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Seamless Vertical Handoff using Invasive Weed Optimization (IWO) algorithm for heterogeneous wireless networks

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Mobile Node (MN)

Abstract Heterogeneous wireless networks are an integration of two different networks. For better performance, connections are to be exchanged among the different networks using seamless Vertical Handoff. The evolutionary algorithm of invasive weed optimization algorithm popularly known as the IWO has been used in this paper, to solve the Vertical Handoff (VHO) and Horizontal Handoff (HHO) problems. This integer coded algorithm is based on the colonizing behavior of weed plants and has been developed to optimize the system load and reduce the battery power consumption of the Mobile Node (MN). Constraints such as Receiver Signal Strength (RSS), battery lifetime, mobility, load and so on are taken into account. Individual as well as a combination of a number of factors are considered during decision process to make it more effective. This paper brings out the novel method of IWO algorithm for decision making during Vertical Handoff. Therefore the proposed VHO decision making algorithm is compared with the existing SSF and OPTG methods.

1. Introduction

Mobile communication is one of the fastest growing sectors in the global scenario. The number of users has increased rapidly over the last few decades. Operators are consistently making an effort to fulfill user requirements. Heterogeneous wireless network is an integration of two different access networks, namely cellular and WLAN. In wireless

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heterogeneous networks, a MN should be able to move from one radio access network to another by performing a Vertical Handoff. During handoff, it is very important to carefully adjust the bandwidth allocation and reallocation which provide better Quality of Service (QoS) for the existing users. Integration of WLAN and cellular networks has additional advantages in terms of mobility, coverage area and bandwidth. WLAN technology provides high bandwidth at low cost and also supports low speed mobility. These features of WLAN make it a suitable technology for deployment at hot spots in heterogeneous networks. UMTS (cellular Network) is the Universal Mobile Telecommunications System, which provides wide coverage and high speed mobility for the users and is used at all locations other than the hot spots [1].

The limitations of Handoff shall not affect the continuity of the session during migration. That is when we move into a new cell in a cellular network (horizontal handoff) or between two subnets in a wireless local area network (WLAN) continuity must be maintained. In addition to horizontal handoff, a roaming within homogeneous sub networks (consisting of Wireless LANs only or cellular networks only), supporting continuous services i.e. continual Vertical Handoffs among heterogeneous wireless networks is essential for achieving QoS and incessant call connectivity [1].

In addition, there are two problems in the present WLAN techniques. First, regardless of other neighboring network status which consumes the least power at a given instant, a mobile device always chooses an access point for which RSS is maximum. Second, power consumption of a MN increases due to delays because of congestion at an AP due to multiple MN performing handoffs with respect to the same AP. In our proposed algorithm, the following parameters such as RSS, load and battery lifetime are taken into consideration, to solve the above issues [1].

In recent years, some of the Algorithms or strategies have been proposed for ultimate coalescing of various wireless networks [1–6]. The evolutionary algorithm meant for invasive weed optimization, widely known as the IWO has been used in this paper, to perform the decision making during handoff. IWO VHD algorithm includes consideration of the battery lifetime of MNs and load balancing across the attachment points. The predominant merit of the IWO algorithm is high accuracy and good convergence speed as the algorithm is free from derivatives. For ultimate unification of WLAN and 3/4G heterogeneous wireless networks, we propose IWO VHD algorithm that performs two tasks. First, battery lifetime of MNs is increased. Second, traffic load among Aps and BSs is equally distributed.

The rest of the paper is organized as follows: In section 2 and section 3, we discuss about the review of related works and Vertical Handoff system description respectively. Section 4 discusses about the IWO algorithm. Section 5 describes the performance fitness calculation. Section 6 explains the IWO in VHO and HHO. Section 7 explains the Implementation of IWO for VHO and HHO problem. Results and discussions are presented in Section 8 and Section 9 contains the conclusion of the study.

2. Review of related works

In Ref. [2] uses an analytical approach to find an appropriate attachment point on the basis of conserving battery lifetime, load balancing and joint optimization of both (battery lifetime and load balancing). The analytical results show that the performance of the Optimization (OPTG) algorithm is much better than the conventional optimization which is based on Strongest Signal First (SSF). In OPTG, the highest load and largest battery power consumption of APs/BSs are not eliminated during further iterations; as a result searching time increases to find the best network. In Ref. [3] includes parameters such as service type, battery power, network latency, and congestion to evaluate the vertical mobility. But optimization techniques are not considered for further process. In Ref. [3] came up with a proposal of end-to-end mobility management system, which can reduce unnecessary handoffs by measuring different network conditions. It is reduced based on RSS and velocity. Other parameters such as network load and battery lifetime of MN are not taken into account.

In Ref. [4], numerous network-layer-based vertical handover techniques are discussed and evaluated in real-time heterogeneous test bed. Velmurugan and SaranyaNath [5] shows the performance of VHO based on load, velocity and Receiver Signal Strength (RSS). The paper presents a novel way to avoid unnecessary handoff. Saravanan et al. [6] proposed IWO, to solve the unit Commitment problem in Power Generation. Due to Optimization, this algorithm effectively reduces the operational cost in terms of fuel.

The Call dropping probability for cellular network [7] is analyzed, but it did not consider the Vertical Handoff schemes. Call dropping probability has been identified using various factors. It is an important parameter to be considered during Vertical Handoff, as it improves the QoS. Varma et al. [8] shows the performance of VHO algorithm with hysteresis and dweller timer approaches have been studied for various topologies of heterogeneous network by considering the constant velocity of the mobile node. VHO algorithm evaluates the decision delay and the number of Vertical Handoffs between the WLAN and 3G. As a result, VHO algorithm shows small delay compared to existing RSS based VHO algorithm. Yang et al. [9] shows the performance of VHO based on SINR and RSS. By considering the Signal to Interference and Noise Ratio (SINR) based VHO, it shows the improvement of the overall throughput of the system.

