Optimized Multi Criteria based Joint Admission Control for Heterogeneous Wireless Networks

Mohammed M. Alkhawlani
Faculty of Engineering
University of Science and Technology, Sana'a. Yemen
m.alshadadi@ust.edu

ABSTRACT: *Heterogeneous Wireless Network (HWN) is defined as a new type of wireless networks where anyone can communicate with anyone else, anywhere and anytime, or enjoy any service of any network operator, through any network of any service provider in the most efficient and optimal way according to the user criteria. The needs for supporting various applications and services and for providing ubiquitous coverage in the HWN require more complex and intelligent radio resource management techniques that enable the coordination among the different radio access technologies. This paper considers the most important radio resource management mechanism in HWN that is Joint Admission Control (JAC). JAC handles all new or handoff service requests in the HWN and checks whether the incoming service requests to be admitted. Then, it allocates the required resources and guarantees the Quality of Service (QoS) constraints for the service. This paper extends our work [1,2] and develops an optimized VIKOR decision support system based algorithm to address the JAC problem in the modern HWN networks. The proposed algorithm aims to decrease the influence of the dissimilar, imprecise, and contradictory measurements for the JAC criteria coming from different sources. It also utilizes the distinct features of Genetic Algorithms (GA) to setup a near-optimal values for the criteria importance weights. A performance analysis is done and the results are compared with traditional algorithms for JAC. These results demonstrate a significant improvement with our developed algorithm.*

Keywords: Joint Admission control, Heterogeneous Wireless Network, VIKOR, GA, Radio Resource Management

Received: 12 November 2014, Revised 28 December 2014, Accepted 7 January 2015

1. Introduction

The Heterogeneous Wireless Network (HWN) integrates different wireless networks into one common network. The integrated networks often overlap coverage in the same wireless service areas, leading to the availability of a great variety of innovative services based on user demands in a cost-efficient manner. The current Radio Resource Management (RRM) solutions and mechanisms for the wireless networks consider only the case of a single Radio Access Technology (RAT) where mobile users can only access that RAT and co-existed sub-networks can only be operated independently. The needs for supporting various applications and services and for providing ubiquitous coverage in the HWN require more complex and intelligent RRM techniques that enable the co-ordination among the different RATs.

Joint Admission Control (JAC) is a new common RRM mechanism that handles all new or handoff service requests in the HWN. It checks whether the incoming service request to the selected RAT by the initial access network selection algorithm or the vertical handover algorithm selection can be admitted. Then, it allocates the required resources and guarantees the QoS constraints for the service.

The authors in paper [3] propose a new call admission control scheme for Universal Mobile Telecommunications System (UMTS) and WirelessLocal Area Networks(WLAN) based heterogeneous networks, where the users relative preference for the WLAN changes adaptively based on the available resources in the WLAN and the location distribution of the cellular users. D. Qiang et al. in [4] propose a JAC scheme for multimedia traffic that exploits vertical handoffs as an effective tool to enhance radio resource management while guaranteeing handoff users QoS requirements. The network resources utilized by the vertical handoff user are captured by a link utility function. X. Li et al. in [5] propose an efficient joint session admission control scheme that maximize overall network revenue with QoS constraints over both the WLAN and the Code Division Multiple Access (CDMA)based cellular networks.

In paper [6] the authors propose admission-control algorithms for connection requests that consider the class of service and the type of user. Both horizontal and vertical handoffs have been considered, and suitable pre-emption rules have been defined for the real time and non real time connections. Authors have formulated a blocking/dropping cost-minimization problem following a joint connection- and packet-level QoS optimization approach. Paper [7] proposes a JAC algorithm to reduce the problem of unfairness. The proposed JAC algorithm makes call admission decisions based on mobile terminal modality, network load, and radio access technology terminal support index. The objectives of the proposed JAC algorithm are to reduce call blocking/dropping probability, and ensure fairness in allocation of radio resources among heterogeneous mobile terminals in heterogeneous networks. The authors in paper [8] propose a JAC and routing scheme for multiple service classes with the objective to maximize the overall revenue from all carried connections and to guarantee QoS constraints such as handoff dropping probability. The authors formulate the problem as a decision process, and apply optimization techniques to obtain the optimal admission control policies. Paper [9] considers optimizing the utilization of radio resources in a heterogeneous networks consisting of a WLAN and a CDMA network. The authors propose a JAC scheme for multimedia traffic that exploits vertical handoffs as an effective tool to enhance radio resource management while guaranteeing handoff users QoS requirements. A signalling cost is used to model the signalling and processing load incurred on the network when vertical handoff is performed.

