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Multi-objective Channel Decision for Adhoc Cognitive Radio Network

Rahul V Awathankar, M S S Rukmini, and Rajeshree D Raut

***Abstract*—Faithfull detection of non-utilized spectrum hole in available channel is a crucial issue for cognitive radio network. Choosing the best available channel for a secondary user transmission includes settling on decision of accessible choices of free frequency spectrum based on multiple objectives. Thus channel judgment can be demonstrated as several objective decision making (MODM) problem. An ultimate goal of this exploration is to define and execute a technique for multiple objective optimizations of multiple alternative of channel decision in Adhoc cognitive radio network. After a coarse review of an articles related to the multiple objective decision making within a process of channel selection, Multiple Objective Optimization on the basis of the Ratio Analysis (MOORA) technique is taken into consideration. Some important objectives values of non-utilized spectrum collected by a fusion center are proposed as objectives for consideration in the decision of alternatives. MOORA method are applied to a matrix of replies of each channel alternatives to channel objectives which results in set ratios. Among the set of obtained dimensionless ratios, all the channel alternatives are ranked in descending order. In MOORA, channel choices with moderate objectives can top in ranking order, which is hardly conceivable with linearly weighted objectives of the different channel by using different decision making technique.**

***Keywords*—cognitive radio networks; ranking and optimization; cooperative network; channel decision; multi objective decision making(MODM); MOORA method**

I. Introduction

THE request of wireless spectrum is expanding quick as the field of media transmission is progressing rapidly. The spectrum was underutilized because of fixed spectrum assignment strategy and thus this profitable spectrum can be used effectively by recent innovation in cognitive radio technology. The word cognitive radio was initially introduced by J. Mitola for usage of underutilized spectrum in the year 1999 [1]. Cognitive radio innovation can play an important role in the field of wireless communication and also in an internet based applications [12]. In cognitive radio networks, cognitive nodes can proficiently change their working parameters as per the network requirement [2]. In this paper we have contemplated multiple objective based channel decision issues in Adhoc cognitive radio network system. Channel sharing and channel dispute issues emerge when multiple secondary clients have a tendency to choose same channel.

As a cost efficient wireless communication framework, a cognitive radio is well known about the spectrum condition. It utilize the communication parameters as a criteria (for example, carrier frequency, energy consumption and bandwidth) to enhance the spectrum use. A most important fundamental aspect in an innovation of cognitive radio system is channel sensing. With this the status of the underutilized spectrum hole in cognitive radio channel can be determined. Thus, if the secondary cognitive node finds that channel is futile then that node can actively participate in transmission so that the interference with primary users can be avoided. In cooperative cognitive spectrum sensing, every nodes from a group of cognitive user share their sensing outcome database with nearby nodes and later makes decision about participation in transmission based on the present availability status of the spectrum. If cooperative spectrum sensing is used, the sensing performance of cognitive radio network system can be improved considerably [3]-[4]. Some cooperation-based protocols are already proposed to work in the CRNs. SUs can create cooperative network group to enhance the transmission quality at the destination and null the transmission at PUs [8].

There is always multiple numbers of channels in cognitive radio spectrum access system and thus channel decision is the key concern. To address the difficulties engaged with channel decision process are broadly contemplated. Game theory for spectrum access system was surveyed in [9]-[10]. A Markovian decision method framework for opportunistic spectrum access technology was suggested in [11]. There are few more schemes that can be extensively used in channel selection process like ALOHA scheme, Evolutionary algorithm and Blind sensing algorithm.

Scheme said above have their individual favorable circumstances in various determined conditions. The auction model based channel selection theme ensures the guarantee of spectrum availability. The auction model is useful when available resource cost is uncertain and furthermore the cost changes in accordance with purchasers' needs. It also ensures the mixed network existence which can be available for totally different service requirements. However, delay of auction method is unpredictable and user's nature isn't stable and cooperative in sensitive conditions, so this kind of scheme cannot satisfy network that have higher requirements for delay. Learning model based spectrum selection scheme is advantageous to the network system where primary user's activity is very regular and known.

