

QoS based Spectrum Selection Scheme in Cognitive Radio Networks

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Abstract – The demand for the wireless spectrum has been increased with the increase in usage of multimedia applications. The available spectrum can be efficiently used with the help of cognitive radio technology. In this paper, spectrum selection techniques in the case of cognitive radio networks are studied. Channel sharing and channel contention problems arise when multiple secondary users tend to select same channel. Here, the objective is to minimize the overall system time and to solve the problem of channel contention and channel sharing. The overall system time of secondary connection is an important performance measure to provide quality of service for secondary users in cognitive radio network. Here, two spectrum selection schemes are considered to reduce the overall system time and solve the problem of channel sharing and channel contention. An analytical model associated with PRP M/G/1 queuing model has been provided to evaluate the suggested spectrum selection scheme. This model also analyzes the effect of multiple handoffs due to arrival of primary users. According to this scheme, the traffic load is distributed among multiple channels to balance the traffic load. Secondary users select the operating channels based on the spectrum selection algorithm. They can intelligently adopt better channel selection scheme by considering traffic statistics and overall transmission time.

Index Terms–Cognitive Radio Network, QoS, Spectrum Selection

1. INTRODUCTION

Cognitive radio is a technique for efficient utilization of spectrum. Here, in this paper the main objective is to minimize overall system time and to solve the problem of channel contention. The overall system time [1] of secondary connection is an important performance measure to provide quality of service for secondary users in cognitive radio networks. It is defined as the duration from the moment that a request for connection arrives at the system until the moment of completing the whole transmission. It is the sum of waiting time and data transfer time. The waiting time is the duration from the moment that connection arrives at system until the moment of starting transmitting data. The data transfer time is the duration from the moment that connection transmission is started until the moment of completing the whole transmission. The selection of the vacant channels is an important task performed by secondary user [2]. For this, various channel characteristics such as shortest expected waiting time, largest idle probability, and largest expected

remaining idle period are considered. Channel contention issue [3] arises when more secondary users select same channel for transmission. An analytical model shown in Fig 1 is reported to evaluate the overall system time of secondary users for the sensing based and probability based spectrum selection schemes. In the suggested method, the arrivals of primary and secondary users follow the Poisson process. According to this model, the secondary user can select one of M independent channels to be its operating channel. The spectrum selection algorithm is either instantaneously sensing-based or probability-based method. Based on the spectrum selection algorithm, each secondary user can select its operating channel. Distribution vector [4] is necessary to describe the result of spectrum selection. The distribution vector will be calculated mathematically for both spectrum selection schemes considering the traffic statistics of each channel.

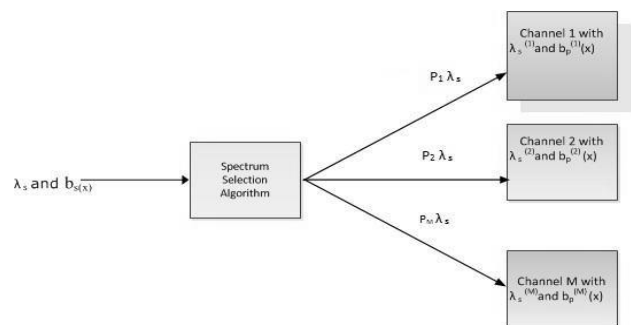


Figure 1 Analytical model for channel selection

Here, arrival process of the primary and the secondary users are considered Poisson process. Let $\lambda_p^{(K)}$ be the arrival rates of primary connection on channel k and λ_s be the arrival rates secondary connections. In addition, $\lambda_p^{(K)}$ represents the transmission duration of the primary connection [5] on channel k and X_s represents the transmission duration secondary connections. $f_p^{(x)}(x)$ and $f_s(x)$ are probability density functions of $X_p(K)$ and X_s respectively. When the request for connection of a secondary user arrives at the

system, the secondary user can select one of M channels for its operating channel depending on spectrum selection algorithm. Each spectrum selection scheme has its own selection algorithm.

