QoS Aware Optimization of Vertical Handover Decision using Cuckoo Search Algorithm in Heterogeneous Wireless Network

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***Abstract*-The new wireless technology creates a unified worldwide network, offering a variety of services to users worldwide. Its primary aim is to enable mobile users to move effortlessly between different parts of the network. Heterogeneous Wireless Networks (HWNs) enable users with international devices to access the necessary services wherever they are located. Wi-Fi (Wireless Fidelity), Wi-Max (Worldwide Interoperability for Microwave Access), UMTS (Universal Mobile Telecommunication Service), and WLAN (Wireless Local Area Network) are just a few examples of the Radio Access Technologies (RATs) that are included in HWNs. Seamless mobility and the transfer of active calls are facilitated through Vertical Handover (VHO) mechanisms. While ensuring seamless mobility across diverse wireless networks remains a crucial area of research, designing an effective vertical handover decision algorithm is paramount. This technique enables multi-mode terminals to choose the most suitable network among the selections provided. Existing research has introduced a vertical handover decision algorithm for multi-mode terminals employing the Modified Topsis Method, yet it overlooks the aspect of seamless mobility support. Hence the intra-transaction and inter-transaction are hard to focus on achieving the QoS-based decision making. So, in this work, the VHO is considered for the service of the WLAN cellular network. The newly developed Cuckoo search optimization technique (CSO) is employed for the VHO in HWN. Enhancing mobility management entails prioritizing handover (HO) procedures, which are pivotal for addressing mobility-related challenges. A CSO technique has been devised to enhance service quality for end-users, focusing on aspects such as call drop probability, handover delay, jitter, end-to-end delay and throughput. Heterogeneous wireless networks (HWN) are leveraged, taking into account network and achieve superior Quality of Service (QoS).**

Keywords: Vertical handover mechanism, Heterogeneous wireless network, Seamless mobility, Cuckoo search optimization, Quality of Services (QoS).

1. INTRODUCTION

In recent years, the exponential growth of wireless communication networks has presented the difficulty of ensuring uninterrupted connection. Simplifying the algorithms related to these networks has become imperative. Call drops persist as a significant concern, especially in remote areas where the user base has grown significantly in the last decade. Various access technologies enable wireless high-speed communication. The future of wireless systems envisions mobile terminals seamlessly connecting to multiple networks simultaneously, including cellular and Wireless Local Area Network (WLAN) [1].The integration of different Radio Access Technologies (RAT) forms a heterogeneous wireless access network (HetNets) aimed at delivering multimedia services and meeting quality of service (QoS) standards for mobile devices. These HetNets consist of diverse wireless networks [2]. Heterogeneous wireless systems enable effective utilization of wireless resources, offering seamless mobility with QoS assurance by distributing the load and closely integrating with higher-layer networks and applications. In Heterogeneous Wireless Networks, it's crucial for mobile users to experience seamless internet connectivity. Service providers must manage wireless resources effectively to maximize efficiency and returns on investment. As mobile devices regularly move between locations, uninterrupted communication is essential [3]. This necessitates frequent transitions between different technologies and therefore requires efficient handoff support to maintain continuous connectivity [4]. Handoff is considered a key component of mobility management [5].User accessibility involves maintaining uninterrupted connection across various access technologies. Handoffs can occur either vertically or horizontally. Horizontal handoffs take place when users transition between similar access technologies, while vertical handoffs occur between different access technologies. In future wireless networks, the aim is to continuously seek the best network solution. Constant revaluation of solutions is necessary, especially with mobile terminal mobility.

In recent years, wireless communication has shown substantial progress. The desire for constant connectivity, whether at work or leisure, has made connectivity a critical concern. Scientists are continually proposing new ideas to ensure uninterrupted wireless services for users. While progress has been made, limited space and resources remain challenges. Small cells, utilizing available frequency bands efficiently, have emerged as a solution in the current scenario. Given cost constraints associated with higher bandwidths, maximizing bandwidth utilization has become imperative. As a mobile terminal transitions between areas, maintaining connectivity to available networks becomes crucial. In such scenarios, handoff functionality is pivotal for ensuring uninterrupted network access. Therefore, there's a requirement for efficient handoff algorithms enabling constant network connectivity for users. Both vertical and horizontal handoffs are significant, but in heterogeneous wireless networks, vertical handoffs assume greater importance. Continuous monitoring of the handoff process is necessary to minimize handoff failures. In the next generation of wireless networks, the objective is to consistently seek optimal solutions for ensuring continuous network availability. The expansion of cellular networks in recent years has surged, posing challenges in network management. This has led to heightened interest in self-tuning networks. Optimizing handoff parameters is crucial for enhancing device efficiency in next-generation wireless networks [6]. Handoff optimization aims for seamless and swift transitions between Base Stations, thereby simplifying network management. Key objectives of handoff optimization include reducing radio link failures (RLF), minimizing call drops, controlling unnecessary handoffs, and mitigating idle mode issues [7].

