Spectrum allocation algorithm based on user requirements under the circumstance of advanced user existence

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Abstract

Since wireless spectrum is a non-renewable resource, how to improve the spectrum utilization is always the problem to be resolved by wireless communication technology. With the development of wireless communication technology, the contradiction between supply and demand for spectrum resource has been more and more intense. In this case, cognitive radio technology emerged. The traditional list-colouring algorithm aims at maximizing the number of allocated bandwidth; CSGC algorithm (Colour Sensitive Graph Colouring algorithm) is to achieve the maximum benefits of bandwidth for the cognitive users; local bargaining algorithm is an improved algorithm on time complexity based on CSGC. However, the three algorithms do not take the bandwidth demand of cognitive users into consideration. Even with the proportion allocation of CSGC algorithm, the problem of ill-considered for the bandwidth demands of cognitive users also exists, which results in irrational allocation of spectrum resources. To solve this problem, this article proposes a priority order with the consideration of cognitive users in spectrum allocation based on advanced users.

Keywords: Cognitive Radio, Spectrum Allocation, Graph Colouring, User Needs

1 Introduction

Cognitive radio is an effective means to alleviate the current tension radio spectrum resources in the international and domestic, more and more research organizations consider that cognitive radio could perfectly play an important role in the next generation wireless communication system; it is a landmark in new wireless technology [1-4].

Dynamic spectrum allocation is one of the key technologies of cognitive radio. A useful dynamic spectrum algorithm can improve the efficient use of spectrum resources, the flexibility use of the spectrum and the throughput of the system effectively [5, 6]. Therefore, dynamic spectrum algorithm has become a hot research spot of cognitive radio.

2 The priority of users participating in spectrum allocation

The purposes of communication are different for different users. Therefore, the demands for bandwidth are not the same [7]. In order to solve the problem of the bandwidth demands for individual cognitive user, the cognitive users involved in spectrum allocation will be divided into distribution levels, and the cognitive users with high level (advanced users) will allocate spectrum in priority. Meanwhile, in order to avoid the case that the users with low level will be allocated with little spectrum after labelled level, small number of cognitive users will be given priority, and the rest of the users do not calibrate the priority or give the same priority level [8, 9]. There are 10 cognitive users, for example, of which there are three advanced users, and then decide priorities based on the three high-level users' information (such as bandwidth demands, communication mode, etc.), then execute the following assignment. It not only can meet the advanced users' demands, but also take the needs of other users into account, and ensure the fairness of spectrum allocation, so that spectrum allocation is more reasonable. Taking the fairness of the distribution, and in order to avoid the case that a small number of users take up too much spectrum resources, the proportion of advanced users is very low [10, 11].

3 Mathematical description of the algorithm

In cognitive radio systems, the wireless environment change. The appearance of authorized users, as well as other factors, changes the channel quality. These changes will affect the users' available spectrum [12, 13]. Dynamic spectrum allocation algorithm studies in a cycle (very short), which allocates the detected available spectrum to cognitive users, and then the cognitive users access and use the spectrum [14]. The proposed spectrum's demand is a short-term demand in one cycle.

Assume that the bandwidth demand of a cognitive user n participating in spectrum allocation in a cycle is λ_n, after one distribution, the unmet bandwidth demands of cognitive user *n* is

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$$US_n = \left(\lambda_n - \sum_{m=1}^{U} a_{n,m} \cdot b_{n,m} \right)^+, \quad (1)$$

where $(x)^+ = \max(x, 0)$. So the sum of all the cognitive users' unmet bandwidth is

$$US = \sum_{n}^{V} US_n = \sum_{n}^{V} \left(\lambda_n - \sum_{m=1}^{U} a_{n,m} \cdot b_{n,m} \right)^+ . \quad (2)$$

The goal of the proposed algorithm is to take the minimum of the sum of the unmet bandwidth in single cycle,

$$\min \sum_{n}^{V} \left(\lambda_n - \sum_{m=1}^{U} a_{n,m} \cdot b_{n,m} \right)^+ . \quad (3)$$

