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A Novel Spectrum Handoff Method Based On Spectrum Reservation

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Abstract

In this paper, we apply fuzzy analytic hierarchy process (FAHP) method in the decision process of Cognitive Radio Networks (CRN) spectrum handoff. Based on the pre-determined target spectrum list model, considering the multiple indicators which influence the handoff performance, we designed a spectrum handoff method based on spectrum reservation strategy. Simulation results show that the algorithm proposed in this paper exceeds the random handoff algorithm without channel order, it can significantly reduce the handoff frequency and time overhead of cognitive users, reduce the system delay and improve the system throughput.

Keywords: *FAHP; channel order; spectrum reservation; multi-attribute decision-making*

1. Introduction

Along with the rapid development of wireless communication technologies, the limited licensed spectrum can not meet the growing demand for wireless communications applications. Cognitive Radio (CR) is a new way to improve the efficiency of utilizing the limited spectrum resource. In recent years, a lots of research have been done [1]-[3]. In CRN, when the primary users (PU) appear, or the channel quality decline so that the transmission can not be completed, the cognitive users will look for a suitable target channel to complete the communication.This process is called spectrum handoff [4], [5].

When switching the spectrum, previous methods have not taken the parameters differences of each target channel into account. Therefore, system resources are not fully utilized. In this paper, we apply FAHP method in the decision process of CRN spectrum handoff. Based on the pre-determined target spectrum list model [6], *c*onsidering the quality indicators, QoS demand indicators and indicators of the continuing validity, we designed a spectrum handoff method based on FAHP algorithm. Simulation results indicate that, this approach can significantly reduce the cognitive user's switching frequency and system latency, improve system throughput.

2. Research Method

In the process of spectrum handoff, we take multiple channel indicators into account. Therefore, the channel selection problem is actually a multi-attribute decision making problems [7]. FAHP is a combination of fuzzy comprehensive evaluation (FCE) and Analytic Hierarchy Process (AHP), it is a qualitative and quantitative analysis model. Generally, it uses AHP to determine factor set first, and then use the FCE to analyze the influence of the factors. By merging them, FAHP has good reliability to the analysis result [8].

According to the hierarchical structure of the model given in Figure 1, suppose we have the following five channels. Based on the comparison criteria given above, we get the ranking compared with each other.

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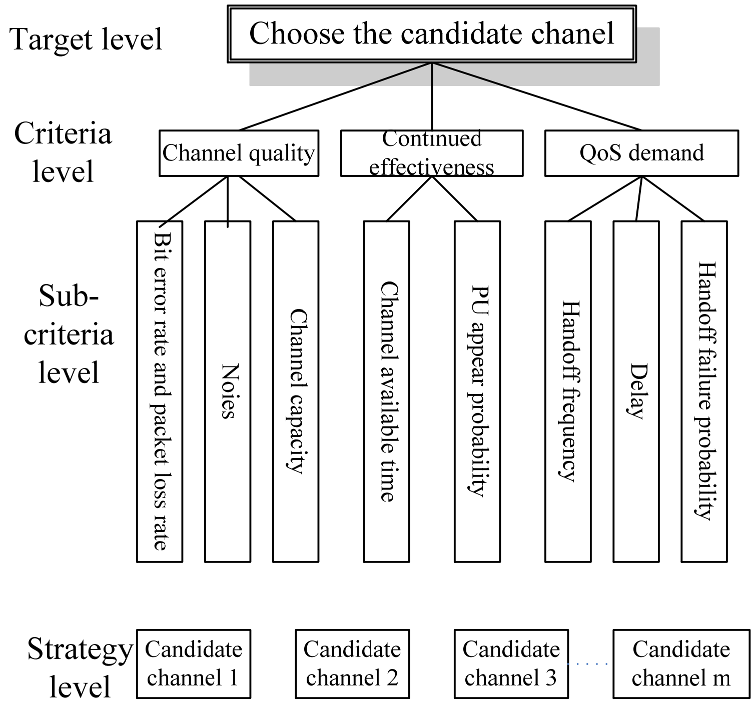

Figure 1. The hierarchy of channel order analysis

Table 1. The ranking of the 5 channels under various parameters

1st layer（A）	Candidate channel selection							
2nd layer（B）	Channel quality			Continuous Availability		QoS Demand		
3rd layer（C）	Packet loss	Noise	Channel Bandwidth	Available time	SU probability	Handoff frequency	Delay	Handoff failure rate
4th layer（D）	3	5	1	2	3	1	2	2
	2	2	3	1	2	3	1	3
	1	3	2	5	5	2	3	5
	4	4	5	3	1	4	4	1
	5	1	4	4	4	5	5	4