In this study, the focus lies on enhancing mobility management, with particular emphasis on handover (HO) as the pivotal element for addressing mobility-related challenges. To improve service quality for end-users in terms of energy efficiency, handover delay, call drop probability, and throughput, a Cuckoo Search Optimization (CSO) technique was developed.

2. RELATED WORKS

Regarding vertical handover, the study concentrates on the handover decision stage, an enhanced network selection algorithm has been developed to optimize the provision of various services. The emphasis is particularly placed on the Quality of Service (QoS). Numerous approaches have been suggested in scholarly literature to identify the most suitable network. While some rely on a single criterion, others employ more intricate schemes incorporating multiple criteria. Almutairi et al. [8] it was suggested to utilize a genetic algorithm to find dynamic weights that optimize network value difference. This method mitigates the inconsistencies generated by SAW and TOPSIS while introducing objectivity to the determination of criteria weights. Al-Gharabally et al. [9] to maximize the absolute difference in ranks between alternatives, the PSO methodology was adopted to determine dynamic weights for characteristics inside the DIA method. This approach brings objectivity to the assignment of weights and demonstrated superior performance over the traditional AHP-based DIA method in terms of ranking irregularities across all service categories.

Goyal et al. [10] using a unique fuzzy Analytic Hierarchy Process (AHP), novel heterogeneous wireless network selection method.In comparing matrices for audio, video, and applications that prioritize performance above reliability, triangular fuzzy numbers indicate things in a broad range of variables that are generally ignored during decision-making.A novel nonlinear fuzzy optimization technique is devised to get precise weights from fuzzy comparison matrices for network selection. Baghla and Bansal [11] suggested is a vector-normalized preferred performance-based normalization methodology combined with the VIKOR method in a vertical handover decision algorithm. This V-VPP algorithm aims to minimize handoffs and ranking anomalies, surpassing traditional MADM methods in performance. Yu et al. [12] presented a network selection technique to match traffic classes with access networks.Potential networks are ranked using the chi-square distance, and decision criteria weights are calculated using entropy theory, inter-criteria correlation (CRITIC), and AHP. However, as performance assessment criteria for vertical handover choices, the algorithm does not take into account ranking irregularity or the number of handovers. Radouche and Leghris [13] suggested is a method for access network selection utilizing a multiple attribute decision-making approach. This new approach integrates subjective and objective weights using integrated weights, and it is based on the cosine similarity metric. The entropy and FANP approaches are used, respectively, to calculate subjective and objective weights. This approach yields superior performance in terms of average handoff numbers and ranking irregularities, surpassing conventional MADM methods like TOPSIS, VIKOR, and GRA.

ShidrokhGoudarzi et al. [14] a VHO system was devised using an optimization algorithm. The most effective network selection in this case is required using the Artificial Bee Colony (ABC) technique. Network selection performance was improved for handover by integrating the SEarch by Fixed Intervals (SEFI) approach with ABC. Parameters such as security, Bit Error Rate (BER), delay, cost, and bandwidth were considered for selecting the optimal network. The efficiency of the developed technique was evaluated to gauge its performance. Achieving a near-optimal solution resulted in improved handover efficiency within optimal timeframes. Anna Maria Vegni, and Enrico Natalizio [15] a VHO system was created to accommodate both soft and hard handovers within the Heterogeneous Wireless Network (HWN). This entailed devising both Mobile Controlled Handover (MCHO) and Network Controlled Handover (NCHO) mechanisms to determine when to initiate handover. The system's efficiency was assessed based on waiting time.

3. METHODOLOGY

The VHO technique in the HWN based on efficient QoS is the most challenging task. The velocity of the mobile node is not considered in the conventional techniques for the VHO decision-making process and decision-making based on multiple attributes is employed for the enhancement of results. Hence, the VHO for the HWN is challenging for the seamless management of mobility. The intra-transaction and inter-transaction are hard to focus on achieving the QoS-based decision making.

System Model

The preliminaries and the assumptions are used to describe the system model of the VHO in the HWN [16].

Assumptions

Small cell coverage makes up the Wireless Local Area Network (WLAN).The access point, denoted as B, is the center of the cellular service region. $B = \{b_1, b_2, \ldots, b_M\}$ is the equation for the access point (AP).With the base station (BS) located in the cellular service region, D is denoted and may be expressed as $D = \{d_1, d_2, \ldots, d_N\}$.N is regarded as N = 1, except for the very dense urban deployment. The AP is regarded as $N > 1$ if it is located inside cellular service area N.We use the VHO Decision Controllers (VHDC) to manage the D and B coverage area data of the associated candidate points. To add the AP load status in B and the BS load status in D, the VHDC is used.$\bar{V} = \{v_1, v_2, \ldots, v_L\}$ is the representation of the available MN in the cellular coverage.Mobility is not required at this moment. The MN is handled by AP, or the HO may request that the AP or BS correspond to D. The MNs are thus divided into subgroups and are represented as,

$$V_s = \left\{v_{m1}, v_{m2}, \ldots, v_{m_{n(s)}}\right\} \quad (1)$$

MNs requesting handoffs are represented as $n(s)$ and their indices as $m_1, m_2, \ldots, m_{n(s)}$throughout the indicated period$s$. The term U_s=$\bar{V} - V_s$ denotes the set of MN with good connection.

