Journal of Engineering and Applied Sciences 13 (21): 9283-9288, 2018
ISSN: 1816-949X

An Enhance Spectrum Sensing Algorithm for the Cognitive Radio Network

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Abstract: Cognitive radio is a communication technology developed to solve the problem of spectrum scarcity. detection of energy depending cooperative spectrum sensing represents a solution to enhance the throughput of CR, since, the information about primary signal absence are collected using many sensing nodes with different channel conditions. However, the throughput cannot be maximized unless efficient decision rules are used to combine the collected information and produce right final decision. In this study, a unified agreeable range detecting calculation is used and two decision rules are proposed to maximize the throughput of CR, these are: Middle Plus One (MPO) rule, Double Threshold Soft Decision rule (DTSD). A complete sensing stage based on the proposed rules is designed and simulated via. MATLAB (m-files) in the presence of AWGN and Rayleigh multipath fading which has route delays range from 1-5 path delays for "ITU indoor channel model A" while the reporting channel is assumed to be free of errors. The simulation results showed that the proposed rules improve throughput. Therefore, the use of the proposed rules can represent an efficient way to enhance the throughput in cognitive radio.

Key words: Cognitive radio, efficient, channel, technology, spectrum, scarcity

INTRODUCTION

Studies have shown that the vast majority of the authorized radio bands are underutilized which results in spectrum holes (white spaces) (Valenta *et al*., 2010). Spectrum scarcity occurred because of the following two reasons; Fixed spectrum allocation policies do not allow unlicensed users for reusing the spectrum band allocated to licensed users and the rapidly increasing demand for wireless services. A promising technology called Cognitive Radio (CR) is emerged to mitigate the spectrum scarcity by enabling the unlicensed clients to get to the void areas in range groups which are as of now appointed to the essential clients when the PUs are inert (Ali and Hamouda, 2017; Ma, 2014; Nivetha *et al*., 2017). The initial phase in CR cycle is range detecting which screens the use of authorized range. Before utilizing the authorized range band, CR clients need to know whether, the authorized client involved the band. The most essential test is to utilize the authorized range by CR client without meddling with the authorized clients as showed in Fig. 1. In subjective radio, optional clients must have the capacity to distinguish the flag from the essential client. For non-agreeable range detecting, this is troublesome, since, the crucial qualities of remote channels, for example, multi-path blurring, shadowing can debase the flag (Wang, 2009). To beat these issues of individual range detecting, helpful range detecting is proposed where send their nearby detecting data to combination focus where a ultimate conclusion is made

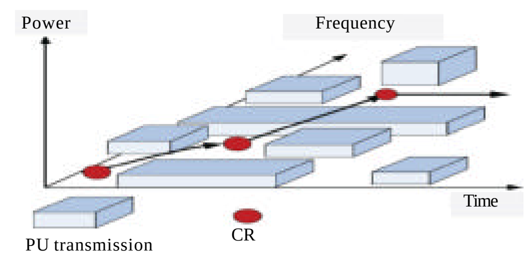

Fig. 1: Spectrum- hole concept (Axell *et al*., 2012)

(Zahmati, 2013; Zhou, 2011; Ejaz, 2008). Helpful range detecting plans can be sorted into two sorts; Delicate mix conspire and hard blend plot (Do and An, 2015):

- Soft combination scheme: in this scheme, SUs send their sensing information to FC without making any decisions
- Hard combination scheme: in this scheme, SUs perform local decisions and send one binary decision bit to FC

Problem definition: In cooperative spectrum sensing, the cognitive cycle which include sensing operation of each cognitive user, transmission of sensing information to FC and finally taking a final decision about PU signal presence should be done as fast as possible and with a high probability of correct decision (Motta, 2014). The performance measure of these two requirements is the throughput. The throughput of CR is characterized as the proportion of the aggregate transmission time to the aggregate frame time after successful final decision is taken. The throughput is normally deteriorated because of the existence of AWGN and rayleigh fading in the sensed spectrum and because of the use of inefficient fusion rules at FC. Therefore, there is always a need for developing efficient approaches to handle this deterioration.

Literature survey: There are many researches in the literature related to the topic of the throughput improvement in cognitive radio networks.