Various methods and algorithms have been used to make decision during Vertical Handoff. Our proposed IWO VHD algorithm considers the parameters such as RSS, load, and battery lifetime to analyze the performance of VHO algorithm. We have developed a analytical study using MATLAB to choose the appropriate network for a Mobile Node (MN). The IWO VHD algorithm not only improves the collective battery lifetime of mobile nodes, but also concentrates on distribution of the load equally for all Aps/BSs. In our proposed algorithm, highest load and highest battery power consumption of APs/BSs are eliminated for further iterations; as a result, it reduces searching time to find the best network. In this paper, we proposed the usage of IWO to make the decision process during Vertical Handoff to obtain optimized solution.

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3. System description

Fig. 1 depicts a simple two tier system architecture which consists of 3/4G networks along with the Wireless LAN networks. The wireless LANs placed inside the coverage area of the 3/4G network and hence it moves to a different environment, so a seamless Vertical Handoff is required. Handoff is the process in which the user can move from one to another network. There are two types of handoff: (1) Horizontal Handoff and (2) Vertical Handoff. In Horizontal Handoff (HHO), Mobile Node (MN) can move from WLAN to WLAN or cellular to cellular system. In Vertical Handoff (VHO) a Mobile Node (MN) can move from WLAN to cellular or cellular to WLAN system [1]. Both APs and BSs include the mobile nodes that have come into the vicinity of a new attachment point by virtue of motion. In order to exchange information about link layer and MN's battery power, Media Independent Handover Function (MIHF) of IEEE 802.21 is used as a common language among multiple operators and multiple access technologies which undergo VHD [11].

The procedure to implement the VHD algorithms is shown in Fig. 1 [1]. VHD algorithms are being implemented in multiple Vertical Handoff Decision Controllers (VHDCs). These VHDCs are located in the access networks, as shown in Fig. 1, and can provide the VHD function for a region covering one or multiple APs and/or BSs. The decision inputs for the VHDCs will be obtained via the MIHF [11], which is being defined in IEEE 802.21. The VHDC is, conceptually, a network-controlled mobility management entity [3] utilizing the IEEE 802.21 MIHF [1]. The MIHF facilitates standards-based on message exchanges between the various access networks (or attachment points) to share information about the current link-layer conditions, traffic load, network capacities and so on. The MIHF at an attachment point, also maintains the battery life information of the MNs, which are currently serviced by it.

4. Invasive weed optimization algorithm

This subdivision explains the conventional procedure of the Invasive Weed Optimization (IWO) algorithm which is given in Fig. 2 [6]. The IWO method is enthused by observing the mushrooming of botanical sea plants namely, weeds. The pioneer attempt and realization applying IWO, to solve design problems in Control Systems were done by Mehrabian and Lucas [13]. The inhabiting behavior of intrusive sea plants namely weeds, provided the basis for the IWO method. The nature of the sea plants, rather weeds extensively occupies the growth area, prompted coining of the word intrusive weed plants. The algorithm is derivative free at the same time highly convergent. It also zeroes in, to the solution of optimizing, thus removing any occurrences of optimal solutions of secondary ones [6].

IWO is an algorithm which is integer coded and it is done by simple coding. Applications for IWO [12–15] are wide and varied; to name a few, Design for Antenna System, DNA Computing, and Piezoelectric actuators were placed in an optimal pattern found on smart structures [6].

The major jargons used in IWO are [6] as follows:

I. Seeds – Values are assigned to all units in the optimization problem with limiting conditions attached to them.
II. Plants – the ones grown as plants, which are germinated from seeds, earlier to evaluation.
III. Fitness value – Indicator of how best the plant is groomed. In simple language, how well optimized the solution is.
IV. Field – Most probable area where the solution or search is lying.

The variables that form the basis are the ones that contribute to optimization of the system, and these are taken as seeds and are randomly distributed in a fixed or definite

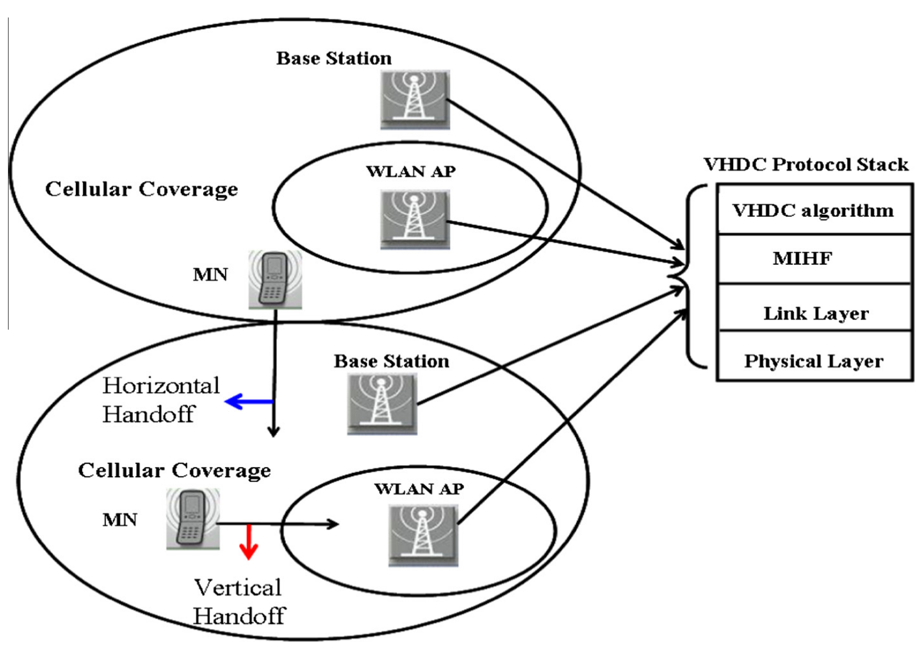

Figure 1 System architecture.

