Computers, Materials & Continua
DOI: 10.32604/cmc.2022.026676
Tech Science Press
Article

An Improved Handoff Algorithm for Heterogeneous Wireless Networks

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Received: 01 January 2022; Accepted: 02 March 2022

Abstract: Heterogeneous Wireless Network is currently a major area of focus in communication engineering. But the important issue in recent communication is the approachability to the wireless networks while maintaining the quality of service. Today, all the wireless access networks are working in tandem to keep the users always connected to the internet cloud that matches the price affordability and performance goals. In order to achieve seamless connectivity, due consideration has to be given to handoff precision and a smaller number of handoffs. Several researchers have used heuristic approaches to solve this issue. In the present work, a hybrid intelligent algorithm has been suggested for vertical handoff decisions. This hybrid intelligent algorithm is based on dual optimization approach which uses "Particle Swarm Optimization (PSO)" and "Mobile Robustness Optimization (MRO)" techniques for improving the quality of services. This approach performs well even in the failure network conditions and gives the best results in terms of connectivity. The results at the last has been compared with the conventional techniques and it has been observed that the proposed methodology outperforms the existing one.

Keywords: PSO; MRO; heterogeneous wireless networks; handoff; seamless connectivity

1 Introduction

As the use of the wireless communication networks is spreading with fast pace in recent years, being always connected to a network poses a big challenge. There is the need to reduce the complexity of the algorithms pertaining to the wireless communication networks. The issue of call drop remains the bone of contention while travelling to the far flung places since the number of users of networked technology has increased multifold over the past decade. Wireless high-speed communications are available via various access technologies. The next generation of wireless systems are being designed with a vision that a mobile terminal can connect to several wireless networks (e.g., cellular, Wireless Local Area Network (WLAN)) [1] simultaneously. The various Radio Access Technologies (RAT) are amalgamated to create a heterogeneous wireless access network (HetNets) for providing the required multimedia services and related quality of service (QoS) specifications to mobile terminals [2]. These HetNets are made up of a variety of wireless networks. Heterogeneous wireless systems can facilitate efficient usage of wireless resources, universal mobility with QoS support through balancing of the load and close integration with higher-layer networks and applications. A mobile user should be capable of having seamless connectivity to the internet in such Heterogeneous Wireless Networks. For optimum efficiency and enhanced return on investment, the wireless resources must be handled effectively from the viewpoint of service providers [3]. The regular transfer of mobile devices from one place to another requires uninterrupted communication. Therefore, there is frequent switching from one technology to another and consequently suitable handoff is required in order to support uninterrupted connectivity [4]. Handoff is regarded as the main mobility management component [5]. The accessibility of users includes continuous contact across different access technologies. The handoff can be vertical or horizontal. When the users switch between homogeneous access technologies, then there is horizontal handoff. Vertical handoff is executed among the heterogeneous access technologies. In next generation wireless networks, the goal is to search for an optimum solution for the network constantly. There is a need of re-evaluating solutions even for a movement of Mobile Terminals.

In the recent years, we have witnessed a lot of development in the field of wireless communication. Everyone wants to stay connected at each and every second whether at job site or sitting idle at home. The problem of connectivity is a sensitive topic now-a-day. The scientists are proposing new ideas quite frequently so that the users can enjoy the uninterrupted services of wireless technologies. A lot of work has been done in this direction but the issue is the limited space and limited number of resources. In the present-day scenario, we have come up with the idea of small cells that uses the frequency of the available band in an effective manner. As the cost is also a constraint with the higher bandwidths, the effective utilization of bandwidth is a necessity. As the mobile terminal moves from an area to another, the connectivity to the available networks becomes a constraint. In this situation, handoff plays an important role for the seamless connectivity to the network. Thus, there is a need of effective handoff algorithm which allows the user to be always connected to the network. Here, both the vertical and horizontal handoffs play an equally important role. But when we talk about the heterogeneous wireless networks, vertical handoffs become somehow more important than horizontal handoffs. There is also a need of continuously checking the handoff procedure for reducing the failures in handoff. In next generation wireless networks, the goal is to search for an optimum solution for the continuous availability of the network. The size and scope of cellular networks has grown exponentially in recent years which makes network management an increasingly difficult job. This problem has sparked a lot of interest in the field of self-tuning networks [6]. Optimizing handoff parameters to increase device efficiency is important in next-gen wireless networks. The goal of handoff optimization is to have a smooth and quick transition from the area under one Base Station to another and keeping management of the network easy. Reducing radio link failures (RLF), minimizing call drops, curtailing unwanted handoffs and lessening idle mode problems are the key goals of handoff optimization [7]. Meta-heuristics used by Particle Swarm Optimization algorithm can be of great help to solve this problem. By performance analysis, it is seen that the proposed approach is effective not only in reducing errors in handoff and unnecessary instances of handoff but also in providing the best quality of QoS for Mobile Terminals. The MRO in combination with PSO technique helps in the reduction of failed handoffs to a great extent.

2 Literature Survey

Many authors have shown their interest in the similar fields and have suggested many methods for improving the connectivity in the heterogeneous wireless networks. Some of their contributions are used in literature survey for this paper. In Fachtali et al. [7], proposed a novel method. In this method mobile terminals uninterruptedly evaluate the system and maintain a databank of the finest networks existing. Their approach is based on quality of service (QoS)-conscious ant colony algorithm made on vertical handoff (VHO) mechanism that makes use of an upgraded version of Ant Colony Optimization for continuous domain (ACOR). Factors such as Received Signal Strength, service cost, bandwidth, Mobile Terminal speed, battery consumption and stability, and module for foreseeing distance to be travelled within an IEEE 802.11 wireless LAN cell are considered.

In Lin et al. [8], suggested a data-driven handover optimization (DHO) method to fix movement issues for example too-early handover (HO), too-late handover, HO to the incorrect cell, onging HO, and excessive HO. The normal distribution of the ratios of these mobility issues is the key performance indicator (KPI). The DHO method gathers information from wireless communication measured data and created an approach to calculate the relationship between both the KPI and the functionality in the dataset. The handoffs parameters, for example the handoffs margin and time-to-trigger, are configured based on the model to reduce the KPI.

In Abdeljebbar et al. [9] aims to provide a quick overview of the IETF HOKEY solution for quickly authenticating subscribers during handover in an LTE/SAE network.

Ramasamy et al. in [10] suggested Ant Colony Optimization (ACO) for the handover process and Mean Opinion Score (MOS) is measured as the fitness value for acquired voice quality assessments. In this study, the Multiplex-Multicast (MM) scheme was introduced to increase Voice over Internet Protocol (VoIP)'s efficiency in WLAN to 100% as a Basic Service Set (BSS) network. Particle Swarm Based optimization to resolve the problem of handoffs delay. The simulation outcomes showed that the suggested procedure performed much better than the visiting scheme for random target channels. PSO's solutions are very close to the ideal solution which also justified the efficacy of the suggested technique.

Bhuvaneswari et al. in [11] proposed an improved ACO handoff mechanism that took into account numerous parameters instead of a particular parameter (i.e., Pheromones) in its decision-making process. ACO typically considers the strength of the pheromone and the rate of evaporation as the parameters for choosing a path. In this paper, they described a method that uses different criteria for determining the evaporation rates for each path linked to the source.

