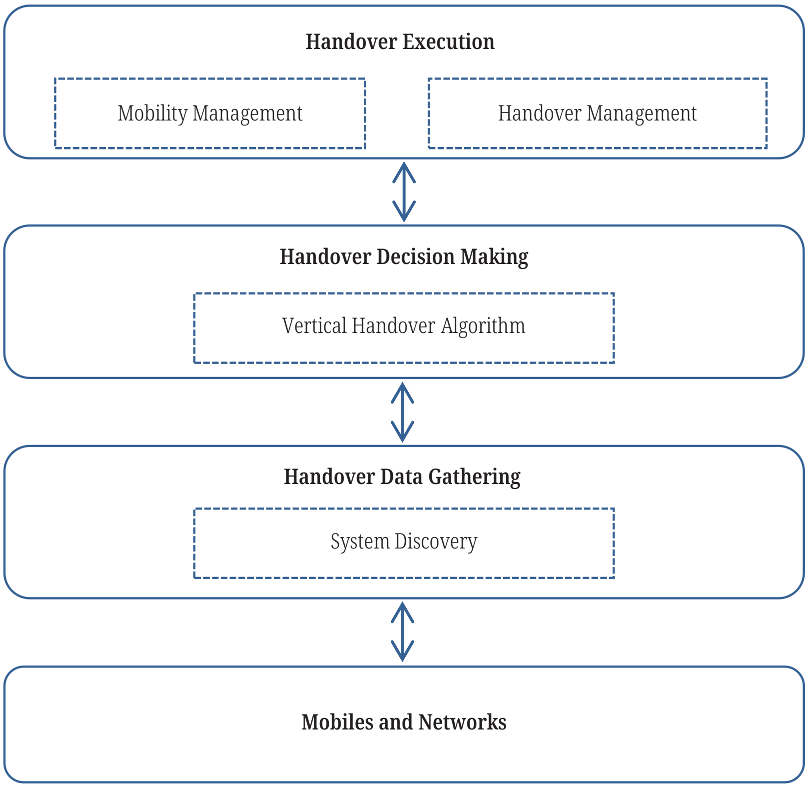

Fig. 2. Vertical handoff process

A key component of HetNet is VHO. Three steps make up the handoff procedure. The first step in the handoff process is information gathering, also called system discovery; the next step is decision-making, also called the handoff decision algorithm; and the last step is execution. Gathering the required data is the initial stage in determining whether a handover is required, after which the procedure may start [9].

It is frequently referred to as the beginning of the handover process or the system discovery phase. By carefully choosing the best access network and supplying the information required for the execution phase, the second phase—also referred to as system or network selection chooses whether and how to execute the handover. Important resources are allocated according to the details decided upon during the decision phase, and in the third stage, channels are modified appropriately [10]. The many phases of the VHO process are shown in Figure 2.

2 LITERATURE REVIEW

[11] suggested leveraging network function virtualization (NFV) and software-defined networking (SDN) to manage and regulate heterogeneous RATs in 5G

wireless networks. A sophisticated SDN/NFV-based architecture for centrally monitoring and controlling a range of RATs in 5G wireless networks was also suggested by them. The suggested design is scalable and performs better than current heterogeneous network (HetNet) designs in terms of network performance.

[12] proposed a modified vertical handoff method called E-TOPSIS to choose the leading network for each traffic type among several other networks. What's the available bandwidth (AB) in Mbps, the packet jitter (PJ) in milliseconds, the cost per byte (CB) in percent, and the packet loss (PL) per every 106 packets? There are the QoS metrics that are utilized. The weighting techniques that are employed include AHP and standard deviation. The most often chosen network using the E-TOPSIS algorithm for both weighting methods was found to be Wi-MAX.

[13] presented the network selection and multi-criteria vertical handoff decision technique for UMTS, WLAN, and WiMAX integration. There are two types of handoffs: the WLAN/WiMAX originating handoff (upward) and the UMTS originating handoff (downward). In terms of lowering the number of vertical handoffs, call dropping probability, GoS, and packet delay, as well as increasing the throughput and utilization of WLAN/WiMAX networks, the multi-criteria vertical handoff algorithm and network selection performs better than the single-criteria and Mamdani fuzzy approaches. Thus, the vertical handoff algorithm's objectives of lowering the number of handoffs, dropping probability, GoS, increasing WLAN/WiMAX use, lowering packet latency, and increasing throughput were all met in this study.