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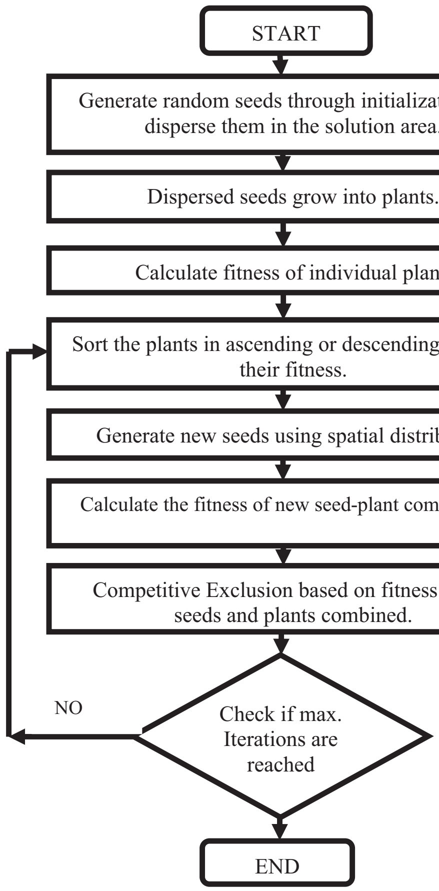

Figure 2 Flowchart of traditional IWO algorithm.

solution space. The seeds grow on to become plants, and fitness of each plant is computed. The plants are then arranged in ascending or descending order based on the requirement [6].

New seeds are generated from those plants whose fitness value meets all the constraints and thus generated seeds are allowed to grow into a plant. Further process includes the computation of the fitness value of both the generated seeds and plants, so that the seeds always approach toward the expected or ideal solution. Objective functions are used as fitness functions to compute the fitness of the seed and the plant so as to obtain the optimized result [6].

4.1. Mathematical steps in the proposed iwo algorithm in the vertical and horizontal handoffs

Step 1: The mobile nodes are initialized depending upon the number of selected variables involved in the process over the probable boundary of the search. The initialization of seeds is random which means that the seeds are dispersed in a random manner in the solution space (Generate random number of mobile nodes and attachment points, so that the seeds are mapped with the number of mobile nodes).

Step 2: The fitness of the initialized MNs is evaluated depending upon the fitness function (or) the objective function chosen for the optimization problem. Calculate the fitness of individual attachment points for handoff. The following equation stands for the Joint Optimization Objective Function.

To achieve load balance and joint optimization of the total battery lifetime in a cellular/WLAN coverage area, a combined cost function is formulated [2]:

$$G(X,\alpha,\beta) = \alpha\sum_{u_j} lt_j(X) - \beta \sum_{1\leqslant i\leqslant N+M} w(i)\left(\frac{\ell_i+\gamma_i(X)}{z_i}\right)^2 \tag{1}$$

Subject to $\ell_i + \gamma_i(X) \leqslant z_i$, for $1 \leqslant i \leqslant N+M$

where α and β are weighing parameters (1) minimizing the cost function in (21); it is equivalent to maximizing the negative value of the same cost function, because $(\ell_i + \gamma_i(\mathbf{X}))/z_i < 1$. Thus, we have the joint optimization statement of the total battery lifetime and the fairness of the load. In (1), when $\alpha = 1$ and $\beta = 0$, it is evident that (1) is an equivalent optimization problem of (20). Furthermore, the optimization problem $\text{Max}\,\forall X \in XG(X,0,1)$ subjected to the constraint in (21) is equivalent to Load (Opt-F) [1].

Case 1: $\alpha \equiv 1$, $\beta \equiv 0$: Handoff decision is taken only when the MN needs to maximize its battery lifetime: $\text{MAX} - L$.

Case 2: $\alpha \equiv 0$, $\beta \equiv 1$: Handoff decision is taken considering the traffic load in the new AP and to balance it across different APs: Opt-*F*.

Case 3: $\alpha \equiv 1$, $\beta \equiv 1$: Decision is made based on whether battery lifetime and Load balancing conditions have been met: OPTG. OPTG Algorithm provides the optimization performance in terms of overall battery lifetime and load balancing.

Step 3: Attachment points are sorted out in the order of their loads and small battery power consumption i.e. the least load and small battery power consumption are given rank 1.

Step 4: The number of MNs to be connected to the attachment Points varies linearly from $M_{\max}$ to $M_{\min}$ which is decided by the formula,

$$\text{Number of mobile nodes} = \frac{F_i - F_{worst}}{F_{best} - F_{worst}}(M_{\max} - M_{\min}) + M_{\min} \tag{2}$$

where

- F_i fitness of the ith network
- F_{worst} fitness value of the worst network
- F_{best} fitness value of the best network
- $M_{\max}$ maximum number of mobile nodes
- $M_{\min}$ minimum number of mobile nodes

Step 5: Handoff MNs are connected based on the comparison between access point loads and battery power consumption. These are computed for MNs having 3 or more access point options and the connection is made with the one with the least load and small battery power consumption.

The MNs requesting Handoff are connected normally over the attachment points with zero Mean and a standard deviation that is varying. It is given by,

$$\alpha_{\text{ITER}} = \left(\frac{\text{ITER}_{\max} - \text{ITER}}{\text{ITER}_{\max}}\right)^n (\beta_o - \beta_f) + \beta_f \tag{3}$$

where

- $ITER_{max}$ maximum value of the iteration assigned by the user
- ITER current iteration value
- β_o and β_f Initial and final values of standard deviations pre-assigned by the user

Step 6: Eliminate the highly loaded and the high battery energy consuming attachment point option and retain the least loaded and small battery energy consumption option.