Zheng et al. [12] has studied the problematic developing target channel visiting order for spectrum handoff to reduce predicted spectrum handoff interruption. To explain the problem, PSO based method is applied. The suggested procedure outperforms the random goal channel visiting scheme, according to the simulation performance. The results achieved by PSO are very similar to the optimum solution, demonstrating the efficacy of the suggested process.

Goudarzi et al. [13] proposed an amalgamated intelligent handoff decision-making method grounded on two foremost important neural network procedures: Artificial Bee Colony (ABC) and Particle Swarm Optimization (PSO) entitled ABC-PSO for selecting the best cellular networks at the time of vertical handoff process. Shidrokh et al. [14] used particle swarm optimization (CF-PSO) based curve fitting and RBF neural networks to predict the obtained signal strength indicator parameter. On the basis of validation dataset, the suggested technique compared the predictive capability in terms of coefficient purpose (R2) and mean square error (MSE). Shidrokh et al. [15] has expressed the vertical handoff (VHO) decision problem as a Markov decision process designed to maximize expected total rewards while minimizing the average count of handoffs. Since the policy decision for an immobile deterministic handoff could be made at the point where the interactions take place.

In Nan et al. [16], proposed vertical decision handover algorithm based on PSO-FNN. The algorithm performs conditioning learning variables for the Fuzzy Neural Network with the aim of equally obstructing the possibility of dynamically adjustment to the load state and coupled with the Particle Swarm Optimization procedure with global optimization ability to set initial parameters for improving the precision of parameter learning. In Das et al. [17], suggested a method to minimalize the cost of routing using ACO with allocated cell in the wireless network. The two elements that are used for optimization of the cost of call routing in wireless network with allocated cell are cost of paging and cost of handover.

Huang et al. [18] has suggested an algorithm based on a user mobility prediction that takes into account the coverage of various types of base stations as well as the unpredictable movement of walkers, cars, and public conveyance. The algorithm also proposes a novel bandwidth management optimization strategy to distribute bandwidth more effectively. Lv et al. [19] introduced Ant Colony Optimization to ICN and proposed a new ACO-inspired ICN Routing mechanism with Movement backing (AIRM) to obtain solution regardless of its location.

Pradeep et al. [20] proposed relative dynamic weight optimization based on layer parameters as measures for network selection in the Dynamic Network Selection Function (DNSF) process. This approach is tested in a heterogeneous wireless environment that includes WLAN and Universal Mobile Telecommunications Service (UMTS). The redundant handoff events combined with the client's Handoff Failure Rate between available schemes is used as performance metrics and the best related system is always selected based on the cost feature.

Malathy et al. [21] offers a comprehensive analysis of vertical handover studies. The research initiatives in this paper are categorized as vertical handover decisions for wireless networks. To determine the course of the vertical handover decision, a fair judgement of conventional and recent techniques is drafted. Velemurugan et al. [22] used Invasive Weed Optimization (IWO) to resolve the problems of Horizontal Handoff and Vertical Handoff. This integer coded procedure was created to adjust the device load and decrease the Mobile Node's power consumption of battery. It is grounded on the colonizing behaviour of Marijuana Plants. Battery lifetime, Receiver Signal Strength, load, motion and other constraints are all taken into consideration.

Zaheeruddin et al. [23] have introduced a new improved vertical handoff procedure for the users to connect to wireless heterogeneous networks seamlessly. The suggested methodology improves network connectivity while reducing the redundant handoffs. All results in the suggested work are carried out in NS3 simulation network with various parameters that are needed for making handoff decisions. The authors have used the convex optimization technique with the Gradient Descent algorithm. Afifi et al. [24] introduced a new scheduling technique to increase the likelihood of conveying accessible resource blocks (RBs) to cell-edge users which increases their achieved throughput.

3 System Model

A small-scale heterogeneous network model is shown in Fig. 1. The system comprises of some mobile nodes moving in the cellular coverage region and Wi-Fi hotspots. Thus, for the smooth movement of the mobile user from one place to another, handoff is needed. The Media Independent Handover Function (MIHF) of IEEE 802.21 is used as a mutual platform among various operators and numerous access technologies undergoing Vertical Handoff Decision (VHD) for the sharing of information about the battery power of the mobile terminal and information on the link layer.

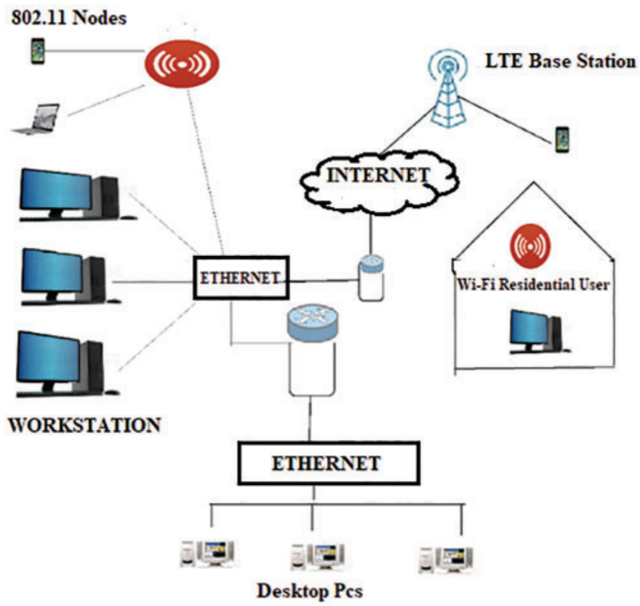

Figure 1: Heterogeneous network system model

4 Optimization Techniques Used

In this section, a brief explanation of optimization methods such as PSO and MRO is provided that we have used in the proposed work.

4.1 Particle Swarm Optimization

In the 1990s, numerous experiments were conducted concerning animal activities. Such studies have shown that several animals related to a specific group, i.e., fishes and birds can exchange information amongst their species which gives them a major advantage for survival [25]. Motivated by such articles, Eberhart and Kennedy in 1995 introduced the Particle Swarm Optimization algorithm [26], a metaheuristic algorithm suitable for optimizing nonlinear unceasing functions. The author deduced the algorithm influenced by the swarm intellect paradigm which is seen in clusters of animals like shoals and flocks. Particle swarm optimization was implemented in various areas of optimization and in conjunction with many other known algorithms. This technique executes the hunt for the best solution via agents known as particles, the orbits of which are modified by a probabilistic and deterministic factor. The particle is determined by its 'best' achieved position and 'best' position obtained in the group but keeps moving arbitrarily. A flowchart for the Particle Swarm Optimization Algorithm is given in Fig. 2.