In paper [10], the authors propose an optimal JAC in next generation wireless networks, and they study the impact of the different RATs radius coverage area in the system performance and optimal policy structure. The Semi-Markov Decision Process (SMDP) framework is used for modelling of the JAC proposed and the value iteration algorithm is used to compute the optimal policy. The authors in [11] propose JAC algorithm that admits an incoming call into two or more RATs. The residual bandwidths in the selected RATs are combined to support the incoming call, and the packet stream of the call is split among the selected RATs, thereby reducing call blocking/dropping probability. At the receiver, the split packet streams are then combined. The authors in [12] propose a joint uplink/downlink connection admission control scheme in WLAN/cellular integrated systems, where thresholds for admission control are adaptively determined to maximize the network capacity by considering uplink and downlink characteristics in WLAN/cellular integrated systems. The proposed scheme is evaluated by Markov chains in terms of blocking cost. The authors in [13] introduce a novel approach for combined joint call admission control and Dynamic Bandwidth Adaptation(DBA) for heterogeneous wireless networks. The JAC and DBA algorithms are realized tightly coupled and ensure that a maximum number of requested services can be supported by the cooperatively managed, wireless systems in the considered service area.Paper [14] studies the performance of admission control in Cognitive Radio Networks (CRNs). JAC that enables secondary users (SUs) to have access to the combined spectrum pool of the cooperating CRNs has been developed. Three JAC schemes are investigated and quantitatively analyzed using continuous-time Markov chain analysis. In paper [15], the authors mathematically formulate the problem of JAC, channel assignment and QoS routing to maximize the coverage of SUs in a cognitive radio cellular networks that supports multi-hop secondary transmissions, taking into account the interference constraints and QoS requirements from the PUs and admitted SUs. In paper [16], the authors propose a call admission control reservation algorithm that takes resource fluctuations into consideration. They consider two types of applications denoted by wide-band and narrow band. The performance of the algorithm is modelled through a queuing theory approach and its main performance measures are compared with a conventional algorithm through simulation. The authors in paper [17], propose an algorithm, which incorporates traditional Admission Control (AC) and Wiener Process (WP)-based prediction algorithms to determine when to carry out Access Service Network Gateway relocation. The authors further develop an analytical model to analyze the proposed algorithm. Paper [18] considers joint admission control and beam forming (JACoB) under a coordinated multi-cell MISO downlink scenario. The authors formulate JACoB as a user number maximization problem, where selected users are guaranteed to receive the QoS levels they requested. In paper [19] the authors consider the spectrum sharing multiple-input multiple-output (MIMO) cognitive radio network, in which single primary user (PU) coexists with multiple secondary users (SUs). In the proposed cross-layer design, the SINR target is dynamically adapted with channel condition and bit-error rate (BER) requirement, and works as admission control implicitly, that is, the cognitive link is dropped as long as its SINR requirement is equal to zero.

The authors in paper [20] consider the problem of joint admission control and resource allocation in a secondary code-division network coexisting with a narrow-band primary system. They try to find out the maximum number of admitted secondary links and the optimal transmitting powers and code sequences of those secondary links such that the total energy consumption of the secondary network is minimized.

2. JAC Solution

Our algorithm has two main components, the MCDM based component and the GA optimization component. Both components are described in the following two subsections.

2.1 MCDM Component

The JAC problem is a multi-criteria problem in nature. This nature has to be utilized to provide a multi-criteria based solution that can give better performance than the single criterion based algorithms due to the flexible and complementary nature of the different criteria. Considering only one or two criteria in the JAC solution is not sufficient to provide a good solution and usually leads to undesirable situations. For example, if the solution is based only on the received signal strength criterion, this can easily lead to congested RATs, many unsatisfied users, inefficient utilization for the Wireless Wide Area Networks (WWAN) links, and many other undesirable situations.

The used MCDM system for JAC has to rank the considered alternatives according to their attractiveness. It aims to a) achieve the highest number of satisfied users by reducing the average of blocked call requests, b) achieve the highest number of users who get better quality by reducing the average of dropped calls, and c) save the resources of high cost networks by increasing the usage of low cost network.

The proposed MCDM system has six input criteria which are the Received Signal Strength (RSS), the User Preferred Price (UPP), the Resources Availability (RA), the Bit Rate Requirements (BRR), The Delay Requirements (DR) and the Mobile Station Speed (MSS) criteria.

In this paper, VIKOR (the Serbian name is ***VIse Kri-terijumska Optimizacija Kompromisno Resenje***) MCDM method is used. The VIKOR method was mainly established by Zeleny [20] and later advocated by Opricovic and Tzeng [21] [22]. The VIKOR method was developed to solve MCDM problems with conflicting and non commensurable (different units) criteria. VIKOR assumes that compromising is acceptable for conflict resolution, the decision maker wants a solution that is the closest to the ideal, and the alternatives are evaluated according to all established criteria. In addition, VIKOR method is an effective tool, specifically applicable to those situations when the decision maker is not able, or does not know to express his/her preference at the beginning of the decision-making process. The steps of applying VIKOR method to JAC problem can be summarized as follows.

