IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 10, Issue 07, February 2022)

Performance Evaluation of Hybrid Relay Selection in Cooperative Communication System

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Abstract – **Energy detectors, feature detectors, and cooperative sensing are just a few examples. During each sensing period, one or more secondary users (SUs) execute sensing on a single and the same channel in these schemes. This method of multiple SUs detecting a single channel at the same time may severely limit sensing efficiency. This paper presents a cooperative spectrum sensing system based on relays. MATLAB 2014a is used to simulate the suggested study. The impact of signal to noise ratio, chance of detection, and throughput on the suggested algorithm has been assessed.**

Keywords –**AF, Cognitive Radio, DF, Spectrum Sensing.**

I. Introduction

The radio spectrum is in high demand in wireless communication. The radio spectrum's resources are insufficient to meet the growing needs of consumers. According to current studies, 80 percent to 85 percent of the overall spectrum is unutilized, with just 15 percent to 20 percent of the spectrum being used for the greatest amount of time. Because the licenced user does not use all of the spectrum available at any given moment. As a result, the unoccupied frequency spectrum band that is not being used by the licenced user at any given time can be found. The CR's most significant function is spectrum sensing. Determining whether the PU is present or missing is critical for effective spectrum sensing. The CR gathers spectrum intelligence from its surroundings and can adjust new settings to fit the scenario. The radio spectrum is divided into two categories: licenced spectrum and unlicensed spectrum. The licenced spectrum is a portion of the radio spectrum that is sold to a user for the purpose of providing a certain service. These precise spectrum bands are always reserved. The unlicensed spectrum bands are not reserved, and certain licenced frequency bands have vacant areas that can be exploited by a variety of unlicensed users [1].
According to recent spectrum consumption measurements, certain wireless systems may only utilise the assigned spectrum to a very limited level, while others are heavily exploited [2], [3], and [4]. Cognitive radio (CR) has been proposed to effectively utilise the spectrum to address spectrum scarcity and underutilization [5], [6]. There are two coexisting systems in a geographic area: a primary system and a secondary system. The licenced system with a heritage spectrum is referred to as a primary system. This system is the only one who has access to the given spectrum. The unlicensed cognitive system is referred to as a secondary system, and it can only access the spectrum holes on a case-by-case basis. Spectrum holes (or, alternatively, spectrum opportunities, white spaces) refer to spectra that are missing from the spectrum. Depending on the context and systems, spectrum opportunities may exist in the time, space, frequency, or angle (in multiple-input–multiple-output systems) domains. The subscribers in the primary system are referred to as primary users (PUs), while those in the secondary system are referred to as secondary users (SUs).
In order to uncover spectrum opportunities, spectrum sensing is an important component of CR networks. The accuracy and efficiency of the found spectrum opportunities are critical to the success of a CR network. The sensing accuracy refers to the accuracy with which a PU signal is detected so that the PU's communications are not disrupted. The number of observed spectrum possibilities within a sensing period and the ensuing overall system performance in terms of throughput and delay are referred to as sensing efficiency. The precision of sensing has received a lot of attention in recent study. Several strategies for improving sensing accuracy have been presented in the literature [7], including energy detectors, feature detectors, and cyclostationary detectors [8]. Cooperative spectrum sensing, which has been intensively studied, is a very promising technology[9]. The major goal of this research is to develop a cooperative spectrum sensing framework based on relays.

II. System Model

Local sensing, which is performed locally at each CR user, is the first step in the cooperative sensing process. Local sensing for primary signal detection

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is typically expressed as a binary hypothesis problem:as follows:

$$x(t) = \begin{cases} n(t), & H_0 \\ h(t).s(t) + n(t), & H_1 \end{cases} \quad (1)$$

Where $x(t)$ denotes the received signal at the CR user, $s(t)$ is the transmitted PU signal, $h(t)$ is the H 0 and H 1 denote the hypothesis of the absence and presence of the PU signal in the frequency band of interest, respectively. n(t) is the zero-mean additive white Gaussian noise (AWGN), and H 0 and H 1 denote the absence and presence, respectively, of the PU signal in the frequency band of interest. The detection probabilities P d and false alarm probabilities P f are defined for evaluating detection performance.

Local sensing, reporting, and data fusion are the three steps in the cooperative sensing process. Other key components of cooperative sensing, in addition to these phases, are essential. The elements of cooperative sensing are what we term these basic but necessary components.

Relaying

Depending on how the relay analyses the information, there are many cooperative relaying approaches.