The overall system time is evaluated based on the above model. Within the transmission period of a secondary connection, it may experience multiple spectrum handoffs [6] due to the interruption from the primary users. The spectrum handoff procedure helps the secondary users vacate the occupied channel and then resume the unfinished transmission when this channel becomes idle. For evaluation of the overall transmission time of the secondary users considering multiple handoffs, the suggested channel selection model is combined with preemptive resume priority (PRP) M/G/1 queuing network.

Based on the PRP M/G/1 queuing network model shown in Fig 2, the spectrum usage behavior between primary and secondary users can be characterized. Each channel has a virtual high priority queue and a low priority queue [7]. Primary user's traffic waits on high priority and secondary user's traffic waits on low priority

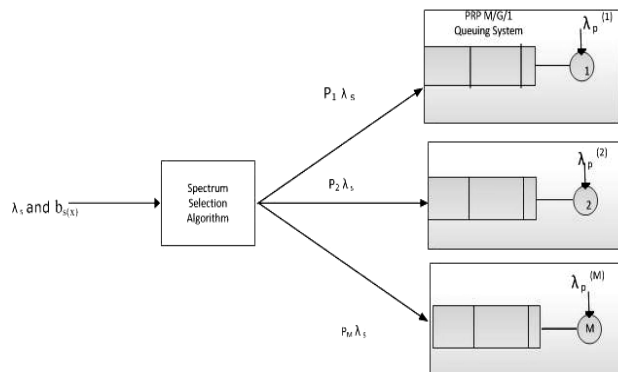


Figure 2 Spectrum usage behavior using PRP M/G/1 queuing network

The total service time of the secondary users is derived considering the average number of interruptions for secondary users of a particular channel and the average busy period resulted from the primary users of that channel. The result of both selection schemes is compared.

2. COGNITIVE RADIO TECHNOLOGY

The issues related to spectrum management are discussed to use the spectrum in a better way. Further, the cognitive radio architecture and cognitive radio environment are discussed in brief.

2.1. Spectrum issues

Radio spectrum is an important source for wireless communication provided by the service providers. It can use in global system of mobile communication by using frequency reuse techniques. The most important research fields are radio spectrum management and utilization [8,9]. The Figure 3 below shows how spectrum management is used. Frequency allocation and standards for new technology are defined by national telecommunication union. For wireless service spectrum is divide in to different segments. It is the right of licensed user to divide allocated spectrum into fixed number of frequency channels.

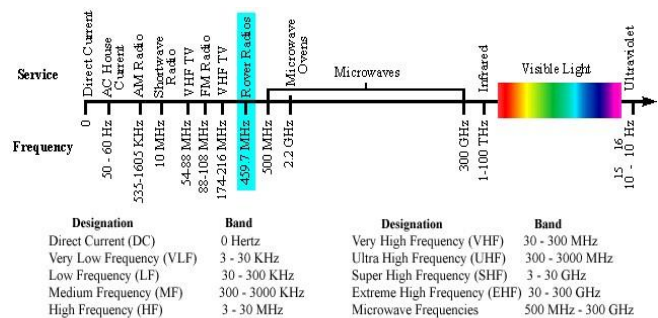


Figure 3 Radio spectrum

FCC is an independent organization of United States of America, which works in areas such as broadband, public safety, media, homeland security and spectrum. In 2002 FCC reported that cognitive radio can help in better usage of spectrum and improve the efficiency of the network. So the cognitive radio can help in effective utilization of spectrum.

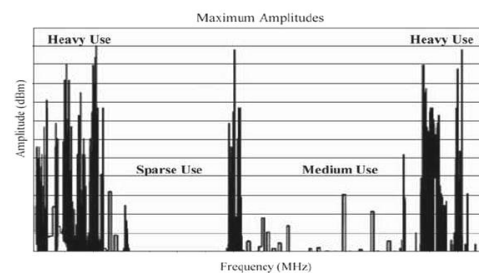


Figure 4 Radio Spectrum Usages

The above Figure 4 shows that licensed radio spectrum is unoccupied and unused. It means that the entire spectrum is not used by the licensed user all the time. So there are always some white holes and spectrum opportunities [10]. To overcome this issue and fill the white holes and to utilize spectrum in a better way a cognitive radio technology is used. Wastage of radio spectrum occurs because it is underutilized from 3GHz to 6GHz.