Preliminaries

This section provides a comprehensive overview of the prerequisites taken into account for the VHO in the HWN. These prerequisites are adaptable and subject to modification based on the network environment. The assumptions made for the VHO are elaborated upon below.

Heterogeneous model

The network-accessing devices exhibit various configurations and settings, encompassing factors such as computational capabilities, battery management, network interface management, mobility patterns, and more.

Model of communication radius

According to the communication model, the coverage area around communication device J is defined by a radius r that is centred at point a,

$$A(a, r) = \{P_1, P_2 \in M : |E(P_1 - P_2) \leq Q_{P1}\} \quad (2)$$

where, the coverage distance is represented as A, $E(P_1 - P_2)$denotes the separation between the deployed base station and the HWN's access point M and Q_{P1}denotes the threshold coverage area.

Scalable Network: In scalable networks, the network is known to represent the closed region, and the HO is used in between the MNs. Between the nodes, the HO is often executed. Consider the 500 m x 500 m enclosed sector with 100 nodes and its surrounding area. In the amended definition, the MN is represented as $h, h–AP/BS$ is the distance between the MN and BS, and Q_h is the threshold coverage area of AP and BS. The expression is$|E(h - AP/BS) \leq Q_h$.

Handover Optimization using Cuckoo Search Optimization (CSO) Algorithm

This section introduces the proposed vertical Handover algorithm designed to manage handoff procedures within heterogeneous networks. The optimization of handovers is achieved through the integration of cuckoo search algorithm features. This involves utilizing the breeding behavior of specific bird species, namely cuckoos, for network initialization, and incorporating characteristics of Lévy flights observed in fruit flies and birds. Handover decisions are made based on the Lévy flights behavior observed in the CSO algorithm. The

VHO procedure implemented in the wireless network to ensure Quality of Service (QoS) is structured into distinct phases: initialization, pre-processing, and execution. Employing these steps aims to enhance overall performance. The phases are outlined as follows: Initialization Phase, Selection Phase, and Execution Phase.

Initialization Phase

The HO initiation utilizes the CSO algorithm, assessing parameters such as security level, battery status, QoS, and received signal strength (RSS) to prompt the handover. Selecting the best network for handover presents a significant challenge in traditional methods. Poor optimization leads to power loss and signal degradation in the mobile device's network. Therefore, it is essential to choose the most suitable network among those available by taking into account Quality of Service (QoS), a task facilitated by the suggested algorithm. Calibrated QoS weights determine the most effective network for handover, with the assignment of weights to QoS parameters enabling the estimation of network conditions. These weights, determined based on service parameters, typically take values of either 0 or 1, as assessed through the cost function.

Selection Phase

The decision on which network to choose is made by taking into account various criteria on both the terminal and service sides. Factors such as battery status, velocity, security, and QoS are assessed. The selection process involves evaluating QoS parameters and the provider's profile to determine the most suitable network. User preferences and QoS considerations also play a role in network selection from the user's perspective. Ultimately, the swarm optimization algorithm is utilized to ensure the most effective network selection for executing the handover process, resulting in the optimal network being chosen.

Execution Phase

The Mobile IP protocol (MIP) is utilized to manage network operations during handover (HO), with decision-making parameters assessed for Vertical Handover (VHO) in Heterogeneous Wireless Networks (HWN). Consequently, with optimization, the best network is selected. Considering the network's lowest cost function guarantees the best VHO is chosen. Using access point sensitivities and importance, the CSO is used to give weights $(w_1, w_2, \ldots\ldots\ldots w_i)$ and to select the network for the VHO's HWN.

In this phase, decision-making for VHO is carried out using the advanced CSO algorithm, leveraging its evolving capabilities for network selection. Moreover, optimization techniques balancing exploration and exploitation are applied to address high-dimensional optimization challenges. Various researchers have devised optimization methods using meta-heuristic approaches to tackle such issues. Consequently, this study builds upon the advantages of CSO to develop a meta-heuristic approach, aiding in the selection of networks from current available sources.

Cuckoo Search Optimization (CSO) Algorithm based Handover Optimization in Heterogeneous Networks

Figure 1: shows the general implementation of the suggested approach for the HO

Initialization: The random population is generated initially based on the n hosts. The host is based Cuckoo birds prefer to lay their eggs in the nests of other birds.