Step 7: The above steps are carried out until maximum required iterations are done and the one attachment point with the best fitness value, at the end of it is the optimized solution.

5. Performance fitness calculation

In the traditional method (Strongest Signal First: SSF), handoff is initiated based on only Received Signal Strength (RSS) [9]. The parameters mentioned above are insufficient to initiate the handoff in heterogeneous wireless networks. In the SSF methods, there may be several issues in heterogeneous networks. The issues are as follows: (1) network load is increased, (2) congestion is more in that particular network, and (3) battery lifetime of the MN is decreased and so on.

In the existing method (SSF), a MN is initiating the handoff process, without considering the network conditions. With the effect of network condition, there is a possibility to cause a heavy load on one particular network even though two Networks are available. For example, while a pedestrian MN is in service at a cellular Network, it checks the neighboring APs. If the RSS of MN in WLANs/APs is greater than the cellular, MN is doing handoff to any one of the WLAN, without considering the network conditions.

When there is a heavy loading on one particular network, battery lifetime of the MN is decreased and handoff call dropping rate is increased. In the Proposed IWO algorithm, network selection is processed based on the following metrics: load and battery lifetime of the MN. VHDC collects the input parameters through MIHF via LLC. Information of Network condition is exchanged from one AP to another using MIHF layer. Calculation of load and Battery lifetime of MN is explained in the later part.

5.1. Load fitness calculation

Load Fitness calculation is used to find the load traffic of all APs/BSs. During Handoff, IWO VHD algorithm distributes the load equally to all APs/BSs. This section describes the system mathematically and how the various parameters that are required for the VHO Decision Making are computed.

The Access point (AP) and Base Station (BS) details are all captured in a set or array named A and C respectively. The number of APs and BSs is obtained from A and C set and let it be N and M respectively i.e. N is the number of APs and M is the number of BSs. The VHDC maintains all set A and C and updates them whenever there is a new entrant to either one of them. The Mobile Node (MN) details are maintained in a set U. Set U is subdivided into two sets U_t and V_t, where U_t is the set of MNs that are in requirement of a handoff and V_t includes the MNs that have a stable and good connection and are not in need of a handoff. U_t includes the MNs that have migrated into a new region and also the MNs that have just been switched ON.

$$V_t = U - U_t \tag{4}$$

The effective bit rate information of AP and BS is available with the VHDC via the IEEE 802.11 MIHF (Media Independent Handover Function) [1–4]. As the effective bit rate information is available, we can compute the load on each of the attachment point (AP or BS). Load is represented as 'ℓ_i' and effective data rate as e_{ij} for AP and $e^{(c)}_{i'j}$ for BS respectively.

For the APs load on each of them is computed according to Eq. (2).

$$\ell_i = \sum_{u_j \in V_a} e_{ij}, \quad \text{for } 1 \leqslant i \leqslant N \tag{5}$$

For the BSs load on each of them is computed according to Eq. (3).

$$\ell_i = \sum_{u_j \in V_c} e^{(c)}_{i'j}, \quad \text{for } N+1 \leqslant i \leqslant N+M \tag{6}$$

Once the initial load on each attach point is calculated, then for all the MNs requesting handoff, the available attachment point(s) for each MN is computed. This is called as an association matrix. The entry in the association matrix is '1' if the Received Signal Strength (RSS) from a particular attachment point is above the threshold [10]. Association matrix is represented as 'X'. The same is expressed mathematically in (4) and (5) as follows:

$$\sum_{1 \leqslant i \leqslant N+M} x_{ij} = 1, \quad \text{for } 1 \leqslant \text{j} \leqslant \text{K} \tag{7}$$

where 'K' is the number of MNs requesting a handoff.

$$x_{ij} \in \{0, 1\} \tag{8}$$

$$x_{ij} = 0 \text{ if } \text{RSS}_{ij} < \{\theta_a, \quad \text{for } 1 \leqslant i \leqslant N \tag{9}$$

$$x_{ij} = 0 \text{ if } \text{RSS}_{ij} < \{\theta_c, \quad \text{for } N+1 \leqslant i \leqslant N+M \tag{10}$$

Let $\Upsilon_i(1 \leqslant i \leqslant N + M)$ denote the total requested data rate on AP $a_i(1 \leqslant i \leqslant N)$ and BS $c_{i'}(1 \leqslant i' \leqslant M)$. Let r_j denote the data rate requested by MN $u_j(1 \leqslant j \leqslant K)$. Then, for any $\mathbf{X} = \{x_{ij}\} \in X$.

$$\Upsilon_i(X) = \sum_{u_j \in U} r_j x_{ij} \tag{11}$$

From the association matrix, we can compute the new load on the attachment point if MN(s) get attached to it. The new load that will be added to the attachment point will be the sum of requested data rates from all the MN(s) that get attached to the attachment point. It is represented as '$\Upsilon_i(X)$'. This can be computed from Eqs. (9) and (10) for AP and BS respectively.

$$\Upsilon_i(X) = \sum_{u_j \in U} e_{ij} x_{ij}, \quad \text{for } 1 \leqslant i \leqslant N \tag{12}$$

$$\Upsilon_i(X) = \sum_{u_j \in U} e^c_{ij} x_{ij}, \quad \text{for } N+1 \leqslant i \leqslant N+M \tag{13}$$

The product of effective data rate and association matrix entry is considered because not all MNs will have the service of all the attachment points. Only the load on the attachment points to which the MN can handoff have to be computed.

The total load on the attachment point will be the existing load on the attachment point by previously connected MNs or the MNs which are being catered by the attachment point added with the MN(s) getting attached to it.