Based on the factors' impotence in the lower lever to the upper lever, we can construct the priority relation matrix. The value in the matrix is expressed by 0.1-0.9 scale [9]. It can accurately describe any two factors on the relative importance of certain criteria

Table 2. 0.1-0.9 scale

Scale	Definition	Explanation
0.5	Equally important	Two elements are equally important
0.6	Little important	An element is little more important than another element
0.7	Obviously important	An element is obviously more important than another element
0.8	Much more important	An element is much more important than another element
0.9	Extremely important	An element is extremely more important than another element
0.1 0.2 0.3 0.4	Anti-comparison	If compare ai and aj we get rij, then compare aj and ai we get rji=1-rij

The matrix between the first layer and the second layer A-B, the matrix between the second layer and the third layer B1-C, B2-C and B3-C, the matrix between the third layer and the fourth layer C1-D, C2-D, …, C8-D, totally 12 matrixes. In view of space limitations, we do not list them all. A-B and B-C matrixes are obtained by service demand for indicators, C-D matrixes are calculated according to table 1 and table 2.

Table 3. A-B priority relation matrix

A	B1	B2	B3
B1	0.5	0.7	0.6
B2	0.3	0.5	0.7
B3	0.4	0.3	0.5

Table 4. B1-C priority relation matrix

B1	C1	C2	C3
C1	0.5	0.6	0.7
C2	0.4	0.5	0.6
C3	0.3	0.4	0.5

Table 5. C1-D priority relation matrix

C1	D1	D2	D3	D4	D5
D1	0.5	0.4	0.2	0.6	0.7
D2	0.6	0.5	0.4	0.7	0.8
D3	0.8	0.6	0.5	0.7	0.8
D4	0.4	0.3	0.3	0.5	0.6
D5	0.3	0.2	0.2	0.4	0.5

Sum the priority relation matrixes by row, $r_i = \sum_{j=1}^{n} f_{ij}$, $i = 1,2,...n.$ Execute the following mathematical transformation $r_{ij} = (r_i - r_j)/2n + 0.5$, the transformation result are fuzzy consistent matrixes. Because fuzzy consistent matrixes are transformation by the priority relation matrixes, so there are 12 also.

Table 6. A-B fuzzy consistent matrix

A	B1	B2	B3
B1	0.5	0.55	0.6
B2	0.45	0.5	0.55
B3	0.4	0.45	0.5

Table 7. B1-C fuzzy consistent matrix

B	C1	C2	C3
C1	0.5	0.55	0.6
C2	0.45	0.5	0.55
C3	0.4	0.45	0.5

Table 8. C1-D fuzzy consistent matrix

C1	D1	D2	D3	D4	D5
D1	0.5	0.44	0.4	0.53	0.58
D2	0.56	0.5	0.46	0.59	0.64
D3	0.6	0.54	0.5	0.63	0.68
D4	0.47	0.41	0.37	0.5	0.55
D5	0.42	0.36	0.32	0.45	0.5

According to the fuzzy consistent matrix, we can calculate the priority of the lower factors under an analytical standard to the upper level.

$$b_i = \frac{1}{n} - \frac{1}{2a} + \frac{\sum_{j=1}^{n} r_{ij}}{na}, i = 1,2,...n \text{ , } (a \geq \frac{n-1}{2}). w_i = (b_1, b_2, ..., b_n)$$

b_i shows each factor's importance order under a certain analysis standard in the upper lever.

Level B relative to lever A, weight of each factor is

$$w_1 = (b_1, b_2, b_3) = (0.3833,03333,0.2833)^T$$

Level C relative to B1, B2, B3, each sub-indicator's weight is

$$w_{21} = (b_{11}, b_{12}, b_{13}) = (0.3833,03333,0.2833)^T$$

$$w_{22} = (b_{21}, b_{22}) = (0.55,0.45)^T$$

$$w_{23} = (b_{31}, b_{32}, b_{33}) = (0.4,0.35,0.25)^T$$

Level D relative to C1, C2…C8, weights of the 8 handoff schemes are

$$w_{31} = (0.195,0.225,0.245,0.180,0.155)^T$$

$$w_{32} = (0.150,0.225,0.240,0.205,0.190)^T$$

$$w_{33} = (0.250,0.200,0.225,0.160,0.165)^T$$

$$w_{34} = (0.225,0.250,0.150,0.200,0.175)^T$$

$$w_{35} = (0.225,0.225,0.145,0.235,0.170)^T$$

$$w_{36} = (0.250,0.200,0.225,0.205,0.150)^T$$

$$w_{37} = (0.225,0.250,0.200,0.175,0.150)^T$$

$$w_{38} = (0.225,0.200,0.150,0.250,0.175)^T$$

Since there are multiple levels of evaluation criteria, we need comprehensive the hierarchical relationships, convert partial importance weight into comprehensive weight to the overall objective. Then the sub-indicators' comprehensive weight in lever C to the overall objective are