Step 1: Calculate the normalized value:assuming that there are m alternatives and n attributes. The j^{th} criteria performance against i^{th} alternative is denoted as xij. The normalized value of the criteria performance could be expressed as shown in formula 1.

$$F_{ij} = \frac{F_{ij}}{\sqrt{\Sigma_{j=1}^{n} F_{ij}^{2}}} \; i = 1, 2, 3, ...m; j = 1, 2, 3, ...n \qquad (1)$$

Step 2: Determine the best and worst values:for each criteria $j = 1, 2, 3, ...N$ determine the best value $bFij$ and the worst value $wFij$ given by:

$$ {}_{b}F_{ij} = (MaxF_{ij} | j \in N_b), (MinF_{ij} | j \in N_c) \quad (2) $$

$$ {}_{w}F_{ij} = (MinF_{ij} | j \in N_b), (MaxF_{ij} | j \in N_c) \quad (3) $$

where N_c is the set of cost criteria and N_b is the set of benefit criteria. If all attributes are benefit criteria, their best and worst values can be calculated using the simplified equations 4 and 5.

$$ {}_{b}F_{ij} = MaxF_{ij} \; i = 1, 2, ...m \quad (4) $$

$$ {}_{w}F_{ij} = MinF_{ij} \; i = 1, 2, ...m \quad (5) $$

Step 3: Compute the distance of alternatives to ideal solution: This step is to calculate the distance from each alternative to the positive ideal solution and then get the sum to obtain the final value according to formula 6 and 7.

$$ S_i = \sum_{j=1}^{n} w_j \frac{{}_{b}F_{ij} - F_{ij}}{{}_{b}F_{ij} i - {}_{w}F_{ij}} \quad (6) $$

$$ R_i = max_j \left[w_j \; \frac{{}_{b}F_{ij} - F_{ij}}{{}_{b}F_{ij} i - {}_{w}F_{ij}} \right] \quad (7) $$

where S_i represents the distance rate of the i^{th} alternative to the positive ideal solution, R_i represents the distance rate of the i^{th} alternative to the negative ideal solution and w_j is the importance weight of attribute *j*.

Step 4: Calculate the VIKOR values Q_i for $i = 1, 2, \ldots m$, which are defined as:

$$ Q_i = \upsilon \left[\frac{S_i - {}_{b}S_i}{{}_{w}S_i - {}_{b}S_i} \right] + (1 - \upsilon) \left[\frac{R_i - {}_{b}R_i}{{}_{w}R_i - {}_{b}R_i} \right] \quad (8) $$

υ is the is the weight of the strategy of the majority of criteria. $1 \geq \upsilon \geq 0$. When the is larger ($\upsilon \geq 0:5$), the index of *Qi* will tend to majority agreement; when is less ($\upsilon \leq 0:5$), the index *Qi* will indicate majority negative attitude. In general, = 0:5, i.e. compromise attitude of evaluation experts.

$$ {}_{b}S = Min \, S_j \; i = 1, 2, ... \, m \quad (9) $$
$$ {}_{w}S = Max \, S_j \; i = 1, 2, ... \, m \quad (10) $$
$$ {}_{b}R = Min \, R_j \; i = 1, 2, ... \, m \quad (11) $$
$$ {}_{w}R = Max \, R_j \; i = 1, 2, ... \, m \quad (12) $$

2.2 The Genetic Algorithm (GA) Component

The GA has been used in our scheme to help the usersor network operator to find suitable values for the importance weight of attributes *wj* in the offline mode. In our study, the GA is used to overcome one of the MCDM drawbacks, which is the finding of suitable weights for thedifferent criteria. The following points summarize the mainadvantages of applying the GA to the JAC problem.

(i) GA can deal with the large number of variables andthe complex search space included on the JAC criteria
weights with high probability of success in findingoptimal, near optimal, or at least good solution.
(ii) GA can handle the different constraints and objectivesof the JAC criteria weights.
(iii) GA does not require derivative information, whichcan help out in the user-centric algorithm where notenough data is existed due to the limitation of storagein the mobile terminal.
(iv) GA is less likely to be trapped by local optimal minimaor maxima.
(v) GA works with numerically generated data, experimentaldata, or analytical functions. This can givedifferent options when designing the JAC algorithm.

Beside the GA advantages mentioned above, our decision to use GA was based on the nature of our objective functions thathave several dynamic and stochastic components, where anyother derivative-based optimization method cannot performwell. Another important issue that encouraged the selectionof GA to our problem is the high interaction betweendifferent variables. At the end, usually the GA is not used tofind an optimal solution andmost of the time it is consideredas a very promising option to find good and acceptablesolution. It is worthy tomention that GA is not used on everyJAC decision. It is optional component on the schemewhere the user can use it or not in offline mode prior to the decision process.

