Interference process of secondary users in 5G cognitive radio networks

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Abstract: This paper analyzes the interference process of secondary users in 5G cognitive radio networks with large-scale cells, the secondary users reuse the primary users' spectrum resources, and the networks with primary and secondary system are considered. The primary system is the spectrum sharing networks base on the wireless protocol, the primary users are uniformly distributed, while the secondary users distributed as clusters in the networks. Then, a series of technologies are adopted into the networks for the system-level simulation, which includes modulation scheme selection, hybrid automatic repeat request, power control, and so on. Then, based on the interference process scheme and secondary user relay technology, the system performance is further enhanced. This paper also analyzes the networks based on a macro view of the system and a micro view of the link. In addition, different cluster distances are considered in the simulation, which demonstrates the system performance, is not only impacted by the relay and the interference, but also by the distribution of the secondary users.

1. Introduction

For the 5G cognitive radio networks, many of our predecessors have discussed the issue of interference handling, and also proposed solutions for enhancing system performance. Literature [1] proposed an interference management scheme based on the interference limited area, which is used to enhance the communication performance of the system. Based on the work related to the interference-limited area, Literature [2] enhances the system reliability by introducing the mode selection scheme into the complex interference environment. Further, the author [3] analyzed resource scheduling in the case of secondary system relay assistance, while satisfying no serious interference to the main system. Another resource optimization problem is proposed in literature [4], in which the secondary system can adaptively utilize the current communication environment for efficient distributed resource scheduling.

On the other hand, in order to further enhance the system performance of the 5G cognitive radio network, it is necessary to analyze the overall performance of the primary and secondary systems. Some prior designs such as the coexistence scenario of primary and secondary systems in 5G cognitive radio networks proposed in literature [5] have deeply analyzed the impact of schemes such as service, terminal discovery and power control on the overall system performance of 5G cognitive radio networks. In literature [6], the author illustrates the impact of wireless resource scheduling mechanism on the signal-to-noise ratio between the secondary system and the primary system. In the related literature [7], by analyzing the user's density in the network, changes in system throughput at different densities.

However, the related researches mentioned above focus only on signal-to-noise ratio changes, power control, relay resource analysis, etc., or only consider the network performance under a single main system base station, however, the analysis of the interference situation in the system and the question of earning money for the performance of the entire network still deserve further study. In this paper, we consider the multi-cell structure with primary and secondary systems coexisting. The primary system is based on the wireless communication network that meets the corresponding protocol standards. The primary users are evenly distributed in the system. In order to observe the effect of spectrum reuse, the secondary system is distributed in clusters on the network. Then we introduce a series of basic communication technologies to the 5G cognitive radio network for system-level simulation, including modulation coding selection, automatic retransmission request, power control and so on. Then the performance of the 5G cognitive radio network is further enhanced based on the secondary system relay selection mechanism and the interference processing strategy.

In the system-level simulation of this paper, two performance enhancement mechanisms, interference handling and secondary system relaying, are applied. Meanwhile, the network performance of 5G cognitive radio networks is observed from the perspective of macroscopic primary and secondary hybrid systems. In addition, a certain number of secondary users in the system constitute secondary user clusters. In this paper, different cluster pitches are also considered in the simulation. It is clarified that system performance is affected not only by relay and interference avoidance mechanisms but also the distribution of secondary system users.

The rest of this article is organized as follows. The second section describes the system scenario, the physical layer and media access control layer design are given in the third section, followed by the fourth section presents the secondary system interference handling and relay selection mechanism, and the simulation results in the fifth Given in the section, the final section VI gives the article summary.

2. System model

2.1 Scene Description

The basic system scenario includes a primary system and a secondary system. As shown in Figure 1, the primary system includes the primary user and the primary cell base station. In addition, the secondary user multiplexes the primary system spectrum, and the distance between the largest secondary base station and the secondary user is $d_{c,da}$, $\left(d_{c,\max} \leq 50m\right)$. This article gives two sub-system transmission modes:

1) The secondary system receiver and transmitter transmit over the direct link;

2) The secondary system receiver and transmitter transmit through the secondary system relay;

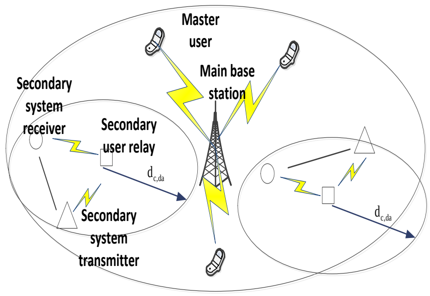

Figure 1 5G cognitive radio network with relay scenario.