In today's era of digital communication, to overcome the complexity of the channel decision issues in cognitive radio technology, we need to apply the procedure that are easy to use and considered less complex to accomplish the desired solution. Incorporated formulas, Adopted algorithms and use of scientific and legitimate methodologies prompt the advancement of decision making strategies. Many more

Rahul V Awathankar and M S S Rukmini are with ECE Department, VFSTRU, Guntur, A.P, India (e-mail: rahulawathankar@gmail.com).
Rajeshree D Raut is with Department of EXTC, GCOE, Nagpur, M.S, India.

approaches to select the best channel from the available set of alternatives, each with different objectives in cognitive radio environment are proposed [7].

Confronting various criteria during channel decision, we cannot rank the channels available by our inclination on a singular basis. In such cases, multiple objectives can be taken into consideration in an expressive way. The key assignment of this research is to deliver easy and indisputable channel decision methods appropriate in cooperative cognitive radio network.

II. Cooperative Spectrum Sensing In Cognitive Radio

In cooperative frequency channel sensing cluster of secondary cognitive radio nodes share the different channel objective database with each other through fusion center. This gives a clear picture of the underutilized spectrum in the area where the cognitive radio network is situated. There are widely two ways to deal with cooperative spectrum sensing, centralized or distributed [5].

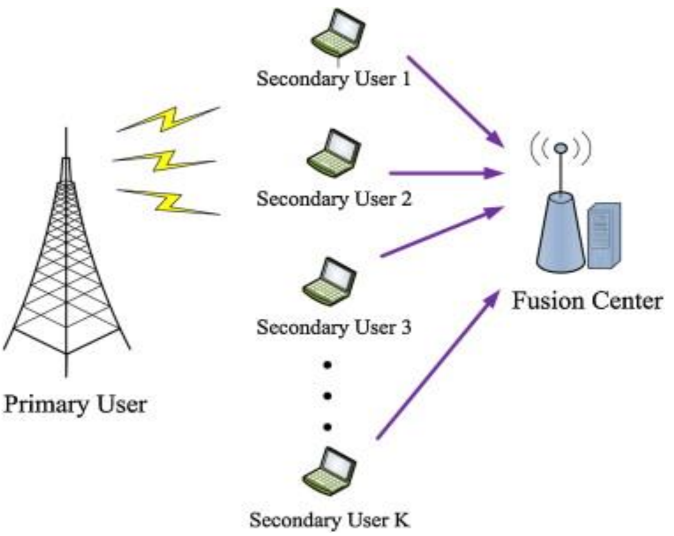

Fig. 1. Cooperative Sensing

A. *Centralized Sensing Approach*

In centralized cooperative spectrum sensing approach, there is a controlling node, a central coordinator or fusion in the cooperative network that gathers the information from all the nearby cognitive nodes surrounded by the network. The fusion center examines the information and decides the channel accessibility that can and can't be utilized. The central node can also establish the various sensor nodes to measure the parameters like channel signal level, signal to noise ratio, channel bandwidth and waiting time at different times. However if central node failure occurs, the whole cooperative network will neglect to accomplish spectrum sensing process.

B. *Distributed Sensing Approach*

In this sensing approach, there is no central node or fusion center to take control. Instead every node is able to share sensed information among each other. However in this approach each individual radio requires substantially larger amount of self-sufficiency, and feasibly should ready to act as cognitive network [6].

In spite of the fact that cooperative spectrum sensing is more entangled than a non-cooperative spectrum sensing, it has numerous preferences that exceed the additional complexity and its uses. Cooperative spectrum sensing is further more beneficial with below said benefits,

- Significantly reduction in unknown node problem
- False alarm rate is extensively diminished.
- Increase in agility.

III. The MOORA Method

For the first time MOORA technique introduced in 2006 by Brauers and Zavadskas [14]. MOORA stands for Multiple Objective Optimization on the basis of the Ratio Analysis. This method is established on the principle of multiple objective decision making algorithm. This strategy begins with matrix representation of replies of of each alternatives on all individual objectives x_{ij} :

$$X=\begin{pmatrix} a_{ij} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix} \quad (3.1)$$

where: x_{ij} = the reply of alternative i on objective j ;
i = 1, 2,… m; m is the sum of available alternatives;
j = 1, 2,… n; n is the total of considered objectives;

The MOORA method comprises of below mentioned two components:
(i) The ratio System Approach
(ii) The Reference Point Theory.

