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Research Article

Comparision Of Soft Fusion Techniques for Cooperative Spectrum Sensing in Cognitive Radio Networks

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ABSTRACT
Spectrum sensing plays a major role cognitive radio networks. To avoid the interference to primary users and to detect the spectrum holes for secondary users and hence to improve the spectrums utilization, the sensing should be more accurate. But, the sensing accuracy in practice is often degraded with shadowing, multipath fading and receiver uncertainty issues. To overcome the impact of these problems, cooperative spectrum sensing is being used to enhance the sensing accuracy with the help of spatial diversity. In cooperative sensing, fusion center will investigate the sensing data received from different nodes and by applying fusion rule final decision will be taken. In this paper hard and soft fusion rules are compared and from simulation results, the soft fusion rule is found to be more accurate than hard fusion rule.

Keywords: Cognitive Radio Networks, Fusion, Cooperative Spectrum Sensing, Sensing Accuracy, signal detection.

Introduction

The demand for radio frequency spectrum is being increased drastically due to rapid growth of number of wireless devices and data sharing in the form of images and videos, which needs more bandwidth. In addition, the upcoming technologies like 5th Generation Communications (5G) and Internet of Things (IoT) also demand more bandwidth. It is possible to increase the bandwidth availability by laying more number of cables in the case of wired communications, but it is fixed in wireless communications for a given geographical region and is hardly same as the capacity of one fibre optic cable.

Satellite communications, cellular communications, terrestrial TV transmissions, navigation applications, military applications, etcetera use wireless spectrum by taking license from respective governments. In addition to give license to use specific frequencies by these applications, the government also provides some Industrial Scientific and Medical bands (ISM bands) at different frequencies like 49 MHz, 900 MHz, 2.4 GHz, and 5.1 GHz to accommodate the requirements of industrial, scientific and medical applications. In addition to the industrial, scientific and medical applications some electronic systems like garage door openers, cordless phones, wireless LAN equipment and Bluetooth systems use ISM bands for their communications. But, due to rapid growth in the number of these applications resulted in crowded ISM bands, which in turn responsible for high bit error rates and packet retransmissions by the applications, which use these ISM bands.

On the other side, according to Federal Corporation Commission (FCC), so many licensed spectrum users are not even using 30% of their allotted spectrum [1], which leads to spectrum underutilization. So, address these two problems of spectrum scarcity and spectrum underutilization, there is a need of developing new techniques, which ensure no disturbance to licensed users. Cognitive Radio [2,3]is one of the technologies to make use of the unused frequency bands of licensed users by the unlicensed users. Here the licensed users are termed as primary users and unlicensed users are called secondary users.

Figure-1 [2,4] shows the life cycle of cognitive radio networks. Spectrum sensing is performed periodically to detect the spectrum holes and to leave the spectrum whenever the licensed users come back while their frequency bands are being used by unlicensed users. [5,6,7,8]. This sensing accuracy affects both the primary and secondary networks. Based on the sensed results spectrum decision will be taken and provides the information of available free channels for unlicensed applications. Then spectrum sharing is done to the competing unlicensed users based on available free channels. In[9], the authors proposed two mechanisms to share the available spectrum holes based on demand and supply concept. In [10], the authors analyzed that for how many users the available spectrum can be distributed without causing interference to all users. Whenever the primary user comes back then the secondary user should vacate the channel and occupy another free channel is called spectrum mobility. If the secondary user is able to predict the re arrival of primary user in advance then its transmissions won't get disturbed and such a scheme is proposed in[11].