5.2. Battery fitness calculation

It is used to reduce the battery power consumption of mobile node. During Handoff, IWO VHD algorithm finds the minimum battery power consumption in the MN when connected to the particular network. Battery power consumption may change depending upon the network load. If load increases battery power consumption may also increase and vice versa. The following equations represent the battery lifetime calculations:

Let l_{ij} represent the battery life of the mobile node 'i' at the attachment point 'j', then

$$l_{ij} = \frac{p_j}{p_{ij}}, \quad \text{for } 1 < i < N \tag{14}$$

$$l_{ij} = \frac{p_j}{p^{(c)}_{i'j}}, \quad \text{for } N+1 < i < N+M \tag{15}$$

where p_j is the available battery power at the MN and p_{ij} is the rate of consumption of power.

The battery lifetime of MN $u_j \in U$ for an association matrix $\mathbf{X} = \{x_{ij}\}$, $lt_j(\mathbf{X})$ is defined as

$$lt_j(X) = \sum_{1 \leqslant i \leqslant N+M} l_{ij} X_{ij} \tag{16}$$

6. IWO in vertical and horizontal handoffs

The proposed IWO algorithm eliminates the APs/BSs which attain the highest load and the highest battery power consumption. As a result, this improves the network performance based on equal load distribution and battery lifetime of the MN. The traditional IWO algorithm has to be modified to meet the requirements of Vertical Handoff optimization problem. We map our modified IWO algorithm with the traditional IWO algorithm. We calculate the optimization of objective functions for the parameters such as load and battery. Section 6.1 calculates the optimized fitness function for battery only. Section 6.2 calculates the optimized fitness function for load only.

6.1. Optimized fitness function for battery

By using optimized fitness function for battery, battery lifetime of the mobile node is maximized. To maximize the battery lifetime, the VHD problem is formulated as follows, for the given battery lifetime matrix L:

$$\text{Max} - L: \ \text{Max}_{\forall X \in \chi} \sum_{u_j \in U} lt_j(X) \tag{17}$$

Subject to

$$\ell_i + \Upsilon i(X) \leqslant B_i, \quad \text{for } 1, \leqslant i \leqslant N \tag{18}$$

$$\ell_i + \Upsilon i(X) \leqslant B^{(c)}_{i'}, \quad \text{for } N+1, \leqslant i \leqslant N+M \tag{19}$$

The conditions in Eqs. (15) and (16) emphasize that the load on the attachment point cannot exceed the required bandwidth.

In the problem formulation of Max $-$ L in (14), the total battery lifetime of the system is maximized, with respect to the lengthening of the individual battery lifetime of different MNs, and the max–min fairness is taken into account as follows:

$$\text{Min/Max} - L: \ \text{Max}_{\forall X \in \chi} \sum_{u_j \in U} lt_j(X) \tag{20}$$

6.2. Optimized fitness function for load

Now we focus on the problem of distributing the overall load in a cellular/WLAN coverage area. Our aim was to calculate the load per AP or BS in the cellular/WLAN coverage area. The proposed IWO algorithm distributes the load equally on the entire network during handoff. By using optimized load fitness function, the network which is having the least load gets connected to the MN. We define a load-based cost function F and formulate the following optimization for reasonable distribution of the load [1].

$$\text{OPT} - F: \ \text{Min } F = \text{Min}_{\forall X \in \chi} \sum_{1 \leqslant i \leqslant N+M} w(i) \left(\frac{\ell i + \gamma_i(X)}{z_i} \right)^2 \tag{21}$$

with the constraint

$$\ell_i + \gamma_i(\boldsymbol{X}) \leqslant \boldsymbol{z_i}$$

where

ℓ_i = Load on the attachment point.

$W(i)$ = weight factor for UMTS and WLAN Bandwidth.

$\ell_i + \gamma_i(X) \leqslant z_i$ = sum of previous load on attachment point with the stray node load attached.

Z_i = Maximum Bandwidth, the attachment point can support.

The formula above is used to compute the load on each of the access point and also the constraint has been applied in the form of total bandwidth being held constant. This limits the number of users that can get hand over to a particular attachment point.

7. Implementation of IWO for VHO and HHO problem

Once the mapping has been done with the variables, the IWO algorithm is modified to meet the requirements of the VHO optimization problem. IWO algorithm has been proposed (Fig. 4) for optimization of network loads and improves the battery lifetime of the MN during handoff. It is described as follows:

The steps (Fig. 3) to be followed are as follows:

1. Estimate the load and battery lifetime of (MN) on each Access point and Base Station.
2. When a MN which is a candidate for handoff occurs in the area of vicinity, for each of the MN compute all the possible attachment points by measuring the RSS.
3. For all the MNs which have only one attachment point (WLAN) option, the connection will be made with that attachment point (WLAN).
4. Next for all the MNs that have 2 attachment points comparison between both the access points' load is made and the connection will be made to the one with lower load and less battery power consumption.
5. Comparison between access point loads and battery power consumption is computed for MNs having 3 or more access

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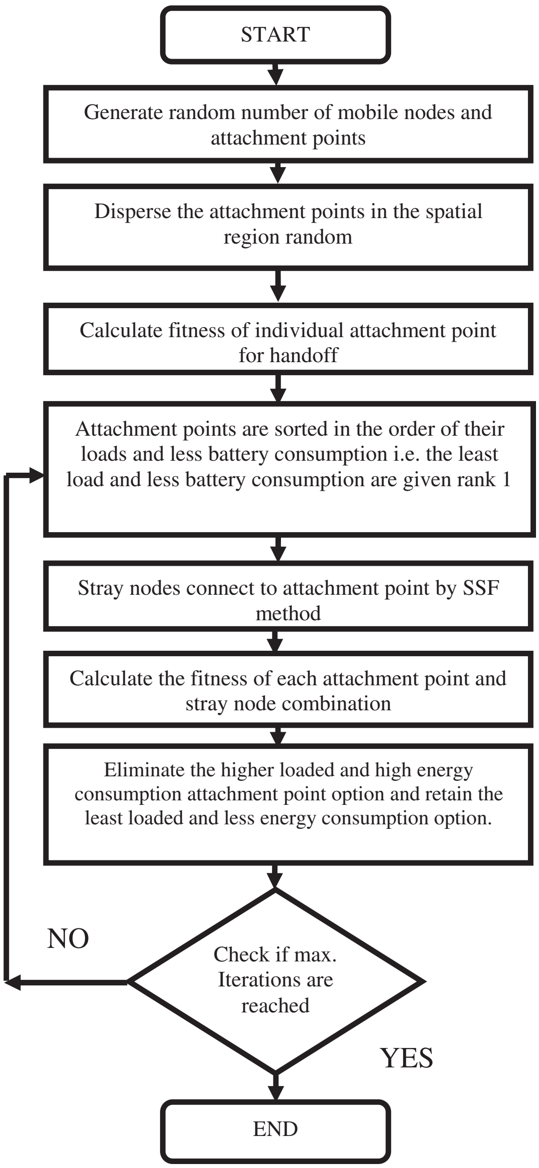

