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Research paper



Channel accessing and handoff mechanisms in TV white spaces based on channel sensing and database information

Krishna Chaitanya K[1*], Meghalatha CK[2], Annapurna K[3], Seetha Ramanjaneyulu B[4]

[1]*Vignan's Foundation for Science, Technology, Research Deemed to be University, Vadlamudi Guntur, Andhra Pradesh, India, 522213.*
**Corresponding author E-mail:krishna.kandregula444@gmail.com*

Abstract

Opportunistic channel accessing and handoff mechanisms are crucial for the successful implementation of cognitive radio networks that depend on vacant channel frequencies of TV white spaces and other primary users. In this work, two such mechanisms that enable quick accessing of vacant channels and cause less interference to primary users are proposed. In these methods, combination of database information and local sensing of channels is used, to know about available vacant channels. If the primary user of incumbent channel returns, the secondary user moves to another vacant channel that is found to be free after scanning. Information from database can be used to speed up the process by limiting the scanning to few probable channels, instead of searching for all. The results show that these methods offer quick handoff of secondary users and cause less interference to primary users.

Keywords: *Cognitive radio, TV white spaces, Dynamic Spectrum Access, TVWS Database, Spectrum Holes*

1. Introduction

Since much of the wireless spectrum is already allotted and is in use for different services, many new wireless technologies and services are starving to get new spectrum allocations. In this context, the concept of 'cognitive networks' is a revolutionary concept that proposes to utilize the licensed spectrum of primary users by unlicensed secondary users in such a way that the transmissions of licensed devices are not disturbed or interfered [1]-[5]. It was proposed by Joseph Mitola in [2], and research is taking place from the last two decades on various aspects of it, like spectrum sensing [6]-[8], sharing [9]-[11], security to licensed users [12], [13], [14], reliability, and Quality of Service (QoS) aspects [6]-[11] etc, by researchers around the world.

The crucial element of the system is spectrum sensing that is carried out by the cognitive device that is vying for the channel. Sometimes, cooperative spectrum sensing is also carried out with the help of a few other such devices in that location. But a more useful thing here is that if some information is available about the vacant channels available at a given location, at a given time, then the secondary user need not carry out extensive spectrum sensing on its own. Some database servers that store the information of available vacant channels at various geographic locations, of various times, are proposed for this activity, in the recent times. This can help in limiting the scanning process. Another development in this is that the primary users themselves will make notifications about their arrival and exit.

Prediction of probable channels is another aspect that will be useful for proper utilization of channels. In this work, a combination of these methods is used. In the first method database information is used for limiting the spectrum sensing. Then, channel sensing is adopted to carry out the sensing of those channels. In the second method, prediction mechanism is used to select one vacant channel that is least used and also most recently used. The results are compared to the method of using only local sensing and without any prediction mechanism. Section 2 of the paper contains the details of dynamic spectrum access method that is used to sense the TV white spaces frequencies and the use of database information to speed up this process. Section 3 details the proposed model of the system that uses the combination of database information, local channel sensing and prediction. Section 4 comprises of simulation results of these methods in comparison with other methods which do not use background channel sensing and database. Section 5 concludes the paper.

2. Database Information and Local Sensing

Cognitive Radio concept was widely acclaimed by researchers all over the world as an immediate solution to cater to the bandwidth requirements of wide-range of new wireless technologies. The conventional spectrum scanning mechanisms have a drawback of scanning every channel which will make the secondary users getting starved of channel for long time. In this regard, methods that make use of database information of vacant channels are found to be better. Also, in most of the cases, the proposals were made by considering only one device, i.e., the transmitter. But in practice, it is required to consider that the channel chosen should be free at the location of receiver also. It is also important to note that most of these transmissions are duplex and need separate channels for transmission and reception. The standards like IEEE802.22 have made provision for this by incorporating the database of spectrum holes information made available from a server, to secondary device. Now, the secondary user can attempt to use those free channels after resolving the contention among other such devices in that location. This database is usually created after conducting surveys at many geographical locations.

