A Review : Spectrum sensing in Full Duplex Cognitive radio in MIMO

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Abstract - *Here, in this paper spectrum sensing method is proposed for full duplex cognitive radio. Spectrum sensing performs essential part in spectrum allocation. Cognitive radio is the very useful option now a days, as the traffic of user increase and less spectrum is available. Here full duplex cognitive radio is proposed for simultaneously transmission and reception for secondary user(SU). Here different case of full duplex system is also proposed. SISO system has less capacity of signal reception and transmission in that sense, here MIMO is proposed for better capacity of transmission. For spectrum sensing energy detection is proposed. This paper provides brief idea about spectrum sensing using energy detection. MIMO system is proposed with its system model.*

Key Words: *Energy detection, Cognitive radio, Full Duplex,MIMO, Probability of Detection, ROC, Probability of false alarm.*

1.INTRODUCTION

The ever-increasing demand for higher data rates in wireless communica-tions in the face of limited or underutilized spectral resources has motivated the introduction of cognitive radio. Traditionally, licensed spectrum is allocated over relatively long time periods and is intended to be used only by licensees. Various measurements of spectrum utilization have shown substantial unused resources in frequency, time, and space. The concept behind cognitive radio is to exploit these underutilized spectral resources by reusing unused spectrum in an opportunistic manner. Cognitive radio systems typically involve primary users of the spectrum, who are incumbent licensees, and secondary users who seek to opportunistically use the spectrum when the primary users are idle[1]. The introduction of cognitive radios inevitably creates increased interference and thus can degrade the quality of service of the primary system. The impact on the primary system, for example in terms of increased interference, must be kept at a minimal level. Therefore, cognitive radios must sense the spectrum to detect whether it is available or not and must be able to detect very weak primary user signals. Thus, spectrum sensing is one of the most essential com-ponents of cognitive radio.

Spectrum sensing is proposed here using energy detection method, because in Matched lter based detection primary knowledge of Primary use(PU) is nec-essary. Whereas Cyclostationary has complexity of calculation. Also, it must deal with all the frequencies in order to generate the spectral correlation func-tion, which makes it a very large calculation[2].

Cognitive radios are conventionally presumed to be halfduplex devices which implies that a secondary user (SU) in an overlay system needs to take breaks from transmission for detecting whether a primary user (PU) has become ac-tive. Alternatively, a half-duplex SU may rely on cooperation with other nearby users who are in a sensing state. Conventional cognitive radios thus su er from inherent overhead due the half-duplex constraint: either lost transmission op-portunities during sensing periods or extra channel uses and transmission energy required by feedback among cooperative users. Therefore new system is pro-posed that is Full duplex cognitive radio where simultaneous transmission and reception on single channel is possible. Cognitive radio systems could bene t signi cantly from the ability to sense and transmit simultaneously.

In a multipleinput/ multiple-output (MIMO) system, if the receiver array has more antennas than the transmitter array, then samples taken by the receiver array at any given point in time must necessarily be correlated[9].

2 System Model

While considering spectrum sensing term, primary user and secondary user comes in picture. Primary user also referred as licensed user. When primary user is not available then there will be space in band which is not occupied. That is termed as Spectrum holes. Now primary user is present or not that is referred as spectrum sense. For that we consider two hypothesis H_0 and H_1. Where H_0 is referred as primary user is not present, and H_1 is referred as primary user is present. So it can be de ned as[2],

$$H_0 : y_i = w_i$$
$$H_1 : y_i = s_i + w_i \quad (1)$$

where w_i is is additive white Gaussian noise with mean zero and variance ^{2}, and s_i is the fading signal. Here zero mean is introduced because there is less power needed at the transmitter side.

Considering Full Duplex cognitive radio system, where transmission and recep-tion is possible simultaneously. Here we considering three di erent case of Full Duplex-CR.