Figure 3 IWO applied to VHO and HHO.

point options and the connection is made with the one with the least load and less battery power consumption.
6. Similar comparisons are done with respect to BS, if more than one BS can cater to the MN.

The IWO algorithm is so devised such that the priority is given to the WLAN, which helps in improving the service to the MN as higher data rates can be provided by the WLAN. Based on the available number of attachment points the decision is made. VHDC chooses the appropriate attachment point. The proposed algorithm is balancing out the load between all the access points and improves the battery lifetime of the MN. Fig. 4 shows that the proposed IWO algorithm eliminates the highest load and maximum battery power consumption of Aps/BSs. As a result, this reduces the searching time to find the best possible network.

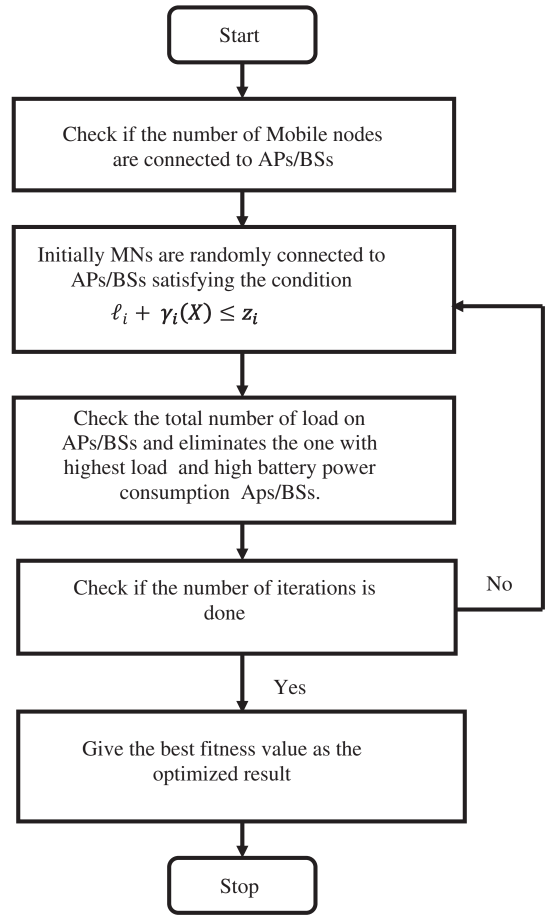

Figure 4 Flowchart of Proposed VHO and HHO decision methodology.

8. Performance measurement of load

Initially the simulation is carried out with a small number of BSs/Aps and MNs. Later simulation is done for the second time with increase in number, as shown in the subsequent section.

The performance of the IWO algorithm in the Vertical Handoff Problem is measured by computing the Covariance of the load for the network.

$$\text{Covariance (CoV)} = \frac{\sum_{i=1}^{N}\sum_{i=N}^{N+M}(X_i - \overline{X})(Y_i - \overline{Y})}{(N+M)-1} \tag{22}$$

The first simulation is as follows.

The system we have considered in our effort to measure the performance of IWO algorithm in VHO problem consists of 2 Base Stations and 4 Access points. Fig. 5 shows the comparison of Covariance of load for the same system with same number of MNs requesting for handoff. Among all the optimization methods IWO performs the best, as it fairly distributes the load among attachment points.

The Proposed algorithm has been compared with SSF and OPT-G algorithms as it is the one most widely used. The graph in Fig. 5 indicates that CoV reduces significantly as the number of MNs requesting for handoff increases. We can observe from the graph in Fig. 5, the CoV of load increases for the SSF

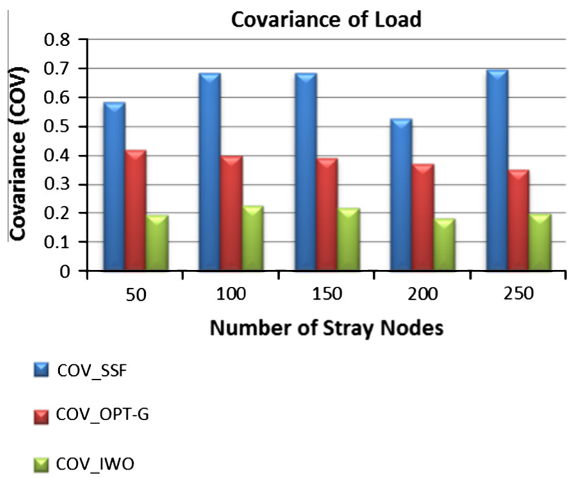

Figure 5 Load distribution for mobile node.

