Optimization of Vertical Handover Performance Using Elimination Based MCDM Algorithm

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Abstract

In heterogeneous networks environment, Vertical Handover Decision (VHD) algorithms help mobile terminals to choose the best network between all the available networks. VHD algorithms provide the QoS to a wide range of applications anywhere at any time. In this paper, a generic and novel solution to solve the Vertical Handover (VHO) problem has been developed. This solution contains two major subsystems: The first subsystem is called elimination system. Elimination system is received the different VHO criteria such as received signal strength, network load balancing and mobile station speed from the different available networks. After that, the inappropriate alternatives are eliminated based on the elimination conditions. The second subsystem is a Multiple Criteria Decision Making (MCDM) system that chooses the appropriate alternative from the remaining alternatives of the elimination phase. For simulate the proposed solution, MATLAB program is used with aid of MATLAB-based toolbox that is called RUdimentary Network Emulator (RUNE). The combination of both subsystems avoids the processing delay caused by unnecessary computation over available networks which do not ensure connection performance. Also it avoids increasing the number of unnecessary handovers, ping pong effect, blocking rate and dropping rate by reducing the handover failure rate. A performance analysis is done and results are compared to other reference algorithms. These results demonstrate a significant improvement over other reference algorithms in terms of handover failure rate, percentage of satisfied users, and percentage of the low cost network usage.

Keywords: Heterogeneous Networks, VHO, Vertical Handover Decision (VHD), MCDM, SMART

1. Introduction

In a typical scenario of the Fourth Generation (4G) networks, mobiles or multimode terminals (MTs) have multiple interfaces and will be able to select the most suitable Radio Access Technology (RAT) among the available alternatives. These alternatives include IEEE 802.16 Worldwide Interoperability for Microwave Access (WiMAX), IEEE 802.11 Wireless Local Area Network (WLAN), satellite

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systems and Bluetooth, in addition to the traditional cellular networks which are nearly universally accessible today.

For a satisfactory user experience, MTs must be able to seamlessly transfer to the best Radio Access Technologies (RATs) between all available candidates with no perceivable interruption to an ongoing conversation, which could be a voice or video session. Such ability to Hand-Over (HO) among Heterogeneous Wireless Networks (HWNs) is referred to as Vertical Handover (VHO). VHO algorithms are one significant challenge for Radio Resource Management (RRM) in HWN. The VHO is one of the key components that must be addressed and considered carefully in the HWN environments and need to be designed to provide the required Quality of Service (QoS) to a wide range of applications [1][2][3][4].

The performance of the VHD algorithms still need to be improved through using new tools and methods to make the handover decision, as well as taking into account the different viewpoints when choosing the criteria of the handover decision. As some of the existing VHD algorithms, do not exploit the advantages of the multi-criteria nature of the VHD that can give better performance than single criterion algorithms due to the flexible and complementary nature of the different criteria [5][6][7][8].

Furthermore, considering only one or two criteria in the VHD solution is not sufficient to provide a good solution and usually leads to undesirable situations. Moreover, some of the current algorithms cannot cope with the different viewpoints and goals of the operators, users, and QoS requirements, where they are often either user-centric or operator centric [10][11][15].

In addition, some of the existing VHD algorithms use complex and indirect methods, which makes them suffer from a long delay during the processing. As a result, they do not provide complete and deployable solutions to the VHO problem [24][30][31].

All the above limitations in the existing work motive us to develop a new class of algorithms to improve the performance of the existing algorithms.

This paper is organized into six sections. Section 2, reviews related work. Section 3 designs and implements the proposed solution. Section 4 focus on the simulation environment, displaying the performance evaluation metrics, testing the proposed solution and comparing it with other reference solutions are presented in section 5. Finally, conclusion and future work are summarized in section 6.

2. Related Work

There are extensive work that could be founded in the area of VHD algorithms in the literature. In this section, some of existing VHD algorithms. We will classify VHD algorithms into two major categories, the first category is single-criterion based VHD algorithms and the second is multi-criteria based VHD Algorithms.

2.1 Single-Criterion based VHD Algorithms

This type of VHD algorithms are based on only one criterion for the appropriate network selection in handover procedure**.**

Authors in [5],[6],[7],[8] and [9] proposed RSS-based VHO algorithms are proposed with a different signal thresholds for each RAT. A mobile node compares between RSS values coming from RATs and the signal thresholds and selects the appropriate RAT for handover.

