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***Research paper***

# Frequency Reuse for Coexistence of Secondary Users and Optimum Utilization of Bandwidth

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**Abstract**

Cognitive radio technology is a promising technology to address the spectrum underutilization of licensed users, called primary users and extreme requirement of unlicensed users, called secondary users. Day to day spectrum requirement of secondary users is being increased dramatically and results in increased blocking and dropping. Call dropping is more exasperating than call blocking. So to reduce the call dropping of secondary users, some of the researchers proposed channel reservation techniques. But they got improved dropping results at the cost of increased blocking. So frequency reuse is proposed in this paper, which improves both blocking and dropping.

***Keywords***: Cognitive radio, blocking, dropping, frequency reuse.

## 1. Introduction

The demand for radio frequency spectrum, a scarce and valuable resource, has been increasing significantly due to the increase in number of wireless devices and information sharing in the form of images & videos, which needs higher bandwidth. In the wired communications, the available bandwidth can be increased by laying more cables, whereas in wireless communications, it is a fixed quantity at the given geographical region and is hardly equal to the capacity of just one fibre-optic cable.

Some electronic systems like wireless LAN equipment, garage door openers, cordless phones, and Bluetooth systems use ISM bands for communication purposes. But, the fast escalation in the number of these devices has resulted in crowded ISM bands, which in turn resulted in higher bit error rates and packet retransmissions by the devices that use these bands.

On the other hand, so many applications like television broadcasters, mobile radio broadcasters, satellite services and navigation services have taken licenses from governments to use major part of the spectrum. But, most of the times it is found that these frequency bands are not being utilized fully, by their licensed users, called primary users. According to FCC (Federal Corporation Commission) of USA, the licensed users are not even using 30% of the allocated spectrum [1]. To address these spectrum scarcity and spectrum underutilization cognitive radio came in to existence in such a manner the opportunistic user (secondary user) not to disturb the primary user [2]-[4].

The functionality of cognitive radio networks can be clearly explained from Fig.1.[4]. Spectrum sensing is a continuous task to be performed by SUs (secondary users) for two reasons. One is to identify the free channels to make use of them and the other is to vacate the occupied channel when the corresponding PU (primary user) comes back. Spectrum analysis and decision take care of proper channel assignment in the presence of many free channels and many SU competitors.

Many researchers used the concept of channel reservation for handoff users, because call dropping is more annoying than call blocking scenario. To understand the terminology used in cognitive radio networks refer Fig.1 [5]. The SUs sense and use free channels, called opportunistic use. Call blocking occurs due to unavailability of free channels at the time of SU request. Whenever PU comes back the SU, which is using its channel should vacate it for PU and occupy another free channel, called spectrum handoff. Call dropping results when no free channels are available during spectrum handoff.

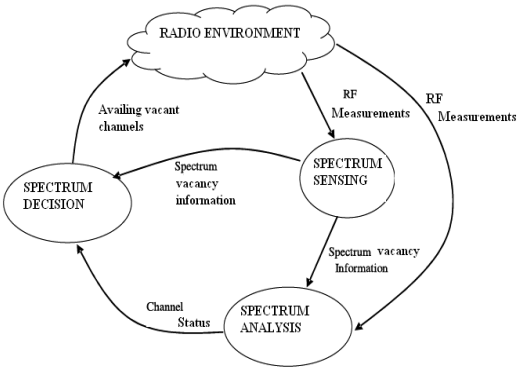



**Fig.1:** Cognitive Radio Life Cycle

In some works, channels are reserved for real-time users. But it will result in more call blocking as some of the available channels are kept aside for handoff users or real-time users. In addition, because the reserved channels are also owned by PUs, there is no guarantee of their availability at the time of spectrum handoffs or request times of new SUs. One more drawback of channel reservation is when a new SU is asking for a channel and no handoffs are taking place or no real-time SUs need service at that time, those reserved channels cannot be used for new SU requests and hence results in wastage of bandwidth.

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So to support the efficient utilization of bandwidth, frequency reuse concept is proposed here instead of channel reservation. Frequency reuse concept is adopted from cellular systems, where the same frequency can be used by more than one user in such a way that there is no co-channel interference.

In this work same frequency is offered to more than one SU if they are displaced by sufficient distances, and the BER values are within the acceptable range. With this frequency reuse, blocking is reduced and call completion rate is improved. Call dropping is also less due to frequency reuse applicability during spectrum mobility also.

According to end user's point of view, the interruption of an ongoing session is more painful than getting rejected to initiate a new session. Therefore, some channels are reserved to take care of handoff SUs [6].