Note that only when the secondary system relay is located between the secondary system transmitter and receiver, that is, when the distance between the secondary system relays reaches less than $d_{c,da}$, the secondary system relays can assist in the transmission. Otherwise, the secondary system transceivers can only use the direct link.

In 5G cognitive radio networks, multiple transmit-receive pairs allow simultaneous reuse of the primary system spectrum, while secondary system relays can also spectrum-multiplex. Therefore, for the sake of simplicity, consider the network has always been the case for business to send, so easy to analyze the actual system interference status.

2.2 Network Model

In order to simulate the real scene well, this paper adopts the classic simulation environment of 57 sectors of 19 cells. Each main system cell is built with a hexagonal structure. The station spacing between primary base stations is 500 meters and each sector in the system has a fixed antenna pattern and satisfies the following equation:

$$A(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, A_m\right] \tag{1}$$

Where $A(\theta)$ denotes the gain of the antenna for the direction θ, ($-180^{\circ} \le \theta \le 180^{\circ}$), θ_{3dB} is the 3dB beam width and $A_m = 20dB$ is the maximum attenuation.

In order to avoid serious interference with the main system, the minimum distance between each main user and the base station is 25 meters. Secondary system trunks and primary users are evenly distributed across the network, and then considering that secondary system users may be present in the network in the form of multiple simultaneous users (eg, actual cinemas, large gatherings, etc.), level users are modeled as clusters. The centers of the clusters are regularly arranged in the network, and the distances between two adjacent clusters are the same. At the same time in order to avoid the secondary system also caused excessive interference, the provisions of secondary users, the minimum distance between the relay is 15 meters. Because it is a system-level simulation, interference is also taken from neighboring cells around each cell. The channel model is a classic channel reference model conforming to IMT-Advanced, which is divided into two types of outdoor and indoor channel models, and the two cases of line-of-sight and non-line-of-sight are considered. Therefore, the corresponding path loss channel model is as follows:

1) Line of sight outdoor channel to meet:

$$PL = 40\log_{10}(d) + 7.8 + 2\log_{10}(f_c) - 18\log_{10}(h_{(BS)}) - 18\log_{10}(h_{UT}) \tag{2}$$

2) Non-line-of-sight outdoor channel to meet:

$$\begin{aligned} PL &= 161.04 - 7.1\log_{10}(W) + 7.5\log_{10}(h) \\ &-\left(24.37 - 3.7(h/h_{BS})^2\right)\log_{10}(h_{BS}) \\ &+\left(43.42 - 3.1\log_{10}(h_{BS})\right)\left(\log_{10}(d) - 3\right) + \\ &20\log_{10}(f_c) - \left(3.2\left(\log_{10}(11.75h_{UT})\right)^2 - 4.97\right) \end{aligned} \tag{3}$$

3) Line of sight indoor channel to meet:

$$PL = 16.9\log_{10}(d) + 46.8 + 20\log_{10}(f_c/5) \tag{4}$$

4) non-line-of-sight indoor channel to meet:

$$PL = 40\log_{10}(d) + 30\log_{10}(f_c) + 49 \tag{5}$$

Among them, PL represents the road loss coefficient, d is the distance, f_c is the carrier frequency, h_{BS} and h_{UT} are the aerial height of base station and user. In addition, system-level simulations also take into account the effects of fast decaying channels, which means that in some cases the channels will have deep fading, which are empirical values obtained by measuring the actual environment.

3. Physical layer and media access control layer system design

This section presents several physical layer and media intervening control layer schemes for a hybrid system of primary and secondary systems that include power control, modem selection, and automatic repeat request mechanisms. Before presenting these solutions, we first explain the SINR calculation in the system.