Levy Flight: It is a random flight or walk. The steps are delineated by their lengths, which follow a particular probability distribution along with random directions. This type of flight is observed in different animals and insects. The following movement is determined by the current position.

Fitness Calculation: Fitness calculation involves employing a fitness function to identify the optimal solution. Initially, a nest is selected randomly. Subsequently, averaging throughput, latency, energy consumption, and call drop determines the cuckoo egg's fitness (the new solution). This fitness value is then compared to the average fitness of the host eggs (throughput, delay, energy consumption, and call drop) in the nest. If the fitness value of the cuckoo egg is equal to or lower than that of the randomly selected nest, the new solution replaces the randomly chosen nest.

Termination: The fitness function assesses solutions in the present iteration, forwarding only the superior solution. The number of iterations fall short of the maximum; the prime nest remains unchanged. Following initialization, levy flight, and fitness calculation, all cuckoo birds are prepared for subsequent actions. The termination of the cuckoo search algorithm occurs upon reaching the maximum iteration limit.

These techniques are repeated until the maximum iterations or perfect solutions are reached. Superior network performance over traditional methods is guaranteed by the recently established CSO algorithm for network selection and handoff decision-making. Below is a comprehensive description of the suggested CSO algorithm.

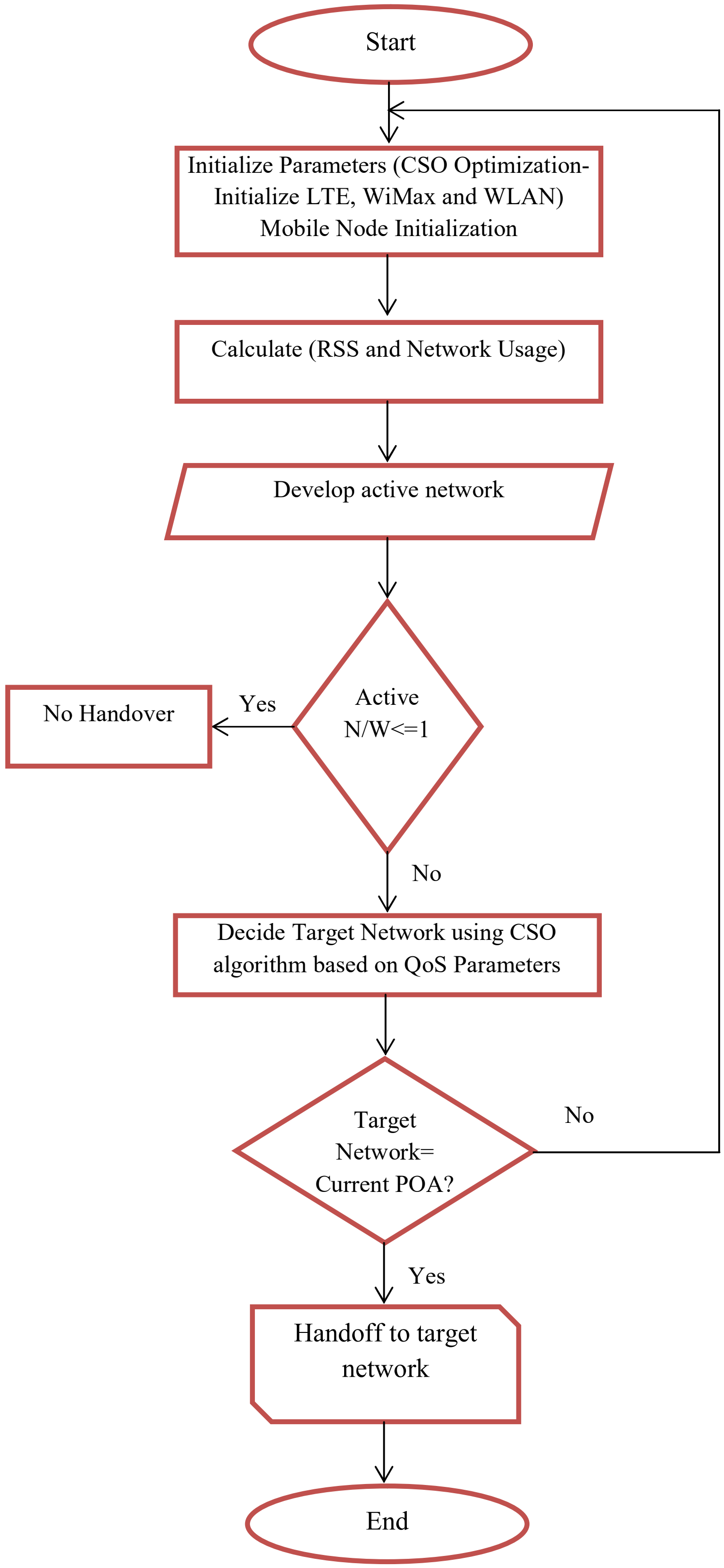

Figure 1: Proposed method for the HO

By [20], a novel meta-heuristic known as the Cuckoo Search (CS) method was presented. As necessary brood parasites, several species of cuckoos deposit their eggs in other birds' nests, and this behavior serves as the model for this algorithm. With the host nests, disputes may sometimes occur. A host bird may decide to reject foreign eggs or completely quit its nest to construct a new one elsewhere if it finds eggs that are not its own. Certain species have developed such that female parasitic cuckoos are very specialized in imitating the design and color of eggs belonging to particular host species. Because of this adaption, their chances of having their eggs rejected are reduced, which increases their chances of successfully reproducing. Furthermore, a great deal of research has shown that a wide range of insects and animals show flight patterns that are indicative of Levy flights. The authors created the CS algorithm [17,18] after taking into account both breeding and flying behaviours.

The three idealized rules listed below are followed by the CS algorithm:
1) Each cuckoo lays one egg in a random nest;
2) The next generations will inherit the best nests with high-quality eggs;