[14] presented a technique for adaptively selecting a wireless access node in a diverse environment. A structural diagram of the optimization steps for wireless HetNet has been devised, allowing them to function more efficiently. A model for investigating the processes of operation in a heterogeneous network environment is proposed. The effectiveness of the proposed solutions is evaluated, and the performance of the heterogeneous network improves by 16% when using the static reservation of network resources, compared to homogeneous networks, and by another 13% when using a uniform distribution of resources and a dynamic reservation process, as well as compared to the previous method.

[15] presented a refined optimal cell selection method that utilizes SDN to tackle the challenges of handover and mobility management in 5G and beyond 5G (B5G) HetNet. The proposed SDN-driven cell selection methodology employs linear programming (LP) to dynamically oversee user mobility, facilitating the choice of the best cell for user equipment (UE) handover. When it comes to cell selection, LP greatly reduces the computational load. The results show that the suggested strategy reduced the number of handovers by 39%. This decrease represents a significant step toward mitigating the problems associated with frequent and superfluous handovers, which will ultimately lead to less signaling overhead between UE and cells.

3 PROPOSED METHODOLOGY

A novel approach is employed in IEEE 802.21 standards are included in the Media Independent Handover (MIH) proposal. This section provides a helpful evaluation of MIHs efficacy. NS-2 (Network Simulator 2) is used to generate a realistic scenario. In order to evaluate performance across different types of video traffic, the study takes into account Link-Layer Event Triggers including Link detected, Link up, and Link down (LD). Numerous tests are carried out to identify QoS metrics, particularly handoff delay and packet loss.

The goal of MIH is to streamline and speed up the handoff process between various wireless networks regardless of the type of media being moved. Enhancing mobile station (MS) performance and usability across a range of wireless network scenarios is the aim of this vertical handover standard. The MIH Function (MIHF) is a crucial component of IEEE 802 because it serves as a consistent interface between protocols at higher layers and the data link layer.

Figure 3 shows the proposed MIH architecture. A 3GPP node is connected to a mobile node with an 802 interface through the same 802 interface in this configuration. All 802.21-compliant nodes have the MIHF, an intermediate interface between the upper and lower layers. The devices involved in handover decision-making and execution are monitored by the MIHF to ensure that data and instructions are sent smoothly. Every node has a group of MIHF users that typically handle and get information about handovers using mobility management protocols.

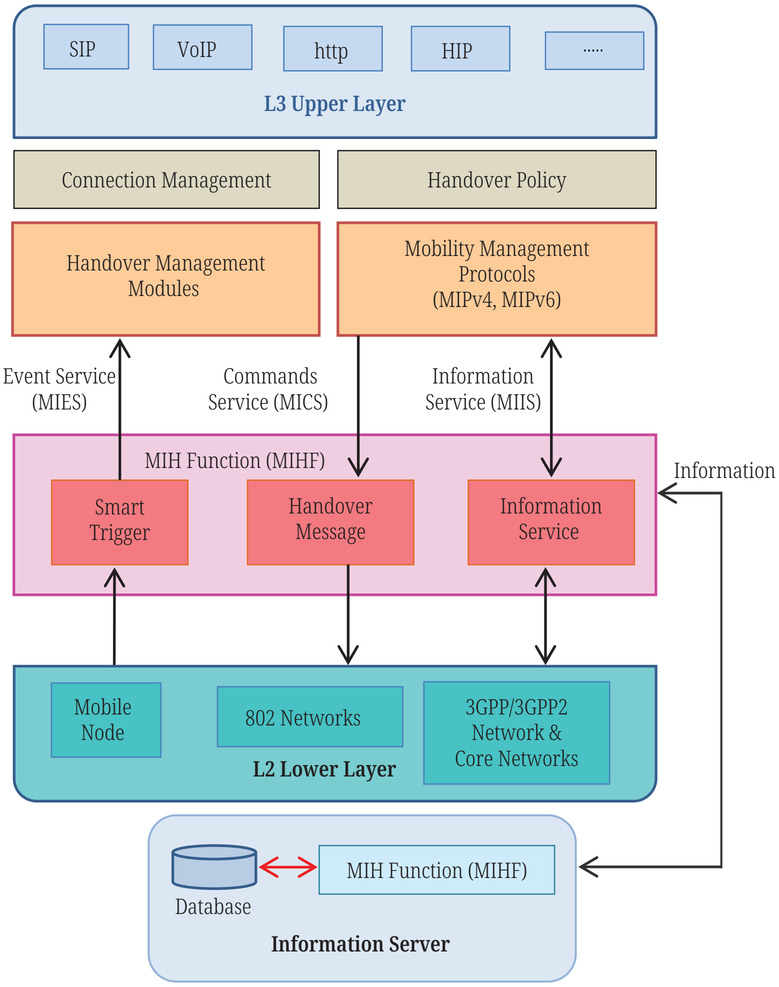

Fig. 3. Proposed MIH architecture

The three primary MIH services have been presented below:

The MIES supports both local and remote alerts and shows changes in the state and transmission behavior of the logical, data, and physical link layers. It can also forecast changes in the states of these levels. Events like "Link Handover Complete" are used to communicate link layer operations, whereas the "Link PDU Transmit Status" event is used to indicate transmission performance. For a variety of technologies, MIES provides connection events in both predictive and reactive modes. “Link Going Down” is a predictive warning, whereas “Link Up” and “Link Down” are reactive alerts.

The media independent command service (MICS) sends commands from superior network levels to subordinate layers. This interaction oversees connections and regulates terminals for peak performance and transfer regulations. Mobility management protocols are essential as they integrate static network conditions and higher-layer service information with fluctuating connection status and specifications to support decision making. Upon receiving a particular command request, an event may be triggered, enabling the network and its elements to observe the command’s outcomes. Commands can be given both locally and from a distance.

Mobile nodes can gain significant advantages from the media independent information service (MIIS) components when selecting a network, especially during handovers. The four primary types of these static information elements (IEs) are higher-layer services/information per point of attachment (PoA), PoA-specific, access-network-specific, and general. On the other hand, MIH event and command services provide current, dynamic data regarding active networks. Notable attributes such as network type, operator identifier, and service provider identifier are part of general information. Information exclusive to an access network encompasses aspects such as security features, QoS details, and updates to technological standards.