3.1 5G cognitive radio network activation link SINR

The system calculates the bit error rate of each active connection based on the SINR of the receiver. Channel interference is divided into inter-cell interference and intra-cell interference. In addition, intra-cell interference also includes intra-sector interference caused by secondary system users because the system allows multiple pairs of secondary systems to share the same resources within the same sector. Another n represents the number of resources used in the same activity connection, and the SNR of the connection is calculated from below:

$$SINR = \frac{\sum_{i=1}^{n} S(i)}{\sum_{i=1}^{n} \left[I_1(i) + I_2(i) \right] + N} \tag{6}$$

Where $S(i)$ is the received power, $I_1(i)$ and $I_2(i)$ of the i-th resource block end user, respectively, representing intra-cell and inter-cell interference. N is the noise power integrated over the target signal bandwidth.

3.2 Power control, modulation and demodulation options

The bit error rate of each active connection is calculated from the look-up table method. The purpose of the look-up table method is to fit the exact SINR - BER curve. When the SINR of each active connection is obtained, the value can be mapped to the actual bit error rate by the bit error rate data of the fitting look-up table method. To ensure accuracy, the original data stored in the look-up table is obtained through the link layer simulation of a large amount of data.In addition, the encoding of each link in the system is chosen based on the SINR we obtained earlier. Different encoding methods are used in different pre-defined range of SINR, up to 10 encoding types, such as BPSK, 16QAM, etc.

3.3 Automatic retransmission request mechanism

The entire system uses an automatic repeat request as a retransmission mechanism so that when an error occurs during transmission some of the errors can be corrected by the error correction code and the receiver will send an error feedback to correct the incorrect data. The automatic retransmission request is also used in stop-and-wait mode. When an automatic repeat request process is waiting for error feedback information, the other can use the channel to send a signal. The receiver uses maximum ratio combining to combine the received signals. For a secondary system in a hybrid network, the secondary system cannot retransmit the signal until it is scheduled again.

4. 5G cognitive radio network interference handling mechanism

Because of the diversity of propagation losses, there may be unreliable communication links between transmitter and receiver pairs of secondary systems in a very similar location. Therefore, the mechanism of interference handling mechanism and the secondary system relaying technology are introduced into the system to enhance the quality of secondary system communication.

4.1 No interference under the relay processing mechanism

When the transmitter of the secondary system transmits a signal to the receiver, the transmitter can interfere with the primary base station because the secondary system transmits uplink resources that share the primary user. Since the primary user is an authorized user in the system, the quality of the primary transmission should be guaranteed. First, the primary base station can obtain the received power of its primary user of the data. Second, since the primary base station and the primary user have relatively large path losses, each primary user can know the interference from within the cell and between cells. Therefore, the master base station can calculate the interference margin. Third, the primary base station broadcasts the interference margin to the secondary system user while the secondary system transmitter calculates its interference with the primary base station and the secondary system will not be able to do so if the interference exceeds the range that the primary system can afford Transmission, or you can send the signal.

Next, it is necessary to use interference handling to protect the transmission quality of the secondary system. In one system, different secondary systems cause different interferences. Before sending a signal, the secondary system transmitter first predicts the interference, and then for each resource block, the secondary system transmitter compares the interference to a predefined threshold, and if interference is low, the secondary system transmitter can signal on the resource block or it will not be able to signal.

4.2 Relay assisted interference handling mechanism

Sometimes secondary system relays can make up for the larger transmission fading at the secondary system receive and transmit end. Therefore, the channel state information and geographic location information are presumed to be available in the network. Therefore, the secondary system relay will have a relatively large fading value in the system Link to compensate. Divided into two simple steps:

1) The secondary system transmitter transmits the signal to the secondary system relay;

2) The relay is sending signals to the secondary system receiver.

The two steps need to be completed in different time intervals, the first step by the transmitter interference margin calculation, the second step by the secondary system relay interference margin calculation, which determines the system which radio resource block can be used.

5. System-level simulation and discussion

In this section, the corresponding parameters of the system-level simulation are given first, and system performance will be evaluated from a macro-wide network perspective and from a microscopic link perspective. The default simulation parameters are shown in the following table.