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In the proposed model of this work, after obtaining the information from database, the secondary device conducts limited scanning on its own. Due to this, scanning time of hunting for the channel is reduced. Also, in the event of primary user returning to use his channel, the secondary user can quickly jump to one of those designated vacant channels after doing a quick scan of it. This way, it can minimize the dropping probability of secondary user. The IEEE has formulated 802.22 standards to utilize the TV white spaces through cognitive radio mechanism. This standard is one milestone in that direction [15], [16]. The policy of national broadband policy and allowing some other non-TV bands also for cognitive radio operations in USA has boosted the research in this field.

3. System Model and Proposed Methods

The proposed system is implemented with multiple primary users and secondary users in the network. All the primary users (PUs) transmit their signals in different frequencies that are licensed to them. Now the secondary user (SU) waits for the opportunistic access of the channel. It gets the vacant channels information from database. It scans those frequencies locally also, and chooses the first available vacant channel. After that, it interrupts its transmissions periodically, say for every ten thousand milliseconds, and checks whether the incumbent primary user has returned. If the PU returns, then the SU will need to implement handoff. Otherwise it will continue to use the same channel for another ten thousand milliseconds. This checking for PU will take about 100 milliseconds. During this time, the SU cannot do its transmissions. If it is found that the PU has returned, then the SU will quit that channel immediately and scan the next probable vacant channel (as per the information received from database). If it finds that channel as vacant still, it claims for it and uses it for its transmissions. If that channel is not vacant, then it will scan the next probable vacant channel to see whether that one is available. This process continues until it gets the vacant channel. Whenever there arises a need to scan more number of channels during this process, then the delay of acquiring the channel will be increasing. When database information is not used, then the device has to search every channel of the spectrum to know whether it is vacant or not. By using database information, this scanning is limited to few channels that are indicated as vacant by database server, but still may be in use locally. These results are shown as Model-1 and Model-2, with model-2 as the proposed method that uses the combination of databases and sensing, while model-1 is the one that doesn't use database information, and hence need to search every channel.

The proposed system is implemented in GNU radio. The random source is used to generate random signal which is modulated by using constellation modulator. This constellation modulator is used to specify the modulation mechanism followed, by using constellation object block. The constellation object block provides greater flexibility in defining the modulation, mostly QPSK or variable constellation is preferred. The constellation modulator uses a root raised cosine (RRC) pulse shaping filter, which gives a single parameter to adjust the roll-off factor of the filter, often known mathematically as 'alpha'. Frequency xlating FIR filter is used as a channelizer. It can select a narrow bandwidth channel from the wideband receiver input and the operating frequency of the user is also mentioned in this block. After FFT filter, attenuation must be added, for which embedded python block is used here. GLFSR source is a Galois LFSR pseudo random source block which is used to control the secondary user transmission. After transmitting the combined signal through channel, the presence of the primary user is detected by PU using power squelch block at the receiver end.

The next method is based on prediction mechanism, to reduce the channel scanning time further. This prediction also helps in retaining the channel by SU for more duration, instead of frequent handoffs. It is implemented by using a channel that is used for lesser time historically. That means, the activity of its primary user is relatively less, compared to other PUs. Another aspect that is considered here is whether that channel was used recently by its PU or not. This information is used to arrive at a conclusion of whether the PU will return soon or much later. It is assumed that, if it is recently used by its PU, then its PU may not need it immediately. Based on these assumptions, the channel is finalized by the device, and that channel is scanned first, if the SU has to quit its present channel. Now, as there is more possibility of this channel to be vacant, then the channel acquiring time of this method is found to be lesser than the previous method.

4. Simulation Results

Simulation of the system with proposed methods is carried out here. The five PUs, whose licensed frequencies are in the ascending order, are implemented here with different occupancy scenarios. The first one is with heavy occupation to the tune of 90%. The next PU is with 80% occupancy. The other PUs has the occupancies of 60%, 40% and 20%. The scenario is created in such a way that when the SU acquires a channel in the sequence, it will have a need of quitting it very soon. Channel acquisition by SU for various instants is shown in Fig. 1. This is mostly true for the conventional method that does not use database information. However, for the proposed methods that make use of database information, the situation will improve, as it selects the channel that is found to be vacant from database information.