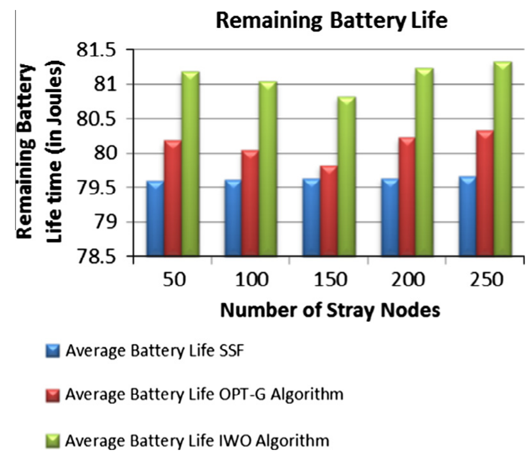

Figure 6 Effective remaining energy of MNs versus number of stray Nodes.

algorithm. But in the case of IWO, the CoV of load decreases. The decrease in CoV with the increase in MNs is a major accomplishment for IWO algorithm. The obtained result shows that IWO performs better than SSF and OPTG in Vertical Handoff Problem, with the load optimization on the network as the primary requirement.

8.1. Analysis of battery lifetime

The network considered has 6 attachment points in which two are UMTS base stations and rest are WLAN Access points. The Received Signal Strength (RSS) values are generated randomly for all the attachment points.

We assumed the initial battery energy as 100 Joules for each mobile. First we calculated the battery lifetime using the SSF method for each stray node. Then by applying the IWO algorithm, we calculated the same battery lifetime. The formulae used for calculation of battery are as follows:

$$\text{Battery energy loss} = \frac{(\text{initial battery} - 5) * (\text{Battery drain rate})}{(\text{Total no of MN connected to attachemet point})} \tag{23}$$

$$\text{Remaining energy in Battery} = 100 - \text{Battery energy loss} \tag{24}$$

The graph of remaining energy Vs numbers of stray nodes is represented in Fig. 6. The observation from this plot is that the effective remaining energy of all MNs remains high and is maximum in the case of IWO scheme, while it is very small in SSF scheme with the increase in the number of stray nodes. The OPTG scheme also gives better result compared to SSF as there is optimization for battery lifetime in this scheme as well. In the SSF scheme all the nodes are getting attached to the same attachment point. As such the bandwidth efficiency is reduced and energy consumption is more compared to other schemes.

8.2. Analysis of battery lifetime with increased number of APs/BSs/MNs

The network to be analyzed is large enough now; it has 14 attachment points of which four are UMTS base stations and others are WLAN Access points. For all the attachment points, the RSS values are randomly generated and given to the MNs. 1500 MNs are present in total. Consider they are with an initial energy of 100 kJ. Simulation is done for a period of 1000 sec and the graphs are plotted with a time interval of every 50 sec. The graph of 'remaining energy' Vs time period is shown in the Fig. 7. The plot infers that the effective remaining energy of all the MNs stays high and is found maximum in IWO method; on the other hand it is found to be very small in the case of SSF method, as time increases. The OPTG method yields better result compared to SSF and in addition there is battery lifetime optimization. In the SSF scheme all the nodes

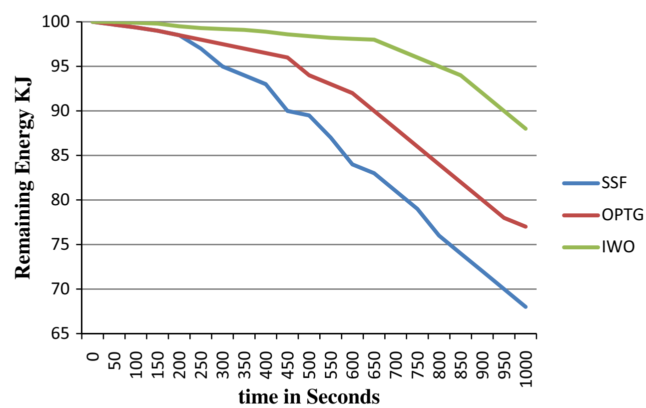

Figure 7 Effective remaining energy of MNs versus time.

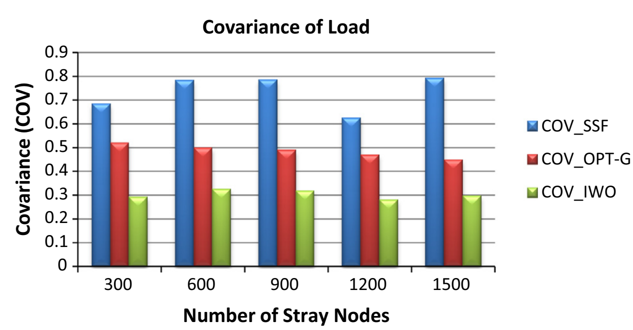

Figure 8 Load distribution for 1500 mobile terminals.

get attached to the same attachment point, irrespective of status of the network. As such there is a reduction in the efficiency of bandwidth and MNs battery power consumption is more compared to all other schemes.

8.3. Performace measurement of load

Fig. 8 shows the comparison of Covariance of load for the same system with the same number of MNs requesting handoff. Among the entire optimization methods IWO algorithm's performance is one of the best, as it evenly distributes the load to all the attachment points.

The Proposed algorithm which is one of the most widely used was compared to SSF and OPT-G algorithms. The graph in Fig. 8 indicates that CoV decreases appreciably when there is an increase in the number of MNs requesting for handoff. We can observe from the graph in Fig. 8, the CoV of load increases for the SSF algorithm, whereas in the case of IWO the CoV of load decreases. The obtained result shows that IWO performs better than SSF and OPTG in Vertical Handoff Problem, with the load optimization on the network as the primary requirement. The decrease in CoV of load is a measure, indicating that the load is being equally distributed amidst all the attachment points.

Table 1 For SSF method load status (in kilobits per second) at the APs and BSs during simulation with four BSs, ten APs, and 1500 MNs (time unit: 1000 s).