Since the JAC is a multi-criteria problem in nature,different objectives need to be optimized. In this paper, a multi-objective function is proposed to cover thedifferent and opposite objectives and requirements of theusers, QoS and operators. The weights of the input criteria *wj* have been encoded using real encoding method. The length of thereal-valued encoding is 4 real floating numbers. The length ofeach floating number is depending on the internal precisionand roundoff used by the computer to define the precision of the floating numbers.The results achieved by extensive comparisons of GAperformance as a function of the different GA parameters(i.e., the population size, themutation rate, and the crossoverfraction) and the different GA operators (i.e., the selection and crossover operators) have been summarized by R.L. Haupt and S. E. Haupt [23]. They have concludedthat crossover fraction, selection operator, and crossoveroperator are not of much importance. On the other side,the population size and the mutation rate have the mostsignificant impact on the ability of the GA to find betterminimum value for objective function.

Based on that, several sets of experiments to determinegood population size and mutation rate for our proposedobjective function have been carried out. Each experimenthas been repeated several iterations while the performance is recorded. The results from all the iterations are then combinedby calculating the average (and standard deviation)for each experiment. Usually, testing GAs includes mainlytwo issues; how far the result obtained by GA is from thebenchmark results, which can be measured by average fitnessvalue. The second issue is how fast GA is in finding the bestsolution, which can be measured by the total number offunction evaluations. Since our GA is working offline, onlythe average best fitness value achieved by the GA is used. Theaverage best fitness and the standard deviation are plottedagainst the tested parameters.When studying a parameter allthe other parameters and operators are kept constant.

Only a sample for the experiments results achieved isgiven in this paper as shown in Figure 1. The lower plotin Figure 1 shows the means and standard deviations of the ObjFun function best fitness values over 20 runs, foreach of the values of the population sizes between 10 and100 with step size equals to 10 individuals. The upper plotshows a color-coded display of the best fitness values in eachrun where dark colour indicates better results. For ObjFun fitness function, setting the population size to 20 individualsor more yields better result. Based on these results,the population size chosen in our GAs has been set to 20.Other sets of experiments have been carried out to determine a suitable mutation rate. Based on the experiments, themutation rate has been set to 0.1.

In addition, our GA uses a roulette selection function. Toensure elitism, the number of individuals that are guaranteed to survive to the next generation has been set to 4 individuals.It uses two-point crossover function and a uniformmutationfunction. The GA terminates if the maximum numberof the GA iterations reaches to 300 iterations, if there is no improvement in the best fitness value for number ofconsecutive generations equals to 100 generation, or if there is no improvement in the best fitness value for an interval oftime equals to 300 seconds.

3. Simulation Models

A modified version of MATLAB based simulator called RUNE [24] has been used. Our models developed in [25] have been updated to be used in this work. The simulation environment defines a system model, services model, a mobility model, and a propagation model.

The system model specifies the type of networks and the number and characteristics of the cells. Our system model considers the coexistence of six types of RATs. The characteristics of the RATs are summarized in Table 1. The services model specifies the type of services and their percentages of use in the system environment. Four types of services have been considered in our simulation. These services are mainly characterized by their Bit Rate Requirements (BRR) and one-way end-to-end Delay Requirements (DR). The first service type needs low bit rate and low propagation delay such as speech and voice. The second service type needs medium bit rate and low propagation delays such as low bit rate real time video telephony. The third service type needs medium bit rate and medium propagation delay such as high bit rate streaming video. The forth service type needs high bit rate and it can accept high propagation delay such as non-real time data traffic. Table 2 summarizes practical values for

RBR and PDR characteristics of the considered services [26], [27].