In this approach, firstly the food's position coordinate is represented as (X_0, Y_0) and each bird's position coordinate and velocity coordinates are (X, Y) and (vX, vY), respectively [27]. Distance among present position and food is used to calculate the performance of present position and velocity. Assuming that every bird has the capability of recalling and can remember the ideal position $P_{best,}$ it has ever attained. α is the velocity adjusting constant, ran signifies an arbitrary number in [0, 1], velocity shift can be set by following rules:

$$\text{If}, \chi > P_{best}\chi, \quad v_\chi = v_\chi - ran \times \alpha, \text{else}, v_\chi = v_\chi + ran \times \alpha \tag{1}$$

$$\text{If } y > P_{best}y, \quad v_y = v_y - ran \times \alpha, \text{else}, v_y = v_y + ran \times \alpha \tag{2}$$

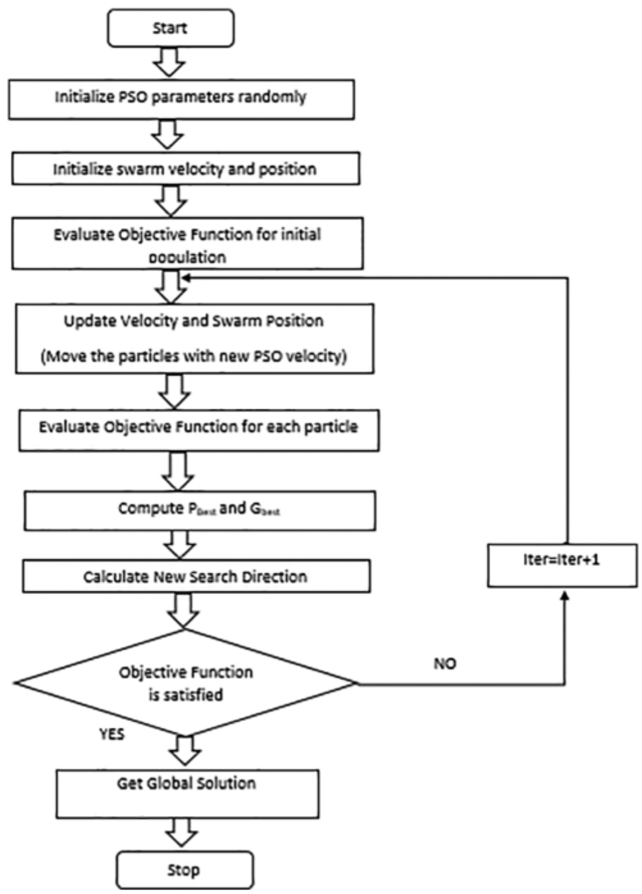

Figure 2: Flowchart for the particle swarm optimization algorithm

Now suppose that swarm may interact in certain way and every agent will be able to learn and remember the best position of the entire swarm so far (marking it as G_{best}), β is the velocity adjustment constant. After the velocity object has been modified in accordance with the rules above, it must also change in accordance with the following rules:

$$\text{If} \chi > G_{best}\chi, \quad v\chi = v\chi - ran \times \beta, \text{else}, v\chi = v\chi + ran \times \beta \tag{3}$$

$$\text{If } y > G_{best}y, \quad v_y = v_y - ran \times \beta, \text{else}, v_y = v_y + ran \times \beta \tag{4}$$

When α/β is comparatively large, all entities gather rapidly around the "food." In contrast, if α/β is small, the particles gather around the "food" unevenly and gradually. Through this simple simulation, the swarm can quickly find the optimum stage. Kennedy et al. [26] developed an evolved optimization algorithm and finally fixed the core algorithm as below after an ocean of trials and errors:

$$v_\chi = v_\chi + 2 * ran * (P_{best}\chi - \chi) + 2 * ran * (G_{best}\chi - \chi) \tag{5}$$

$$\chi = \chi + v_\chi \tag{6}$$

4.2 Mobile Robustness Optimization (MRO)

The small cell is among the upcoming generation network's key technologies as it can share the power burdens and the demands for coverage. Small cells configured are profitable and energy-optimized, covering smaller regions and may be deployed in ultra-dense outdoor or indoor positions like schools, offices, arenas, airports, and many other big locations [28,29]. Due to a huge number of small cells and complexities of unintended positioning, manual design of such a network is thus challenging [30]. This implemented the self-organizing network (SON) to inevitably optimize and configure a heterogeneous wireless network using human intervention. Self-optimization aims to improve throughput by adaptive modification of network status-based system parameters. In mobile communications, smooth handoff is essential. Furthermore, conventional handoff optimization is inadequate for mass positioning and frequent on/off cells. MRO has currently been analysed as one of the important cases in the SON to minimize RLFs and Redundant Handoffs due to unsuitable selection of the parameters for the handoff.

Detection of MRO Events

Unsuitable parameters of handoff could result in handoff failures. LTE (Long Term Evolution) SON describes three types of MRO in relation to RLFs: (i) Too Early Handover, (ii) Too Late Handover and (iii) Wrong Handover. MRO identified two forms of Unnecessary Handovers: Continue Handoffs and Ping-Pong Handoffs. MRO includes tools for identifying and helping to correct (1) Connection errors triggered by intra-next generation mobility and (2) Unwanted inter-system handoff to other access technologies. Following are the scenarios where MRO can be helpful:

- Too Late Handoff: Radio connection failures occur in the source cell prior to the start of the handover and the User Equipment attempts to restore its radio connection to another cell. Conversely, radio link loss occurs in the source cell during the handoff process and the User Equipment attempts to restore its radio connection in the destination cell.

- Too Early Handoff: Radio link failures occur in the aimed cell after a handoff has been completed and the User Equipment is trying to restore its radio link to the source cell. Instead, a failure of the radio connection happens in the target cell during the handoff process and the User Equipment is attempting to restore the radio link in the source cell.

- Wrong Handoff: Radio link failures occur in the target cell after a handoff has been completed and the UE is attempting to re-establish its radio connection in a cell that is neither the source cell nor the target cell. Instead, failure of the radio connection happens in the target cell during the handoff cycle and the User Equipment tries to restore its radio linkages in a cell that is not the source cell or the aimed cell.

5 Factors Considered for Handoff

There are many factors which are responsible for Handoff. Some of the key factors are discussed as below:

5.1 Received Signal Strength

For the wireless communication networks, for attaining the uninterrupted Vertical Handoff (VHO), it is vital to take into consideration the received signal strength (RSS). A mobile node chooses an Access Point (AP) that provides the best signal strength. When the RSS from an Access Point drops to a value less than the threshold value because of the different fading effects, HO is initiated.

The Received Signal Strength threshold is set on the basis of position and velocity information for the mobile node (MN). RSS calculation [31] involves the fading effect that is widely classified as:

Fast Fading

The impulse response of the channel changes significantly within the communicated baseband signal which causes dispersion of frequency due to Doppler spread. Here the Jake model and Rayleigh fading channel are taken for the fast-fading calculations. Rayleigh fading is seen as a rational prototype for the propagation of ionosphere and troposphere signals and also the influence on radio signals in dense urban environments. It is most relevant if there is no dominant propagation among the receiver and the transmitter in a LOS (line of sight). The fast-fading evaluation could be attained from the Jake's model. Jake pioneered a model for fading Rayleigh on the basis of sinusoids summing up. Suppose the scatters be spread evenly round a circle at angles α with k rays evolving from every scattered ray [31]. The Doppler action on ray n is

$$F_n = f_d \cos\alpha \tag{7}$$

where f_d is Doppler shift

The Doppler shift f_d can be calculated as:

f_d = (mobile node's velocity × network frequency)/velocity of light

Taking N such scattering objects into consideration, Rayleigh fading of the Kth wave during time t is shown as

$$R\ (t, \kappa) = \sqrt{\frac{2}{M}\left[\sum_{n=1}^{N} A_\kappa\ (n)\ (\cos\beta_n + j\mathrm{Sin}\beta_n)\cos\left(2\pi f_n t + \theta_{n,\kappa}\right)\right]} \tag{8}$$

$A_\kappa(n)$ is the κ_{th} function and β_n is the phase shift which signal has suffered.