Lee and Yener (2007), proposed a helpful range detecting plan in which intellectual clients share their choices concerning range inhabitance of the essential clients this plan demonstrated a change in throughput around 15.5% and diminishes the impedance to the essential clients contrasted and non-agreeable plan.

So, Lee *et al*. (2009), proposed a proficient choice manage (Majority control) keeping in mind the end goal to improve the identification of the unused range. In this control, the essential client is announced to be available, assuming half and a greater amount of clients show the nearness of the essential client. This manage is more dependable than traditional choice principles as in AND as well as standards.

Liang *et al*. (2008) considered the issue of finding the suitable detecting term to boost the achievable throughput with the limitation that the authorized clients are adequately shielded from any destructive impedance. The examination demonstrated that the presence of an ideal detecting time that accomplishes the best exchange off in light of hard joining plan. Besides, the investigation exhibited a correlation of the hard choice standards concerning throughput and detecting time.

Alemseged *et al*. (2009), displayed the detecting plans in light of a two-organize discovery conspire that utilizations both delicate joining and hard consolidating. The two-organize choice plan gives enhanced discovery contrasted with detecting in view of either hard joining or delicate consolidating alone. This plan functions as takes after: at the main stage, the hard joining is utilized by CR. In the event that the worldwide choice on the nearness of the essential client is 0, the CR ventures into the second stage identification by asking for the sensors to give delicate data to play out the delicate consolidating. This method reduces the unnecessary use of the soft combining. The two-stage detection has higher sensing time because of the two detection stages. A temporary storage area required to store the soft information to be available for soft combining in the second stage. EI-Saleh *et al*. (2009) displayed the throughput improvement for non-helpful and agreeable range detecting in intellectual radio by fluctuating the detecting time and various helpful clients. The execution assessment demonstrated that there is an ideal detecting time at which the throughput of non-agreeable or helpful clients is boosted. Expanding the quantity of agreeable clients prompt increment the most extreme throughput and reduction the relating ideal detecting time. The expanding in detecting time cause diminishing throughput of non-agreeable or helpful clients. Althunibat *et al*. (2012), displayed a correlation amongst delicate and hard range detecting plans, the reenactment demonstrated a superior of delicate joining as contrasted and hard consolidating.

Aim of the study: The aim of this research can be summarized as follows:

- Simulating the throughput of existed cooperative spectrum sensing based on traditional fusion rules
- Proposing fusion rules for enhancing the throughput and detection probability
- Evaluating the enhancement of the proposed rules as compared with traditional ones via. MATLAB Simulations

MATERIALS AND METHODS

Concept of cognitive radio: The fast evolution in wireless communication has led to the huge request of the frequency spectrum. Some frequency bands are congested and other frequency bands are underutilized. In this regard, cognitive radio has been created as another innovation to maintain a strategic distance from this issue. It empowers the entrance to empty range openings. The intellectual radio offers the unused range with the optional unlicensed client (SU) without making any obstruction the essential client (PU) (Sun *et al*., 2013). Cognitive radio is a promising innovation that permits the entrance of empty range groups, called blank area or range gaps. Every CR client identifies the essential clients (authorized clients) on the off chance that they are available or truant. This is generally accomplished by detecting the range groups and the procedure called range detecting (Dahal and Adhikari, 2014).

Spectrum sensing: The spectrum sensing is the first step in cognitive radio which locating the presence or absence of the hole on a band (Sriharipriya and Baskaran, 2015). The CR user monitors spectrum bands and search for the un-used portions of the bands. The goal of the spectrum sensing is to decide between the two hypotheses, namely (Shailesh *et al*., 2015) Eq. 1 and 2:

$$H_0: R(J) = (J) \quad (1)$$

$$H_1:(J) = K(J)+M(J) \quad (2)$$

Where:
R(J) = The gotten flag
K = The channel pick up
K(J) = The transmitted flag by essential client
M(J) = The added substance white Gaussian commotion (AWGN)

K0 is an invalid theory which expresses that the authorized client is truant in a specific range band and the presence of range gap. K1 is an elective speculation which shows that the essential client flag is available and there is no range opening. The parameters that influence the execution of range detecting are i.

Likelihood of error caution: It is the likelihood of undetected range gaps. A vast PFA produces poor otherworldly effectiveness in subjective radio as a result of error choices which prompt expanding the impedance between the optional client and essential client.