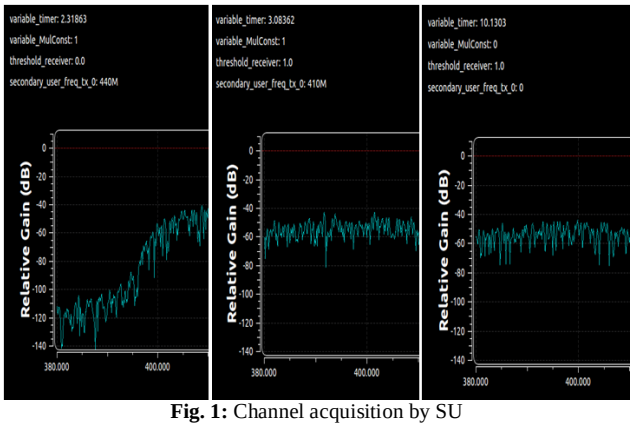


Fig. 1: Channel acquisition by SU

Typical information of database offers the vacant channel status at various locations. It considers five frequencies and their availabilities at five locations. For example, it indicates that 410 MHz is vacant at location-1. Then the SU will limit its scanning to that channel only. This scanning is shown in Fig. 2.

Performance comparison of the proposed methods is offered in Fig. 3. As evident, using the combination of database information along with local sensing offered lesser delays, when compared with the conventional method that is entirely based on scanning. The next method that uses prediction offered further improvement. The peak values of delay are around 500 mSec in the conventional method, when compared with 300 mSec and 200 mSec in proposed methods. The average value of the delay also offers similar level of improvement.

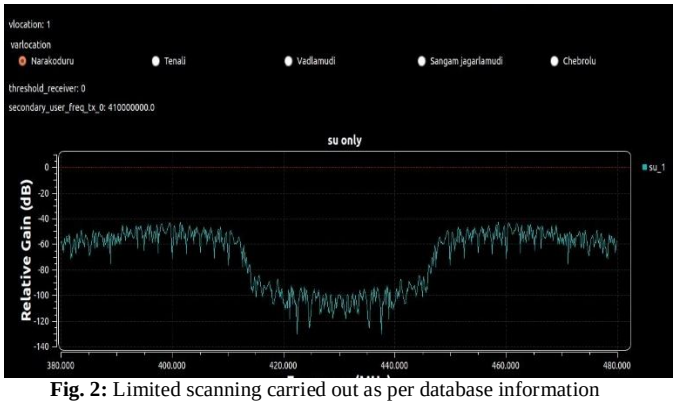


Fig. 2: Limited scanning carried out as per database information

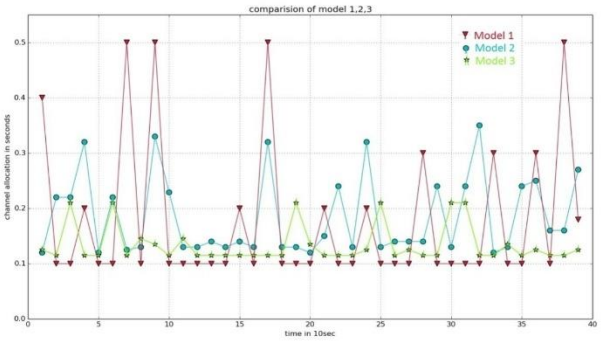


Fig. 3: Performance Comparison of the proposed methods with conventional method

5. Conclusion

Cognitive radio system that makes use of database information of vacant channels along with local sensing and prediction of channel vacancy is implemented in this work. By using database information, channel scanning is limited to few channels thereby reducing the delay of channel acquisition. Channel prediction has offered further improvement. The least used and latest unused mechanism will increase is used for prediction. Overall, the proposed methods offer a reduction of 40-60% delay for channel acquisition. If a control channel is used through which the information of the primary user's return is indicated, then the SU need not interrupt its transmissions periodically to check for the arrival of PU. In such cases, whenever it gets such information, it can quit that channel and search for the next available channel. Through this, it can cause less interference to primary users also. However, an appropriate method of control channel implementation is needed for this.

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