3) With a probability $p_a \in [0, 1]$, the host bird discovers the cuckoo's egg. There is a limited quantity of accessible host nests. Here, the host bird has the option of tossing the egg or leaving the nest to construct a new one.

The percentage $p_a$of the n nests that were replaced by new nests with fresh random solutions, according to the authors, might be used to estimate this last assumption. A Lévy flight is carried out by this equation to get a new solution $x_i^{(t+1)}$ for a cuckoo i:

$$x_i^{(t+1)} = x_i^t + \alpha \oplus \text{Levy}\ (\lambda) \quad (3)$$

x_i^t represents samples (eggs), t represents iterations, i represents sample number, and $\alpha > 0$ represents step size. To achieve the problem's constraint-controlled step size, tweak this value. The product ⊕ represents entry-wise multiplication. Calculating Levy (λ) from Lévy distribution:

$$\text{Levy}\ (\lambda) \approx y = l^{-\lambda}\ ; 1 < \lambda < 3 \quad (4)$$

The following formula may be used to simplify the Lévy distribution:

$$\alpha \oplus \text{Levy}\ (\lambda) \approx k \times \left(\frac{u}{(|v|)^{1/\beta}}\right)(x_{best} - x_i) \quad (5)$$

where the normal distribution curves' u and v are subtracted, $\beta = 1.5$is the Lévy multiplication coefficient set by users and k.

The fitness evaluation is re-assessed to determine both individual and overall best solutions: Solutions within the search space are adjusted using the CSO Lévy flight principle, and the top global solutions are identified. The best global solutions are identified when the allotted number of iterations has been attained. To find the best solution, factors like jitter, Delay, call drop, end-to-end delay and throughput are considered. Based on these parameters, the VHO in the HWN is then run.

4. EXPERIMENTAL RESULTS

This section examines the effectiveness of the newly introduced CSO technique in network selection by exploring variations in population size, the number of nodes, and speed. like jitter, Delay, call drop likelihood, and throughput are the main topics of the examination.

Table 1: Simulation Parameters setup

Parameter	Value
Channel	Wireless channel
Radio Propagation Model	Two ray ground
Antenna Model	Omni Antenna
Number of packets	**100**
Number of Base station	**25**
Routing Protocol	AODV
Simulation Area	500x500
Simulation Time	2500 sec
MAC Bandwidth	1M bit
MAC Protocol	802.11

In this section, the implementation of QoS aware vertical Handover Process (QoS-VHP) andQoS-VHP-CSO is done in the NS2 simulation environment. M-ANP, TOPSIS and QoS-VHP -Modified TOPSIS algorithm is compared using various scenarios. These include delay, throughput, likelihood of handover failure, and the number of handovers. The comparison has been made between the proposed methods and the existing method M-ANP and TOPSIS.

Call Drop Probability Comparison

With 0.060 Call Drop Probability, the suggested method outperforms the others on average, as Table 3 shows, which is better than the existing approaches like M-ANP, TOPSIS and QoS-VHP -Modified TOPSIS.