Authors in [10] and [11] developed a new type of algorithms called a travelling distance prediction based algorithm, targeted to eradicate the unnecessary handovers in the above RSS-based algorithms. This method depends on the estimation of network connection time (i.e. time that the mobile node is estimated to spend within the cell) and the calculation of a time threshold. A handover to a new network is triggered if the new network coverage is available and the estimated traveling time inside the cell is larger than the time threshold. Authors in [12] suggests two dissimilar schemes, in the first scheme users connect to nearest network, while in the other scheme the users are connected to the RAT where the average user bit rate is maximized.

Authors in [13] proposed a method based on that the mobile nodes connect with the higher throughput RAT while taking into consideration RSS threshold. In [14], a user throughput-based VHD algorithm is proposed, where the mobile node selects the network with the highest per user throughput.

Authors in [15],[16] and [17], a service-type-based VHO algorithms are proposed, which the mobile node chooses WWAN for real time services (voice services) and WLAN for non-real time services (data services).

Also, [18] investigate a service type based VHO algorithms with some improvement where the real time services blocked by WWAN are converted into Voice over IP (VoIP) and sent to WLAN, while non-real time services are served by WLAN (if inside the coverage) are directed to WWAN. In [19], a utility-based VHO algorithm targeted to accomplish a load balancing between WWAN and WLAN networks is developed.

Generally the main shortcomings of single-criterion based VHD algorithms are rigid and take one or two of criterion, which is not sufficient to make a VHO decision in HWNs environment.

2.2 Multi-Criteria based VHD Algorithms

These algorithms make vertical handover decision based on multiple criteria, not only one criterion.

Authors in [20] proposed a fuzzy logic-based VHD algorithm for enhancing the performance of HWN. The input criteria to the algorithm are received signal strength, mobile speed, available bandwidth and interference rate. The simulation results show that this algorithm is acceptable in determining the most suitable network under different dynamic working situations. Authors in [21] designed and implemented a fuzzy logic based handover controller on a Field-Programmable Gate Array (FPGA). The input criteria to the system are received signal strength, network load balancing and distance between MS & BS. The suggested system can be reconfigured and extra features could be achieved by adding additional criteria.

Authors in [22] suggested algorithm based on Analytic Hierarchy Process (AHP) and the input criteria to be used are available bandwidth, packet loss, cost, jitter, end-to-end delay, and the security of the network.

Authors in [23] proposed a VHD algorithm where AHP-MADM method is used. The used criteria are received signal strength, network load balancing, available bandwidth, network connection time, monetary cost, service type and velocity.

Authors in [24] proposed a new method to make VHO decision based on Fuzzy Analytical Hierarchy Process (FAHP) and the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS). The FAHP technique is used to choose a suitable weight for each criterion and the TOPSIS technique is applied to rank the alternatives.

In addition to available bandwidth, packet loss, jitter, end-to-end delay, and security of the network criteria, the proposed method takes into account a new criterion namely history. The use of this criterion assists to reduce of ping-pong effect by reducing the number of handovers.

Authors in [25] suggested a new technique that is created on mahalanobis distance which takes into consideration the relationship with dissimilar criteria and also goals to select the optimal network while reducing the number of unnecessary handovers. The proposed technique uses the criteria of available bandwidth, packet loss, jitter, end-to-end delay, security of the network and monetary cost.

Authors in [26] suggested a VHD algorithm based on fuzzy logic. The proposed algorithm uses the criteria; network throughput, packet loss, jitter, end-to-end delay, security of the network and monetary cost. Authors in [27] proposed fuzzy logic-based handover decision algorithm. The main input criteria to the algorithm are available bandwidth, user preference and received signal strength. The suggested algorithm has acceptable performance in choosing the required network, compared with the traditional algorithms. This algorithm decreases number of handover which can reduce ping-pong effect.

Authors in [28] invented a novel ranking algorithm, which syndicates Mahalanobis distance and multi-attribute decision making (MADM). The proposed algorithm is divided into three main stages. The first stage is called the classification stage, which is divided into homogeneous criteria to internal and external layers. In the second stage, the Fuzzy AHP method is used to calculate weights of inter-layers and intra-layers. Lastly, mahalanobis distance is applied to rank the alternatives.