Fast fading is given by the following expression:

$$\text{Fast Fading} = 10\log 10(E|R\ (t,\kappa)|^2) \tag{9}$$

where $(E|R\ (t,\kappa)|^2)$ signifies the mean of $R\ (t, \kappa)$

Slow Fading: The response to the channel-impulse differs at a rate lower than the communicated modulating signal. The slow fading is calculated as

$$P_K = 32.44 + 20\log_{10}R + 20\log_{10}f + L_{Rain} + L_{Pol} + L_{Gas} + L_{Coup} + L_{Imp} - GRdB - GTdB \tag{10}$$

where P_K is the propagation loss experienced by the signal, R is range of Mobile Node in km, f is the frequency of network and L_{gas} to G_R dB all are the losses because of the environmental factors like transmitter and receiver antenna losses, polarization, coupling, noise levels etc.

From Eqs. (1) and (2), RSS is calculated and the fast-fading value is evaluated as

$$(\text{RSS})\ \text{Wi} - \text{Fi} = 23 - (\text{slow fading} + \text{fast fading}) \tag{11}$$

$$(\text{RSS})\ \text{Cellular Network} = 33 - (\text{fast fading} + \text{slow fading}) \tag{12}$$

Hard Handover Algorithm in LTE with Avg. RSRP Constraint

The avg. RSRP is evaluable from the following equation:

$$\mathrm{RSRP}_{avg.} - J = \frac{\sum_{n=1}^{N} \mathbf{RSRP}\ (\mathbf{nT}\mathfrak{y})}{\mathbf{N}} \tag{13}$$

where RSRPS-J ($\mathcal{T}_{\mathfrak{m}}$) is the Reference Signal Received.

Power (RSRP), mobile node J is receiving from serving cell S at nth handoff calculation phase of $T_{\mathfrak{m}}$ and N represents the total number of phases of time-period $\boldsymbol{T}_{\mathfrak{m}}$. An avg. RSRP of cell serving S, the mobile node J ($RSRP_{avg}$-J) is receiving can be assessed by a total of every nth handoff measurement period $T_{\mathfrak{m}}$ up toN, divided by N times. An average RSRP condition is shown as:

$$\mathrm{RSRP}\,(\mathrm{t}) \;>\; \mathrm{RSRP}_{\mathrm{avg}} - \mathrm{J} \tag{14}$$

Here RSRP $\boldsymbol{T}$ (t) is the real RSRP which is obtained from $\boldsymbol{T}$ (target cell).

$RSRP_{avg}$-j is the average RSRP determined using previous equation. The decision on the handoff shall be taken under the same conditions as shown below:

$$\mathrm{RSRPS} + \mathrm{HOM} < \mathrm{RSRP}_{\tau} \tag{15}$$

$$\mathrm{TTT} \;\leq\; \mathrm{HOTrigger} \tag{16}$$

where RSRPS and $RSRP_{\boldsymbol{T}}$ are the RSRP received from the serving cell and the target cell and $HO_{Trigger}$ is the handoff trigger timer that initiates counting when the Eq. (16) is fulfilled. HOM is the handoff margin that reflects the threshold value of the variance between the target and serving cells in the received signal power. HOM make sure that the cell which is targeted is the most suitable cell the mobile is handed over to. TTT is the time it takes to fulfill the HOM condition.

5.2 Cost of the Network

The vertical cost function of the handoff is a calculation of the gain attained by distributing to a particular network. For the Network n covering the user's service area, it is evaluated. The network option which results in the lowermost measured cost function value is the network which will offer the user with the greatest gain [32]. The cost feature is calculated according to

$$\mathrm{n\_opt} = \mathrm{Min}\left(\mathrm{C}\underline{\mathrm{n}}\right) \tag{17}$$

where C$\underline{\mathrm{n}}$ is the network cost function evaluated. C$\underline{\mathrm{n}}$ covers the costs of providing each demanded service from network $\underline{\mathrm{n}}$ and is measured as follows:

$$\mathrm{C}\underline{\mathrm{n}} = \sum C_{\underline{\mathrm{n}}}^{S} \tag{18}$$

where S is the index signifying the user-demanded services and $C_{\underline{\mathrm{n}}}^{S}$ is the per-service cost function for network $\underline{\mathrm{n}}$.$C_{\underline{\mathrm{n}}}^{S}$ is evaluated as

$$C_{\underline{\mathrm{n}}}^{S} = E_{\underline{\mathrm{n}}}^{S} Q_{\underline{\mathrm{n}}}^{S} \tag{19}$$

Here $E_{\mathrm{n}}^{\mathrm{S}}$ is the elimination factor for network for the demanded service s at Network n and $Q_{\underline{\mathrm{n}}}^{\mathrm{S}}$ is the QoS factor for service s. The network elimination factor is determined by

$$E_{\underline{\mathrm{n}}}^{S} = \prod_{i} E_{s,i}^{\underline{\mathrm{n}}} \tag{20}$$

where $E_{s,i}^{n}$ indicates that network n will come across the minimum limit i for service S because a huge cost would result in the removal of a network from attention. The purpose of the removal factor is to result in a high value when a limitation couldn't be met. Consequently, $E_{\mathrm{s,i}}^{\underline{\mathrm{n}}}$ is evaluated by

$$\mathrm{E}_{\mathrm{s,i}}^{\underline{\mathrm{n}}} = \frac{1}{\mathrm{I}_{\mathrm{s,i}}^{\underline{\mathrm{n}}}} \tag{21}$$

here $I_{s,i}^{n} = \begin{cases} 1, & \text{if constraint can be satisfied} \\ 0, & \text{if constraint cannot be satisfied} \end{cases}$

The implementation of the VHO cost feature is versatile for allowing diverse vertical handoff policies.

5.3 Velocity

Velocity is the factor which helps in avoiding the unnecessary handoffs and the probability of the velocity is given as [33]

$$p = \begin{cases} e^{-Kv_j}, & v_j > v_{th} \\ 0, & v_j < v_{th} \end{cases}$$

$$K \geq \frac{-\ln(p)}{v_j}$$

where vj is speed of Mobile Node j. Vth is the threshold level, and K controls the slope of the probability. If the operation of a Mobile Node at a Wi-Fi meets the limitations of time interval and RSS, the Mobile Node is classified with a probability of (1 − p) as a 'handoff candidate.' When Mobile Node is in operation at a Base Station and fulfils the other limitations, the Mobile Node is selected with a probability p as a handoff candidate. The greater is the rate, the greater is the possibility to live in the cellular network, thus eliminating needless Vertical Handoff. The Velocity and position are measured using the Mobile Node's GPS system coordinates. The velocity is determined using the 'distance formula' after the Mobile Node's co-ordinates are obtained.

$$R = \sqrt{(\chi_2 - \chi_1)^2 + (y_2 - y_1)^2}$$

Here (χ_1, y_1) and (χ_2, y_2) are the earlier and current coordinates of the Mobile Node. The velocity can be evaluated as:

v = R/t, where it is time needed to update Mobile Node co-ordinates.