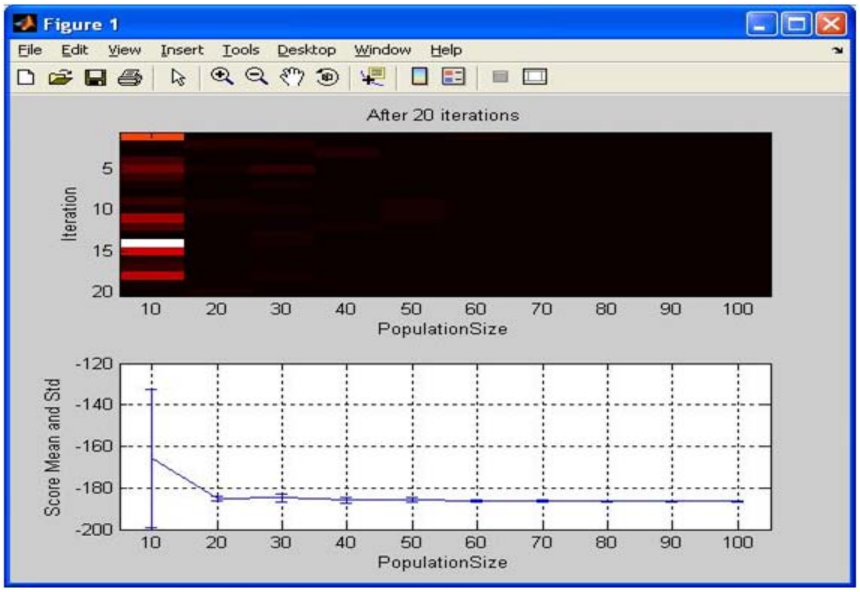

Figure 1: The effect of population size on objective function

RAT No.	Multiple Access Type	Antenna Type	Cell Radius	Number of Cells
RAT1	CDMA/WWAN	Omni-directional	1000m	7
RAT2	CDMA/WMAN	Omni-directional	500m	12
RAT3	CDMA/WLAN	Omni-directional	100m	27
RAT4	TDMA/WWAN	Omni-directional	800m	3
RAT5	TDMA/WMAN	Omni-directional	500m	7
RAT6	TDMA/WLAN	Omni-directional	50m	84

Table 1. System models details

ServiceType	BRR value(kbps)	DR value(ms)	Service type example
First Type	12.2	200	speech and voice
Second Type	64	600	real time video telephony
Third Type	144	400	streaming video
Forth Type	384	1400	non-real time data traffic

Table 2. The services characteristics

The users of all four services are generated according to the Poisson process. The service holding time is exponential distribution with a mean holding time equal to 50 seconds. The mobility model simulates the mobility of the users in the system environment. In our mobility model, 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 i^{th} mobile is updated according to equation 13.

$$V_i = V_{i-1} . P + \sqrt{1-P^2} . V_m . X \qquad (13)$$

where V_i is the complex speed [m/s]. V_{i-1} is the complexspeed in the previous time step. X is a Rayleigh distributedmagnitude with mean 1 and a random direction. V_m is the mean speed of mobiles. P is the correlation of the velocitybetween 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 5 [m/s] and the mean acceleration has been set to 1[m/s^2].

The propagation model simulates the different losses andgains during the signal propagation between the transmitterand the receiver in the system environment. The wireless propagationmodel used in this paper is described in a logarithmicscale as in equation 14.

$$G = G_D + G_F + G_R + G_A \qquad (14)$$

Equation 14 contains four components, the first component isthe distance attenuation *GD* that is calculated by Okumura-Hata formula. The second component is the shadow fading *GF* that is modelled as a log-normal distribution with standarddeviation of 6 dB and 0 dB mean. The third component isthe Rayleigh fading *GR* that is modelled using a Rayleigh distribution. The forth component is the antenna gain *GA* that adds the antenna gain in dB.

4. Performance Evaluation

In this section, the first subsection describes the used reference algorithms and performance metrics. In the second subsection, some results are presented and analyzed.

4.1 Reference Algorithms and Performance Metrics

Three different alternative algorithms are simulated and evaluated against the proposed solution. The first alternative algorithm does not take into account the JAC concept (it is denoted as NJAC) and the local RRM entities take the full responsibility to admit or reject the users. The second reference algorithm is denoted as Load-based JAC (LJAC) and it selects the least loaded RAT for new or handoff request. Finally, the third algorithm selects the RAT in which the mobile measures the strongest received signal strength, and it is denoted as Signal Strength JAC (SSJAC). In all the three cases, once the RAT has been selected, the bandwidth assigned to each user is the maximum bandwidth considered for this RAT for this type of service.

The performance of the proposed JAC algorithm is evaluated using three performance evaluation metrics. The used metrics can be described briefly as follows.

- Blocking probability (P_b) is defined as the ratio of the number of blocked users to the total number of new users requesting admission. A user is blocked if at the session start the JAC algorithm assigns a bit rate of 0 kb/s.

- Outage probability (P_o) is calculated as the ratio of the number of users not fulfilling their Guaranteed Bit Rate (GBR) requirement, to the total number of admitted users.

- Unsatisfied user probability (P_u) that could be calculated based on P_b and P_o as shown in equation 15.

$$P_u = 1 - (1 - P_b)(1 - P_o) \qquad (15)$$

Using the mentioned reference algorithms and performance metrics, some simulation results for different sets of users are presented in the current section.

4.2 Results Study

Table 3 and Figure 2 illustrate some numerical results for the *Pb* values in all algorithms. The results show that our non-optimized solution achieve good performance enhancement over other reference algorithms. On average, our algorithm achieves around 6%, 4%, and 4% enhancement over NJAC, LJAC, and SSJAC algorithms respectively. Better results also gained by using suitable weights achieved from the GA component.

Table 4 and Figure 3 illustrate some numerical results for the *Po* values in all algorithms.The results show that our non-optimized solution achieve good performance enhancement over other reference algorithms. On average, our algorithm achieves around 13%, 2%, and 3% enhancement over NJAC, LJAC, and SSJAC algorithms respectively. Better results also gained by using suitable weights achieved from the GA component.