4 The design of allocation algorithm

After taking the advanced users' participation in the distribution into account, the proposed algorithm makes an adjustment on the traditional CSGC algorithm. In the traditional CSGC algorithm, all nodes simultaneously participate in the distribution, and then the band label corresponding to each node in the figure will be calculated. The user corresponding to the largest label will be assigned to the band, until all the bands are allocated. This article considers the advanced users' involvement in spectrum allocation, which is different from CSGC algorithm. First of all, the advanced users participate in the spectrum distribution in accordance with the priority order. For example, when the advanced user s participates in spectrum allocation, make a label according to its colour (spectrum) in the list based on the corresponding criteria of CSGC algorithm, and allocate the spectrum to the user s with the largest label. And then calculate its benefits. If it does not meet the demands, then continue to allocate spectrum until meet the minimum bandwidth requirements. Delete the nodes interfering with the user s and the colour (spectrum) has been assigned to the user s in the list. The following step is to allocate spectrum to the advanced user with a lower priority than user s. After the assignment for the advanced users, the ordinary users take part in the spectrum allocation. The method is to allocate spectrum corresponding to label criterion among the ordinary users. To be fair, the advanced users are not allowed to participate at this time. Calculate the unmet basic bandwidth demands of a related user after assigned a spectrum. Until all the bandwidth demands meet the basic needs of the users, the rest of the spectrums are allocated to all users (for advanced users and ordinary users), then the CSGC algorithm will be conducted till the rest of the spectrums are allocated.

The allocation steps of the algorithm are:

Step 1: According to the users' information, the cognitive users are divided into advanced users and ordinary users;

Step 2: The advanced user are calibrated priorities, in an order of priority , set a node as a unit and then select the colour that can bring maximum benefit to the user in the list of available colours, and assign to the user;

Step 3: Update topology and delete the colour, which is corresponding to the node interference with the assigned node in the colour list, and delete the nodes whose colour is empty;

Step 4: Make sure whether the advanced users meet the bandwidth requirements or not, if yes, then go to Step 5; if not, judge if the chart is empty. If it is empty, then go to the end; if it's not empty, judge whether the list of available spectrum is empty or not, if it is empty ,then go to step 5; if it's not empty, return to step 3;

Step 5: Allocate spectrum for ordinary users, and the advanced users do not take part in the allocation. Calculate the colour label of each node (ordinary user). The corresponding colour (spectrum) is assigned to the maximum value of the node labels. Then delete the corresponding colour and nodes whose colour list is empty. Determine whether it meets, the user's needs, the users whose demands are meted exit the distribution and wait to allocate with the senior users;

Step 6: If the graph is not empty, then return to step 5; if it is empty and all ordinary users are satisfied, then go to step 7. If not satisfied, then go to step 10;

Step 7: All cognitive users (including advanced users and ordinary users) participate in spectrum allocation accordance with the corresponding algorithm;

Step 8: Update topology, delete the colour, which is corresponding to the node interference with the assigned node in the colour list, and delete the nodes whose colour is empty;

Step 9: If the graph is not empty, then return to step 7; if it is empty, then go to step 10

Step10; The spectrum allocation ends up.

5 Analysis of algorithm simulation

To test the performance of the improved algorithm when advanced users exist, simulation and analysis between the improved algorithm and CSGC algorithm will be taken. The paper mainly discussed the bandwidth demand for advanced users and ordinary users, as well as the total bandwidth of improved algorithm and CSGC algorithm when advanced users exist with or without user priority.

This algorithm mainly considers the spectrum allocation under the condition that advanced users exist, and the simulation parameters are shown in Table 1. The bandwidth need of users mainly depends on its type of business. Different business types are corresponding to different bandwidth requirements. According to IEEE802.22, 7 kinds of bandwidth demand levels can be obtained, as shown in Table 3.