In [7], a sensing scheme named RECOG that is suitable to satisfy the QoS of VoIP is suggested. In RECOG, combination of multiple procedures is proposed. While the secondary device is engaged in transmitting the VoIP traffic, it has to sense the spectrum periodically to find out whether the primary user is back or not. To do so, it has to suspend its transmission for about 100 ms and then resume its VoIP transmission. As 100 ms is a large break for VoIP traffic, it causes jitter. To address this problem, the authors have divided the sensing period into multiple sub-slots, and based on the sensing information in each such sub-slot, a conclusion is made about the presence of primary user.

The authors of [8] have used two buffers, one for handoff SUs and the other for new SUs. Some channels are reserved for handoff SUs. They have considered that SUs are leaving the queues due to impatience because of long waiting times. Under these circumstances they have derived blocking and dropping probabilities using Markov chains.

In [9], the authors have considered two types of priorities for SUs: Streaming and Non-Streaming. They find the best set of successive PU channels such that cumulative bandwidth satisfies the requirement of SUs. They have derived the optimum number of channels to be kept for reservation of channels to streaming type SUs. Here they support the real-time SUs by reserving some channels for them. But reservation of channels may increase unnecessary blocking.

Some channels are reserved for hand off SUs in [10] to decrease dropping probability but at the cost of blocking probability. Performance metrics considered are blocking probability, termination probability and completed traffic.In most of the above works, channel reservation is employed to support real-time users or handoff users, but at the cost of blocking new SU requests. There are three problems with channel reservation. Firstly, the reserved channels may not be available when they are needed by the handoff SUs or real-time SUs. Secondly, even when there is no need of the reserved channels for handoff SU or real-time SU, when some new SUs are requesting at a time instant, these reserved channels cannot be allotted. Finally call blocking will be increased as number of free channels available is reduced.

Section 2 describes the model considered, results are analyzed in section 3 and section 4 concludes the paper.

## 2. Model

The network considered is a centralized network, where a central coordinator manages the traffic of all SUs in a given region. For three different cases of number of channels, results are obtained. Blocking probability, dropping probability and call completion rate are obtained with respect to number of SUs located in the area. Fig.2 explains the terminology used in cognitive radio networks. Blocking probability represents the chance of not getting the free channel due to unavailability of free channels. Dropping probability is the chance of not getting free channel during spectrum handoffs. Call completion rate represents successful completion of the average number of calls [11].

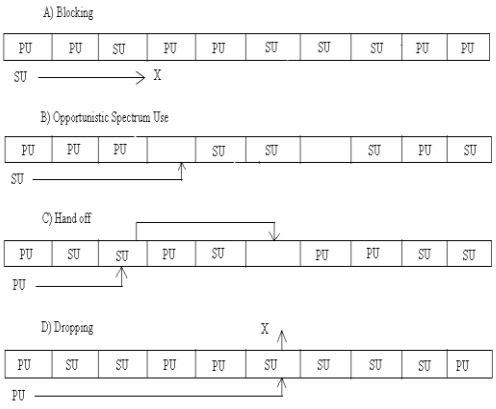



**Fig.2:** Terminology used in Cognitive Radio Networks

When a channel request is received from an SU by the central coordinator, it checks for the availability of free channels and assign a channel if found, otherwise it will check the distance between the requesting SU and an SU which is already assigned channel and assign the same channel if they are displaced by sufficient distance. It is decided by the BER values experienced by both the SUs. This frequency reuse is applicable during the spectrum handoffs also. So with this concept the utilization of bandwidth is improved.

## 3. Results and Discussion

The comparative results are taken for various channel availability scenarios as shown in Table.1 and SU requesting scenarios as shown in Table.2.

**Table.1:** Simulation parameters of channel occupancies

| Parameter | High PU occupancy | Medium PU Occupancy |
|---|---|---|
| Maximum holding time of PUs | 30 minutes | 20 minutes |
| Maximum number of times each PU is reappearing | 30 | 20 |

**Table.2:** Simulation parameters of SUs

| Parameter | High SU demand | Medium SU Demand |
|---|---|---|
| Maximum holding time of SUs | 30 minutes | 20 minutes |
| Maximum number of times each SU is reappearing | 30 | 20 |

The frequency reuse concept is more advantageous when there is high PU occupancy and high demand from SUs.

Fig.3 shows the average number of SU requests for high SU demand scenario; Fig.4 shows the blocking probability of secondary users corresponding to the high SU demand scenario, Fig. 5 shows the dropping probability of secondary users and Fig.6 shows the call completion rate of SUs in both Channel Reservation (CR) and Frequency Reuse (FR) concepts.