Table 2: Call Drop Probability Comparison

Number of Nodes	**Call Drop Probability**			
	M-ANP	**TOPSIS**	**QoS-VHP - Modified TOPSIS**	**QoS-VHP-CSO**
50	0.080	0.050	0.065	0.051
100	0.082	0.063	0.066	0.055
150	0.088	0.065	0.067	0.058
200	0.090	0.070	0.070	0.060

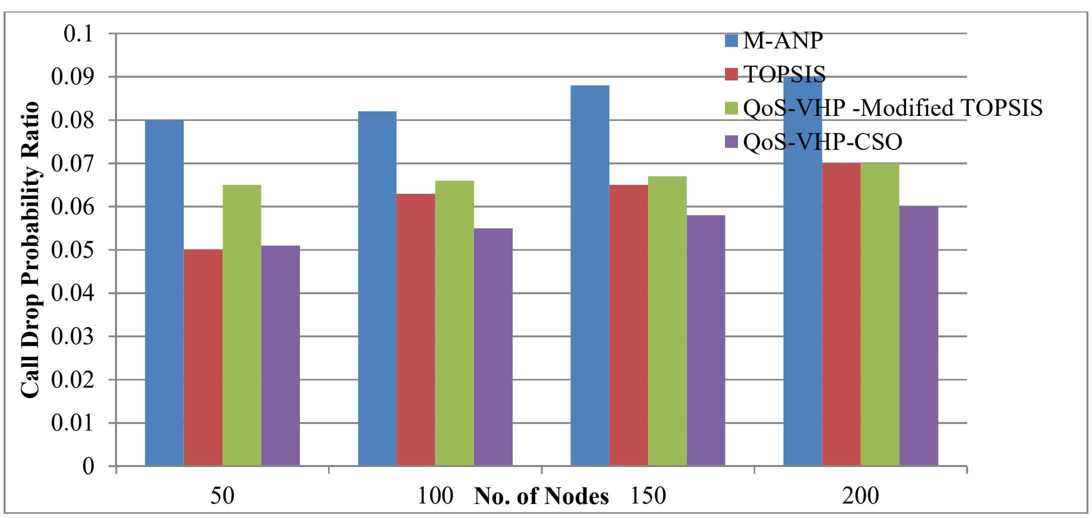

Figure 2: Comparison Analysis of the proposed methods using Call Drop Probability

Figure 2 presents a comparative analysis utilizing the call drop probability of the suggested strategies. It demonstrates that, on average, the suggested technique performs better than the current methods, such as M-ANP, TOPSIS, and QoS-VHP -Modified TOPSIS, with a Call Drop Probability ratio of 0.06.

Handover Delay

Table 3 shows the Proposed method obtains a better delay value of0.47 (s) for 200 no. of nodes, which is better than the existing approaches like M-ANP, TOPSIS and QoS-VHP -Modified TOPSIS.

Table 3: Handover Delay Comparison

Number of Nodes	**Handover Delay (s)**			
	M-ANP	**TOPSIS**	**QoS-VHP - Modified TOPSIS**	**QoS-VHP-CSO**
50	0.31	0.24	0.21	0.17
100	0.42	0.33	0.29	0.26
150	0.57	0.51	0.47	0.39
200	0.62	0.59	0.55	0.47

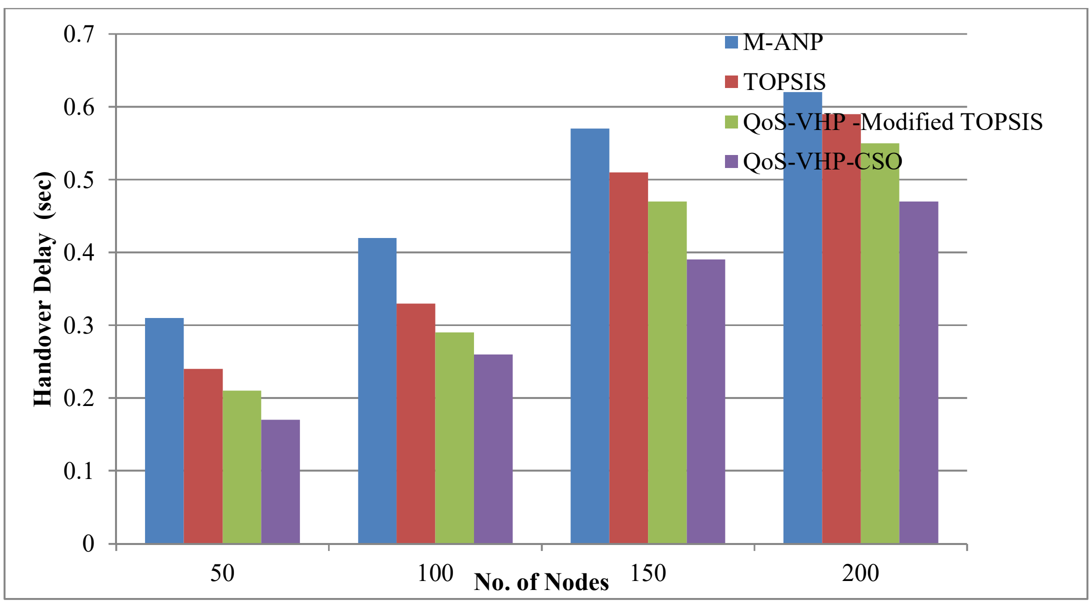

Figure 3: Comparison Analysis of the proposed methods using Handover Delay

The Comparison Analysis of the suggested techniques employing Handover Delay is shown in Figure 3. It shows that the proposed QoS-VHP-CSO method has an average better performance delay value of 0.47 (s) for 200 no. of nodes, which is better than the existing approaches like M-ANP, TOPSIS and QoS-VHP -Modified TOPSIS.