$$w_0 = (b_1 * b_{11}, b_1 * b_{12}, b_1 * b_{13}, b_2 * b_{21}, b_2 * b_{22}, b_3 * b_{31}, b_3 * b_{32}, b_3 * b_{33},)^T =$$

$$(0.3833*0.3833,0.3833*0.3333,0.3833*0.2833,0.3333*0.55,0.3333*0.45,0.2833*0.4,0.2833*0.35,0.2833*0.25)^T =$$

$$(0.1469,0.1278,0.1086,0.1833,0.1500,0.1133,0.0991,0.0708)^T$$

On the basis of hierarchy single order and AHP comprehensive, we can calculate the priority degree of each handoff scheme T_i. By sorting T_i, we can get the best scheme.

$$T = (T_1, T_2, T_3, T_4, T_5) = (w_{31} w_{32} w_{33} w_{34} w_{35} w_{36} w_{37} w_{38}) * w_0 =$$

$$\begin{bmatrix} 0.195 & 0.150 & 0.250 & 0.225 & 0.225 & 0.225 & 0.225 & 0.225 \\ 0.225 & 0.225 & 0.200 & 0.250 & 0.225 & 0.200 & 0.250 & 0.200 \\ 0.245 & 0.240 & 0.225 & 0.150 & 0.145 & 0.225 & 0.200 & 0.150 \\ 0.180 & 0.205 & 0.160 & 0.200 & 0.235 & 0.205 & 0.175 & 0.250 \\ 0.155 & 0.190 & 0.165 & 0.175 & 0.170 & 0.150 & 0.150 & 0.175 \end{bmatrix} * \begin{pmatrix} 0.1469 \\ 0.1278 \\ 0.1086 \\ 0.1833 \\ 0.1500 \\ 0.1133 \\ 0.0991 \\ 0.0708 \end{pmatrix} = (0.2137, 0.2247, 0.1963, 0.2002, 0.1668)^T$$

From all above we can know, the 5 candidate channels' sorting result in accordance with the overall evaluation criteria is:

Channel 2> Channel 1> Channel 4> Channel 3> Channel 5.

When cognitive radio network faces spectrum handoff, the channel chosen can be based on the sort results above.

3. Result and Discussion

Through simulation experiments, we evaluated the performance of the proposed handoff scheme. Assume cognitive user need to transfer a length of 60s data in a communication process, the access probability of cognitive users is 20% [10]. In order to improve the accuracy of the results, we conduct 100 experiments. Assume there are 5 idle spectrum resources in the simulation scene, part of the parameters as shown in Table 9.

Table 9. Parameters of idle spectrum

Channel	Delay(ms)	Available time(ms)	Packet loss rate (%)	Bandwidth(Kbps)
A	40	2700	3	5000
B	30	3000	2	4000
C	50	1800	1	4500
D	60	2400	4	3000
E	70	2000	5	3500

From 100 groups of comparative data from the simulation results in Figure 2 we can see, under random handoff method without channel order, the switching frequency is up to 60 times, the average switching frequency is 43 times. After channel order based on FAHP algorithm, the switching frequency is 40 times, the average switching frequency is 29 times. It means that, the method proposed in this paper can significantly reduce the switching frequency compared to the previous scheme.

Simulation results in Figure 3 represent that, for different number of cognitive users, the comparison of total system delay. From the chart we can see clearly, the handoff method based on FAHP has greatly improved on delay performance than the random handoff method. And along with the increase of the user number, the advantage is more obvious.