Authors in [29] suggested a new method to execute vertical handover using neural networks and fuzzy logic. They use congestion as the major criteria in making VHO decision. In addition the available bandwidth, received signal strength and monetary cost, are used as the secondary criteria. Authors in [30] proposed a system called Adaptive Traffic Dependent Fuzzy-based Handoff decision System (ATD-HDS). This system uses fuzzy logic to improve the intelligence of the handover decision. The results show that the proposed system significantly enhance the handover decision efficiency. The proposed system uses the criteria; available bandwidth, monetary cost, Jitter, handover latency, power consumption and packet loss.

Authors in [31] suggested a user-centric algorithm hat uses Artificial Neuro-Fuzzy (ANFIS) and Sugeno Fuzzy Inference System (FIS) to order diverse wireless

networks for the handover procedure. This algorithm is based on a collection of criteria; user preferences, received signal strength and network load balancing.
Authors in [32] proposed a VHO algorithm based on fuzzy logic. This algorithm named as Fuzzy Controller for Handoff Optimization (FCHO).The main input criteria to the proposed algorithm are received signal strength, available bandwidth, monetary cost and velocity of the vehicle. The results show that the proposed algorithm meaning fully enhance the handover decision efficiency compared with traditional algorithms.
Authors in [33] suggested a new technique based on fuzzy logic to appraise the necessity of handover and rank diverse networks for the handover procedure. The used criteria in this algorithm are received signal strength, available bandwidth, end-to-end Delay, velocity of the vehicle, network load balancing and monetary cost.
For the multi-criteria based VHD algorithms. In general, the shortcomings could be summarized in two major shortcomings. The first one these algorithms cannot cope with the different viewpoints and goals of the operators, users, and QoS requirements, where they are often either user-centric or operator centric. The second one most of these algorithms use complex and indirect methods, which makes them suffer from a long delay during the processing.
In this paper, a new class of algorithms to improve the performance of the existing algorithms has been developed.

3. VHO Proposed Solution

A generic and novel solution to solve the VHO problem and any other comparable optimized selection problem is presented in this section. The solution consists of two major phases as shown by Figure(1).

The first phase is called elimination/removal phase where the measurements of the different VHO criteria such as Received Signal Strength, Network Load, User preferences, etc.. are received from the different alternatives (RATs) and the non-appropiate alternetives are eliminated based on the elimination conditions. The second phase is a Multiple Criteria Decision Making (MCDM) system that choose the appropriate alternative from the remaining alternatives of the previous phase. The next subsections illustrate these two phases with more details.