Throughput

Table 4 shows the Proposed method obtains a better throughput value of 94 (kbps) for 200 no. of nodes, which is better than the existing approaches like M-ANP, TOPSIS and QoS-VHP-Modified TOPSIS.

Table 4: Throughput Comparison

Number of Nodes	Throughput (kbps)			
	M-ANP	TOPSIS	QoS-VHP - Modified TOPSIS	QoS-VHP-CSO
50	40	61	79	85
100	44	63	81	88
150	48	65	85	91
200	51	69	86	94

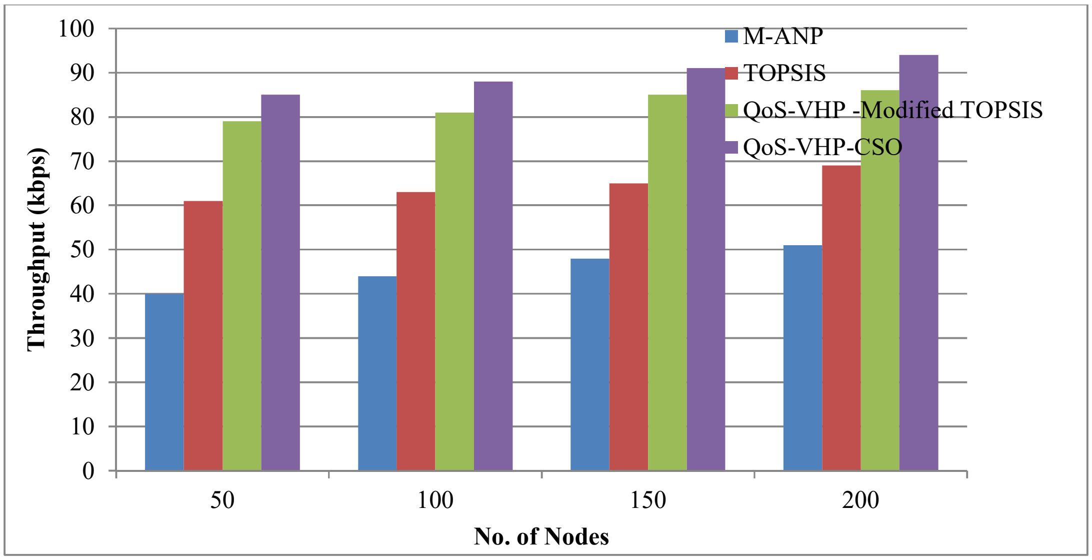

Figure 4: Comparison Analysis of the proposed methods using throughput

According to the Figure 4, it can notice that the evaluation of previous and presented system in relation to throughput metric. Plot the y- and x-axes with the throughput and node counts, respectively. In presented system, the throughput value is increased considerably by utilizing the QoS-VHP-CSO technique. Therefore, it proves that proficient detection is carried out by utilizing presented technique.

End-to-end delay

Delay from beginning to finish of a packet is the amount of time a packet needs to travel via a network from its source to its destination. In IP network monitoring, this idea is often used. Because all it does is calculate the amount of time data takes to go from its source to its destination, it differs from round-trip time (RTT).

Table 5 shows the Proposed QoS-VHP-CSO method obtains a lesser delay value, which is better than the existing approaches like M-ANP, TOPSIS, Modified TOPSIS and QoS-VHP.

Table: 5 Comparison of End-to-End Delay

Number of Nodes	End-to-End Delay (s)			
	M-ANP	TOPSIS	QoS-VHP - Modified TOPSIS	QoS-VHP-CSO
50	0.31	0.24	0.21	0.17
100	0.42	0.33	0.29	0.26
150	0.57	0.51	0.47	0.39
200	0.62	0.59	0.55	0.47