TABLE 1 Simulation Parameters Settings

The total number of users (Number of nodes)	10
The number of advanced users	3
The number of channels (The number of colors)	20
Available matrix **L**	Randomly generated 0, 1 binary matrix
Efficiency matrix **B**	total of 6 level, as shown in table 4-4
Interference matrix collection **C**	Each matrix is the randomly generated 0, 1 binary symmetric matrix
The number of trials	10000

TABLE 2 Business Source Parameters

Name		business	Packet size (bit)	packet rate (packets/s)	The average data rate (kbps)
UGS		VOIP	528	17.561	9.3
rtPS	down	MPEG	1504	1263	1900
	up			126.3	190
nrtPS	down	FTP	1536	6.5104	10
	up			1.3021	2

TABLE 3 Parameters of Bandwidth Requirement

Level	Business combination type	Bandwidth requirements per cycle（bit/period）
1	VIOP	9.3×20=186
2	MPEG Upside	190×20=3800
3	VIOP+MPEG Upside	199.3×20=3986
4	MPEG Downside	1900×20=38000
5	VIOP+MPEG Downside	1909.3×20=38186
6	MPEG Upside + Downside	2090×20=41800
7	VIOP+MPEG Upside + Downside	2099.3×20=41986

Make a simulation with the unmet demands of advanced users and the ordinary users, as well as the total bandwidth of the system based on the rule of CMSB.

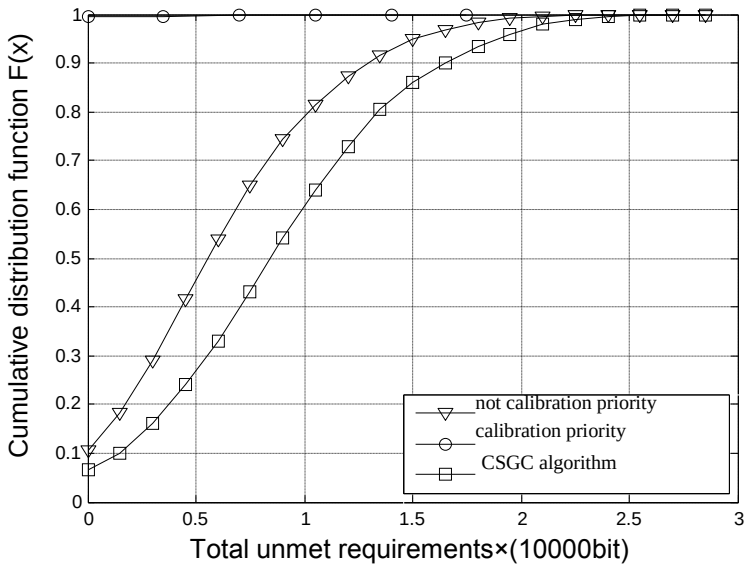

FIGURE 1 Bandwidth unmet for advanced users under the rule of Collaborative Max Sum Bandwidth (CMSB)

Figure 1 shows that the distribution situation that the bandwidth is not satisfied for advanced users under the rule of Collaborative Max Sum Bandwidth (CMSB). It can be seen from the figure that the function value generated by the algorithm based on demand is smaller than the CSGC algorithm without differing ordinary users and advanced users. It indicates that a demand-based algorithm satisfies the needs of ordinary users. After calibration advanced users priority, the needs of advanced users get better satisfied. One of the basic purposes of the calculation is achieved: ensure that the bandwidth requirements for advanced users.

Figure2 shows distribution situation that the bandwidth is not satisfied for ordinary users by Collaborative Max.

Sum Bandwidth, CMSB. It can be seen from the figure that the algorithm based on demand can content the requirement of the users well. After calibration advanced

user priority, the total demand of the users has increased. It follows that if bandwidth demand for advanced users is guaranteed, it has to sacrifice the benefits of ordinary users. Therefore, this article proposed the algorithm controls the number of advanced users. It ensures that the distribution is reasonable. Although the improvement of total demand is unmet, it is less than CSGC algorithm. In accordance with the purpose of the proposed algorithm, it meets the need of ordinary users.