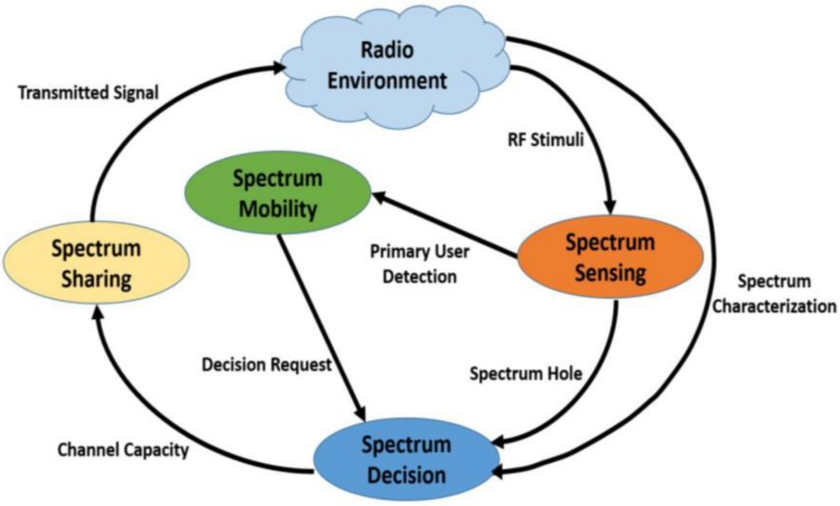

Fig.1: Life cycle of Cognitive Radio Networks

In spectrum sensing four cases of results are possible. First, there is a chance of concluding that the primary user is presence in its absence and is termed as false alarm. Second, there is a chance of concluding that the primary user is absent in its presence and is termed as misdetection. Third, there is a chance of concluding that the primary user is presence in its presence and is termed as detection. Fourth, there is a chance of concluding that the primary user is absent in its absence. shadowing, multipath fading and receiver uncertainty issues are the reasons for probability of false alarm and misdetection.

All CR users won't sense the same amount of PU signal strength due to spatial diversity. That is, shadowing, multipath fading and receiver uncertainty issues won't influence all the secondary users' sensing performance in the same manner due to spatial diversity. So instead of taking individual sensing results alone to occupy free channels, it is better to collect sensing results from few secondary users and by applying some rule to decide whether the primary user is present or not will improve the detection performance and is called cooperative spectrum sensing [12].

The remaining paper is organized as follows. Section 2 deals with various hard fusion rules, section 3 covers different soft fusion rules, section 4 illustrates the results and section 5 concludes the paper.

Hard Fusion Rules

In hard data fusion, the secondary users send their decision to fusion centre and the fusion centre gives final decision based on the individual decisions received from the secondary users and fusion rule. There are basically three types of hard fusion techniques [13]. The major advantage of hard fusion is it requires less bandwidth [14].

K out of N Rule

It is also termed as majority rule. If the fusion centre is receiving inputs from N number of nodes and if at least K number of nodes send that the channel is occupied then only it decides that the channel is occupied. Mathematically

$$\sum_{i=1}^{N} d_i \geq K \Rightarrow H_1$$

$$\sum_{i=1}^{N} d_i < K \Rightarrow H_0$$

Where d_i represents the local sensing decision of i^{th} secondary user.

OR Rule

In OR rule the fusion centre decides that the channel is free only when it receives all local decisions as channel is free.

$$\sum_{i=1}^{N} d_i > 0 \Rightarrow H_1$$

$$\sum_{i=1}^{N} d_i = 0 \Rightarrow H_0$$

i· 1

AND Rule

In AND rule the fusion centre decides that the channel is free even when at least one local decision is channel free.

N
. d_i . · N · · H_1
i· 1
N
. d_i . · N · 1· · H_0
i· 1

Soft Fusion Rules

In soft fusion the individual secondary users forward the sensed energies instead of their local decisions to fusion centre[13]. Then the fusion centre gives decision based on based on received energy levels with the help of some soft fusion rule. Computational complexity of soft fusion is more compared to hard fusion, but it is efficient and needs less bandwidth [15].

SLC

SLC means square law combining. Here the sensed energies of each secondary user is sent to fusion centre. Then the fusion centre checks the sum of all the energies received with a threshold and if the sum is greater than the threshold then it decides that the primary user is present else absent [16].

N
. d_i . · T · · H_1
i· 1
N
. d_i . · T · · H_0
i· 1

where T denotes the decision threshold.

MRC

MRC refers to maximum ratio combining.

Here all the received energies are normalized and weights are assigned to secondary users based on their sensed energy levels. The weighted sum is calculated and is compared with a threshold to decide the presence or absence of a secondary user [17].

N
. W_i E_i . · Th · · H_1
i· 1
N
. W_i E_i . · Th · · H_0
i· 1

SC

SC refers to selection combining. Here the fusion centre selects the input, which is having highest signal to noise ratio [18].

Results and Discussion

Figure-2 shows the probability of misdetection, which indicates the probability of detecting spectrum hole but actually when it is not a spectrum hole. It should be as minimum as possible; otherwise the primary transmissions will be disturbed by secondary users and hence violates the concept of cognitive radio networks. From Figure-2, it can be observed that MRC fusion technique offers better misdetection probability compared to SLC fusion technique. It can also be observed that the probability of misdetection is reducing with increasing number of secondary users, which is due to increased accuracy of detection with more number of secondary users.

