Application of SMART, TOPSIS, and VIKOR Systems in Joint Admission Control

Mohammed M. Alkhawlani

Abstract- ***Joint Admission Control (JAC) handles the admis-sion of all new or handoff service requests in the mod-ern heterogeneous networks and allocates the required resources and guarantees the QoS constraints for the service. JAC is a multi-criteria problem in nature, and the usage of MCDM system is mandatory to decrease the influence of the dissimilar, imprecise, and contra-dictory measurements for the JAC criteria coming from different sources. In this paper, three different decision support systems are developed to address the JAC problem in the modern heterogeneous networks. These systems use SMART, TOPSIS, and VIKOR MCDM methods. Illustrative numerical examples for the devel-oped systems are presented. The examples show that the choice of the MCDM tool can directly affect the ranking order of the available access networks, and hence, the selection of the MCDM methods is highly critical in any JAC solution.***

Keywords- ***Joint Admission Control (JAC), heterogeneous networks, QoS, MCDM, TOPSIS, VIKOR MCDM methods.***

I. INTRODUCTION

The Heterogeneous Wireless Network (HWN) com-bines different wireless networks into one common network to utilize 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) 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. Paper [1] studies the performance of admission control in cognitive radio networks (CRNs). The au-thors propose a CRN architecture featuring cooperation among several CRNs in the same geographical area. Three joint admission control schemes are investi-gated and quantitatively analyzed using continuous-time Markov chain analysis. The authors in [2] aim to design an OFDMA frame-based resource allocation scheme allowing the power consumption minimization, the throughput enhancement and the queue’s stability.

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Mohammed M. Alkhawlani, Faculty of Science and Engineering, University of Science and Technology, Sanaa, Yemen.

They have proposed a novel proportional fairness admission control strategy in order to guarantee the desired QoS for each user. In paper [3], the authors first reformulate the problem of Joint power and admission control as a sparse minimization problem and then relax it to a linear program (LP). Then, they derive an easily-checkable necessary condition for all links in the network to be simultaneously supported at their target SINR levels, and use it to iteratively remove strong interfering links. The authors in paper [4] pro-pose a common framework to jointly study dynamic base station operation and user equipment admission and, they introduce a novel concept of BS admission control, and propose an optimal joint BS-UE admission control scheme considering both dynamic BS operation and dynamic UE traffic. The proposed scheme can maximize energy efficiency while guaranteeing user QoS. To ensure maximum operator gain and optimized system performance, the authors in paper [5] propose a solution to handle diverse user service requests, rang-ing from voice only to bandwidth-consuming stream-ing services, collaboratively by a combined, heuristic Joint Call Admission Control (JCAC) and Dynamic Bandwidth Adaptation (DBA) approach. A cognitive VAN gateway is designed to meet requirements of the heterogeneous network in paper [6] . The mul-tichannel joint rate and admission control (MJRAC) with better quality of services (QoS) is proposed in multi-channel VAN scenarios based on the joint rate and admission control (JRAC) method. For a joint power and admission control in a cellular cognitive radio network, the authors [7] derive a simple one-to-one relation between the signal-to-interference-plus-noise ratio (SINR) vector and its corresponding power vector of all users, and based on this they propose two new admission metrics. Then, in an infeasible system, where the minimum acceptable target-SINRs for all primary and secondary users are not simultaneously reachable, two centralized algorithms are proposed. Paper [8] considers the chance (probabilistic) SINR constrained Joint power and admission control (JPAC) problem, where each link’s SINR outage probability is enforced to be less than or equal to a given tolerance. Authors handle the computationally intractable chance SINR constraints by doing sample approximations. In paper [9], a utility-based joint power and admis-sion control (U-JPAC) algorithm is presented for data networks, in order to allocate radio resources in an efficient manner to the requesting links, while the in-terference constraints are not violated and considering the total utility of secondary users as the objective. Paper [10] solves the problem of long-term revenue maximization of a spectrum database operator, through joint pricing of spectrum resources and admission control of secondary users. The authors formulate the problem as a stochastic dynamic programming problem, and consider the optimal solutions under both static and dynamic