5.4 Call Dropping Rate

Handover decision is taken for choosing the network with lowest call drop rate. The probability of call drop, PD can be determined as [34]

$$PD = 1 - P\underline{n}t$$

The possibility that a call is normally ended is given by P$\underline{n}$t. The probability P$\underline{n}$D that a call is not convoluted in a particular drop event amongst κ active ones (i.e., call is not dropped), is $(\kappa-1)/\kappa$ during the period time T = t. Given that drop events are believed to be autonomous, this probability will become if there are n number of drop events

$$P\underline{n}D\,(n) = \left(\frac{\kappa - 1}{\kappa}\right)^n \tag{22}$$

On the other hand, falling events constitute a cycle of Poisson. Let its intensity be v_d, then the probability that there are $\underline{n}$ drops for interval T= $\dot{t}$ is

$$P\left(\underline{n}\right) = \frac{\left(v_d \dot{t}\right)^n}{\underline{n}!} e^{-v_d i}, \ \underline{n} \geq 0 \tag{23}$$

Here, v_d is the rate of call drop, tis the length of call, and n is the no. of reported calls which are dropped. It is a poison probability function that has a discrete variable counting the number of calls dropped. The probability, a call with length T = t will usually be dismissed in the existence of k existing calls and n drop measures, is equivalent to the chance that drops occurrences will not interrupt the ongoing session. Now using Eqs. (14) and (15), we find that

$$\mathrm{P\underline{n}t}\left(\bar{\mathrm{T}}=\mathrm{t},\kappa,\mathrm{n}\right)=\mathrm{P\underline{n}D}\left(\mathrm{n}\right).\mathrm{P}\left(\mathrm{Y}\ =\ \underline{\mathrm{n}}\right)\ =\ \left(\frac{\kappa-1}{\kappa}\right)^{\underline{\mathrm{n}}}\frac{(v_d t)^{\underline{\mathrm{n}}}}{\underline{\mathrm{n}}!}e^{-v_d\dot{t}} \tag{24}$$

By using the total probability theorem to the number of drop cases, it is possible to estimate the possibility that a call with length ∓ = t will usually be ended in the existence of contemporary k calls (i.e., Pn̲t (∓ = t, ĸ), the call will not be dropped).

$$\mathrm{P\underline{n}t}\left(\bar{\mathrm{T}}\ =\ \dot{\mathrm{t}},\kappa\right)=\sum_{n=0}^{\propto}P\underline{n}t\left(\bar{\mathrm{T}}=\dot{\mathrm{t}},\kappa,\underline{\mathrm{n}}\right) \tag{25}$$

Substitute (16) into (17),

$$\mathrm{P\underline{n}t}\left(\bar{\mathrm{T}}\ =\ \mathrm{t},\kappa\right)\ =\sum_{\underline{\mathrm{n}}=0}^{\propto}\mathrm{P\underline{n}t}\left(\left(\frac{\kappa-1}{\kappa}\right)^{\mathrm{n}}\frac{\left(\mathrm{v_d}\dot{\mathrm{t}}\right)^{\underline{\mathrm{n}}}}{\underline{\mathrm{n}}!}\mathrm{e}^{-\mathrm{v_d}\dot{\mathrm{t}}}\right) \tag{26}$$

$$=\mathrm{e}^{-\mathrm{v_d}\dot{\mathrm{t}}}\sum_{\underline{\mathrm{n}}=0}^{\propto}\frac{1}{\underline{\mathrm{n}}!}\left[\frac{(\kappa-1)\,\mathrm{v_d}\dot{\mathrm{t}}}{\underline{\mathrm{n}}!}\right] \tag{27}$$

$$=\ \mathrm{e}^{-\mathrm{v_d}\dot{\mathrm{t}}}.\mathrm{e}^{\left(\frac{\kappa-1}{\kappa}\right)\mathrm{v_d}\dot{\mathrm{t}}} \tag{28}$$

$$=\ \mathrm{e}^{\frac{-\mathrm{v_d}\dot{\mathrm{t}}}{\kappa}} \tag{29}$$

5.5 Battery Fitness Calculation

Let us assume that, $A_i \in$ A (1 ≤ i ≤ N_A) and Ci’ ∈ C (1 ≤ i′ ≤ M_B) are points of attachments [35]. Let U= {u1 . . . u_K} represents the set of all Mobile Nodes in the area of cellular coverage. Also assume that Ut = {u_{n1}, u_{n2} . . . . u_{nm}}, where m is the no. of Mobile Nodes demanding handoff at time t. Every Mobile Node is either demanding a handoff or currently an Access Point is giving service to the mobile node. $V_{\text{Ʈ}}$ = U – $U_{\text{Ʈ}}$ which signifies the set of Mobile Nodes having a right connection (i.e., not demanding handoff) to an Access Point of Wi-Fi or a Base Station. Let A_N = {a1 . . . a_{N_A}} are the sets of Wi-Fi Access Points in coverage area of a cell and C = {c1 . . . c_{MB}} is the set of access points in the Base Stations covering the cellular coverage area. The Vertical Handoff algorithm proposed here sums up all the available Wi-Fi Access Points to the set A and gathers the load status information for each Access Point in set A_i and each Base Station in set C_i. Here, two different weights are considered, subject to whether the access network is a cellular network or Wi-Fi network. That is, for Wi-Fi Access Points, A_N ∈ Ai (1 ≤ i ≤ N_A), w(i) = wa, and for Base Stations Ci′ (1 ≤ I ≤ M_B), w(i) = wc. Generally, M = 1, except where urban deployments is extremely dense. Even if M is greater than 1, M is much lesser than N, since a number of Wi-Fi Access Points are usually installed within the coverage area of a cell. Set VƮ is divided into subsets VƮ(a) and VƮ(c), subject to whether uj∈ VƮ is connected to a Wi-Fi or a cellular network [36].

Thus, each Access Point (A_N∈ A_i) or Base Station (C_i ∈ C) may preserve the actual data rates eij and $e^{©}_{i'j}$ for Mobile Node uj, when it in to VƮ (a) or VƮ(c) correspondingly. Though, for every Mobile Node, uj∈ UƮ, the Access Point to which the Mobile Node will handoff is not able to calculate the actual data rate for the Mobile Node because of the absence of active signalling between the Access Point and the Mobile Node when they are not in connection mode. Thus, a requested data rate Rj is well-defined for every Mobile Node, $u_j \in U_{\mathrm{T}}$.

Let $L = L_{ij\left(N_A+M_B\right)\times K}$ be the battery lifetime matrix where matrix element L_{ij} $(1 \le i \le N_A + M_B)$ signifies the life time of battery for mobile node u_j. Suppose that Mobile Node u_j needs handoff, then for every Mobile Node u_j $(1 \le j \le K)$,

$$L_{ij} = \frac{p_j}{p_{ij}}, \quad for\ 1 < i < N_A \tag{30}$$

$$L_{ij} = \frac{p_j}{p^{(c)}_{i'j}}, \ for\ N_A + 1 < i < N_A + M_B \tag{31}$$

Let RSS_{ij} $(1 \le i \le N_A + M_B)$ be the RSS for Mobile Node j from Access Point Aior Base Station Ci′. Let xj be a binary variable which is having value 1 when mobile node uj is linked to any Access Point, Ai $(1 \le i \le N_A)$ of Wi-Fi or Base Station, $C_{i'}(N_A + 1 \le i' \le N_A + M_B)$, and value zero otherwise. The lifetime of battery of Mobile Node $u_j \in U$ for an association matrix X = {xij}, Ltj(X) is given as

$$L_{tj}(X) = \sum_{1 \le i \le + N_A} L_{ij} x_{ij} \tag{32}$$

Let τ_i $(1 \le i \le N_A + M_B)$ signifies the total demanded data rate on Access Point Ai $(1 \le i \le N_A)$ and Base Station Ci′ $(1 \le i' \le M_B)$. Thus, for any X = {xij} ∈ X.

$$\tau_i(X) = \sum_{u_j \in U} R_j x_{ij}$$

To calculate the effective bit rates eij and e(c) i′j from the candidate Access Points and the candidate Base Stations, τ_i (X) is given as

$$\tau_i(X) = \sum_{u_j \in U} e_{ij} x_{ij}, \ 1 \le i \le \ N_A$$

And $\tau_i(X) = \sum_{u_j \in U} e^{(C)}_{i'j} x_{ij}$, $N_A + 1 \le i \le \ N_A + M_B$

Optimization problem for battery life time is given as

$$Max\, \forall X \in \chi = \sum_{u_j \in U} L_{Tj}(X) \tag{33}$$

$$L_i + \tau_i \ \ (X) \ \le B_i, \quad for\ 1 \le i \le N_A \tag{34}$$

$$L_i + (X) \ \le \ B^{(C)}_{i'}, \quad for\ N_A + 1, \ \le i \le N_A + M_B \tag{35}$$

where B_i is the Maximum bandwidth that an Access Point A_i $(1 \le i \le N_A)$ can give $B^{(C)}_{i'}$ is the Maximum bandwidth which a Base Station $c_{i'}$ can offer.