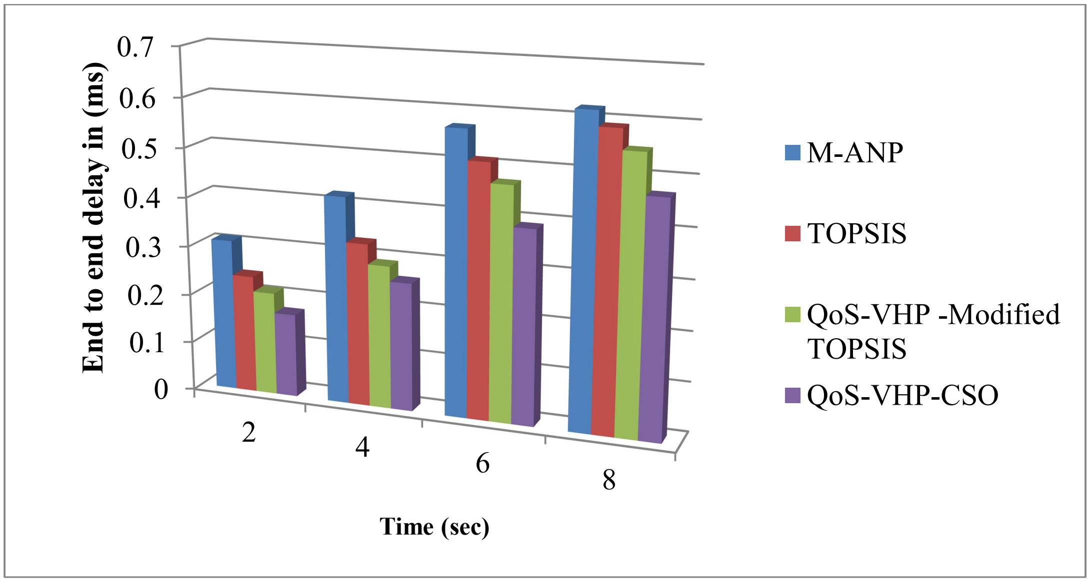

Figure 5: Comparison Analysis of the proposed methods using End to End delay

According to the Figure 5, the End to End delay value is decreased considerably by utilizing the QoS-VHP-CSO technique. Therefore, it proves that proficient detection is carried out by utilizing presented technique.

Jitter Comparison

Table 6: Comparison of Jitter

Number of Users	Jitter (ms)			
	M-ANP	TOPSIS	QoS-VHP - Modified TOPSIS	QoS-VHP-CSO
50	73	68	60	53
100	69	64	58	48
150	66	61	56	45
200	61	56	53	41

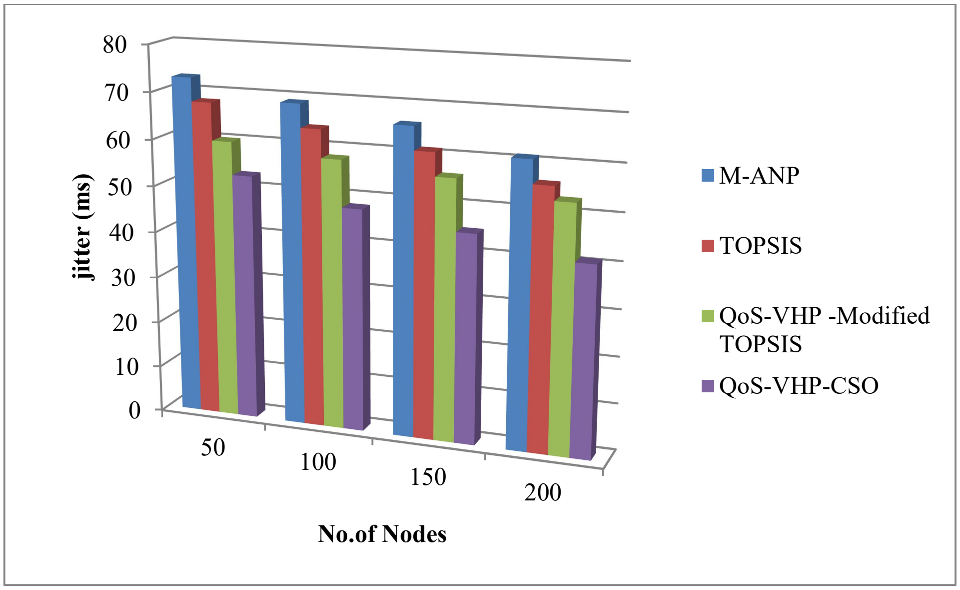

Figure 6: Comparison of Jitter

From Figure 6, it is observed that for a varying number of users, jitter is significantly decreased for proposed QoS-VHP-CSO when compared with the existing approaches like M-ANP, TOPSIS and QoS-VHP-Modified TOPSIS. Moreover, with the application of optimization, data were significantly transmitted over the network which decreases the jitter.

5. CONCLUSION

Seamless management is the most significant factor considered to obtain reduced service loss while switching the network. The primary focus of the proposed Cuckoo search optimization technique (CSO) is the development of a vertical handover mechanism aimed at ensuring seamless service for mobile nodes as they move across heterogeneous wireless networks. Various QoS parameters are taken into account for this vertical handover. The NS2 simulation approach was used to evaluate performance measures, including jitter, delay, call drop, end-to-end delay and throughput. Results indicate that this approach offers superior optimization for vertical handover mechanisms in heterogeneous wireless networks compared to existing methods such as M-ANP, TOPSIS, and QoS-VHP-Modified TOPSIS.

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