Likelihood of detection: It is the probability of detected spectrum holes, larger PD is preferred because it gives precise decisions.

Number of sensed spectrum samples NS: A large number of sensed spectrum samples improves the probability of detection, so, gives true decisions. But from another side, increasing the number of samples leads to increase the sensing time. Therefore, the number of samples can be expressed as (Zahmati, 2013) Eq. 3:

$$Ns = \tau^* FS \quad (3)$$

Where:
τ = The detecting time
FS = The inspecting recurrence

Threshold λ: Predefined threshold is required to decide the absence or presence of the primary user signal. The threshold selection affects PD and PFA where increasing the threshold will decrease PD and PFA (EI-Saleh *et al*., 2009). The common Eq. 4-5 for setting the threshold assuming PD is constant as by Alemseged *et al*. (2009) and Sun *et al*. (2013):

$$\lambda_h = \frac{Q^{-1}(PD) * \sqrt{1+2SNR}}{N_S} + 1 + SNR \quad (4)$$

For a hard decision rule

$$\lambda_S = \frac{Q^{-1}(P_{FA})}{N_S} + 1 \text{ For a hard decision rule} \quad (5)$$

where, Q^{-1} is the inverse of complimentary error function Q(.). The threshold level selection is based on maximizing the difference between PD and PFA. This can be achieved by making PD as high as possible and PFA as low as possible.

RESULTS AND DISCUSSION

Sensing of spectrum schemes: Various schemes for sensing of spectrum depending on the CR network operation scenarios has suggested. Figure 2 shows the classification of spectrum sensing schemes. The different spectrum sensing schemes will be explained in this study after defining the operation mechanism of each scenario.

Non-cooperative scenario: CR non-cooperative spectrum sensing occurs when only one secondary user performs the primary user detection process. According to this scenario, there are three spectrum schemes.

Energy Detection (Lee and Yener, 2007): Energy detection has turned into a broadly utilized procedure to detect the essential client flag. Vitality recognition does not require any information of the essential client flag attributes. The flag measurements (the figured vitality) are contrasted with a foreordained edge. The normal aggregate vitality recognized E, utilizing N_s tests is characterized as Eq. 6:

$$E = \frac{1}{N_s} \sum_{i=1}^{N_s} |r(n)|^2 \quad (6)$$

If, E is more than or equal to λ this indicates that the spectrum is used (hypothesis H_1) and if E is smaller than λ this means there is hole in spectrum (hypothesis H_0). Energy detection spectrum sensing figure is shown in Fig. 3.

Matched filter: Coordinated channel is a straight channel. and used at the point when an optional client has an earlier information of the PU flag. This prior information includes carrier frequency, modulation type and pulse shape. A coordinated channel boosts the SNR of the got flag, so, it is the ideal signal detection. Its performance degrades when there is a reduction of channel knowledge due to rapid changes in the channel conditions (Alemseged *et al*., 2009; EI-Saleh *et al*., 2009; Althunibat *et al*., 2012).

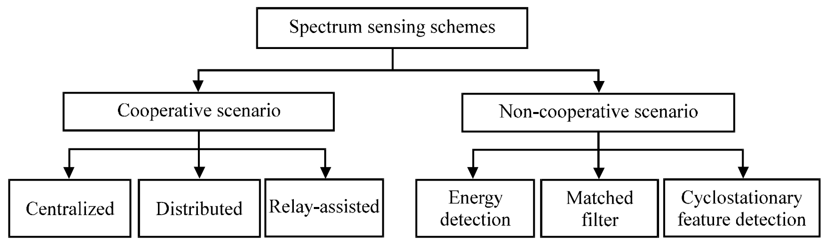

Fig. 2: Classification of spectrum sensing schemes

Cyclo-stationary property checking: A flag is said to be cyclo-stationary if its autocorrelation is an intermittent capacity of time with some period. Cyclo-stationary highlight recognition abuses the periodicity of the got flag to recognize the nearness or nonappearance of essential clients. The periodicity is ordinarily installed in sinusoidal bearers, spreading code and cyclic prefixes of the essential signs. Because of the periodicity, these cyclo-stationary flags show the highlights of intermittent measurements and ghastly relationship (Althunibat *et al*., 2012; Sun *et al*., 2013).