3.1 An enhanced vertical handoff algorithm

The speed of the mobile node, RSS, link layer triggers, and AB are the foundations of the proposed method. This simple method for making handoff decisions is based on MIH, or the IEEE 802.21 standard.

```
Step 1: Start
Step 2: Mobile node links to 4G connection (LTE/WiMAX)
Step 3: Identifying the new connection (Wi-Fi) using RSSI
Step 4: Maintain the existing interface (4G) ON/OFF after handoff to Wi-Fi
Step 5: Determine the speed of the mobile node $V_{node}$
Step 6: Is $V_{node}$ smaller than Threshold Speed ($V_{th}$) Proceed to step 7
        Otherwise
        Proceed to step 10
Step 7: Is session Bandwidth (BW) smaller than available BW? Proceed to step 9 (Switch to Wi-Fi network)
Step 8: Examine the video traffic category importance to determine if HIGH/LOW exits the Wi-Fi network using the application-specific link trigger LGD/LD.
Step 9: Change to Wi-Fi network
Step 10: Continue using the existing 4G network
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4 RESULTS AND DISCUSSION

A structure known as MIH was developed to facilitate handoffs in wireless communication systems more seamlessly. The primary objective of IEEE 802.21 is to enhance handoff procedures both within and among network systems (inter-system and intra-system). These systems may differ, such as cellular networks and Wi-Fi.

By delivering lower-layer (link layer) data to higher-layer protocols, IEEE 802.21 streamlines the handoff process. This involves sharing important information from the physical and data connection layers, including link type, quality, and identification, with higher-layer network management and decision-making activities. A core characteristic of IEEE 802.21 is its ability to enable mobile nodes (MNs) to discover and select the best network in their nearby environment. This is essential for ensuring that Minnesotans can easily access the network with the highest availability and performance.

Ensuring secure communication is essential when a mobile device links to various PoA within a network. In order to protect data privacy and integrity, security measures—such as encryption keys and authentication details—must be maintained.

Mechanisms for establishing and maintaining security associations at both lower and upper layers—like the data link layer and the network or transport layer—are facilitated by IEEE 802.21. This flexibility enables the execution of comprehensive security protocols during handoffs.

The key element influencing network performance and throughput is the QoS. The critical QoS parameters of VHO are as follows:

4.1 Handoff latency

This parameter considers the time required to complete the three phases of VHO, specifically, the time needed for VHO initiation, decision-making, and conclusion. This value ought to be minimized for enhanced quality of service.

$$\begin{aligned} \mathit{Handoff\ Latency}\ (HL) = {} & \mathit{Time\ of\ Initiation\ Point} + \mathit{Time\ of\ Decision\ Point} \\ & + \mathit{Time\ of\ Completion\ Point} \end{aligned}$$

$$HL\ (Sec) = (TI + TD + TC) \tag{1}$$

4.2 End-to-end delay or latency

The duration needed to send a data packet from its origin to its endpoint is known as end-to-end delay or latency. This metric represents the total of the network and handoff delay combined. It reflects the effectiveness of VHO, the performance of the candidate network, and the state of the network conditions.

$$EEL\ (Sec) = \mathit{Network\ Delay}\ (Sec) + \mathit{HO\ Delay}\ (Sec) \tag{2}$$

4.3 Packet loss

The PL is the total number of packets that were lost throughout the VHO process. This component establishes how effective the VHO process is. For VHO approaches, the PL must be minimized. The delay during the handoff is the main source of PL, which affects VHO performance.