No. Of Users	Non-optimized solution	Optimized solution	NJAC solution	LJAC solution	SSJAC solution
50	0.013	0.009	0.061	0.033	0.041
150	0.045	0.038	0.094	0.053	0.084
250	0.083	0.081	0.133	0.091	0.114
350	0.101	0.10)	0.133	0.122	0.142
450	0.123	0.123	0.171	0.164	0.163
550	0.134	0.122	0.192	0.193	0.184
650	0.174	0.168	0.224	0.221	0.203
750	0.192	0.190	0.253	0.252	0.230
850	0.234	0.225	0.294	0.283	0.264
950	0.232	0.231	0.310	0.304	0.283

Table 3. *Pb* values in all algorithms

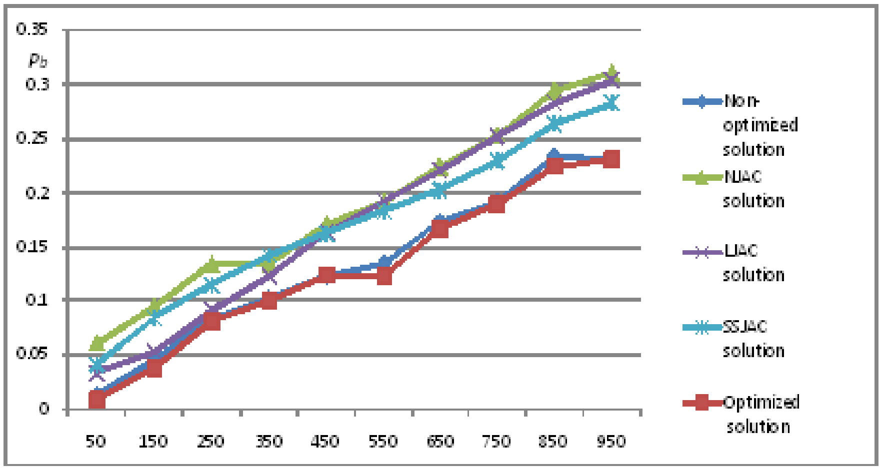

Figure 2: *Pb* values for all algorithms

No. Of Users	Non-optimized solution	Optimized solution	NJAC solution	LJAC solution	SSJAC solution
50	0.031	0.028	0.073	0.05	0.06
150	0.070	0.069	0.104	0.08	0.09
250	0.113	0.111	0.151	0.13	0.14
350	0.154	0.144	0.182	0.16	0.16
450	0.195	0.191	0.213	0.20	0.2
550	0.223	0.212	0.234	0.23	0.22
650	0.241	0.229	0.271	0.26	0.25
750	0.251	0.250	0.310	0.27	0.26
850	0.274	0.268	0.351	0.30	0.32
950	0.290	0.278	0.402	0.33	0.41

Table 4. *Po* values in all algorithms

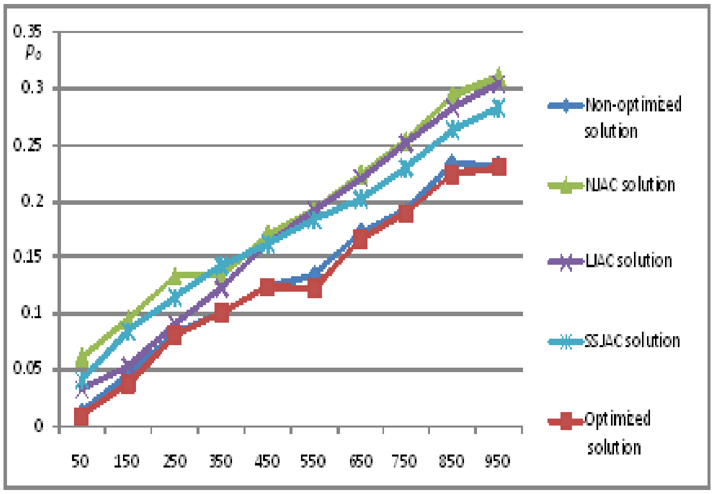

Figure 3:P_o values for all algorithms

Table 5 and Figure 4 illustrate some numerical results for the *Pu* values in all algorithms. The results show that our non-optimized solution achieve good performance enhancement over other reference algorithms. On average, our algorithm achieves around 7%, 3%, and 5% enhancement over NJAC, LJAC, and SSJACalgorithms respectively. Better results also gained by using suitable weights achieved from the GA component.