5.6 Load

For each Access Point $A_i \in A$ $(1 \le i \le N)$, the load on Access Point A_i is [37]:

$$p_i = \sum_{u_j \in V_{\mathrm{T}(A)}} e_{ij} \ \text{for } 1 \le i \le N_A \tag{36}$$

and the load on the Base Station $c_{i'}$ is given as

$$p_i = \sum_{u_j \in V_{\tau(C)}} e_{i'j}^{(C)} \text{ for } \mathrm{N_A} + 1, \leq \mathrm{i} \leq \mathrm{N_A} + \mathrm{M_B}.$$

The minimizing function of the load is given as

$$\text{Min F} = min_{\forall X \varepsilon x} \sum_{1 \leq i \leq N_A + M_B} w(i) . \left(\frac{L_i + \tau_i(X)}{z_i} \right)^2 \quad (37)$$

$$\text{With constraints } \mathrm{L_i} + \tau_\mathrm{i}\ (\mathrm{X}) \leq z_i \quad (38)$$

where L_i is the attachment point load, w(i) is the weight factor for Cellular or Wi-Fi bandwidth and z_i is the extreme bandwidth the attachment point may handle. The weight factor w(i) is used to find the load. Fixed weight factors are allotted to Mobile Systems and Wi-Fi. The mobile network's weight factor is lesser than the Wi-Fi weight factor, since the mobile network's bandwidth (BW) is lesser than the Wi-Fi bandwidth. The weight factor assignment is randomly distributed on the basis of system load in the suggested algorithm.

Joint Optimization Problem

The optimization problem of the proposed PSO-MRO VHO expression includes the optimization of the lifetime of the battery, balancing of the load, and cost of the network. As we know if we need to minimize a function to optimize it, we can maximize the negative of it. Thus, the multi-objective optimization problem for the proposed algorithm can be stated as follows using Eqs. (18), (23), (33) and (37):

Maximize

$$(X, \delta, \mu, \pi, \sigma) = -\delta \sum_{u_j} C_{\underline{n}}^S - \mu \frac{(v_d \mathrm{t})^{\mathrm{n}}}{\underline{\mathrm{n}}!} e^{-v_d \mathrm{t}} + \pi \sum_{u_j \in U} L_{Tj}(X) - \sigma \sum_{1 \leq i \leq N_A + M_B} w(i) . \left(\frac{L_i + \tau_i(X)}{z_i} \right)^2 \quad (39)$$

$$\text{Subject to} \quad Li + \tau\, i(X) \leq zi,\ for\ 1 \leq i \leq N_A + M_B \text{ and } \underline{\mathrm{n}} \geq 0 \quad (40)$$

Here δ, μ, π, σ are the coefficients given to the particular functions. For Eqs. (39) and (40), we are taking δ, μ, π, σ all equal to one.

6 PSO and MRO Based Handoff Decision Algorithm in Wireless Heterogeneous Networks

In proposed methodology, the objective is to find the optimal channel and network for the handoff but PSO-MROVHO works on the single criteria. So, we need to modify it to consider multiple criteria for best decision. Available handoff strategies result in higher power consumption and minimal throughput. We propose enhanced PSO-MRO VHO based strategy which considerably reduces power consumption, increases throughput, and selects accurate networks. Advantages of this approach are that it can minimize the number of handoffs that in turn decreases the consumption of power and increases the QoS. Three major stages in the approach are: (1) Cost factor calculation, (2) Network selection based on QoS and Channel capacity, and (3) Avoiding unnecessary handoffs

Algorithm

The algorithm proposed below has two parts in it.

(i) Handoff methodology in initial conditions and
(ii) Handoff methodology in fail over conditions

6.1 Initial Condition

The optimization process begins when the call connection is initiated and all ant agents are initialized which continues till the end of the call or disconnection. Every entity shows a candidate solution, and entities travel through the search space to find the best solution(s) by modifying their positions on the basis of their own and neighbouring entities' experiences. The personal best, or P_{best}, of an entity is registered, and the paramount position achieved by the swarm till this time seems to be the global best, or G_{best}. PSO looks for the best solution(s) by updating each entity's position and velocity as per the calculations below.

$$V_{ij}(\tau + 1) = wv_{ij}(\tau) + C_1R_1(P_{ij}(\tau) - X_{ij}(\tau)) + C_2R_2(PG_j(\tau) - X_{ij}(\tau))$$
$$X_{ij}(\tau + 1) = X_{ij}(\tau) + V_{ij}(\tau + 1),$$

where τ signifies the no. of generations at the time of the evolution, w is the inertial weight, and C_1 & C_2 represented the acceleration constants, and R_1, R_2 are the different values homogeneously distributed in [0, 1], and P_{ij} & P_{Gj} refers to the elements of P_{best} and G_{best} in the j_{th} dimension.

There are three different ways to analyse PSO based algorithm.

- Based on Particle density
- Based on particle cycle
- Based on particle quantity

Procedure:

Step1: Initiate signal request Si
Step2: Parameter initialization for PSO MRO-VHO is performed.
Step3: Select the suitable antenna randomly and agents take initial path
Step4: call initializes
Step5: During this step agents keep on searching for multiple criteria. Various Factors considered for multiple search criteria are: (1) Sample RSS, (2) Velocity of vehicle, (3) Battery Life of the mobile, (4) Cost of the Network, (5) Load on the Target Base Station, and (6) Call Drop
Step6: Predicting the vehicle time spent in current cell. Let Le be the entry location, L_m be the middle position of the cell, L_l be the last position of the cell, V be the velocity of the vehicle, and Tc is time spent in cell, then

$$T_c = L_l - L_e/V \tag{41}$$

To reduce the total number of handoffs, we want to check threshold number of handoffs. Let L_d be the location in the cell where RSS drops below Threshold, T_{hd} be the handover delay between two cells, D_d be the drop distance or distance between L_d and L_l, and V is velocity of vehicle, then

$$D_d = L_l - L_d \tag{42}$$

$$T_d = D_d/V \tag{43}$$

From above Eqs. (41)–(43), it can be concluded that Handover fails when

$$T_d > T_{hd} \tag{44}$$

T_{hd} can be equated as follows

$$T_{hd} = r_2 - lrss + V2\,(t_{rss1} - t_{rss2})\,2/V_2\,(t_d - t_e) \tag{45}$$

where r is radius of cell, l_{rss} is the location where signal strength samples is obtained, V is the velocity of vehicle, t_{rss} is the time of RSS samples, t_d is the time of drop location entry, and t_e is the time of exit

Step 7: Calculating cost of the network based on multiple parameter

$$C_t = W_1P_i + W_2B_{ci} + W_3N_p \tag{46}$$

Where C_t is cost, W_1, W_2, W_3 are the weight co-efficient, Pi is the Battery consumption, B_{ci} is the channel bandwidth, and N_p is the network bandwidth.