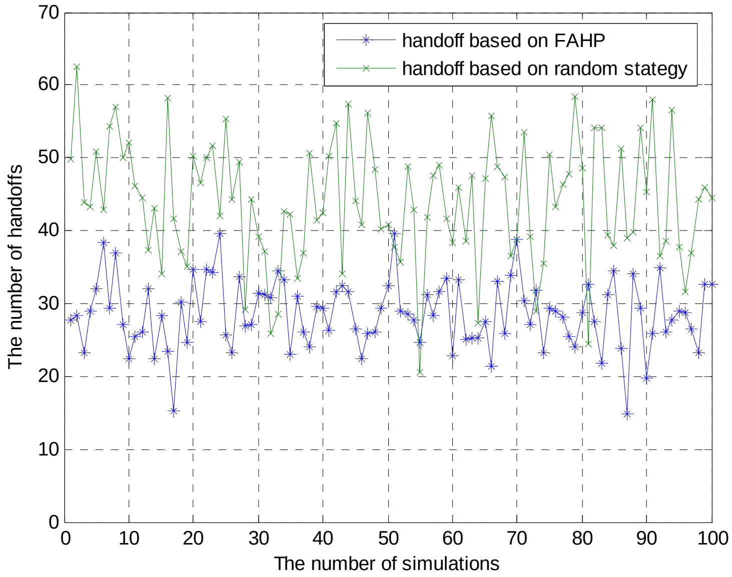

Figure 2. Handoff frequency under different method

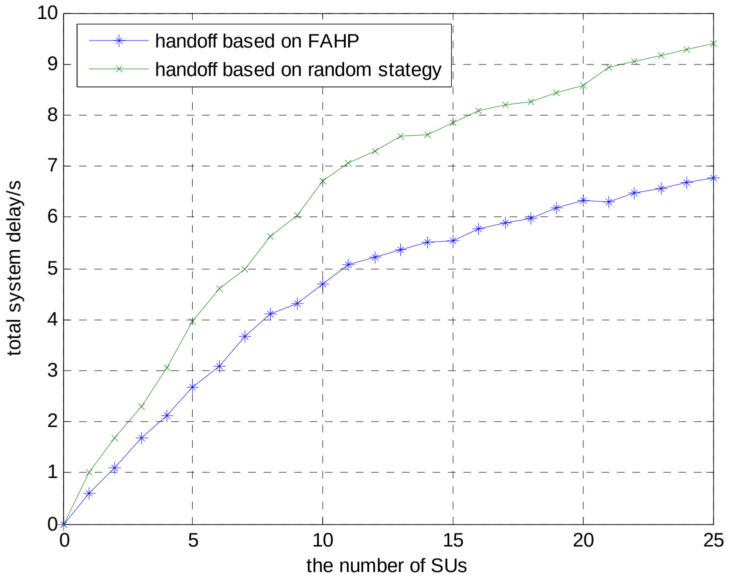

Figure 3. Total delay under different method

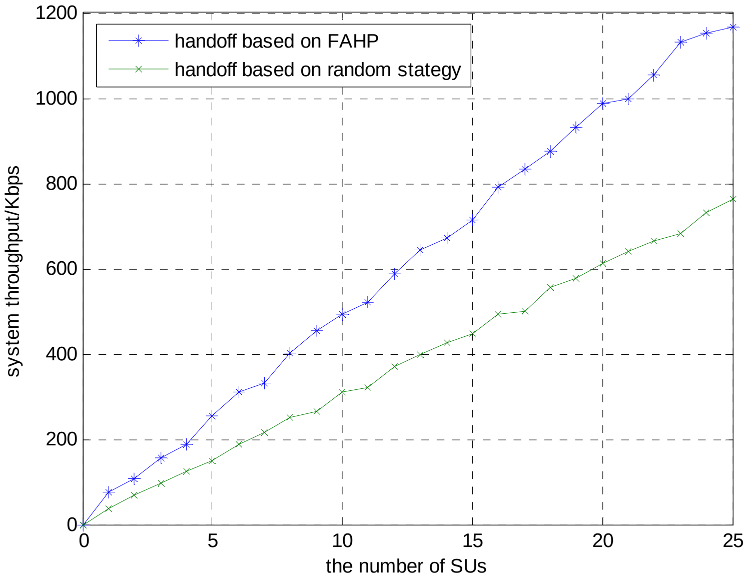

Figure 4. Throughput under different method

Figure 4 shows the throughput comparison under different method. From the figure we can see that, since the method proposed in the paper considered the multiple indicators of candidate channels, it makes cognitive users tend to choose the handoff target with larger bandwidth, higher data transmission efficiency, so that the throughput of the system has been greatly improved.

4. Conclusion

This paper proposed a spectrum handoff method based on channel ordering with FAHP algorithm, overall considered many indicators such as the channel quality, the continuous effectiveness and the QoS demand, etc. Then through the simulation experiment, from switching frequency, total system delay and system throughput, the 3 aspects, to validate the effectiveness of method. Simulation results show that, compared with the traditional random handoff method, the method proposed in this paper can effectively reduce the handoff frequency, reduce the system latency and improve the system throughput.

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