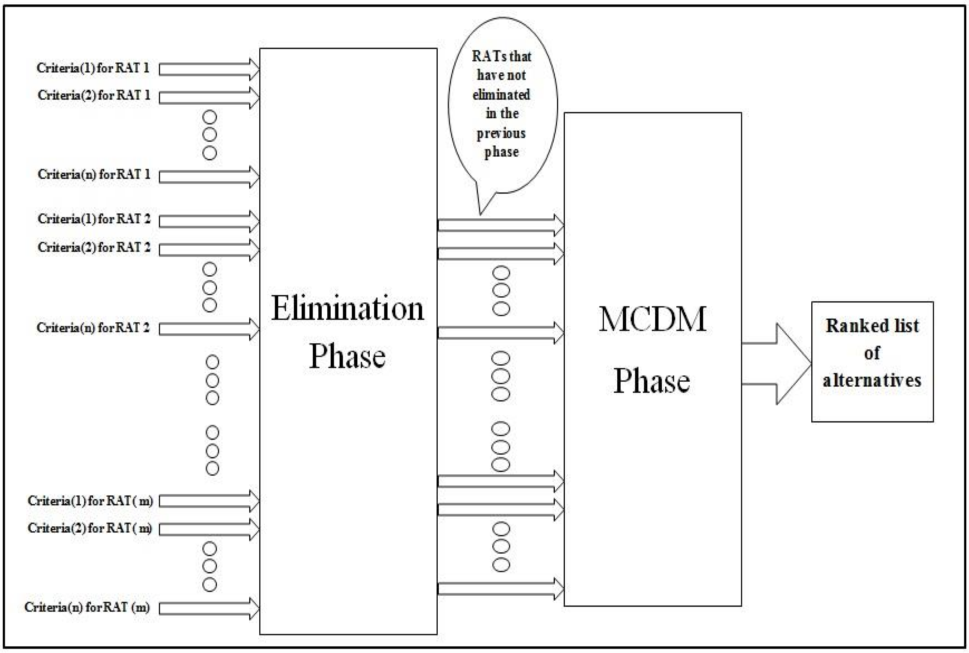

Figure (1): Generic VHO problem proposed solution

3.1 Phase1: Elimination System

Elimination system aims to eliminate the alternatives that do not meet the minimum criteria values that achieve good performance of the communication process. The input criteria of the elimination system are the Received Signal Strength (RSS), Network Load Balancing (NLB), User preferences (UP), Mobile Station Speed (MSS) and Monetary Cost (MC).

The first input criteria "RSS" defines the received signal strength from the base station (BS). RSS is selected based on the manuals and operation instructions of existed networks such as IEEE802.11, UMTS, GSM and IEEE802.16. RSS values ranging from -150 to -50dBm. The second input criteria "NLB" describes the network load balancing. It is important to balance the network load to avoid deterioration in quality of services. The third input criteria "MSS" describes the mobility of user, where the user is divided into fixed, pedestrian and running user.

The forth input criteria "MC" describes the monetary cost, where the different operators may operate heterogeneous wireless networks and may have varying costs associated with them. So, the network with the least cost should be a preferred target of handover. The last input criteria "UP" to describe user preferences, where the users have more options for heterogeneous networks according to their preferences and network performance parameters.

Four alternatives are applied to the system. The first alternative is called RAT_1 is a WWAN- CDMA based network, the second one called RAT_2 is a WWAN-TDMA based network, the third called RAT_3 is a WMAN network and the fourth one called

RAT_4 is a WLAN network. The outputs of this system are the candidate RATs for the next phase. These networks are not complying with the conditions of elimination.
The elimination conditions are represented through a range of values of the criteria between high threshold (Thr_H) and low threshold (Thr_L). In this subsystem, the elimination criteria are RSS and NLB for all RATs. MSS criterion is used only for the fourth network. The elimination mechanism used in our system can be summrized in the following steps:

Step1: Monitor the criteria RSS, NLB and MSS of all RATs.

Step2: Check the first elimination condition of all RATs ($Thr_L < RSS_{1,2,3,4} < Thr_H$**)**.

Step3: Eliminate the RAT, which applies the first elimination condition**.**

Step4: Check the second elimination condition for the rest of RATs ($Thr_L < NLB_{1,2,3,4} < Thr_H$**)**.

Step5: Eliminate the RAT, which applies the second elimination condition**.**

Step6: Check the third elimination condition only for the fourth RAT ($Thr_L < MSS_4 < Thr_H$).

Step7: Eliminate the fourth RAT, if it is applicable for the third condition**.**

Step8: Move the remaining candidate RATs to the next phase.

3.2 Phase2: The MCDM system

MCDM system aims to rank the rest of the alternatives after previous phase according to specific input criteria. The input criteria of the MCDM are the RSS, NLB, MSS, MC and UP. The outputs of this system are the probability of selection specific alternative to perform vertical handover process. Our MCDM system uses the SMART decision making tool. SMART is the simplest form of the Multi-Attribute Utility Theory (MAUT) methods. The ranking value *xj* of alternative A*j* can be calculated as shown in Equation1 [34].

$$x_j = \sum_{i=1}^{m} w_i a_{ij} \Big/ \sum_{i=1}^{m} w_i \,, j = 1,2, \dots \dots, n \qquad (1)$$

The weights will be assigned manually according to the experience of the decision makers about the importance of each criterion.

4. Simulation Environment

A modified version of MATLAB based simulator called RUNE [35][36] has been used. The simulation environment defines system model, mobility model, propagation model, services model and user's profiles model.
The system model considers the coexistence of four types of wireless access networks. The first network is a CDMA based WWAN with twelve clusters in each cluster seven cells and cell radius of 1000m. The second one is a TDMA based WWAN with twelve clusters and each cluster has seven cells with 700m radius. The third one is a CDMA based WMAN with twelve clusters and each cluster has seven cells with 325m cell radius. The forth one is a CDMA based WLAN with twelve clusters and each cluster has nineteen 100m cells. All cells have standard hexagonal shapes with Omni-directional antennas. The mobiles are randomly distributed over

the system. In every slot each mobile is moved a random distance in a random direction at defined time steps. The movement pattern of each mobile depends on the velocity and acceleration. The velocity is a vector quantity with magnitude and direction. The velocity of the *ith* mobile is updated according to Equation 2 [34].

$$V_i = V_{i-1} * C + \text{sqrt}\,(1\text{-}C\string^2) * V_m * R \qquad (2)$$

Where V_i is the complex speed [m/s]. V_{i-1} is the complex speed in the previous time step. R is a Rayleigh distributed magnitude with mean 1 and a random direction. V_m is the mean speed of mobiles.