Table 1 Simulation Parameters

Parameters	Value
Station spacing	250 meters
Carrier frequency	1800MHz
Time slot interval	0.5 millisecond
Primary user, secondary user, number of trunks	100,50,50
Secondary user cluster spacing	100 meters
Base station antenna number	4
Noise spectral density	-174dBm/Hz
Road damage factor	0.8
Automatically request the number of retransmissions	3
Noise pattern	5dB

5.1 Primary and secondary system performance analysis of hybrid networks

As shown in Figure 2, as the interval increases, the primary user's throughput increases while the secondary system's throughput decreases. This is due to the fact that when the secondary cluster has a small center-to-center spacing, the density of the secondary system users will be greater, which will result in an increase in the secondary system throughput but will cause serious interference to the primary system so that the primary user's throughput decrease. Second, with the help of the interference handling mechanism, the user avoids the reuse of resource blocks that can cause serious interference, so the throughput of both the primary user and the secondary system is increased. On the basis of the interference handling mechanism, after adding the secondary system relay scheme, the throughput further increases but the degree of increase is small. Because secondary system communication is a short-range communication, the quality of the link between most secondary system pairs is quite good, whereas the secondary system relay scheme only improves the part of the secondary system that has large transmission losses. Similarly, after adding secondary system relays, the primary user throughput is almost unchanged because the interference is essentially unchanged.

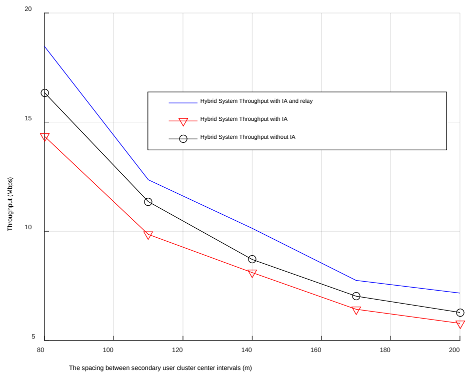

Figure 2 5G cognitive radio network with relay scenario.

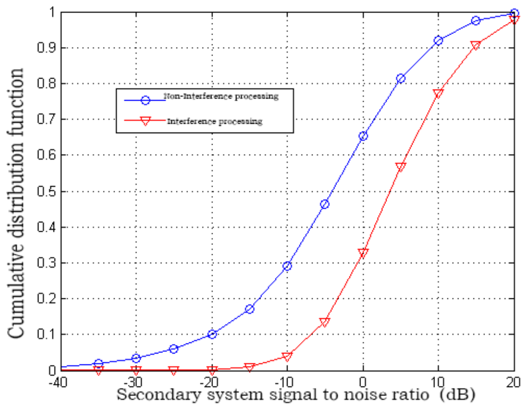

Figure 3 Cumulative distribution function of SINR for secondary system

Referring to Figure 3, after adding the secondary system relay, the curve is better promoted in the part with lower SINR. This is because secondary system relays can reduce the propagation loss between them for poor secondary system pairs. Noting that the effect of improving the quality of poor secondary system linkages when adding secondary system relays to interference-free mechanisms is more pronounced than when adding secondary system relays to existing interference mechanisms. This is because the interference handling mechanism is a mechanism that allows the secondary system to avoid the use of very serious resource blocks. When the secondary system relay scheme is applied in a hybrid network, secondary system relays cannot improve those resource blocks that have been avoided from being reused. Based on the mechanism of interference handling mechanism, the secondary system relay mechanism can only improve the performance of the secondary system on resource blocks with large propagation loss but less interference.