$$\begin{aligned} \mathit{Packet\ Loss} = {} & \mathit{Total\ Packets\ Transmitted\ by\ the\ Source} \\ & - \mathit{Number\ of\ Packets\ Received\ by\ Receiver} \end{aligned} \tag{3}$$

4.4 Packet loss ratio

The PL ratio is calculated by dividing the total packets lost by the total packets sent by the source.

$$Packet\ Loss\ Ratio = \frac{Total\ Packets\ Transmitted\ by\ the\ Source - Number\ of\ Packets\ Received\ by\ Receiver}{Total\ Packets\ Transmitted\ by\ the\ Source} \tag{4}$$

The comparative average QoS characteristics for the enhanced vertical handover algorithm (EVHA) and basic MIH are displayed in Table 1. For all application traffic combined, the average latency and PL characteristics are assessed at all terminal speeds.

Table 1. Comparison of basic MIH and EVHA Qos parameters

Parameter	Basic MIH	EVHA	Factor Enhanced
Average Latency (4G-WiFi)	0.7956 sec	0.3800 sec	0.4156
Average Latency (WiFi-4G)	0.0897 sec	0.0560 sec	0.0337
Average % Packet Loss	1.5250	0.8221	0.7029

We have proposed an EVHA in this part that makes VHO decisions based on the RSS, link layer prompts, and device speed constraints. In order to assess EVHO effectiveness, both interactive and non-interactive video data are present. When evaluating EVHA, the simulation parameters stay the same. The QoS metrics are compared to the conventional MIH after being obtained for the EVHA. With respect to the average QoS metrics of the existing basic MIH, it is found that the EVHA exhibits an improvement of 44 to 60%.

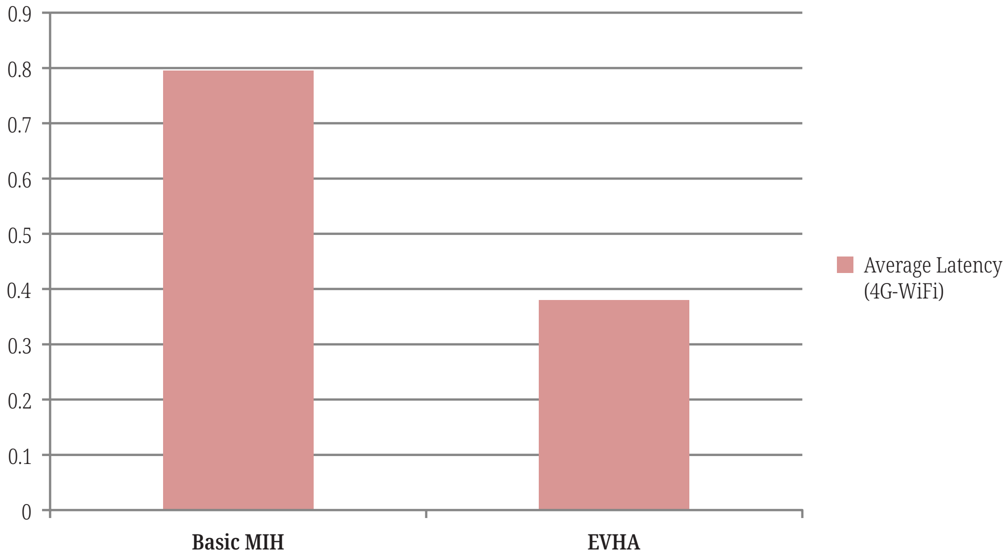

Fig. 4. Average latency (4G-WiFi)

When transitioning from 4G to WiFi, Figure 4 illustrates the standard latency of the EVHA in comparison to Basic MIH. Unlike Basic MIH, which shows a significantly higher standard latency of around 0.8, the chart distinctly reveals that EVHA reaches a markedly lower standard latency of about 0.3. This suggests that EVHA is more skilled at reducing latency during changes in the network. EVHA represents a superior option for applications that necessitate continuous connectivity, such as IoT-based systems or mobile networks, as its reduced latency indicates enhanced overall performance.

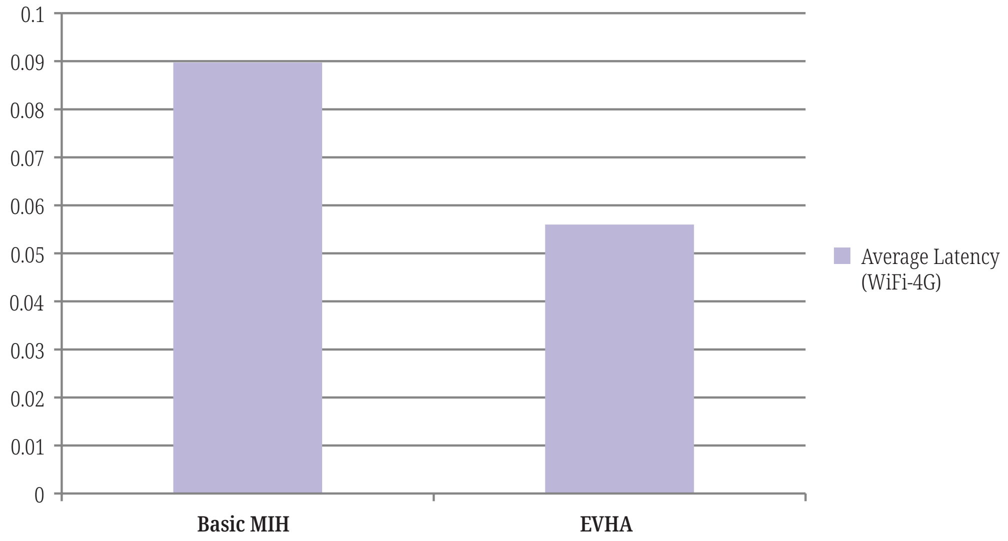

Fig. 5. Average latency (WiFi-4G)

Figure 5 displays the typical latency for the Basic MIH and EVHA systems during WiFi to 4G network transitions. The average delay for EVHA is approximately 0.05 whereas the average delay for Basic MIH is approximately 0.09. By reducing latency EVHA makes network transitions faster and more seamless demonstrating its remarkable ability to manage WiFi to 4G handovers. Such developments are particularly crucial for applications that require low latency such as mobile applications and real-time IoT communications in order to guarantee a better user experience and reliable connectivity.

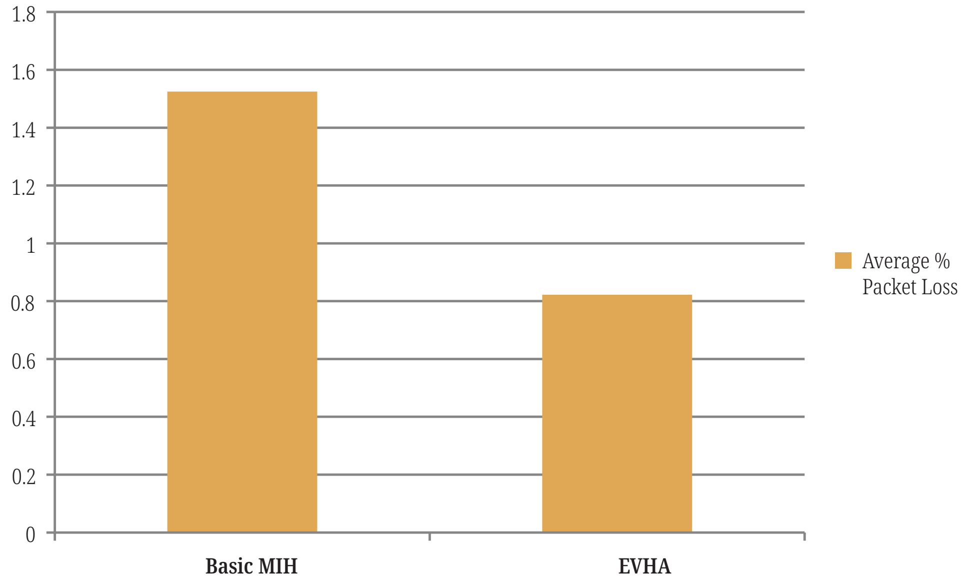

Fig. 6. Average percent packet loss

Concerning the average percentage of PL, Figure 6 illustrates the Basic MIH and EVHA. The PL for basic MIH is roughly 1. 6%, which is considerably greater than that of EVHA, which is around 0.8%. EVHA improves reliability during network transitions by decreasing data loss and enabling more reliable and seamless communication. The lower PL in EVHA is especially beneficial for real-time applications where preserving data integrity is vital for optimal performance, such as voice-over IP, video streaming, and IoT systems.

5 CONCLUSION