Each mobile user has one antenna at the transmitter (Tx), and reception diversity is an option in the system. We might be able to'm' antennas at the receiver (Rx) or destination (Destination). At the base station of a LAN, there are multiple antennas. The information bits are encoded by the channel encoder for each of the nodes, and two nodes T1 and T2 may have a shared destination. For cooperation, the coded symbols are correctly multiplexed.Node i; i=1,2 transmits the output of the modulator at each discrete time slot ‘t’ is the signal $X_i(t)$j is the received signal by antenna ‘j’ of the destination at time ‘t’ due to transmission from node ‘i’. Received signal antenna $y_j^d(t)$

$$y_j^d(t) = h_j^{i,d}(t)x^i(t) + \eta_j^d(t) \quad (2)$$

$h_j^{i,d}(t)$ is the coefficient reflects the fading level from transmit antenna on node ‘i’ to the received antenna ‘j’ ,$1 \leq j \leq m$. $x^i(t)$ denoted as channel coefficient, $\eta_j^d(t)$ is the noise samples are modulated as independent realizations of a zero-mean complex GRV (Gaussian random variable) with variance $N_0/2$ per dimension.

We define a number of low-complexity cooperative diversity protocols, including fixed, selection, and incremental relaying, that can be used in a network. Different methods of processing are used by the relay terminals, as well as different types of combining at the destination terminals, in these protocols. We allow fixed relays to either amplify their received signals within their power constraints or decode, re-encode, and retransmit the data. Selection relaying, one of many possible adaptive techniques, builds on fixed relaying by enabling transmission. terminals to select a suitable .Based on the measured SNR between them, they take cooperative (or non-cooperative) action. By utilising restricted feedback from the destination and relaying only when necessary, incremental relaying enhances the spectral efficiency of both fixed and selection relaying. The radios may use repetition or more stronger codes in any of these situations. Throughout the sequel, we emphasise on repetition coding because of its minimal implementation cost and ease of exposition. The control information in the protocol headers allows destination radios to blend their received signals correctly.

Amplify and Forward (A&F)

It represents the simplest method among the several cooperative techniques and is a non-regenerative relay. Information is sent to the relay through a noisy channel, where it is amplified and forwarded to the destination without further processing. In cooperating Amplify and Forward system, symmetric transmission exists between source and relay.

The source transmitted signal $X_{si}(l)$, the relay transmitted signal $X_{ri}(l)$. Source transmitted signal $X_{si}(l)$ to the destination and it is overhead by the relay as $y_{si,d}(l)$

$$y_{s_i,d}(l) = \sqrt{\varepsilon}h_{s_id}X_{si}(l) + \eta_{s_id}(l) \quad (3)$$

Where l=1,2,……..L_1,$L_1$is denoted as length of the first segment. In the second segment, the relay amplifies its overhead signal $y_{s_ir_i}(l)$

$$y_{s_ir_i}(l) = \sqrt{\varepsilon}h_{s_ir_i}x_{s_ir_i} + \eta_{s_ir_i}(l) \quad (4)$$

Where l=1,2,………L_2,L_2 denoted as length of the second segment using maximum likelihood detection method

$$X^1{}_{ri}(l) = \beta y_{s_ir_i}(l) \quad (5)$$

$X^1{}_{ri}(l)$is denoted as transmitted to the destination through relay.

Where $\beta = \sqrt{\frac{1}{|h_{s_ir_i}|^2 \varepsilon + N_0, s_i, r_i}}$, $X^1{}_{ri}(l)$ will be transmitted to the destination through relay uplink channel as:

$$y^1{}_{r_i,d}(l) = \sqrt{\varepsilon}h_{r_id}X_{r_i}(l) + \eta_{r_id}(l) \quad (6)$$

Where l=1,2……L_2 is indices the length of the second segment signal and $L_1 = L_2$ After the two

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segments, the destination will be combine the received signal $y_{s_i,d}(l)$ and $y^1{}_{r_i,d}(l)$

Using the Z-F and MMSE detection:

$$r_{s_i,d}(l) = \frac{h^*_{s_i d}\sqrt{\varepsilon}}{N_{0_{s_i d}}} y_{s_i,d} + \frac{h^*_{r_i d}\ \beta\, h^*_{s_i r_i}\sqrt{\varepsilon}}{|h_{r_i d}|^2 \beta^2 N_{0,s_i r_i} + N_{0,r_i d}} \quad (7)$$

$r_{s_i,d}(l)$ is further passed to a decoder in to retrieve source information from equation (2) and equation (7).The energy symbol (ε) which is normalized in channel nodes p and q. They change independently from (two segment) process yielding a slow fading channel $n_{pq}(l)$ denoted by the additive noise which is modeled as a zero mean, mutually independent complex Gaussian sequence with variance $N_{0,pq}$. For channel between nodes p and q if the instantaneous channel received signal to noise ratio (SNR) is:

$$\gamma_{pq} = \frac{|h_{pq}|^2 \varepsilon}{N_{0,pq}} \quad (8)$$

The average channel received SNR between nodes p, q expressed as:

$$\overline{\gamma_{pq}} = \frac{E\left[|h_{ij}|^2\right]\varepsilon}{N_{0,pq}} \quad (9)$$

If source and relay have similar uplink channel quality as $\overline{\gamma_{s_i d}} = \overline{\gamma_{r_i d}}$, the system is defined as having symmetric up links. If $\overline{\gamma_{s_i d}} \neq \overline{\gamma_{r_i d}}$ the system is defined as having asymmetric uplinks.