2.2. Cognitive radio Architecture

In cognitive radio network shown in Figure 5, there are two categories of users. They are licensed (primary) and unlicensed (secondary) users. In radio spectrum primary user is the main owner of the spectrum. For using this radio spectrum customer has to pay government authorities. Various operating parameters [11] for PU are control by the base station. The licensed user also known as primary user has the right to use spectrum anywhere at any time, whereas the secondary needs permission to use the spectrum. If some spectrum is not used by the primary then cognitive radio provides opportunity to the secondary user to use that particular spectrum.

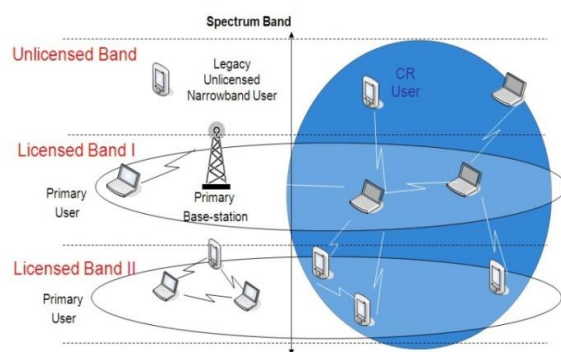


Figure 5 Cognitive radio Network setup

The SU can sense the presence of primary user. If there is no primary user then that spectrum band can be used by the secondary user. Therefore we need some spectrum sensing [12] techniques to meet QoS requirements in Cognitive radio networks.

3. SPECTRUM MANAGEMENT FOR COGNITIVE RADIO

3.1. Spectrum Management in Cognitive Radio network and its challenges

Wireless networks are characterized by static spectrum allocation policy. In this policy the governmental agencies assign wireless spectrum to license holder. Due to increase in demand of spectrum this policy faces some problems in particular spectrum bands. The large amount of spectrum is used irregularly which leads to underutilization of the spectrum band. The dynamic spectrum access techniques can solve these spectrum efficiency [13] problems. Cognitive radio provides the capability to share the channel with licensed users. Using dynamic spectrum access [14] techniques the CR can provide high bandwidth to mobile users. This goal can only be achieve through efficient

spectrum management techniques and dynamic spectrum access. The CR faces new challenges because of high fluctuation in available spectrum and QoS requirement [15] for different application. Cognitive radio can change its transmitter parameters on interaction with environment in which it works. The two main characteristics of cognitive radio are as follows:

Cognitive Capability: Cognitive capability [16] refers to the ability of the radio to sense the information from its radio environment.

Reconfigurability: To transmit and receive a variety of frequencies, to use different transmission access technologies a cognitive radio can be programmed. The cognitive capability and reconfigurability [17] help the secondary user to use the unused spectrum in network.

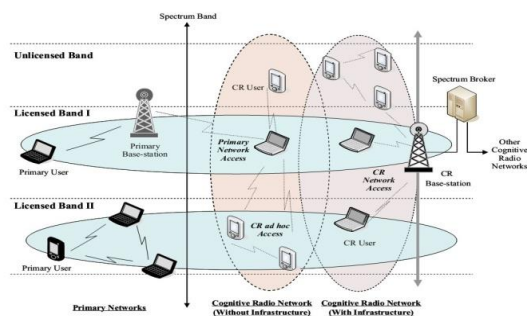


Figure 6 Cognitive radio architecture

The cognitive radio operating in heterogenous network environment addresses four main challenges: spectrum sensing, spectrum decision, spectrum sharing, and spectrum mobility.