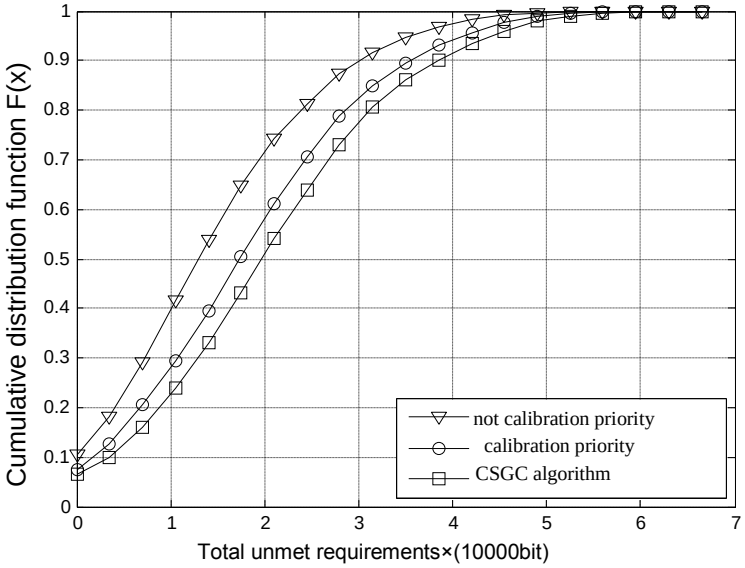

FIGURE 2 Unmet bandwidth for ordinary users under the rule of the total bandwidth under the rule of Collaborative Max Sum Bandwidth, CMSB

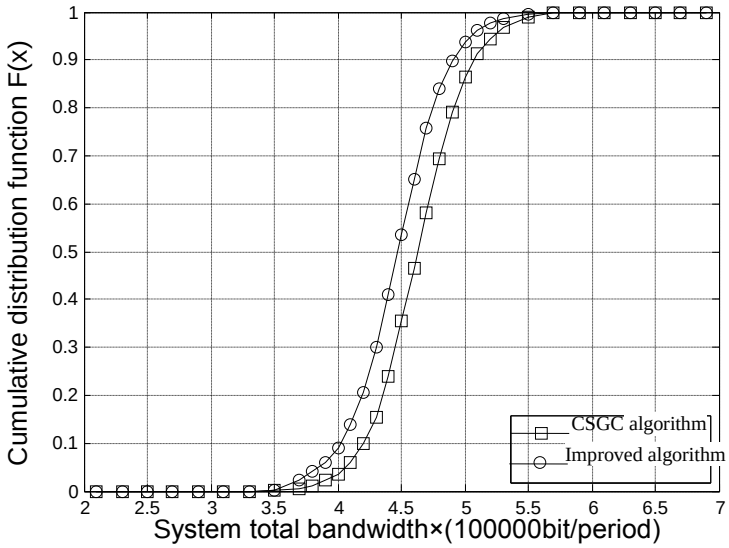

FIGURE 3 Total bandwidth under the rule of Collaborative Max Sum Bandwidth

Figure 3 shows the results of the two algorithms. It can be seen from the figure that the total system bandwidth of the improved algorithm is less than the CSGC algorithm. It suggests that it has to sacrifice the benefits of total system bandwidth to fulfil the needs of users better by the proposed algorithm.

6 Summary

In this paper, the traditional spectrum allocation algorithms had been analysed. The traditional algorithms consider the total system bandwidth or fairness. This paper gives the improved algorithm of spectrum allocation taking the different communication purposes of different users with the present of demand of advanced users into account. The target of the algorithm is to minimize the unmet demand of the total bandwidth for cognitive user when the advanced users are in normal communication (meet the demand of minimum bandwidth for advanced users in normal communication).

Simulation results show that it can meet the bandwidth requirements for advanced users better. The unmet total demand for bandwidth of the domestic users increased than not prioritized ones. But it is still has a better performance than CSGC algorithm.

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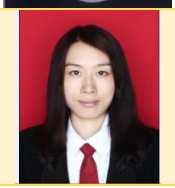

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