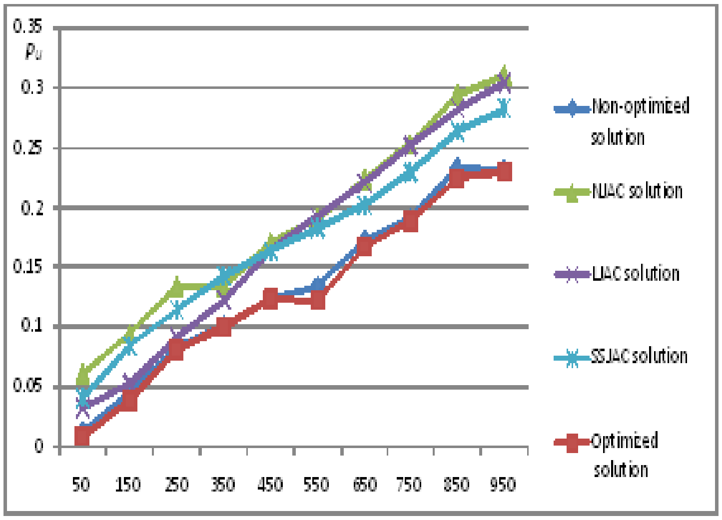

Figure 4:*Pu* values for all algorithms

Our algorithm has been simulated in ten different numbers of users. Although it achieves good enhancement with respect to the different performance metrics, no clear monotonic de-creasing or increasing relationship could be directly observed between the number of users and the performance metrics. Because it is too complex and meaningless to keep increasing the number of users in the simulation; some statistical indicators such as the arithmetic means, standard deviations, and correlation coefficients could be used to predict the behaviours of the algorithms on the future based on the achieved results.

The Pearsons Correlation Coefficient (PCC) is one of the most powerful statistical indicators that is used to check if there is any linear relationship between the number of users and the achieved performance metrics. PCC investigates the strength and direction of a linear relationship between two random variables. PCC = +1 means very strong positive linear relationship. PCC = -1 means very strong negative linear relationship. PCC = 0 means no linear relationship is existed between both variables. Our results shows that the values of the PCC are all around +1 which means very strong positive linear relationship and we hence expect that our algorithm will keep outperforming the other algorithms at very high number of users.

No. Of Users	Non-optimized solution	Optimized solution	NJAC solution	LJAC solution	SSJAC solution
50	0.041	0.040	0.133	0.081	0.100
150	0.112	0.108	0.184	0.131	0.161
250	0.184	0.175	0.262	0.210	0.234
350	0.244	0.240	0.291	0.262	0.284
450	0.292	0.279	0.344	0.334	0.332
550	0.322	0.310	0.380	0.383	0.362
650	0.371	0.333	0.432	0.424	0.401
750	0.394	0.375	0.481	0.451	0.431
850	0.443	0.435	0.541	0.502	0.503
950	0.450	0.430	0.593	0.532	0.583

Table 5. *Pu* values in all algorithms

5. Conclusions and Future Work

This work explores the issue of JAC in the HWN. It presents a new JAC algorithm that has been designed, implemented and evaluated. The developed JAC solution attempt to increase the user satisfaction and guarantee the QoS constraints. Our developedalgorithm is simulated, evaluated, and compared withthree reference algorithms using three different performance metrics. Better blocking and dropping call rates have been achieved using our algorithms. Accordingly, higher satisfied users is also achieved. All the statistical indictors show that our algorithm will keep performing around the mean values of the achieved results.

Different aspects of our work can be further developed.Firstly, The relationship between the JAC and the otherCRRM mechanisms such as joint load control and vertical handover can be investigated to achieve a joint optimizationof these mechanisms and enhance overall system performance.In addition, this study has developed generic JAC algorithm.The developed algorithm can be tailored to specific wirelessstandards such as UMTS, IEEE802.16, and IEEE802.11.

References

[1] Alkhawlani, M. M. (2012). Multi Criteria based Joint Admission Control for Heterogeneous Wireless Networks, Journal of Science & Technology, 17 (2), p. 69- 76.

[2] Alkhawlani, M.M. (2012). MCDM based Joint Admission Control for Heterogeneous Wireless Networks, Seventh International Conference on Computer Engineering & Systems (ICCES), p. 3 - 8, Nov. 2012

[3] Kyung Kim, D., Griffith, D., Golmie, N. (2010). A New Call Admission Control Scheme for Heterogeneous Wireless Networks. IEEE Transactions on Wireless Communications, 9(10), p. 3000 – 3005, October.

[4] Qiang, D. Bo, H., Yan, S., Shan-zhi, C. (2010). Joint Admission Control through Vertical Handoffs in Heterogeneous Wireless Network, Global Mobile Congress (GMC), p. 1-5, November

[5] Li, X., Ji, H., Si, P., Zhang, L. (2010). Joint session admission control scheme in integrated WLAN and 3G networks, 5th International CST Conference on Communications and Networking in China (CHINACOM 2010), p.1-5, August.

[6] Stevens-Navarro, E., Shah-Mansouri, V., Wong, V. W. S. (2010). Handoff Management and Admission Control Using Virtual Partitioning With Preemption in 3G Cellular/802.16e Interworking, IEEE Transactions on Vehicular Technology, p.431-445.