A. *The Ratio System Approach*

In ratio system approach the initial step is matrix normalization. In matrix normalization, ratio of x_{ij} to a value of each alternatives with reference to the individual objective is considered. For this the best way we can do with is to determine the sum of squares of every single alternative per objective and then perform square root operation [20]:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i \in N} x_{ij}^2}} \quad (3.2)$$

Where, r_{ij} is a value signifying the normalized reply of alternative *i* on objective *j;*

Second step is to construct the weighted normalized matrix from normalized decision matrix as:

$$v_{ij} = w_j * r_{ij} \quad (3.3)$$

Third step is optimization. In optimization, maximum and minimum value solution are determined by adding and subtracting the responses obtained in second step respectively:

$$S_i^+ = \sum_{j \in J^{\max}} v_{ij} \quad (3.4)$$

Where, j=1,2 … $J^{\max}$ is set of higher values for beneficial objectives,

$$S_i^- = \sum_{j \in J^{\min}} v_{ij} \quad (3.5)$$

Where, j=1,2 … $J^{\min}$ is set of lower values for non-beneficial objectives.

After optimization in fourth step evaluate the overall performance rating for each alternative considering the beneficial and non-beneficial objectives are intended as:

$$S_i = S_i^+ - S_i^- \quad (3.6)$$

Fifth step is ranking of the alternatives. All alternatives are organized in descending order of S_i and ranked accordingly. More preferred alternative is the higher value of S_i.

B. The Reference Point Theory

The reference theory begins with the ratio found in equation (3.2). Next, for maximum and minimum value, a reference point picks up the uppermost and lowermost value per objective among all the number of alternatives. For an instance, if we have three options defined as: *X*(10; 50), *Y*(50; 30) and *Z*(50; 50). Thus here *Rp* (50; 50) marks as a maximal reference point. The Maximal Objective trajectory is self-determined if the available choices are characterized in porper manner. Having given the dimensionless number representing the normalized response of alternative *i* on objective *j*, i.e. r_{ij} in formula (3.2), we come across the following equation:

$$(r_j - r_{ij}) \quad (3.7)$$

The Tchebycheff Min-Max metric is carefully chosen in the direction to determine the distance between the alternatives and the reference point [19]:

$$\min_i \max_j (r_j - r_{ij}) \quad (3.8)$$

Where r_j is the j^{th} value of the maximum reference point objective. Every reference point value is selected as the uppermost resultant value among all the alternatives.

IV. Channel Decision Approach

A. System Model

When the secondary user joins any communication network, he expects quality of service from the networks. The ultimate goal of our approach is to elect the best channel alternative from the group of available alternatives. Fusion center collects information from all nearby cognitive radio nodes and checks whether the channel is occupied or free. Weighing method like entropy technique is used to calculate the weight trajectories so that the relative importance of each objective can be defined. Subsequently TOPSIS and MOORA are applied to the weighted metrics to determine the ranking. A ranking order is organized in descending manner among the set of available alternatives. The top ranked alternatives should get the highest preference.

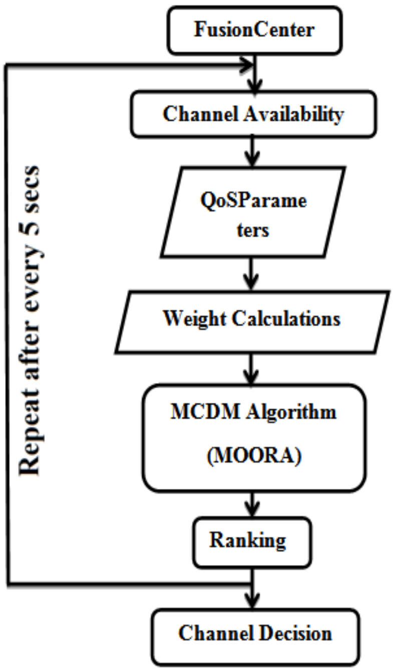

Fig. 2. System Model

B. Channel Decision Strategy

The motto of this research is to deliver simple and undeniable channel alternatives ranking method which will fit in cooperative cognitive network. To ensure optimal quality of service by a cognitive radio network, system has to control certain parameters like jitter, delay, SNR, packet loss and bandwidth. But it is not practically possible to measure parameters such as delay and packet loss before channel decision. Here limited information used as constraints for channel decision includes SNR, bandwidth, waiting time, economic cost and information rate.