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prices. In paper [11], the authors formulate the admission control problem as a Semi-Markov Decision Process (SMDP) and present a Lin-ear Programming (LP) based solution approach. The authors develop a novel femtocell power adaptation algorithm, which can be implemented in a distributed manner jointly with the proposed admission control scheme. Paper [12] studies the performance of admis-sion control in cognitive radio networks (CRNs). The authors propose a CRN architecture featuring cooper-ation among several CRNs in the same geographical area. Joint Admission Control (JAC) enables secondary users (SUs) to have access to the combined spectrum pool of the cooperating CRNs. Paper [13] considers the spectrum sharing multiple-input multiple-output (MIMO) cognitive radio network, in which single pri-mary user (PU) coexists with multiple secondary users (SUs). Joint beamforming and admission control with adaptive modulation technique is designed to maximize the number of the serviced SUs and the transmit rate of the secondary links while imposing upper limits on the interference temperature to the PU by using the least transmit power. The authors [14] consider the problem of joint admission control and resource allocation in a secondary code-division network coexisting with a narrow-band primary system. Their objective is to find the maximum number of admitted secondary links and then find the optimal transmitting powers and code sequences of those secondary links such that the total energy consumption of the secondary network is minimized subject to the conditions that primary inter-ference temperature constraints, secondary Signal-to-Interference-plus-Noise Ratio (SINR) constraints and secondary peak power constraints are all satisfied. In paper [15], the authors propose the use of transport-layer data Admission Control (AC) in each Femto User Equipment (FUE) as well as interference-aware Resource Allocation (RA) in each base station to manage the inter-cell interference. They formulate the problem as a constrained Markov decision problem which aims at maximizing the time average throughput of the entire FC tier subject to queue stability con-straint for each FUE. And Then, the propose a Joint Admission Control and Resource Allocation (JACRA) algorithm to obtain the optimal AC and RA policies. The authors [16] presented a centralized new linear programming deflation (NLPD) algorithm for the joint power and admission control problem. The authors develop a distributed implementation of the NLPD algorithm that uses the projected alternate Barzilai-Borwein (PABB) algorithm with the continuation tech-nique to carry out power control. An JAC solution for modern heterogeneous net-works is proposed in section II where three different MCDM methods have been used. Illustrative Numeri-cal Examples for all proposed algorithms are presented in section III. The conclusions and future works are presented in section IV.

II. JAC SOLUTION

The JAC MCDM based solution has to rank the considered alternatives according to their attractive-ness. For simplicity and without loss of generality, three alternatives are considered by the MCDM, the first one is a WWAN network, the second one is a WMAN network, and the third one is WLAN network. Also, six input criteria for MCDM are considered which are, Mobile Station Speed (MSS), Received Signal Strength (RSS), Service Type (ST), User Pre-ferred Price (UPP), Resource Availability (RA), and Security (SEC). The alternatives performance scores against criteria are “RSS_1, “RSS_2, “RSS_3, “MSS_1, “MSS_2,“MSS_3, “ST_1, “ST_2,“ST_3, “PR_1, “PR_2, “PR_3 , “RA_1, “RA_2,“RA_3, “SEC_1, “SEC_2, and “SEC_3.

2.1. The SMART MCDM

Simple Multi-attribute Rating Technique (SMART) is one of the simplest MCDM methods. The SMART employs a relatively uncomplicated and straightfor-ward manipulation method. SMART can be quickly and easily understood by inexperienced decision mak-ers. This method utilizes simple utility relationships. Each alternative A_j has a ranking value X_j that is obtained simply as the weighted algebraic mean of the utility values a_{ij} associated with it according to equation 1.

$$x_j = \frac{\sum_{i=1}^{m} w_i a_{ij}}{\sum_{i=1}^{m} w_i} j = 1, 2, ...n \tag{1}$$

Equation 2 shows the alternatives performance scores matrix “Alts” for the MCDM.

$$Alts = \begin{pmatrix} RSS_1 & RSS_2 & RSS_3 \\ MSS_1 & MSS_2 & MSS_3 \\ ST_1 & ST_2 & ST_3 \\ UPP_1 & UPP_2 & UPP_3 \\ RA_1 & RA_2 & RA_3 \\ SEC_1 & SEC_2 & SEC_3 \end{pmatrix} \tag{2}$$