As per seen in g 1 SU is able to sense and transmit signal having two di erent antenna mounted on it at di erent channel having di erent SNR values. But here the most problem occurred is that self residual interference. A SU has two antenna, one for sensing and one for transmitting. Now receiving antenna is

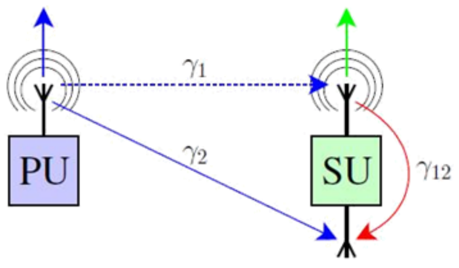

Figure 1: A two-antenna full-duplex (FD2) secondary user (SU) exploits one antenna for sensing the potential transmission of a primary user (PU) while simultaneously transmitting to a secondary receiver from the other antenna. Variables 1, 2, and 12 denote instantaneous signal-to-noise ratios (SNRs)[4].

per seen in fig 1 SU is able to sense and transmit signa having two different antenna mounted on it at different channel having different SNR values. But here the most problem occurred is that self residual interference. A SU has two antenna, one for sensing and one for transmitting. Now receiving antenna is also receive the signal from the its own transmitting side, that is referred as Self residual interference. The keys for successful full-duplex operation are efficient interference cancellation and adaptation to inevitable residual distortion.

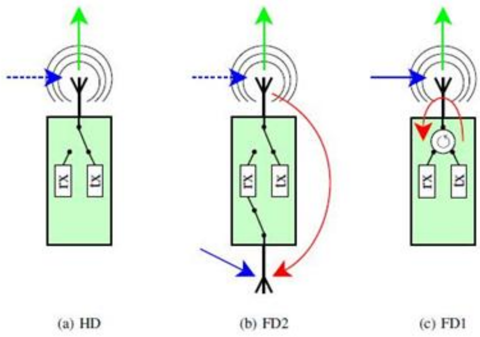

Figure 2: Three variations for implementing a cognitive radio using a single transmit-ter/receiver (tx/rx) pair and an optional auxiliary antenna element for facilitating full-duplex operation.[4]

Here from Fig 2 it can be seen that di erent three variation are consider. Here Fig 2(a) gives Half duplex system with one antenna. Fig2(b) provides full duplex system with two antenna, where one antenna is for sensing and other antenna for transmitting. Here system able to receive and transmit simulta-neously at two di erent channel with two di erent SNRs. Fig2(c) shows full duplex system with single antenna with the help of circulator.

3. Energy Detection Calculation

From equation (1) the joint probability density function (PDF) of the sam-ples can be derived as,

$$p(y|H_0) = \frac{1}{\left(\sqrt{2\pi\sigma^2}\right)^n} e^{-\frac{\sum_{i=1}^{n} y_i^2}{2\sigma^2}}$$

for $H_0$and

$$p(y|H_1, s) = \frac{1}{\left(\sqrt{2\pi\sigma^2}\right)^n} e^{-\frac{\sum_{i=1}^{n} (y_i - s_i)^2}{2\sigma^2}}$$

Using the generalized likelihood ratio test approach together with the Gaussian distribution of s_i, the conventional energy detector can be derived. Now considering energy detection case we measures energy of signal by squaring, summing then averaging over time period, that becomes our received signal y_i. Now this received signal is compared with predetermined threshold value. That determines the presence of primary user.

$$W = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{y_i}{\sigma}\right)^2 \begin{cases} < T, for H_0 \\ > T, for H_1 \end{cases} \quad (4)$$

Using PDF, calculating probability, we have,

$$P_F = P_r\left(W > T/H_0\right)$$
$$P_D = P_r\left(W > T/H_1\right) \quad (5)$$

where P_D is probability of detection and P_F is probability of false alarm. The receiver operating characteristics (ROC) curve is the most important perfor-mance measure for a hypothesis testing problem. It describes the relationship between P_D and P_F .

Now for the full duplex CR, self residual interference occurs due to imperfect interference cancellation in addition to usual thermal noise. So here probability of detection and probability of false alarm can be calculated as follow.

$$P_f = Pr(Y > \lambda|H_0) = \frac{\Gamma(u, \frac{L}{2})}{\Gamma(u)}$$

$$P_m(\gamma) = Pr(Y \leq \lambda|H_1) = 1 - Q_u\left(\sqrt{2\gamma}, \sqrt{\lambda}\right)$$

where it contain the upper incomplete gamma function and Time- bandwidth product u=TW [4].