The first proposed rule

Middle Plus One MPO: The first proposed rule is named: Middle Plus One MPO. It is a kind of hard decision rules. Its mechanism is as follows: the fusion center indicates that the hole is present and makes a final decision of "0" when half plus one or more of the local decisions sent to the fusion center are "0" (indicating the existence of hole), therefore, K is set to $(N_u/2)+1$ in equation.

This rule will increase the throughput, since, it increases the number of secondary users that give the same decisions which decrease the probability of error alarm. The likelihood of discovery and the likelihood of error alert of MPO rule is given in the following Eq. 7 and 8:

$$P_{D,MPO} = \begin{cases} \sum_{j=ceil\left(\frac{N_u}{2}\right)+1}^{N_u} \binom{N_u}{j} \left(P_{D,i}\right)^j \left(1-P_{D,i}\right)^{N_u-j} \\ \sum_{j=ceil\left(\frac{N_u}{2}\right)+1}^{N_u} \binom{N_u}{j} \left(P_{D,i}\right)^j \left(1-P_{D,i}\right)^{N_u-j} \end{cases} \quad (7)$$

$$P_{FA,MPO} = \begin{cases} \sum_{j=ceil\left(\frac{N_u}{2}\right)+1}^{N_u} \binom{N_u}{j} \left(P_{FA,i}\right)^j \left(1-P_{FA,i}\right)^{N_u-j} \\ \sum_{j=ceil\left(\frac{N_u}{2}\right)+1}^{N_u} \binom{N_u}{j} \left(P_{FA,i}\right)^j \left(1-P_{FA,i}\right)^{N_u-j} \end{cases} \quad (8)$$

where ceil $(N_u/2)$ rounds the elements of $N_u/2$ to the nearest integers greater than or equal to $N_u/2$. The flow chart for this rule is just like the flow chart for hard decision rules in Fig. 3 but the overall P_D and P_{FA} is found from Eq. 1 and 2, respectively.

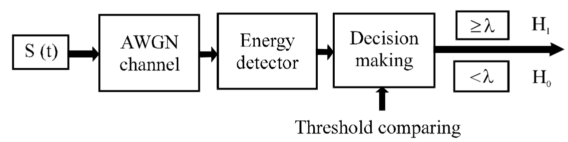

Fig. 3: Vitality identification range detecting scheme (Liang *et al*., 2008)

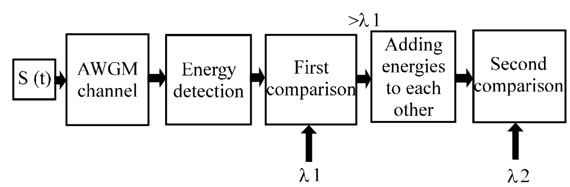

Fig. 4: Block diagram of DTSD rule

The second proposed rule

Double Threshold Soft Decision DTSD: The second proposed rule is named: Double Threshold Soft Decision rule DTSD. It falls in the class of soft decision rules. This rule uses two thresholds for energy comparison purposes. The mechanism of its operation is as follows: all the secondary users send their detecting data (energies) to combination focus. At the combination focus, all energies are compared individually with the first threshold λ1. Then the energies that fall below this threshold are excluded to reduce the probability of error alarm. Finally, the rest of energies are add together and compared with the second threshold λ2. This rule will improve throughput because it decreases the error alarm probability. The test statistic for this proposed rule is:

$$EDTSD = \Sigma Ei\lambda 1Ei \quad (9)$$

DTSD rule is presented in Fig. 4 and the flow chart is demonstrated in Fig. 6.

Simulation results of the first proposed rule (MPO): This study presents the simulation results of middle plus one MPO decision rule as compared with other rules. Figure 5 and 6 present P_{FA} versus SNR in AWGN and Rayleigh multiple route blurring channels individually where the