The criteria weights matrix CW is shown in equation 3.

$$CW = \begin{pmatrix} W_s & W_v & W_t & W_u & W_r & W_e \end{pmatrix} \tag{3}$$

W_s is the assigned weight for the RSS criterion, W_v is the assigned weight for the MSS criterion, W_t is the assigned weight for the ST criterion, W_u is the assigned weight for the UPP criterion, W_r is the assigned weight for the RA criterion, and W_e is the assigned weight for the SEC criterion. The criteria weights can be real or integer numbers. For real-value weights, they should be between [0,1] and they are subject to the constraint stated in equation 4.

$$W_s + W_v + W_t + W_u + W_r + W_e = 1 \tag{4}$$

The weights are usually assigned manually accord-ing to the experience of the decision makers about the importance of each criterion. The ranking value (i.e. the total score) of WWAN network X_W , the ranking value of WMAN network X_M and the ranking value of WLAN network X_L are calculated according to equations 5, 6 and 7 respectively.
where TW is the total weight and is calculated using equation 8.

$$TW = W_v + W_s + W_t + W_u + W_r + W_e \tag{8}$$

2.2. The TOPSIS MCDM

TOPSIS (Technique for Order Preference by Sim-ilarity to Ideal Solution) is a widely used MCDM algorithm developed by Yoon and Hwang [20]. The algorithm

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calculates perceived positive and negative ideal solutions based on the range of attribute values available for the alternatives. The best solution is the one with the shortest distance to the positive ideal solution and longest distance from the negative ideal solution, where distances are measured in Euclidean terms. The decision problem can be concisely expressed in the normalized decision matrix shown in equation 9

$$NDM = \begin{pmatrix} RSS_1 & RSS_2 & RSS_3 \\ MSS_1 & MSS_2 & MSS_3 \\ ST_1 & ST_2 & ST_3 \\ UPP_1 & UPP_2 & UPP_3 \\ RA_1 & RA_2 & RA_3 \\ SEC_1 & SEC_2 & SEC_3 \end{pmatrix} \quad (9)$$

The next step is to decide on the relative importance of each of the attributes involved in the decision about network selection Ws, Wv , Wt , Wu , Wr , and We. The criteria with more importance to the operator and user can be assigned higher weight. Using these assigned weights, the matrix in equation 9 is updated as shown in 10.

$$WDM = \begin{pmatrix} W_s*RSS_1 & W_s*RSS_2 & W_s*RSS_3 \\ W_v*MSS_1 & W_v*MSS_2 & W_v*MSS_3 \\ W_t*ST_1 & W_t*ST_2 & W_t*ST_3 \\ W_u*UPP_1 & W_u*UPP_2 & W_u*UPP_3 \\ W_r*RA_1 & W_r*RA_2 & W_r*RA_3 \\ W_e*SEC_1 & W_e*SEC_2 & W_e*SEC_3 \end{pmatrix} \quad (10)$$

The next step is to find the best and worst value for each of the attribute. Depending on the attribute, the best (or the worst) value can be either the maximum or the minimum value. For each of the alternatives under consideration (WWAN, WMAN, and WLAN), the measure of separation, both for the best and worth cases, is calculated as shown in equations 11 and 12 respectively. The preference order for each alternative P_i, measured in terms of distances S from the best and worst solutions, is represented by the following formulation

$$P_i = \frac{{}_iS_{worst}}{{}_iS_{worst} + {}_iS_{best}} \quad (13)$$

2.3. The VIKOR MCDM

The VIKOR (the Serbian name is Vlse Kriterijum-ska Optimizacija Kompromisno Resenje which means multicriteria optimization (MCO) and compromise so-lution) method was mainly developed by Zeleny [17]

$$X_W = \frac{RSS_1*W_s + MSS_1*W_v + ST_1*W_t + UPP_1*W_u + RA_1*W_r + SEC_1*W_e}{TW} \quad (5)$$

$$X_M = \frac{RSS_2*W_s + MSS_2*W_v + ST_2*W_t + UPP_2*W_u + RA_2*W_r + SEC_2*W_e}{TW} \quad (6)$$