Step 8: Unnecessary handoffs lesser than threshold can be avoided.
Step 9: Select the best target network from table with lowest cost.

6.2 Failover Conditions

In the present work we are considering failed handover incidents to be recovered by following methodology:

Step1: Each mobile node uses a reconnection message (RRC) with a flag set to High, which includes radio link failure information.
Step2: Once UE detects flag, it requests eNode for information request.
Step3: If RRC link re-establishment is being accomplished at a cell which doesn't belong to the source eNodeB, then the eNodeB which has established the radio link failure information can send the information to the source eNodeB.
Step 4: Cell identifies failure details using physical layer cell identity and extracts data from RRC Request message.
Step 5: Then following process is followed for connection reestablishment.

CASE 1: Handoff Failure

(a) Calculate the Media Access Control, MAC-I (16 bit) using security configuration of source cell.
(b) The User Equipment Radio Connection Failure information is derived from the User Equipment Info Reply message. It involves RSRP (Reference Signal Received Power) and optionally, dimensions of RSRQ from the source cell, i.e., calculated from the cell where a failure of the radio link was encountered. This also includes optional neighbouring cell measurement tests.
(c) The Location Information permits the User Equipment to track the position where the failure of radio link was encountered. This depends on User Equipment knowing about its location.
(d) The re-establishment Cell Identity describes the Cell Global Identity (CGI) of the cell where connection re-establishment was tried after the radio link failure.
(e) The Failed Primary Cell Identity (PCI) determines the chief cell where failure of the radio link was observed or the primary target cell of the failed handoff. Identity of the cell could be stated by use of either the Cell Global Identity (CGI) or a recipe of Peripheral Component Interconnect and Absolute Radio-Frequency Channel Number (ARFCN).
(f) The Time Connection Failure describes the time interval among the radio link failure and handoff initiation.
(g) The Connection Failure Type specifies whether the failure was a handoff failure or a radio link failure.
(h) The Previous Primary Cell Identity describes the primary source cell of the last handoff.
(i) The RRC Connection Setup Indicator is a flag that is considered the User Equipment only if the radio link failure report after an RRC linking setup technique rather than an RRC connection re-establishment process.

(j) In case handoff recovery process fails algorithm, high is called to re-establish new link.

Case 2: Early Handover

(a) The User Equipment tries to re-establish its connection with the source cell.
(b) The Handoff Cause stipulates the reason for the handoff, e.g., 'Handover Required for Radio Reasons'. This reproduces the cause value.
(c) User Equipment re-initiates handoff process.

Case 3: Wrong Cell Handover

(a) In this case, the third eNodeB gives the target eNodeB with a Radio Link Failure suggestion message whereas the target eNodeB gives the source eNodeB with a Handoff Report message
(b) The 'Handoff to Wrong Cell' scene doesn't every time has to include 3 eNodeBs. For instance, after RLF, the User Equipment could attempt RRC connection re-establishment to a second cell that belongs to the target eNodeB.
(c) After receiving the Handoff Report message, the source eNodeB can use the data to correct its handoff causing confirmation.
(d) The second objective of MRO is to sense and help to curb redundant inter-system handoffs.

7 Simulation and Results

The Wi-Fi hotspots are usually configured as small unit cells within cellular area, which are comparatively larger than the Wi-Fi hotspots as shown in Fig. 1. The simulation of the proposed work is done in the NS3 (network- simulator 3) software. The network model considered here is for cellular network/Wi-Fi coverage. The proposed work is implemented using few mobile nodes moving in the coverage area of cellular/Wi-Fi. The velocity of the mobile node is between 0–40 km/hr. The various simulation parameters are shown in Tab 1.

Table 1: Simulation parameters

Parameter	Number of eNodeB	Num Bearers Per UE	Simulation time	Distance	Data rate	MTU	Delay
Value	4	4	490 ms	100 mts	10 mbps	1500	0.01 sec

Here the eNodeB is an LTE (Long Term Evolution) Base Station. Such nodes are positioned on the cell towers of mobile operators and can be seen as tall antennas. Bearers are the portals used in a mobile network using LTE architecture to connect user equipment like the Internet to Packet Data Networks (PDNs). In practice, bearers are data frame tunnels that link the user equipment to the PDN through the Packet Data Network gateway. A maximum transmission unit (MTU) is the largest frame or packet size defined in octets (eight-bit bytes) that could be transmitted to a network based on frames or packets. Delay here represents the delay in Handoff. The results shown below are compared with already existing Vertical Handoff Algorithms.

i. ***Remaining Energy:*** Increasing the working hours of a Mobile Node is an important parameter in an efficient Handoff Algorithm. The nodes in case of PSO-MROVHO have more remaining energy as compared to the existing handoff algorithms as shown in Fig. 3

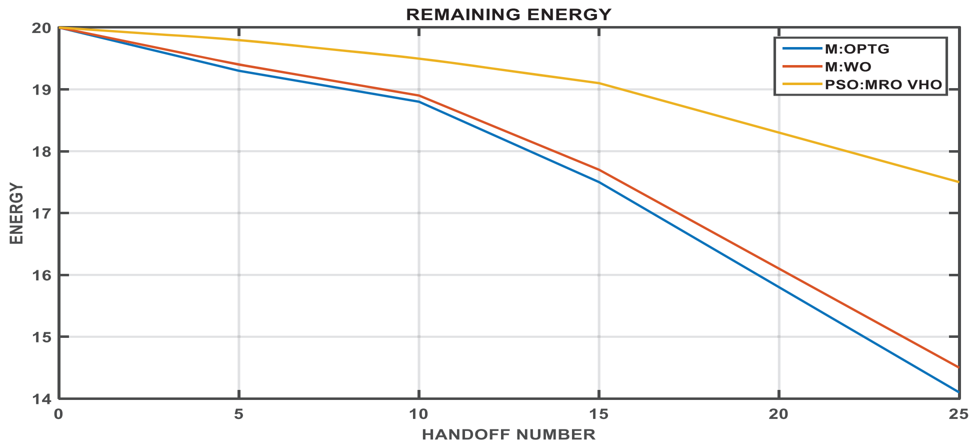

Figure 3: Remaining energy *vs.* handoffs for different algorithms

ii. ***Number of Successful Handoffs:*** When the mobile node is moving from one place to another with some higher velocities, then there is need of an efficient handoff algorithm, which can give us higher rates of successful handoffs. It is evident from Fig. 4.