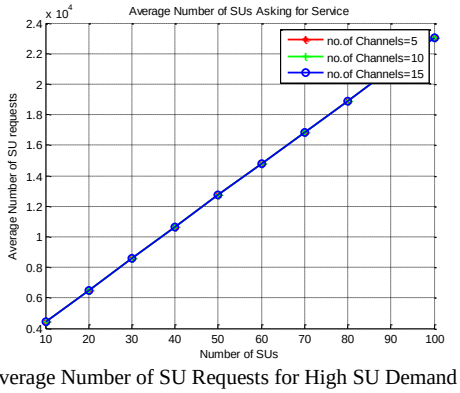



**Fig.3:** Average Number of SU Requests for High SU Demand Scenario

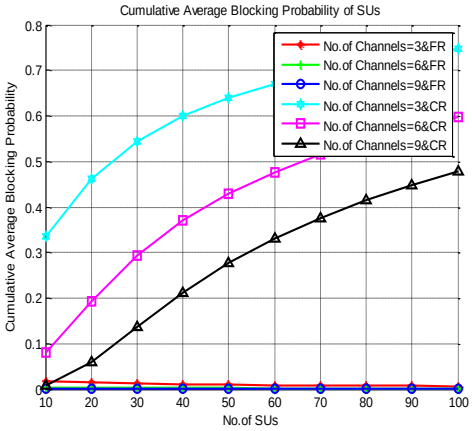



**Fig.4:** Cumulative Average Blocking Probability of SUs for High PU Occupancy and High SU Demand Scenario

From Fig.3, it is observed that the average number of SU requests is linearly increasing with number of SUs. It is common for all cases as it depends only on number of SUs, but not on PUs or on the type of technique to be used.

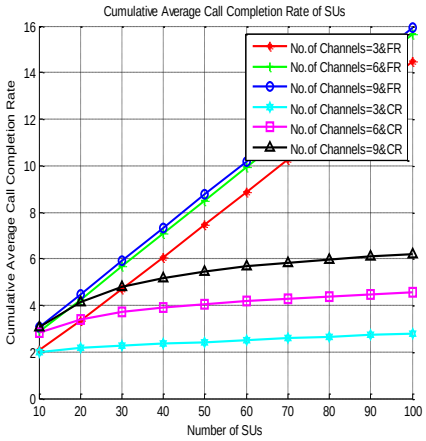



**Fig.5:** Cumulative Average Dropping Probability of SUs for High PU Occupancy and High SU Demand Scenario

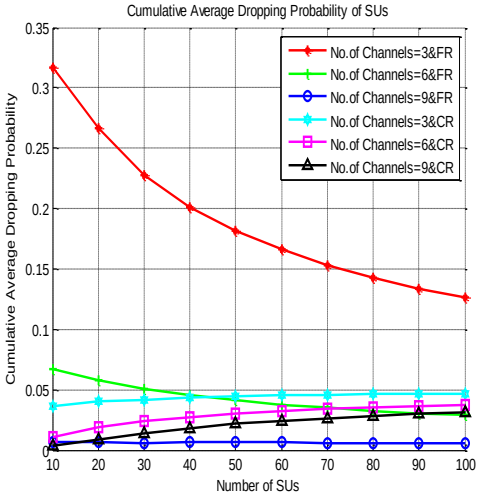



**Fig.6:** Cumulative Average Call Completion Rate of SUs for High PU Occupancy and High SU Demand Scenario

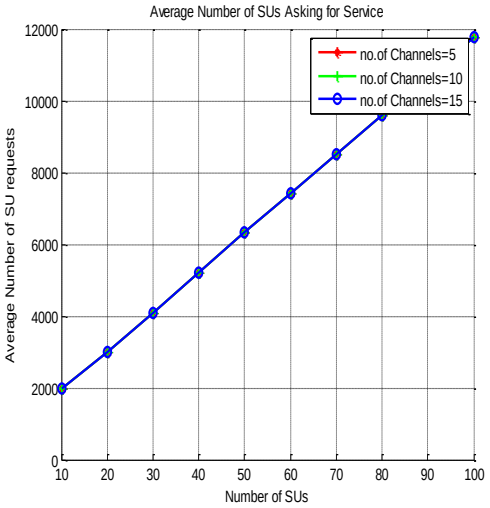



**Fig.7:** Average Number of SU Requests for Medium SU Demand Scenario

SUs for both CR and FR scenarios. It can be observed that the blocking of SUs is more in CR case compared to the proposed FR case. In addition, blocking is reducing with number of channels used, because of getting the more spectrum hole opportunities. It can also be observed that the blocking probability is directly proportional to the number of SUs in CR case, but not in FR case as some more opportunities are getting from frequency reuse concept. Dropping probability of SUs is more in FR compared to CR as observed in Fig.5. It is due to the fact that some channels are reserved for spectrum handoff in CR, so dropping is less. As the number of channels are increased the dropping probability of FR also very less.