C is the correlation of the velocity between time steps. P depends on both a_{mean} which is the mean acceleration of the mobile user and V_{mean}. V_m has been set to 10 [m/s] and the mean acceleration has been set to 2.

The propagation model simulates the different losses and gains during the signal propagation between the transmitter and the receiver in the system environment. The wireless propagation model used in this paper is described in a logarithmic scale as in Equation 3 [34].

$$G = GD + GF + GR + GA \text{ [dB]} \qquad (3)$$

Equation 3 contains four components; the first component is the distance attenuation G_D that is calculated by Okumura- Hata formula presented in [37]. The second component is the shadow fading G_F that is modeled as a log-normal distribution with standard deviation of 6 dB and 0 dB mean. The third component is the Rayleigh fading G_R that is modeled using a Rayleigh distribution. The forth component is the antenna gain G_A that adds the antenna gain in dB.

Adaptive service model is considered in our simulation. The service *i* is mainly characterized by its bit rate requirement, delay requirement and cost of services. The users are generated according to Poisson process. The service holding time is exponential distribution with mean holding time equals to 50 seconds.

The user profiles model specifics categories of users where users are divided into four categories according to the standard of living for them. The first category is a VIP users, the second one is a business users, the third one is a middle-income users and the last category is a standard users.

5. Results & Discussion

In this section, the used performance metrics and the simulation results of the different number of users are presented and discussed.

5.1 Performance Evaluation Metrics

The used performance metrics are presented in this subsection. Three performance evaluation metrics have been used to evaluate the performance of our algorithms and they are described briefly as follows [34]:

- Handover Failure Rate (P_{HFR}): a handover failure occurs when the handover is initiated but the target network does not have sufficient resources to complete it, or when the mobile terminal moves out of the coverage of the target network before the process is analyzed. P_{HFR} can be calculated as shown in equation 4.

$$P_{HFR} = \frac{Number\ of\ Unsuccessful\ Handover\ of\ Request}{Number\ of\ Handover\ Request} \quad (4)$$

- Percentage of satisfied users (P_{SU}): the percentage of users who are assigned to networks of their preference. This metric reflects the user point of view about the performance of the VHO process. P_{SU} can be calculated as shown in equation 5.

$$P_{SU} = \frac{Number\ of\ Users\ with\ Preferred\ Network\ for\ them}{Total\ Number\ of\ Users} \quad (5)$$

- Percentage of the low cost network (PLC): The usage percentage of the low cost network resources (i.e., WLAN).This metric reflect the operator point of view because it utilizes the resources of the high cost networks (i.e., WMAN and WWAN). Simply, *PLC* can be calculated as the percentage between the number of users in RAT with low cost network and the total number of users as shown in equation 6.

$$P_{LC} = \frac{Number\ of\ Users\ in\ Network\ with\ Low\ Cost}{Total\ Number\ of\ Users} \quad (6)$$

Two different reference algorithms are used to compare with our proposed algorithms. The first algorithm is a single-criterion RSS based VHO algorithm where the users are assigned to the network with higher signal strength.

The second algorithm is a multi-criteria based VHO algorithm where the SMART technique has been used to take multiple decision. The input criteria for the MCDM algorithm are the RSS, NLB, MSS, MC and UP.

5.2 Results

The simulation results of the different number of users are presented in this subsection. As shown by Figure 2, the reduction in the handover failure rate in the developed algorithm can be seen. For example, with 1186 users in the environment, the handover failure rate with the RSS based algorithm is 34.32%, 27.06 % with the SMART based algorithm, and 13.24% with the developed algorithm. The numerical values for P_{HFR} is shown in Table[1].