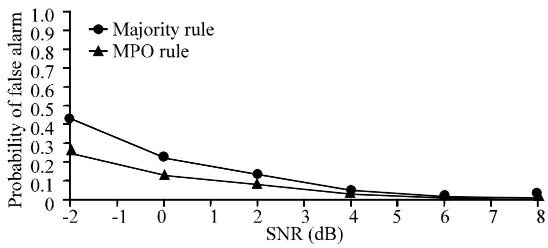

Fig. 5: Likelihood of error caution versus SNR over AWGN

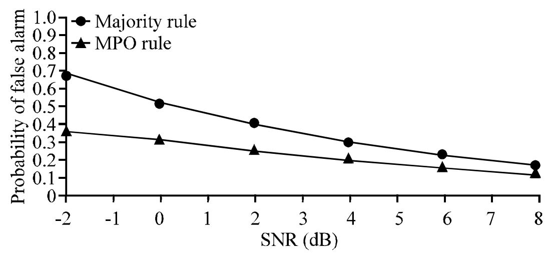

Fig. 6: Likelihood of error alert versus SNR over Rayleigh blurring channel

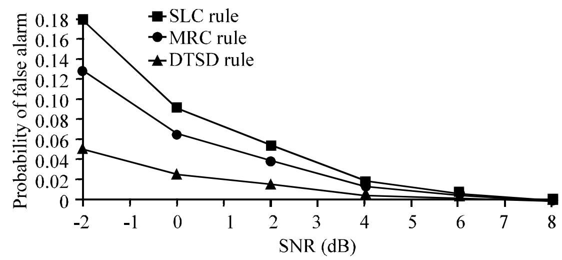

Fig. 7: Likelihood of error alarm versus SNR over AWGN channel

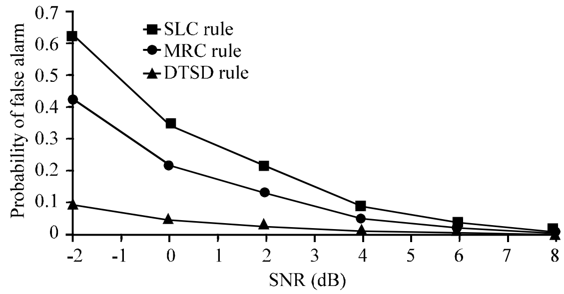

Fig. 8: Likelihood of error alarm versus SNR over Rayleigh blurring channel

quantity of clients is 7. It can be seen from these assumes that P_{FA} diminishes as SNR increments. This is on account of when SNR is high the clamor control turns out to be low while the essential client flag control remain as it is which prompts high likelihood of recognition and low likelihood of error caution. MPO rule achieves less error alarm probability as compared with majority rule, especially at lower signal to noise ratio values <4 dB. For instance, the P_{FA} enhancement of MPO rule reaches 38.7% as compared with the conventional one in 5 when SNR equals -1dB. Under Rayleigh fading condition shown in Fig. 6, the improvement introduced by MPO rule over majority rule at SNR equals -1dB is around 44%.

Figure 6 shows the comparison of throughput achieved between MPO rule with majority rule. It can be seen that the throughput is increased with the increase of SNR because when SNR increases the probability of error alarm decreases and this leads to increase throughput. A significant improvement in throughput is achieved by the use in the proposed rule (MPO), especially at low values of SNR. For example, when SNR is 2dB the enhancement of throughput using the proposed rule over majority rule by 63%.

Simulation results of the second proposed rule (DTSD): This study presents the performance curves of Double Threshold Soft Decision rule DTSD as compared with other rules. Figure 7 and 8 present PFA versus SNR in AWGN and Rayleigh multipath fading channels, respectively when the clients number is 4. likelihood of error alarm decreases as SNR increases as well. These two figures demonstrate that DTSD rule achieves less error alarm probability as compared with SLC and MRC rules especially at low SNR values less than 4dB. For instance, the PFA enhancement of DTSD rule reaches 71 and 60% as compared with the SLC and MRC in AWGN channel when SNR equals -1dB. Under Rayleigh fading condition shown in 8 the improvements introduced by the proposed rule over SLC and MRC rules at SNR equals -1dB are around 84 and 74%, respectively.

CONCLUSION

Many conclusions can be obtained from to the results of the simulations of the proposed rules. These conclusions include the following: The likelihood of error alarm decreases as the SNR increases. The range of error alarm probability values can be controlled by changing the threshold level. Furthermore, increasing the number of cognitive users and using suitable global decision rule can reduce the likelihood of error alarm and increase the throughput as well. Moreover, the decision rules can be either hard or soft, local or global. The use of mixed types of decision rules can improve the decision credibility and the throughput as a result.

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