Spectrum Sensing: Unused portion of spectrum can be allocated to a cognitive radio user. Therefore available spectrum bands should be monitored by the CR user. CR user needs to capture their information and detect the spectrum holes.

Spectrum Decision: Users can allocate a channel, based on spectrum availability. This allocation not only depends on availability of spectrum but also based on internal policies.

Spectrum Sharing: If there are multiple CR users trying to access the spectrum, in this case to prevent multiple users colliding in overlapping portions of the spectrum, the CR network access should be coordinated.

Spectrum Mobility: CR users are visitors to the spectrum. If the portion of the spectrum is required to be used by the

primary user, the communication needs to transfer to another unused portion of spectrum.

3.2. PRP M/G/1 queuing model

Many challenges [19] are faced by secondary user SU during its operation in licensed user to meet QoS requirements. The main challenges are: Availability of the spectrum and to find best available channel. For evaluation of the overall transmission time of the secondary users considering multiple handoffs, the suggested channel selection model is combined with preemptive resume priority (PRP) M/G/1 queuing network. The primary users have preemptive priority to interrupt the transmission of the connections of the secondary users. The interrupted connection of the secondary user can resume the unfinished transmission when the channel becomes idle, instead of retransmitting the whole data.

4. SYSTEM MODEL

This section gives an overview of determining optimal distribution vector of the two proposed channel selection scheme, evaluation of the overall transmission time, multiple handoffs and calculation of channel utilization.

4.1. Instantaneously sensing based scheme

According to instantaneously sensing based scheme all secondary users perform spectrum sensing to find an idle channel from all channels. If more than one channel is found vacant, one channel will be selected uniformly by the secondary user as its operating channel from those entire vacant channels. On the other hand, if all channels are found busy, the secondary user will conduct spectrum sensing on next sensing interval. The probability of a selecting a particular channel n depends on the traffic statistics [20] of primary and secondary users and determine inherently. We consider the set of all channels $\alpha = \{1, 2, \dots, M\}$, then a particular channel n will be selected by the secondary users as an operating channel with the following probability [31].

$$p_n = (1 - \rho^n) \sum_{\omega \subseteq \alpha / \{n\}} \left[\frac{1}{1 + |\omega|} \prod_{i \in \omega} (1 - \rho^{(i)}) \prod_{j \notin \omega} \rho^{(j)} \right] + \prod_{i \in \alpha} \rho^{(i)} p_n$$

Where ρ^n = busy probability of channel n and it is determined by the arrival rates and service times of the primary and secondary users.

4.2. Probability based scheme

In probability bases channel selection scheme, a predetermined distribution vector is used by the secondary users to select its operating channel. To determine the distribution vector a transmission time minimization is formulated as follows.

$$P = \arg \min E[T_{pr}(p)]$$

Where $E[T_{pr}]$ = Average overall transmission time of secondary user in probability based scheme. Here is the function of distribution vector. Solution of this optimization problem finds the set of probability distribution vector for which overall transmission time will attain a minimum value.

4.3. Evaluation of Overall transmission Time

For better Quality of Service of SU we need to minimize the overall transmission time. This is important factor for better Quality of Service (QoS). The overall transmission time is denoted by (T). It consists of the waiting time and the total service time. Waiting time [22] is defined as time from which data enters the system to time at which system start transmitting the data and the total time is define as the instant at which system start transmitting data until it completes the transmission. During the transmission SU may experience multiple handoffs because of the interruptions that are caused by primary user. Handoff method in spectrum helps the secondary user to vacate the channel and later if the channel become idle then it can resume and finish its job. So, overall transmission time is affected significantly by multiple handoffs. It will increase the transmission time and Effect the Quality of Service (QoS). To evaluate the overall transmission time with multiple handoffs, PRP M/G/1 queuing model is associated with the proposed channel selection schemes. This queuing model help analyzing the spectrum usage behavior. Depending on the analytical result the best scheme is selected for transmission. The channel selection scheme for which overall transmission is lowest is the optimal selection scheme and the optimal transmission time can be determined as follows.

$$T = \min(T_{sc}, T_{pr})$$

Where T_{sc} = The overall transmission time of SU for sensing based channel selection scheme and T_{pr} = The overall transmission time of SU for probability based channel selection scheme.