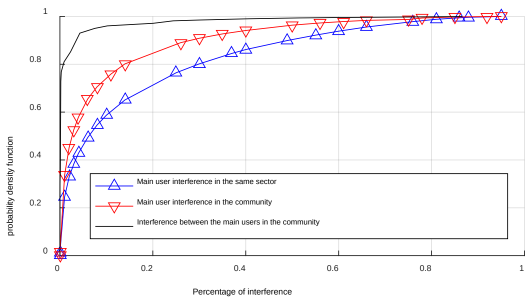

Figure 4 Addition of Interference Processing Probability Density Function

In Figure 4, interference processing mechanism technology makes the most disturbances in the same sector, because the main user is directly interfered by the secondary system of the same sector. In order to protect the main transmission in the same sector, the interference handling mechanism needs to prohibit the secondary system that uses resource blocks when the main users of the same sector are occupied. This reduces the primary user interference in the same sector for the secondary system network while increasing the proportion of other types of interference. Finally, the secondary system interference does not change with the number of secondary system users, and the distribution does not change in either case.

5.2 Secondary System User Performance Analysis

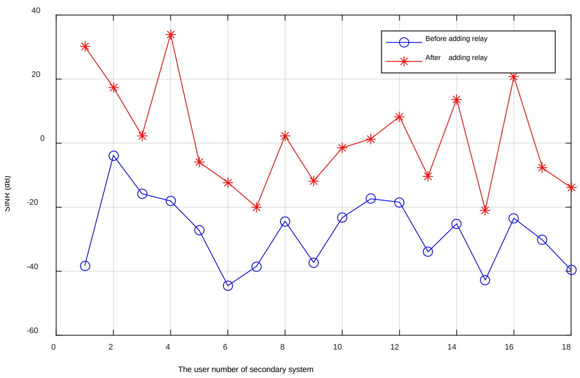

Figure 5 Signal to Noise Ratio vs. Secondary System Subscriber Number

As you can see in Figure 5, 18 users of the relay-based secondary system were selected. All abscissa represents the secondary system user's serial number. As shown in Figure 5.4, the secondary system has a fixed sender transmit power with the addition of a secondary system relay. And the power of secondary system receiver is obviously higher than that of no relay, because the transmission loss is better. Most of the interference values are lower than before the secondary system was added because we only focused on the interference of the secondary system receiver, whereas the communication link from the secondary system relay to the receiver was on every two Interval scheduling only once. It can be noticed that although the secondary system relays are very close to the transmitters and receivers of the secondary system, they still change the local interference environment. Since the secondary system's receiver is very close to the other secondary system's relays, it receives more interference after adding the relay.

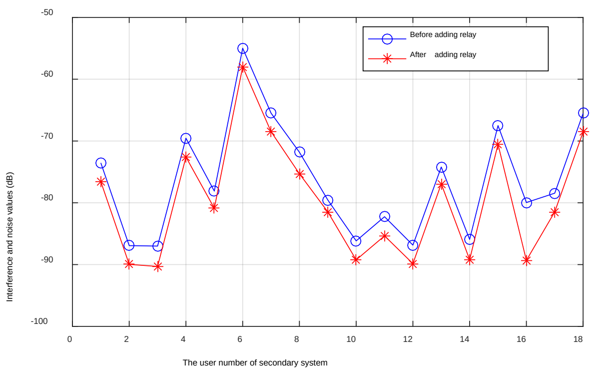

Figure 6 Signal to Noise Ratio vs. Secondary System Subscriber Number

Figure 6 shows the difference between a single secondary system in a real-time environment with and without relay. As can be seen from the figure, the fluctuations in receiver power reflect the effects of fading and the receiver power is boosted because the secondary system relay can improve a large amount of propagation loss. As shown, the receiver of the secondary system is boosted by the relay, because the secondary system is a short-range communication technology, only a small part of the secondary systems need to be relayed to change the propagation loss while the interference environment is not changed much due to the presence of primary users and other secondary system pairs. So the total amount of relay upgrade is not too much.

6. Summary

This article describes multi-cell system architecture for an underlying primary network based on secondary system communications. A series of technologies and propagation models that meet the IMT-Advanced standard are used in this system design. By introducing this interference avoidance mechanism and secondary system relay selection mode in a hybrid network of multi-cell and sub-systems, the system performance has been greatly improved. Through simulation, the different characteristics of this network and individual users of the secondary system are analyzed in depth. The final results confirm that interference avoidance and relay techniques can effectively improve system performance, and the results also show that the system is not only affected by the secondary system cluster center spacing, but also secondary system relays can enhance the chain under poor transmission loss Road quality.

Acknowledgments

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