Bandwidth is one of an essential consideration for channel decision in cognitive radio network. As per the IEEE 802.22 standard, expected spectrum that can be recycled as cognitive radio are in the range of 6MHz, 7 MHz and 8MHz [17]. The information rate is specifically corresponding to the degree of the bandwidth. In [17], the spectral efficiencies as defined by IEEE 802.22 standard are in the scope of 0.5 to 5 bit/sec/Hz with an expected normal of 3 bits/sec/Hz. As indicated by the standard, the normal information rate in the decision matrix can be evaluated as 18 Mbps for 6 MHz, 19.5 Mbps for 6.5 MHz, 21 Mbps for 7 MHz, 22.5 Mbps for 7.5 MHz and 24 Mbps for 8 MHz. An economic cost is an important parameter for the selection of vacant space in cognitive radio network as channel decision. Economic cost of the channel varies as per the availability of bandwidth. Higher the bandwidth more will be the cost.

Suppose there are four vacant channels A_1, A_2, A_3, A_4 as objective and X_1, X_2, X_3, X_4, X_5 are the attributes SNR, bandwidth, waiting time, economic cost and information rate respectively to be considered for channel selection. The decision issue can be briefly communicated in the decision matrix, where the capacities of every channel are exhibited. Waiting time and economic cost are scaled utilizing a similar unit separately.

$$D = \begin{array}{c} \\ A1 \\ A2 \\ A3 \\ A4 \end{array} \begin{array}{c} \begin{array}{ccccc} \boldsymbol{X1} & \boldsymbol{X2} & \boldsymbol{X3} & \boldsymbol{X4} & \boldsymbol{X5} \end{array} \\ \begin{bmatrix} 80 & 8 & long & high & 24 \\ 80 & 7.5 & short & medium & 22.5 \\ 20 & 7 & medium & low & 21 \\ 40 & 6 & short & low & 18 \end{bmatrix} \end{array}$$

A1 and A2 have much higher waiting time than A3 and A4 whereas the cost of A3 and A4 is lower than A1 and A2. As per as SNR is concerned A1 and A2 have much higher value than A3 and A4. Suppose the user is running voice application. The SNR and waiting time are considered as important for voice application.

C. Weight Calculation

Here we present a novel objective weighting method related to Shannon entropy technique as follows:

Let D be the decision making matrix. First step is to calculate the S matrix from D matrix. Second step is normalizing the S matrix:

$$\overline{S} = \begin{bmatrix} \overline{S_{ij}} & \cdots & \overline{S_{1n}} \\ \vdots & \ddots & \vdots \\ \overline{S_{m1}} & \cdots & \overline{S_{mn}} \end{bmatrix} \quad (4.1)$$

$$\text{Where } \overline{s_{ij}} = s_{ij} \Big/ \sum_{i=1}^{m} s_{ij} \quad (4.2)$$

i= 1…..m and j=1….n;

Third step is determine the weight of objectives as follows:

$$E_j = -\frac{1}{\ln m} \sum_{i=1}^{m} \overline{s_{ij}} \ln \overline{s_{ij}} \quad (4.3)$$

The objective weight defined by

$$w_j = \frac{1 - E_j}{\sum_{j=1}^{n} (1 - E_j)} \quad (4.4)$$

The above objective weighting method utilizes Shannon information entropy technique to express the relative intensities of objective importance and the differences among objectives. Then, the attributes weights are determined through equation (4.4).