This research introduces an enhanced vertical handover technique founded on the MIH standard to facilitate seamless mobility in future heterogeneous wireless networks. In addition to handover latency, we have discovered a significant relationship between PL and terminal speed. As the terminal's speed rises, both latency and loss rates increase as well. The proposed method yielded a PL ratio of under 1% and decreased latency relative to the previous scenario. Our solution is straightforward and resource-efficient, rendering it compatible with the MIH framework. When compared to the results documented earlier, our algorithms' QoS parameters nearly align with the acceptable limits defined by the MIH standard. Our proposed method enhances network load, bandwidth utilization, and terminal battery longevity in wireless networks by effectively minimizing unnecessary handovers. We determined that when assessed on a single node, the results demonstrated an average parametric enhancement of 44% to 60%.

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7 AUTHORS

Vishnu Kumar Kaliappan received the M.Tech degree in communication engineering from VIT University, Vellore, India, and the Ph.D. degree in computer and information communication engineering from Konkuk University, Seoul, South Korea, in 2011. He is currently working as an Associate Professor with the Computer Science and Engineering Department, KPR Institute of Engineering and Technology, Coimbatore, India, and has 13.8 years of Teaching and Research Experience. He is also an Editorial Manager with the International Society of Intelligent Unmanned System (ISIUS), South Korea. He worked on a project under the Korean Aerospace Research Institute (KARI), Degu, South Korea, and the Centre for Air Born System (CABS), DRDO, Bengaluru, India. He received one of the Korean prestigious Scholarship International Information Technology Admission (IITA) from Ministry of Information Technology, Seoul, from 2007 to 2012. His name has been indexed in world's popular and leading biographical data base "Marquis Who's Who in the World" in the year of 2014–2017. His teaching is primarily focused in the area of mobile computing, cyber security and wireless sensor networks. The focus of his research is on bio mimetic algorithms, cyber physical systems, hardware in the loop simulation (HILS), and control algorithms for unmanned aerial vehicles. He has acted as a reviewer and an editorial member for more than 50 journals. (E-mail: vishnukumar.k@kpriet.ac.in).

Dr. T. Padmapriya is Managing Director of Melange Publications, Puducherry, India. She obtained her PhD at Puducherry Technological University, Puducherry, India. Her area of research interest is LTE and wireless networks. She has number of international publications to her credit and is a reviewer for various international journals (E-mail: padmapriyaa85@ptuniv.edu.in).

Dr. S. V. Manikanthan is Director of Melange Academic Research Associates, Puducherry, India. His area of Research Interest is Wireless Sensor Networks. He has 21 years of experience in Anna University Affiliated Colleges and in Industrial Research Projects (E-mail: prof.manikanthan@gmail.com).

S. Ilavarasi, started her profession as an Assistant Professor in the year of 2012 and I completed my UG degree in Annamalai University, Chidambaram in the year 2008, M.B.A in Alagappa University distance education, M.E at K.S.R Engineering College, Tiruchengode in the year 2012 and is pursuing PhD since 2023 (E-mail: ilavaishu@gmail.com).

Mr. B. Suresh Kumar is working as an Assistant Professor in the Department of Electronics and Communication Engineering in The Kavery Engineering College. He has a teaching experience of 13.5 years. He received undergraduate degree from Maha College of Engineering, Anna University, Chennai and received postgraduate from College of Engineering, Guindy Campus, Anna University Chennai. His areas of interest are Signal Processing, Image processing and Wireless Sensor Networks (E-mail: surece.brills@gmail.com).