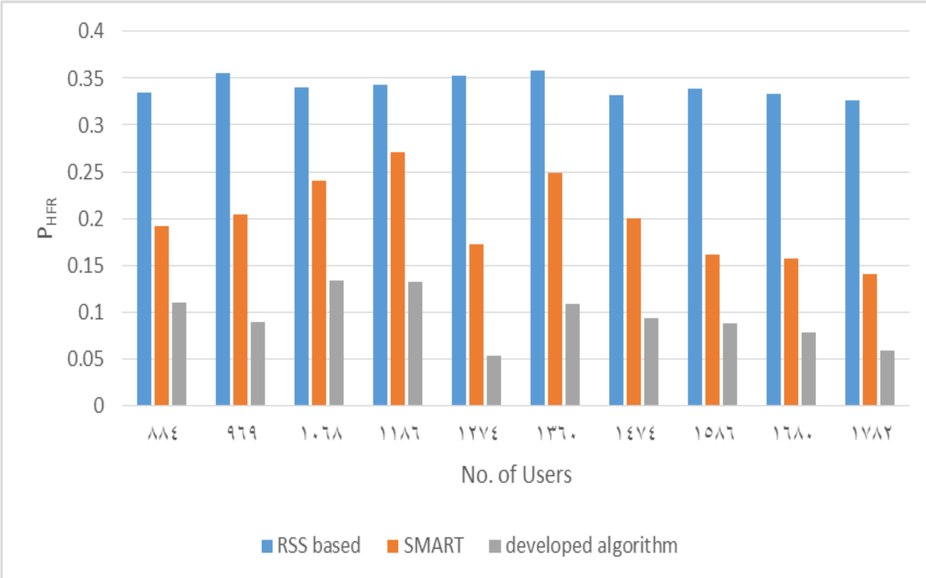

Figure (2): P_{HFR} values of developed algorithm and the reference algorithms

Table (1): The numerical values of P_{HFR} for developed algorithm and the reference algorithms

No. of Users	RSS based P_{HFR}	SMART P_{HFR}	developed algorithm P_{HFR}
884	0.334842	0.191176	0.109729
969	0.356037	0.204334	0.088751
1068	0.339888	0.240637	0.133895
1186	0.34317	0.270658	0.132378
1274	0.353218	0.1719	0.053375
1360	0.358824	0.248529	0.108088
1474	0.33175	0.200136	0.093623
1586	0.338588	0.161412	0.087011
1680	0.332738	0.157143	0.077381
1782	0.326599	0.140292	0.058361

As shown by Figure 3, the improvement in the percentage of the users who are assigned to the network of their preference in the developed algorithm can be seen.

For example, with 1360 users in the environment, the percentage of satisfied users with the RSS-based algorithm is 24.19%, 29.63 % with the SMART based algorithm, and 38.45% with the developed algorithm. The numerical values for P_{SU} is shown in Table [2].

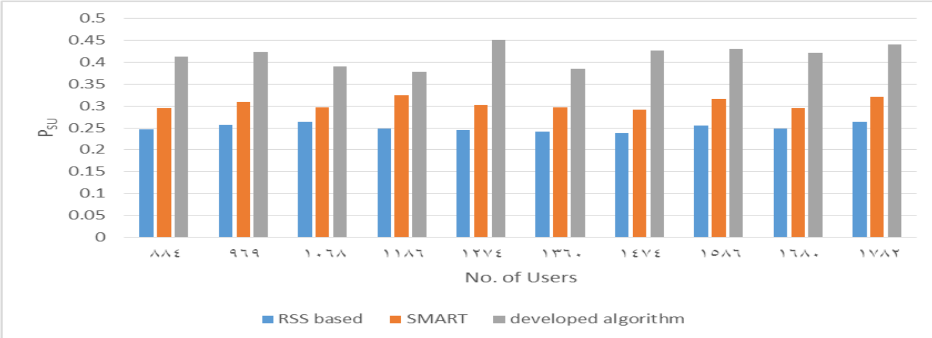

Figure (3): PSU values of developed algorithm and the reference algorithms

Table (2): The numerical values of P_{SU} for developed algorithm and the reference algorithms

No. of Users	RSS based P_{SU}	SMART P_{SU}	developed algorithm PSU
884	0.246606	0.295249	0.412896
969	0.256966	0.308566	0.423117
1068	0.264045	0.296816	0.390449
1186	0.248735	0.324621	0.378583
1274	0.244113	0.302198	0.452119
1360	0.241912	0.296324	0.384559
1474	0.238128	0.292402	0.42673
1586	0.25599	0.31652	0.431274
1680	0.247619	0.295833	0.422024
1782	0.26431	0.321549	0.441077

As shown by Figures 4, the improvement in the percentage of the users who are assigned to low cost networks (i.e. RAT_4) in the developed algorithm can be seen. For example, with 969 users in the environment, the percentage with the RSS based algorithm is 2%, 7% with the SMART based algorithm, and 21% with the developed algorithm. The numerical values for P_{SU} is shown in Table [3].

