Research on Dynamic Allocation Strategy of KU Satellite Spectrum Based on Cognitive Radio Technology

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Abstract. Aiming at the problem of insufficient satellite spectrum resources in the KU band, combined with the most advanced cognitive radio technology in the communication field, this paper proposes a dynamic spectrum allocation strategy for KU satellites based on cognitive radio technology. By dynamically allocating frequency resources, the spectrum resources are greatly improved. Use efficiency, while improving the anti-interference ability of the satellite system.

1. Introduction
Satellite communication has become the most important part of modern communication system because of its advantages such as long communication distance, large coverage, and no impact from landform and land-based disasters. VSAT is the acronym for Very Small Aperture Terminal. Because of its simple structure, easy installation and removal, convenient mobility, and free from natural conditions such as mountains, lakes, oceans and deserts, the band used by VSAT developed from c-band to Ku-band, and in recent years began to develop toward the higher frequency of ka-band. Up to now, the application of VSAT satellite communication system in China mainly focuses on Ku-band, and gradually develops to Ka-band. However, the management of satellite transponder resources is based on static allocation, that is, the spectrum resources on transponder are usually pre-allocated according to the system task requirements. With the increasing number of users, the division of regions becomes more and more detailed, and the transmitted voice and data capacity increases day by day, resulting in an increasing shortage of allocated spectrum resources.

1.1. Overview of Cognitive Radio Technology
CR (Cognitive Radio) technology can be said to provide solutions to the above problems.

In 1999, Joseph Mitola first proposed the concept of cognitive radio in his academic paper. In a notice issued in December 2003, FCC made the following definition of cognitive radio: cognitive radio is a radio capable of interacting with the communication environment and changing its transmission parameters according to the results of the interaction. The core idea of cognitive radio is to make wireless communication devices have the ability to find "spectral holes" and make rational use of them.

The rise and development of cognitive radio technology provides a new way to solve the problem of shortage of wireless spectrum resources. By allowing users to adaptively perceive the spectral holes in time and space of the authorized frequency band, it can use the holes to carry out signal transmission opportunistically, so as to improve the utilization rate of the spectrum. CR also enables the wireless communication system to use the frequency band with better transmission characteristics and wider bandwidth without authorization, which helps balance the communication cost and
performance. At the same time, broadband wireless communication system usually has a large dynamic range of traffic characteristics, which is suitable for opportunistic transmission in a wide dynamic available frequency band. Therefore, introducing cognitive mechanism is not only an effective way to improve the spectrum utilization of future wireless communication system, but also an urgent demand in technology and application.

The core idea of cognitive radio is that it has the ability to learn, to interact with the surrounding environment, to perceive and utilize the available spectrum in space, to limit and reduce conflict. Cognitive radio technology introduces the idea of artificial intelligence and machine learning to make intelligent comprehensive use of various resources, so cognitive radio is also known as intelligent radio. It is characterized by flexibility, intelligence and reconfiguration, through the perception of the external environment, purposefully real-time changing some operating parameters, such as transmission power, carrier frequency and modulation technology, the received radio signal statistical learning and adaptation, so as to realize high reliable communication, and not limited by time and place of efficient utilization of limited radio spectrum resources.

2. Cognitive Radio Technology

2.1. The Need for the KU Satellite to Introduce Cognitive Radio Technology

KU band uplink downlink is 11/14ghz, bandwidth is 500M, covering a wide range, covering VHF voice, synchronization radar and other important services. At the beginning of the construction, the bandwidth capacity of each station was allocated statically, and the voice signal transmitted by the satellite was compressed. With the increasingly fine division of the region, the demand for data and voice capacity is increasing, resulting in an increasing shortage of satellite frequency bandwidth resources, which may lead to communication bottlenecks. In just one station, the number of VHF communication links has nearly tripled in the last two years. In the process of satellite debugging, it is found that the transmission quality of satellite signals is closely related to the bandwidth allocation and occupancy. In the case of loose bandwidth resources, the satellite signal transmission quality is good; in the case of tight bandwidth resources, the satellite signal transmission quality is extremely poor. For statically allocated bandwidth of satellite communication, bandwidth resources are increasingly occupied, but as an emergency system, its spectrum utilization rate is very low. At the same time, the communications satellite in orbit most transparent transponder is satellite, due to all kinds of communications relay satellite in the open space, will face all kinds of interference effects, intentionally or unintentionally, to make some satellite channel can't normal communication, when the end user when interference on the channel of communication, signal quality will be significantly lower, if the control channel interference, the users will be affected even more. Cognitive radio technology not only can improve the efficiency of KU satellite frequency spectrum resource, can also according to the priority judgment, choose the right channel to improve the anti-interference ability of the system, can effectively solve the problems existing in the KU satellite, therefore, in this paper, the main work is combined with the advantage of cognitive radio technology, put forward a kind of cognitive radio technology based KU satellite dynamic spectrum allocation strategy.

3. Design of KU Satellite Spectrum Dynamic Allocation Scheme Based on Cognitive Radio Technology

The proposed scheme is mainly composed of two parts: the KU satellite spectrum detection system model and the analysis of the KU satellite spectrum dynamic allocation algorithm.

3.1. KU Satellite Spectrum Detection System Model

In order to ensure the reliability and timeliness of the satellite frequency spectrum detection system, the scheme is designed to use multiple frequency spectrum detection devices for networking. The model is divided into one main control station device and several monitoring devices distributed in different places, as shown in figure 1.
Each monitoring device detects the frequency band specified for monitoring. The detection method is the most commonly used spectrum sensing technology. Through monitoring and detection, the carrier spectrum parameters in the monitored frequency band are automatically identified, including the performance indicators such as center frequency, bandwidth and signal-to-noise ratio. Identify the occupation of signals in the monitoring frequency band; Identify distractions and alarms; At the same time, all the received information is sent to the master control station equipment and the control information is received from the master control station equipment.