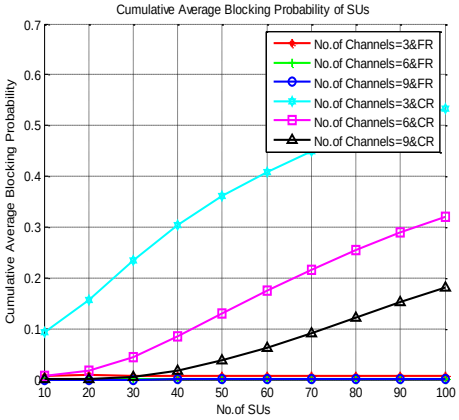



**Fig.7:** Average Number of SU Requests for Medium SU Demand Scenario

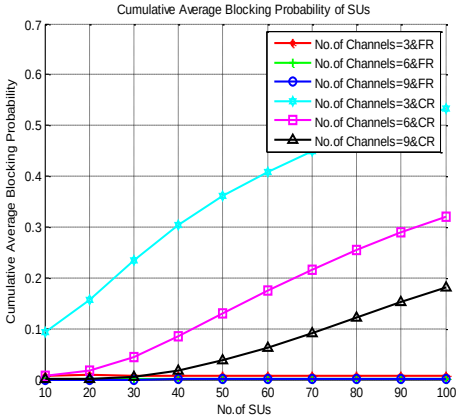



**Fig.8:** Cumulative Average Blocking Probability of SUs for Medium PU Occupancy and Medium SU Demand Scenario

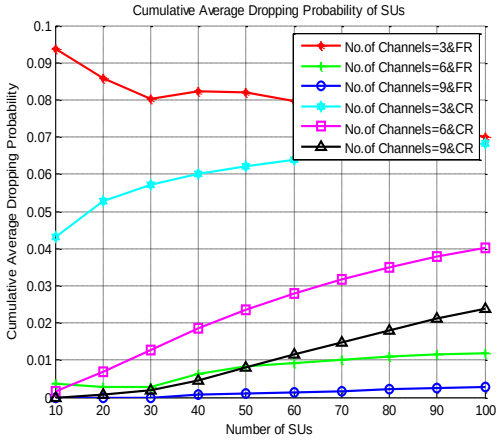



**Fig.9:** Cumulative Average Dropping Probability of SUs for Medium PU Occupancy and Medium SU Demand Scenario

The call completion rate of FR is better than CR scenario as shown in Fig.6. It is due to the fact that even if dropping is increased there is great decrease of blocking.
The results for medium PU occupancy and medium SU demand are shown in Figs 7 to 10. Here number of requests is less and hence it results in less blocking, less dropping and improved call completion rate as number of requests received is less.

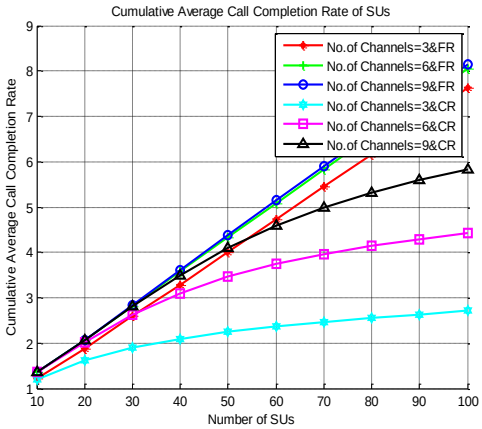



**Fig.10:** Cumulative Average Call Completion Rate of SUs for Medium

## 4. Conclusion

Due to frequency reuse, call blocking is reduced as number of offered channels available to secondary users is more when compared to channel reservation methods. However, a negligible instead of significant increase in call dropping probabilities is observed, due to the provision of frequency reuse during spectrum handoffs also. Finally call completion rate, which represents successful completion of calls, is improved in frequency reuse method when compared to channel reservation methods.
Frequency reuse is more advantageous when there is more demand from SUs and PUs' occupancy is high. The only care that needs to be taken is that frequency reuse should be applied such that there is no co-channel interference.

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