V. Numerical Example

This segment introduce the numerical simulations of the strategies MOORA and TOPSIS. To figure the score of the accessible channels specified by the strategies on the basis of five objectives, the issue is additionally stated as:

$$D = \begin{array}{c} A1 \\ A2 \\ A3 \\ A4 \end{array} \begin{bmatrix} 80 & 8 & 0.75 & 7 & 24 \\ 80 & 7.5 & 0.25 & 5 & 22.5 \\ 20 & 7 & 0.50 & 3 & 21 \\ 40 & 6 & 0.25 & 3 & 18 \end{bmatrix} \quad (5.1)$$

User preference, i.e. weight of objective for voice application is calculated using entropy technique. The normalized preferences, i.e. the weighting factor are w_v

w_v = [0.3971 0.0178 0.3538 0.2135 0.0178] (5.2)

In the below segment, TOPSIS and MOORA strategy are applied and the performance outcomes are analyzed.

A. TOPSIS

In TOPSIS, the constructed weighted normalized decision matrix by using equation 3.1 and 3.2 is as follows

$$V = \begin{array}{c} A1 \\ A2 \\ A3 \\ A4 \end{array} \begin{bmatrix} 0.3971 & 0.0178 & 0.3538 & 0.2135 & 0.0178 \\ 0.3971 & 0.0167 & 0.1179 & 0.1525 & 0.0167 \\ 0.0993 & 0.0155 & 0.2359 & 0.0915 & 0.0155 \\ 0.1986 & 0.0133 & 0.1179 & 0.0915 & 0.0133 \end{bmatrix} \quad (5.3)$$

After finding positive idyllic solution and negative idyllic solution, the comparative familiarity to the idyllic solution is as follows,

C_v = [0.7094 0.8300 0.9815 1.000] (5.4)

B. MOORA Method

In MOORA Ratio System approach, the constructed weighted normalized decision matrix is as follows,

$$V = \begin{array}{c} A1 \\ A2 \\ A3 \\ A4 \end{array} \begin{bmatrix} 0.3971 & 0.0178 & 0.3538 & 0.2135 & 0.0178 \\ 0.3971 & 0.0167 & 0.1179 & 0.1525 & 0.0167 \\ 0.0993 & 0.0155 & 0.2359 & 0.0915 & 0.0155 \\ 0.1986 & 0.0133 & 0.1179 & 0.0915 & 0.0133 \end{bmatrix} \quad (5.5)$$

After optimization the overall performance for voice S_v is as follows,

S_v = [0.5374 0.3626 0.2437 0.2250] (5.6)

VI. Performance Analysis

Ranking results using TOPSIS and MOORA methods are outlined below in Table I. For certain application (voice or data) TOPSIS ranks A4 as the finest and MOORA ranks A1 as the best. The outcomes obtained by MOORA techniques are more reasonable, because A1 has decent scores on bandwidth, SNR and information rate while A4 has good scores on economic cost and waiting time only.

TABLE I
CHANNEL RANKING COMPARISON

Channel	TOPSIS		MOORA RS	
	Overall Performance Score	Rank	Overall Performance Score	Rank
A1	0.7094	4	0.5374	1
A2	0.8300	2	0.3626	2
A3	0.9815	2	0.2437	3
A4	1.000	1	0.2250	4

We have observed that in TOPSIS, performance is mainly based on one or two attributes only while in MOORA performance is completely based on analysis of multiple attributes.

VII. Conclusion

In TOPSIS, the relative significance of multiple objectives cannot be deliberated, though it is having a key important in decision making. In MOORA technique decision is based on response of alternatives considering two or more objectives. MOORA method ratios are applied to a matrix of replies of each channel alternatives to channel objectives. Among the set of obtained dimensionless ratios, all the channel alternatives are ranked in descending order. Out of available ratio systems, it is demonstrated that MOORA method outrank the others.

From the simulation results some fundamental conclusions can be drawn.

1. In MOORA, channel choices with moderate objectives can rank in top, which is not conceivable with linearly weighted objectives of the different channel.
2. Consideration of conflicting objectives is conceivable.
3. The result obtained here are even though based on simulations of theoretical structures, it can be concluded that MOORA is effective and can be used practically when statistics related to different objectives are available from fusion center.

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