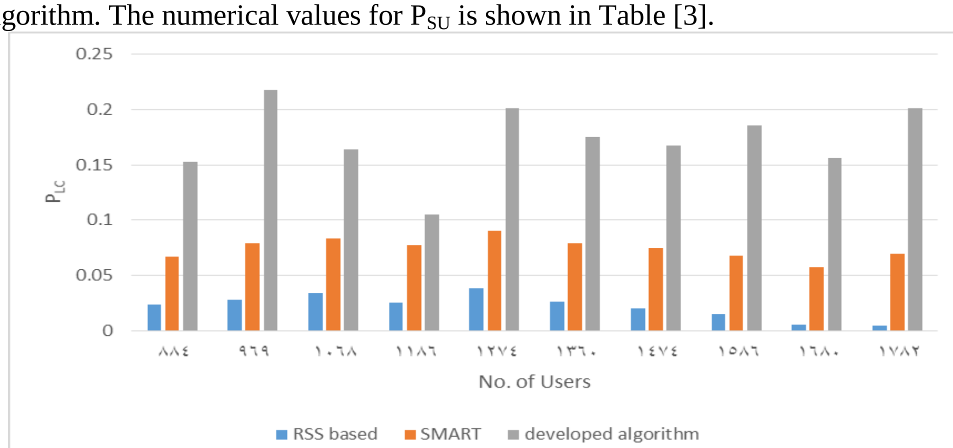

Figure (4): PLC values of developed algorithm and the reference algorithms

Table (3): The numerical values of PLC for developed algorithm and the reference algorithms

No. of Users	RSS based P_{LC}	SMART P_{LC}	developed algorithm P_{LC}
884	0.023756	0.066742	0.152715
969	0.027864	0.079463	0.21775
1068	0.033708	0.083333	0.163858
1186	0.025295	0.077572	0.105396
1274	0.038462	0.090267	0.201727
1360	0.025735	0.078676	0.175735
1474	0.019674	0.074627	0.167571
1586	0.015132	0.067465	0.185372
1680	0.005357	0.057738	0.155952
1782	0.004489	0.069585	0.201459

5.3 Discussion

In general, the results demonstrate a significant improvement over other reference algorithms in three performance evaluation metrics.

In the first metric (P_{HFR}) the developed algorithm achieves around 14% enhancement over the SMART based algorithm and around 21% over the RSS based algorithm. The second metric (P_{SU}) the developed algorithm achieves around 9% enhancement over the SMART based algorithm and around 14% over the RSS based algorithm. The third metric (P_{LC}) the developed algorithm achieves around 5% enhancement over the SMART based algorithm and around 19% over the RSS based algorithm.

6. Conclusions and Future Work

This paper proposes a generic and novel solution to solve the VHO problem. The developed solution is based on the elimination system and on the SMART multiple criteria decision making tool. The proposed solution avoids the processing delay caused by unnecessary computation over available networks which do not ensure connection performance.

This solution avoids increasing in the number of unnecessary handovers, ping pong effect, Blocking rate and dropping rate by reducing the handover failure rate. The solution can cope with the different viewpoints and goals. Also the solution uses the uncomplicated and straightforward SMART MCDM method, which makes it stronger and easier to use in a hybrid and more complex environment such as HWNs. The simulation results show that the proposed algorithm has a better and more robust performance over the several VHO reference algorithms.

This paper can be extended through: More VHO criteria could be involved such as network connection time and security. More performance evaluation metrics could be measured such as resource utilization, and call blocking and dropping probability. A global searching method such as genetic algorithm can be used to find an optimum values for the weights of the different criteria. This paper algorithm can be compared with more reference algorithms such as MSS-based algorithm.

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