[7] Falowo, O. E., Chan, H. A. (2010). Joint Call Admission Control Algorithm for Fair Radio Resource Allocation in Heterogeneous Wireless Networks Supporting Heterogeneous Mobile Terminals, 7th IEEE Consumer Communications and Networking Conference(CCNC-2010), p.1-5.

[8] Zhang, S., Yu, F. R., Leung, V. C. M. (2010). Joint Connection Admission Control and Routing in IEEE 802.16-Based Mesh Networks, IEEE Transactions on Wireless Communications, p.1370 - 1379.

[9] Deng Qiang., Hu Bo., Shi Yan., Chen Shan-zhi., (2010). Joint Admission Control through Vertical Handoffs in Heterogeneous Wireless Networks, 6th International Conference on Wireless Communications Networking and Mobile Computing (WiCOM2010) , p.1 - 4.

[10] Coutinho, R.W. L., Coelho, V. L., Costa, J. C.W. A., Carvalho, G.H.S. (2010). Opti-mal Policy for Joint Call Admission Control in Next Generation Wireless Networks, 2010 International Conference on Network and Service Management (CNSM), pp.214 - 217.

[11] O. E. Falowo. (2010). Joint Call Admission Control Algorithm for Reducing Call Blocking/dropping Probability in Heterogeneous Wireless Networks Supporting Multihoming, 2010 IEEE GLOBECOM Workshops (GC Wkshps) , pp.611 - 615, 2010

[12] Hyung-Taig Lim., Younghyun Kim., Sangheon Pack., Chul-HeeKang., (2011). Joint Uplink/Downlink Connection Admission Control in WLAN/Cellular Integrated Systems, 2011 Fifth International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS) , p.470 - 474.

[13] Klein, A., Lottermann, C., Mannweiler, C., Schneider, J., Schotten, H. D. (2011). A Novel Approach for Combined Joint Call Admission Control and Dynamic Bandwidth Adaptation in Heterogeneous Wireless Networks, 7th EURO-NGI Conference on Next Generation Internet (NGI), p.1-8.

[14] Jin, L., Dutkiewicz, E., Ping Liu, R., Vesilo, R., (2011). Joint Admission Control for Cooperative Cognitive Radio Networks," Sixth International ICST Conference on Cognitive Radio Oriented Wireless Networks and Communications (CROWNCOM2011) , p.276 - 280.

[15] Qin Xin., Xin Wang., Jiannong Cao., Wei Feng. (2011). Joint Admission Control, Channel Assignment and QoS Routing for Coverage Optimization in Multi-hop Cognitive Radio Cellular Networks," IEEE 8th International Conference on Mobile Adhoc and Sensor Systems (MASS 2011), p.55 - 62.

[16] Khabazian, M., Kubbar, O., Hassanein, H. (2012). Call Admission Control with Resource Reservation for Multi-service OFDM Networks, 2012 Inter-national Conference on Computing, Networking and Communications (ICNC), p.781-785, Feb.

[17] Hoi-To Wai., Wing-Kin Ma., (2012). A decentralized method for joint admission control and beam forming in coordinated multicell downlink, The Forty Sixth IEEE Conference on Signals, Systems and Computers, November, p. 559 – 563

[18] Huiqin Du., Ratnarajah, T. (2012). Joint admission control and beam forming with adaptive modulation for cognitive radio network, 2012 IEEE International Conference on Communications (ICC), June, p. 4648 – 4652

[19] KankeGao., Ozdemir, O., Pados, D. A., Batalama, S. N. (2012). Joint admission control and resource allocation in cognitivecode-division networks, IEEE 13th International Workshop on Signal Processing Advances in Wireless Communications (SPAWC), June, p. 149 – 153

[20] Zeleny, M. (2002). Multiple Criteria Decision Making, (McGraw Hill, New York.

[21] Opricovic, S., Tzeng, G. H., Compromise Solution by MCDM Methods: A Comparative Analysis of VIKOR and TOPSIS, European Journal of Operational Research, 156, pp 445-455

[22] Opricovic, S., Tzeng, G. H. (2007). Extended VIKOR Method in Comparison with Outranking Methods, European Journal of Operational Research, 178, p 514-529.

[23] Haupt, R., Haupt, S. (2004). Practical Genetic Algorithms, John Wiley and Sons, 2nd Edition, 2004.

[24] Zander, J., Kim, S. (2001). Radio Resource Management for Wireless Networks, Artech House.

[25] Mohammed, M., Alkhawlani. (2011). Intelligent Vertical Handover for Hetero-gonous Networks Using FL And ELECTRE," International Journal of Computer Networks and Communications (IJCNC), 3 (4), July.

[26] Holma, H., Toskala, A. (2004). WCDMA for UMTS Radio Access for Third Generation Mobile Communications, John Wiley and Sons Ltd, West Sussex, England.

[27] 3GPP Technical Specifications TS 23.107, Quality of Service (QoS) concept and architecture (Release 6), 6.3.0, June 2005