When setting constant values for the decision threshold ƛ and for the sensing time–bandwidth product u, the probability of false alarm Pf is the same for all the considered SU variations, irrespective of whether the full-duplex SU transmits during sensing or not. Especially, the level of residual distortion or the channel gains do not directly affect Pf. However, it should be noted that _ is defined relatively to the power spectral density of sensing noise which itself is higher when the full-duplex SU is subject to self-interference [4]

4. MIMO SYSTEM

In multiple antenna spectrum sensing we use single antenna at primary user and multiple antennas at secondary user. Multiple antenna techniques currently are used in communications and their e ectiveness has been shown in di erent aspects. It is assumed that there is no any primal knowledge of primary user signal, the channels between the primary user and cognitive user is available to the system. A new approach that is known as generalized likelihood ratio test (GLRT) is developed to detect the presence/absence of the primary user. By using MIMO the same frequency is reused in the same geographic region to deliver great amount of data tra c than could be expected from SISO. MIMO techniques deliver signi cant performance enhancement in terms of data trans-mission rate and interference reduction. By using multiple antennas at Receiver and Transmitter in a wireless system the rich scattering channel can be exploited to create a multiplicity of parallel links over the same radio band and thereby to either increase rate of data transmission through multiplexing or to improve the system reliability through the increased antenna diversity[9]. To evaluate the

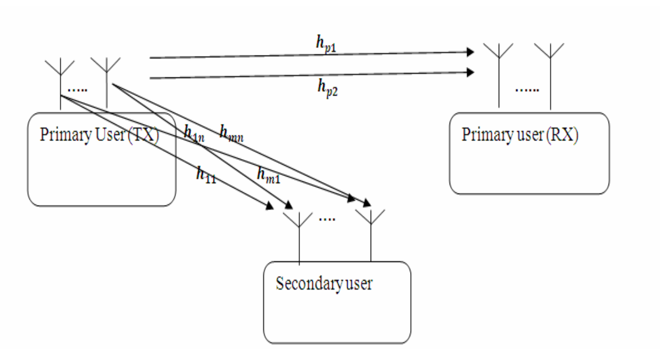

Fig. 3. Spectrum sensing using MIMO [9]

performance of MIMO, optimal detector is used. Assumption is that optimal detector needs to know the noise and PU signal variances and channel gains. To reduce the complexity of the system here only 2 antenna system is consider for implementation. Two antennas at transmitter and two at receiver are mounted. Mathematically , it can be given as,

Y = HS + N

where H is channel matrix, S is signal and N is noise. Here defining LLR(Log likelihood Ratio) for calculating received signal's energy, then it is compared with predetermined decision threshold.

$$LLR = \frac{tr(X)^2}{2\sigma_n^2}\left(\frac{1}{1+\frac{\sigma_n^2}{\sigma_s^2}}\right) - \frac{L}{2}ln(\sigma_s^2)$$

where X= signal element, σ_n^2= noise variance , σ_s^2= signal variance, L=number of samples which antenna receives [9].

$$LLR \underset{>}{\overset{<}{-}} n$$

where n is decision threshold. In case of SISO In SISO method, we find the capacity,

$$C = B\log_2\left(1+\frac{S}{N}\right)$$

Where in MIMO method, since it has been using M antennas, so

$$C = MB\log_2\left(1+\frac{S}{N}\right)$$

Where B= channel bandwidth. MIMO is one way in which wireless communications can be improved and as a result it is receiving a considerable degree of improvement.

5. CONCLUSION

Hence here we defined spectrum sensing using energy detection method. Energy detection is easy one to implement with respect to other method. Then we proposed full duplex cognitive radio and its different prospects. Full duplex system provides more communication in less time due to its nature to receive and transmit the signals simultaneously. Then MIMO system is proposed. Advantage of MIMO is more beneficial then the SISO system.

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