SSF (number of mobile nodes 1500)														
Time (sec)	AP10	AP9	AP8	AP7	AP6	AP5	AP4	AP3	AP2	AP1	BS4	BS3	BS2	BS1
100	2560	3520	2240	6080	3200	2304	3168	2016	5472	2880	2020	614	512	2304
200	5120	5440	6400	6720	5760	4608	4896	5760	6048	5184	624	0	1024	512
300	5440	7040	3840	5860	5760	4896	6336	3456	5274	5184	1305	0	0	1088
400	3520	6720	4480	4160	7680	3168	6048	4032	3744	6912	969	0	0	832
500	5120	6720	2880	5120	7360	4608	6048	2592	4608	6624	988	0	0	832
600	3840	3520	4160	8320	5760	3456	3168	3744	7488	5184	1536	0	0	1280
700	3200	4480	5120	8000	5440	2880	4032	4608	7200	4896	1459	0	0	1216
800	3200	4800	5440	4480	5760	2880	4320	4896	4032	5184	1920	0	0	1600
900	3840	5120	5760	5120	3840	3456	4608	5184	4608	3456	2034	0	0	1856
1000	4480	4480	3200	5120	1920	4032	4032	2880	4608	1728	2150	0	0	1792

Table 2 For OPTG method load status (in kilobits per second) at the APs and BSs during simulation with four BSs, ten APs, and 1500 MNs (time unit: 1000 s).

OPTG (number of mobile nodes 1500)														
Time (sec)	AP10	AP9	AP8	AP7	AP6	AP5	AP4	AP3	AP2	AP1	BS4	BS3	BS2	BS1
100	5760	7040	5440	8000	5760	5184	6336	4896	7200	5184	1920	2240	1728	2016
200	6080	3520	9600	4800	5440	5472	3168	8640	4320	4896	1280	1280	1152	1152
300	6400	5440	6720	6720	4800	5760	4896	6048	6048	4320	3200	1920	2880	1728
400	7040	7360	6720	5440	6720	6336	6624	6048	4896	6048	640	1600	576	1440
500	5440	8000	4160	6400	7360	4896	7200	3744	5760	6624	0	0	0	0
600	4160	4480	5440	11520	4160	3744	4032	4896	10,368	3744	1280	640	1152	576
700	3840	5440	6080	8960	5760	3456	4896	5472	8064	5184	1280	960	1152	864
800	8000	5120	5440	5120	5120	7200	4608	4896	4608	4608	320	960	288	864
900	7680	6400	6720	5760	3200	6912	5760	6048	5184	2880	2560	2880	2304	2592
1000	6130	6080	8320	5120	3520	5517	5472	7488	4608	3168	960	960	864	864

Table 3 For IWO method load status (in kilobits per second) at the APs and BSs during simulation with four BSs, ten APs, and 1500 MNs (time unit: 1000 s).

IWO (number of mobile nodes 1500)														
Time (sec)	AP10	AP9	AP8	AP7	AP6	AP5	AP4	AP3	AP2	AP1	BS4	BS3	BS2	BS1
100	5760	6720	5440	6400	6720	5184	6048	4896	5760	6048	2240	2240	2016	2016
200	5760	5440	6080	6080	6080	5184	4896	5472	5472	5472	1280	1280	1152	1152
300	6080	5760	5760	6080	6080	5472	5184	5184	5472	5472	2560	2560	2304	2304
400	6720	6720	6400	6720	6720	6048	6048	5760	6048	6048	640	1920	576	1728
500	6080	6080	6080	6080	6080	5472	5472	5472	5472	5472	0	0	0	0
600	5440	4160	6720	7040	7040	4896	3744	6048	6336	6336	960	960	864	864
700	5760	6080	7040	6080	6080	5184	5472	6336	5472	5472	960	1920	864	1728
800	5760	5440	5440	5760	5760	5184	4896	4896	5184	5184	960	320	864	288
900	6080	7040	5760	6080	5760	5472	6336	5184	5472	5184	2240	2560	2016	2304
1000	5440	5440	5760	5760	5760	4896	4896	5184	5184	5184	960	960	864	864

8.4. Inference

In the SSF method shown in Table 1, it can be seen that the load is not evenly distributed among APs/BSs. But from Table 2 for OPTG method, it indicates a considerable improvement in load distribution among APs/BSs compared to SSF method. The IWO algorithm has an edge over the former two methods, in the even distribution of load during HHO and VHO mechanisms. Since data rate is more for WLAN compared to cellular network high priority is given to WLAN. So, from the tables it is clear that data rate entry values are larger for WLAN (see Table 3).

9. Conclusion

The proposed IWO algorithm optimizes the load on the access points and also provides handoff to the most congestion free access point for a particular MN. The performance of the IWO is already depicted in Section 8. The advantages of IWO algorithm are as follows:

1. The network load is optimized and the handoff is made to the least congested attachment points unlike the SSF which makes the handover based on the signal strength alone.
2. As the number of available access points increases for a particular MN(s) the load is evenly distributed among all the Access points and thus the CoV for load decreases.
3. During the times when the mobile nodes requesting for handoff are small, then the performance of the algorithm is similar to SSF algorithm. But when the number of MN (s) requesting for handoff increases the performance of IWO is much better when compared to that of SSF.
4. The attachment points make the decision based on all the available information i.e., all the probable attachment points for a particular MN(s) at the time of handoff.

This paper shows the successful implementation of a genetic or evolutionary algorithm of Invasive Weed Optimization (IWO) in Vertical Handoff (VHO) application. The IWO algorithm is implemented in VHO decision making problem where the balancing of Network load is the chief constraint. The algorithm is developed to overcome the constraints of imbalance in network load and more battery consumption rate. As there are a number of parameters that can be considered as dependent variables for making the handoff decision, the algorithm can be enhanced by using a collection of other parameters or variables. The performance of the network must be measured with all the variables and the handoff be made, if the collective performance is beyond the defined threshold.

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