$$X_L = \frac{RSS_3*W_s + MSS_3*W_v + ST_3*W_t + UPP_3*W_u + RA_3*W_r + SEC_3*W_e}{TW} \quad (7)$$

$$S_{best} = \sqrt[2]{(RSS_i - RSS_{best})^2 + (MSS_i - MSS_{best})^2 + (ST_i - ST_{best})^2 + (UPP_i - UPP_{best})^2 + (RA_i - RA_{best})^2 + (SEC_i - SEC_{best})^2} \quad (11)$$

and later advocated by Opricovic and Tzeng [18] [19]. The VIKOR method was developed to solve MCDM problems with conflicting and non commensurable (different units) criteria, assuming 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 estab-lished criteria. The steps of VIKOR method can be summarized as follows. Step 1: Determine the best and worst values: For each criteria j = 1; 2; 3; :::N determine the best value ${}_bF_{ij}$ and the worst value ${}_wF_{ij}$ given by:

$${}_bF_{ij} = (MaxF_{ij} \mid j \in N_b), (MinF_{ij} \mid j \in N_c) \quad (14)$$

$${}_wF_{ij} = (MinF_{ij} \mid j \in N_b), (MaxF_{ij} \mid j \in N_c) \quad (15)$$

where N_c is the set of cost criteria and N_b is the set of benefit criteria. For all attributes, the best and worst values can be calculated using the simplified equations 16 and 17.

$${}_bF_{ij} = MaxF_{ij} i = 1, 2, ...m \quad (16)$$

$${}_wF_{ij} = MinF_{ij} i = 1, 2, ...m \quad (17)$$

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Step 2: 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 (4) and (5).

$$S_i = \sum_{j=1}^{n} w_j \frac{{}_bF_{ij} - F_{ij}}{{}_bF_{ij} - {}_wF_{ij}} \quad (18)$$

$$R_i = Max_j[w_j \frac{{}_bF_{ij} - F_{ij}}{{}_bF_{ij} - {}_wF_{ij}}] \quad (19)$$

where S_i represents the distance rate of the ith al-ternative to the positive ideal solution, R_i represents the distance rate of the ith alternative to the negative ideal solution and w_j is the importance weight of attribute j. Step 3: Calculate the VIKOR values Qi for i = 1; 2; ; m, which are defined as:

$$Q_i = v[\frac{S_i - {}_bS_i}{{}_wS_i - {}_bS_i}] + (1-v)[\frac{R_i - {}_bR_i}{{}_wR_i - {}_bR_i}] \quad (20)$$

v is the is the weight of the strategy of the majority of criteria. 1 0. When the is larger (0:5), the index of Q_i will tend to majority agreement; when is less (0:5), the index Q_i will indicate majority negative attitude. In general, = 0:5, i.e. compromise attitude of evaluation experts.

$$ {}_bS = MinS_i i = 1, 2, ...m \quad (21)$$

$$ {}_wS = MaxS_i i = 1, 2, ...m \quad (22)$$

$$ {}_bR = MinR_i i = 1, 2, ...m \quad (23)$$

$$ {}_wR = MaxR_i i = 1, 2, ...m \quad (24)$$

III. ILLUSTRATIVE NUMERICAL EXAMPLES

This section illustrates the developed JAC MCDM based systems by giving some numerical examples for real cases. The first step is the pre-processing stage (i.e. JAC initiation phase) where the suitable information required for the admission decision is gathered from the different sources to be available at the CRRM entity, where the developed JAC algorithm resides. Assuming six alternatives networks (WWAN1, WWAN2, WMAN1, WMAN2, WLAN1, and WLAN2) and six criteria, table 1 summarizes the normalized values of the collected information and measurements in the pre-processing step. In the following paragraphs, the total ranking values for the three networks are calculated according to the MCDM method that is used. The used weights are 0.2, 0.1, 0.3, 0.1, 0.1, and 0.2 for W_s, W_v, W_t, W_u, W_r and W_e respectively. Using the equations 2 to 3, the total ranking values and ranking order of the six networks accrording to SMART method are shown in table 2.