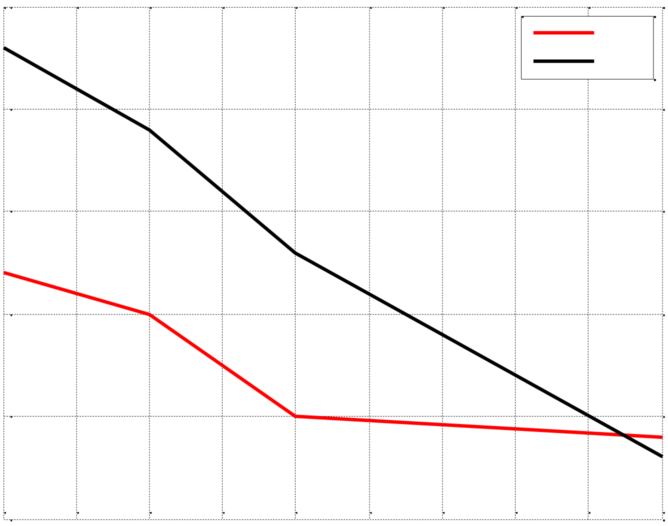

Fig.2: Probability of Misdetection

Figure-3 shows the probability of false alarm, which indicates the probability of missing the spectrum holes detection. Its value should be as low as possible; otherwise the secondary user will lose the opportunities to make of use of available free spectrum. From figure-3 it can be observed that SLC fusion is giving better response compared to MRC fusion. In addition the probability of false alarm is reducing with increasing the number of secondary users, as the decision accuracy will be improved with number of secondary users.

Figure-4 indicates the detection accuracy of MRC and SLC fusion techniques. It can be observed that the detection accuracy is improving with increasing number of secondary users. For less number of secondary users MRC fusion is giving better results compared to SLC fusion and vice versa.

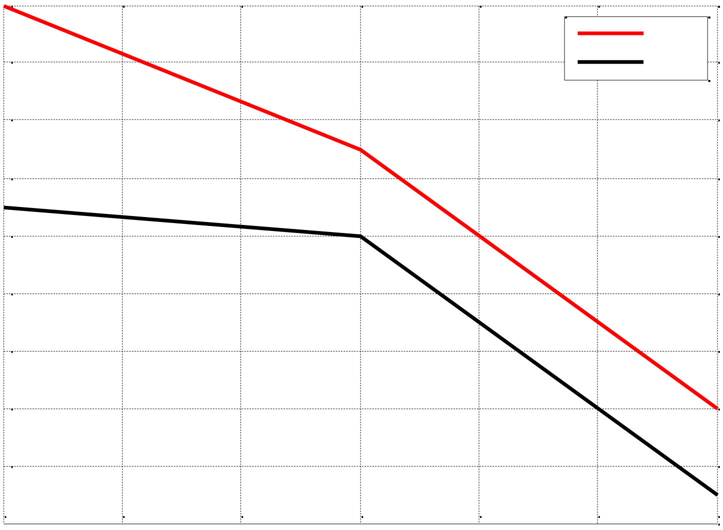

Fig.3: Probability of False Alarm

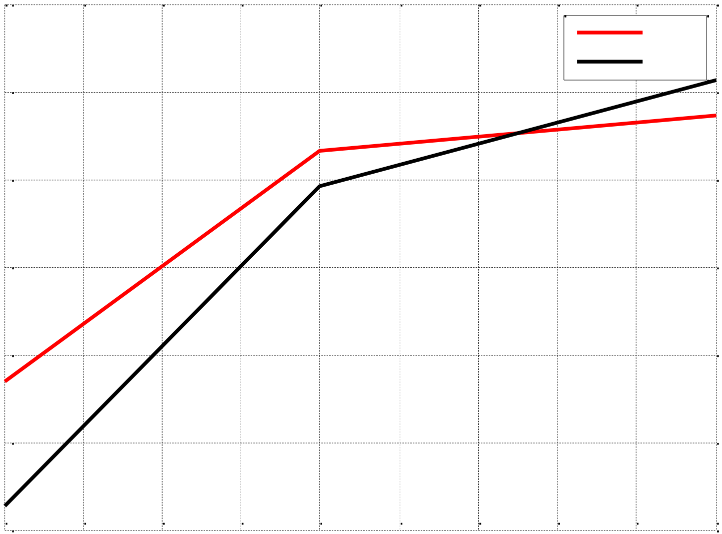

Fig.4: Percentage Detection Accuracy

Conclusion and Future Scope

Cooperative spectrum sensing technology ensures better detection by making use of the spatial diversity by placing sensing nodes in different geographical locations. In cooperative sensing, the presence of primary users is decided by the fusion center with the help of fusion rules. In this paper the famous soft fusion techniques namely maximum ratio combining and square law combining are compared in terms of probability of false alarm, probability of misdetection and detection accuracy with respect to number of secondary users. The detection accuracy increases with increase in number of secondary users. MRC is giving good results with respect to SLC.

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