The main control station equipment has two functions: first, after receiving the effective information from the monitoring equipment in various places, it will summarize the information, and then classify and mark the spectrum into spectral holes, in-use spectrum and interference spectrum, among which different spectrum is defined by power, time and frequency, as shown in figure 2. The second is to process the spectrum information, dynamically select and allocate the spectrum through the spectrum dynamic allocation algorithm, and form the control information feedback back to the monitoring equipment.

**Figure 1.** model of KU satellite spectrum detection system

**Figure 2.** Sample diagram of spectrum analysis of Ku satellite
3.2. Analysis of KU Satellite Spectrum Dynamic Allocation Scheme

There are many dynamic spectrum allocation mechanisms. In terms of spectrum acquisition, there are competition mode, auction mode, and long time mode and real-time mode. In the dynamic spectrum allocation algorithm of KU satellite proposed in this paper, the idea of spectrum pool is adopted, priority is set through the tag mechanism, and the algorithm is designed by using the non-cooperative game theory. Professor of the University of Karlsruhe in Germany F.K.J ondral in 2004 first put forward the idea of spectrum pool, in this paper, using the ideas of spectrum pool, incorporating all KU satellite nodes spectrum become uniform spectrum pool, pool and spectrum classified as units of channel frequency spectrum, the spectrum and spectrum is divided into control channel and data channel spectrum, high degree of control for important channel allocation and node number is equal to or more channel resources, the resources are allocated to all data channel. In this way, spectrum resources are no longer statically allocated to a single node.

For the users who apply for the use of spectrum, this paper designs a priority queuing mechanism to set different priorities for users of different nature. The priority of users is set by analyzing the strength and coverage of signals, as well as the main and standby emergency situations and taking them into comprehensive consideration. For authorized users, set the highest priority, non-authorized users set the general priority, and secondary users set the lowest priority. For authorized users, it is set that the spectrum they use does not overlap with other users. Once they have a transmission task, they will be transmitted immediately to ensure the minimum impact on authorized users. Between ordinary users and secondary users, ordinary users can occupy secondary users' spectrum because their priority is higher than that of secondary users, and require secondary users to release their spectrum; For users with the same priority, a first-come, first-served service model is adopted when occupying the spectrum.

3.3. Algorithm Description

There are \( N = \{1,2,3...n\} \) pairs of cognitive user I in the network, each pair of nodes has two interfaces, one is the control channel interface, which is responsible for interacting with the Master Control Station to control information, the other is the communication data channel interface. The operating frequency of Control Channel is fixed, and the operating frequency of data channel is dynamically adjusted according to the result of the Algorithm. In this region, the number of channels available to cognitive users varies dynamically based on spectrum resources, as follows:

Step1: The user who needs to communicate sends an application to the master control station according to his/her business needs, and at time \( T_i \), the queue priority of user I is

\[
\eta_i(t) = \mu_i \exp \left( w_i \cdot \frac{(t-1) - T_{i-1}}{T_{i-1}} \right)
\]

(1)

Among them, \( \eta_i(t-1) \) is the use of user's ranking in the last round of queue, \( T_i \) is the transmission delay limit of the user's bearer service, \( w_i \) is the service delay priority weighting factor for user I, \( \mu_i \) is the priority weighting factor of user i;

Step2: The master control station receives applications according to the priority of users and the order of application. The applications with higher priority are first satisfied, and the applications with the same priority are provided to users in a first-come, first-served service mode by selecting the free channel of spectrum from the spectrum pool and marking the spectrum as \( FS_{\text{use}} \) in use;

Step3: When the user is using a spectrum, if he finds any interference signal in the spectrum channel, he will immediately report to the master control station, raise the priority and reapply for the spectrum. After receiving the report, the main control station immediately marks the spectrum segment as interference spectrum \( FS_{\text{si}} \) and forbids the allocation;

Step4: When the user completes the communication task, a spectrum release request is issued to the master control station. After receiving the application, the master control station marks this section of spectrum as free spectrum \( FS_{\text{free}} \);
Step5: The master control station periodically tests all the spectrum, marking the spectrum with interference signal $I_S_{int}$ as interference spectrum, and disables allocation. For the spectrum previously marked $I_S_{int}$, change to the free spectrum $I_S_{free}$ if the interference has been recovered.

4. Performance Simulation Analysis

In order to validate the proposed based on the cognitive radio technology KU satellite performance of dynamic spectrum allocation, assume that coexistence environment the total channel number is $M$, interfere with the channel number of $m$ ($m << M$, if $m = 1$), the number of cognitive users in current cognitive radio network for $N$, including the number of users work at the same time, the user signal pipe $P$ for normal user accounts for ratio, and considering the time delay problem, take $M = 10$. when $N$ is increasing, the simulation as shown in the figure below:

![Figure 3. Schematic diagram of simulation results](image)

As can be seen from the figure, in the static allocation scheme, when the number of users $N$ is much less than the number of frequency spectrum channels $M$, the user signal integrity rate is better. However, as the number of users $N$ increases and exceeds the number of channels $M$, the user signal integrity rate drops sharply. The dynamic spectrum allocation scheme proposed in this paper can guarantee the integrity of user signals when spectrum resources are limited. The simulation results show that this scheme can obviously improve the sharp decline of signal quality when spectrum resources are scarce, effectively use the spectrum resources and ensure the availability of signals.

5. Conclusion

The dynamic spectrum allocation scheme of KU satellite based on cognitive radio technology designed in this paper can not only effectively solve the problem of tight spectrum resources of KU satellite, but also increase the reliability of KU satellite transmission, which has an important application prospect in satellite system security.

6. References

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