$$S_{worst} = \sqrt[2]{(RSS_i - RSS_{worst})^2 + (MSS_i - MSS_{worst})^2 + (ST_i - ST_{worst})^2 + (UPP_i - UPP_{worst})^2 + (RA_i - RA_{worst})^2 + (SEC_i - SEC_{worst})^2} \quad (12)$$

Table 2. SMART Ranking Values

Network	WWAN1	WWAN2	WMAN1	WMAN2	WLAN1	WLAN2
Total Ranking Value	0.433	0.409	0.376	0.356	0.73	0.193
Ranking Order	2	3	4	1	5	6

Table 3. S_{best}, S_{worst}, P_i and ranking order for all alternatives

	$WWAN_1$	$WWAN_2$	$WMAN_1$	$WMAN_2$	$WLAN_1$	$WLAN_2$
S_{best}	0.141	0.153	0.169	0.176	0.004	0.253
S_{worst}	0.137	0.117	0.107	0.091	0.254	0.009
P_i	0.494	0.433	0.388	0.341	0.985	0.036
Ranking Order	2	3	4	5	1	6

Table 1. The normalized values of the collected information and measurements in the pre-processing step

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Alternative	RSS	MSS	ST	UPP	RA	SEC
$WWAN_1$	0.43	0.75	0.50	0.42	0.30	0.25
$WWAN_2$	0.35	0.32	0.45	0.22	0.60	0.45
$WMAN_1$	0.56	0.42	0.25	0.35	0.24	0.44
$WMAN_2$	0.22	0.24	0.40	0.45	0.35	0.44
$WLAN_1$	0.85	0.80	0.70	0.84	0.56	0.65
$WLAN_2$	0.10	0.20	0.15	0.25	0.33	0.25

Table 4. The matrix of weighted criteria values

Alternative	S_i	R_i	v	Q_i	Ranking
$WWAN_1$	0.580	0.200	0.50	0.624	4
$WWAN_2$	0.550	0.136	0.50	0.498	2
$WMAN_1$	0.670	0.245	0.50	0.749	5
$WMAN_2$	0.662	0.168	0.50	0.611	3
$WLAN_1$	0.011	0.011	0.50	0.000	1
$WLAN_2$	0.970	0.300	0.50	1.000	6

Using the equations 9 to 12 the total ranking values and ranking order of the six networks accrording to TOPSIS are calculated as shown in table 3. Using the equations 14 to 24, the total ranking values and ranking order of the six networks accrord-ing to VIKOR method are shown in table 4. More experiments have been carried out under different sets of weights and criteria input values. The results are summarized in table 5. As shown in table 5, the ranking orders resulting from the three MCDM methods are not exactly the same in all examples. Example 1 and example 4 shows exactly similar orders in all methods, which are 2> 3> 4> 5> 1> 6 and 6> 3> 2> 4> 1> 5 respectively. Example 3 shows a little bit differences in the orders, however, in all methods, the most preferable networks are networks 4 and 5 and the most undesirable networks are 3 ad 1. Example 2 shows clear differences between all methods. These differences is due to the mathematical background for all three types and their way of taking the decision.

IV. CONCLUSIONS AND FUTURE WORK

Three new JAC MCDM based solutions have been presented in this paper. The numerical results show that the choice of the MCDM tool can affect the ranking order of the available access networks, and hence, the selection of the MCDM methods is highly critical in any JAC solution. Our future works can be extended in several directions. More suitable criteria weights could be found using a global optimization method. A detailed comparison between the three algorithms and other reference algorithms with respect to JAC performance criteria such as blocking rate should be carried out.

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Table 5. Ranking Values Examples

Example1			Example2			Example3			Example4		
SMART	VIKOR	TOPSIS	SMART	VIKOR	TOPSIS	SMART	VIKOR	TOPSIS	SMART	VIKOR	TOPSIS
2	2	2	5	3	4	4	4	5	6	6	6
3	3	3	4	2	2	5	5	4	3	3	3
4	4	4	3	1	1	6	2	2	2	2	2
5	5	5	2	5	6	2	6	6	4	4	4
1	1	1	6	4	3	3	1	1	1	1	1
6	6	6	1	6	5	1	3	3	5	5	5

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