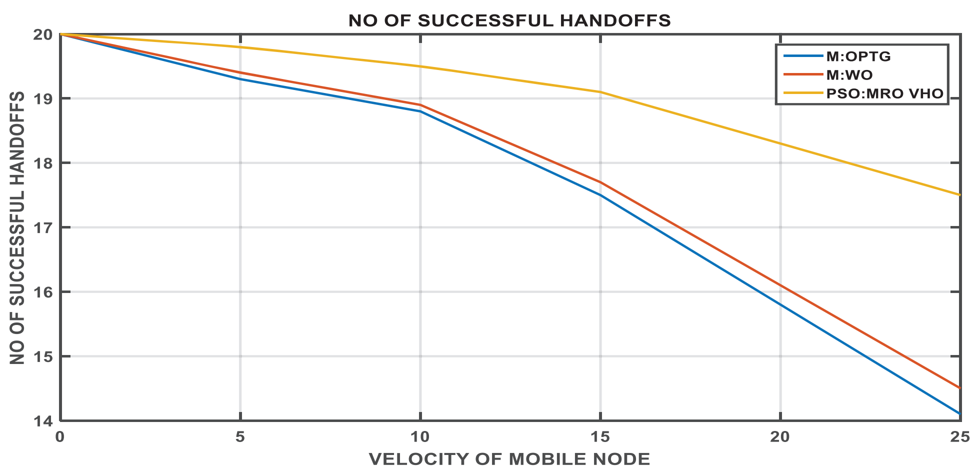

Figure 4: Number of successful handoffs *vs.* velocity of mobile nodes

iii. ***Handoff Failures:*** As the vehicles are moving at higher speeds, there is a possibility of handoff failures due to higher speed and a greater number of vehicles. The PSO-MRO VHO algorithm reduces the chances of handoff failures with a considerable number as is evident from Fig. 5.

iv. ***Unnecessary Handoffs:*** As the vehicle moves at high speeds from the coverage area of one base station to another base station or some access points of Wi-Fi. There is high probability of unnecessary handoffs, e.g., if a vehicle is moving with a very high speed and enters a new cell area B from the cell area A and stays there for very less time and again shifts towards A, then the Handoff from cell A to cell B will be redundant handoff. Thus, from the graph of Fig. 6, it can be seen that the proposed algorithm reduces the redundant Handoffs to a great extent.

v. ***Call Drop Rate:*** One of the constraints in the handoff is the call drop rate. In this work, it was seen that the call drops probability has been reduced and there were lesser number of calls dropped as compared to the existing algorithms. The Fig. 7 shows that the proposed algorithm has reduced the calls drop to a significant level.

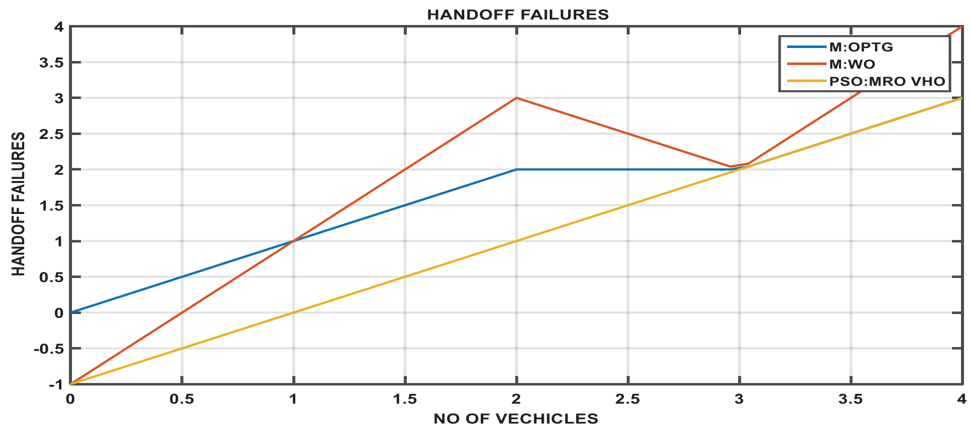

Figure 5: Number of handoff failure *vs.* number of vehicles

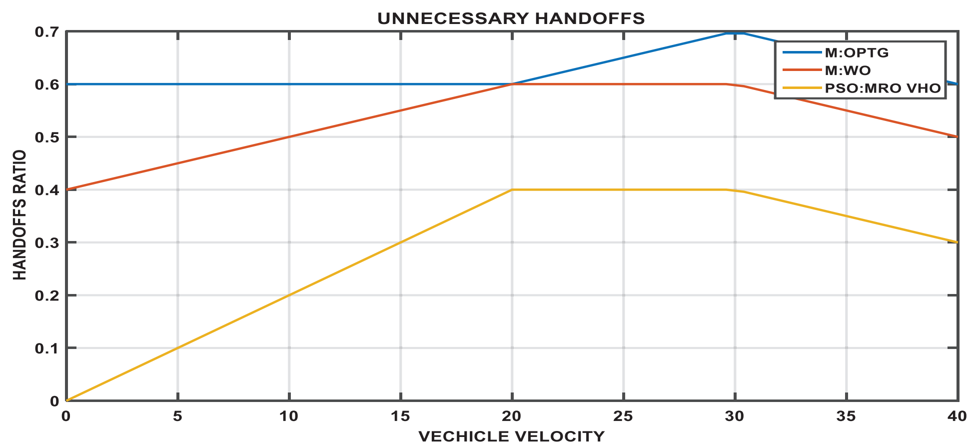

Figure 6: Number of handoff ratio *vs.* velocity of vehicles

But sometimes, instead of constant efforts, the handoff process gets failed.

In order to prevent the Handoff Failures and for the assurance of the seamless connectivity. We have proposed, the use of mobile robustness optimization (MRO). So that there are reduced number of call drops and interruptions in ongoing call and data sessions are also reduced with the use of Mobile Robustness Optimization.

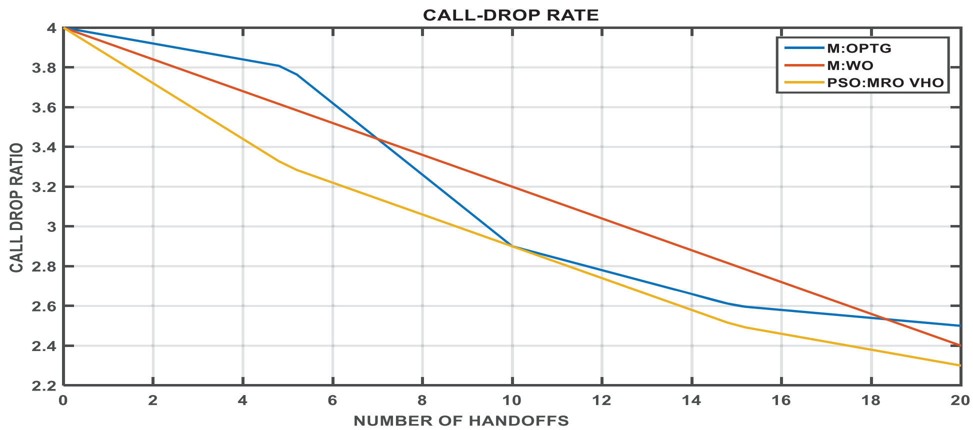

Figure 7: Call drop ratio *vs.* number of handoffs

8 Conclusion

For making the Handoff decisions in the Heterogeneous Wireless Network, an efficient Vertical Handoff (VHO) Algorithm is necessary. The VHO algorithm should be multi-criteria based, as a number of parameters are needed to be considered for deducting the Handoff decisions. In this proposed work, a proficient VHO algorithm is suggested which is best suited to work in this heterogeneous environment. All the simulations are done in the real-time using NS3 software. A number of parameters are suggested forming a joint optimization problem which is then solved as an optimization problem using Particle Swarm optimization and Mobile Robustness Optimization technique. It is seen that the proposed PSO-MROVHO algorithm works effectively and the results drawn are better in comparison to the already existing Handoff algorithms.

Funding Statement: Deepak Dahiya would like to thank Deanship of Scientific Research at Majmaah University for supporting this work under Project No. R-2022-74.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

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