5. RESULTS AND DISCUSSION

Fig.7 describes the effect of arrival rate of secondary users on overall transmission time for three spectrum selection schemes. It is evident from the figure 5.10 that both sensing based and probability based scheme considerably reduce the overall transmission time in comparison with traditional scheme. In traditional method secondary tends to select same channel for transmission. In traditional scheme the secondary users selects channel based on the lightest traffic load, the shortest expected waiting time, the longest expected remaining idle period and maximum throughput.

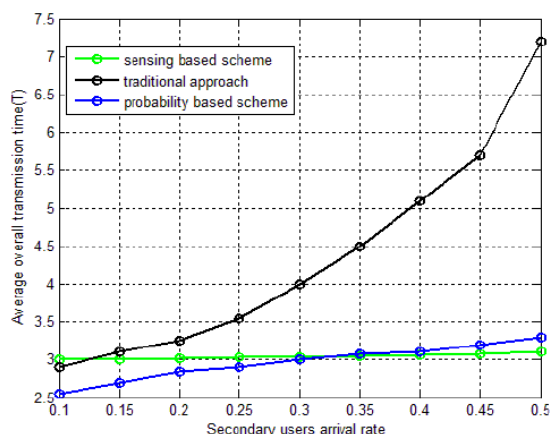


Figure 7 Comparison of overall transmission time for different channel selection schemes with different arrival rate of secondary users.

It is seen from the figure 5.10 that probability based scheme has shorter overall transmission time in lower arrival rate of secondary users whereas with higher arrival rate of secondary users sensing based scheme has the shorter overall transmission time. This is because probability based scheme tend to select channel which has the lowest interrupted probability and sensing based scheme considerably decrease the waiting time.

Fig.8 shows the optimal overall transmission time adopted from both scheme. Secondary user can chose the best spectrum selection scheme to reduce the overall transmission time.

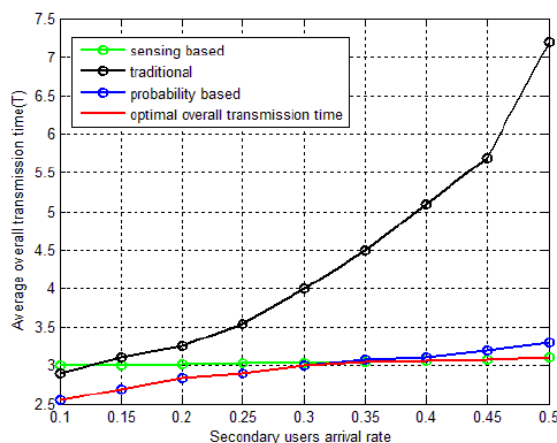


Figure 8 Optimal overall transmission time for different arrival rate of secondary users

6. CONCLUSION

This paper presented the secondary users overall transmission time, the effects of channel contention and spectrum sharing problems, and multiple handoffs. Two spectrum selection

schemes were suggested which considerably reduce the overall system time, increase the utilization of all channels by a balance distribution of traffic load among them, resolve the problems of channel contention and evaluate the multiple handoffs. Thus it also provides an insight view of spectrum selection technique in cognitive radio network. From the numerical result it is evident that overall system time of secondary users' significantly reduces and utilization of all channel increases. In addition, probability based channel selection scheme perform better while secondary users' arrival rate is lower. In contrast, instantaneous sensing based channel selection scheme perform better while secondary users arrival rate is higher. Moreover, secondary users can intelligently choose the better spectrum selection scheme with variable traffic parameter. Although cognitive radio convey a greater potential to overcome the underutilization of spectrum in future it has many theoretical limit still unresolved.

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