Decode and Forward (D&F)

In this case, the relay is regenerative, because it receives the information from the source and it decodes it before retransmitting it to the destination. Decode and forward transmission, the appropriate channel model is for cooperative diversity transmission, we model the channel during the first half of the block is:

$$y_{s_i r_i}(l) = h_{s_i r_i} x_{s_i}(l) + \eta_{r_i}(l) \quad (10)$$

If $l = 1 \ldots \frac{L}{4}$ where $x_{s_i}(l)$ is the source transmitted signal and $y_{r_i}(l)$ is the relay signal. The second half block, we model the received signal,

$$y_{s_i d}(l) = h_{r_j,d} x_{r_j}(l) + \eta_d(l) \quad (11)$$

The source mobile transmits its information as $x_{s_i}(l)$, l=0 . . .$\frac{L}{4}$ during this interval the relay process $y_{r_i}(l)$ by decoding an estimate $x'_{s_i}(l)$ of the source transmitted signal. The relay transmits the signal $x_{r_i}(l) = x'_{s_i}\left(l - \frac{L}{4}\right)$ for l=$\frac{L}{4+1}$- - --- -,$\frac{L}{2}$

Decoding at the relay can take on a variety of forms. For example, the relay might fully decode the source message by estimating the source code word, or it might employ symbol by symbol decoding and allow the destination to perform full decoding. These options allow for trading off performance and complexity at the relay mobile. Because the performance of symbol by symbol decoding varies with the choice coding and modulation. We focus on full decoding in the sequel, symbol by symbol decoding of binary transmissions has been treated form uncoded perspective.

Maximal Ratio Combining is used in this study (MRC). It solves the restrictions of selection combining by combining all diversity branches' input signals. Because of its ability to improve the instantaneous output SNR, MRC has been deemed the best combining technique in the presence of additive white Gaussian noise (AWGN). This is represented in the diagram below. Assume a system with N d diversity branches, and the instantaneous output SNR is:. Assume a system with N_d diversity branches, the instantaneous output SNR is given by:

$$SNR = \left(\frac{E_b}{N_0}\right) \frac{\left|\sum_{i=1}^{N_d} \mu_i \beta_i e^{j\theta_i}\right|^2}{\left|\sum_{i=1}^{N_d} \mu_i\right|^2} \quad (12)$$

Where E_b is bit energy; N_0 is noise spectral density, μ_i is the combining weight and β_i and θ_i are the magnitude and phase of the received signal respectively.

To obtain the maximum instantaneous output SNR, Cauchy-Schwarz inequality is applied, giving the maximum value as:

$$SNR \leq \left(\frac{E_b}{N_0}\right) \frac{\left|\sum_{i=1}^{N_d} \mu_i\right|^2 \left|\sum_{i=1}^{N_d} \beta_i e^{j\theta_i}\right|^2}{\left|\sum_{i=1}^{N_d} \mu_i\right|^2}$$

$$= \left(\frac{E_b}{N_0}\right) \sum_{i=1}^{N_d} \beta^2{}_i = \sum_{i=1}^{N_d} SNR_i \quad (13)$$

The only condition to reach this maximum value is to set:

$$\mu_i = c\beta_i e^{-j\theta_i}\, for\ i = 1,2, \ldots . N_d \quad (14)$$

Where c is some arbitrary complex constant. According to (14) in MRC, the combining weight's magnitude is proportional to the received signal's magnitude, and the combining weight's phase is the negative value of the received signal's phase.

The maximum SNR in (13) also shows that MRC can yield an output SNR equal to the sum of each diversity branch's unique SNRs. As a result, MRC has the advantage of delivering a satisfactory output

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SNR even when none of the SNR in individual branches is satisfactory.

III. Simulation and Results

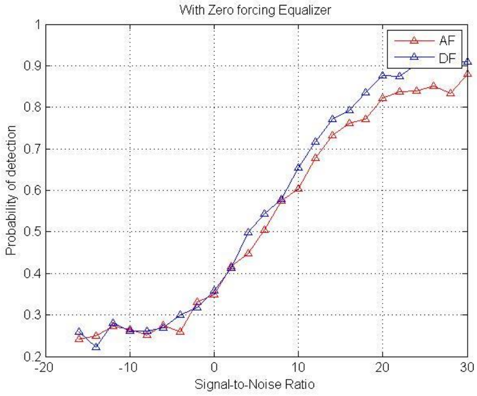

Figure 1: Comparative analysis of probability of detection for AF and DF using ZF equalizer

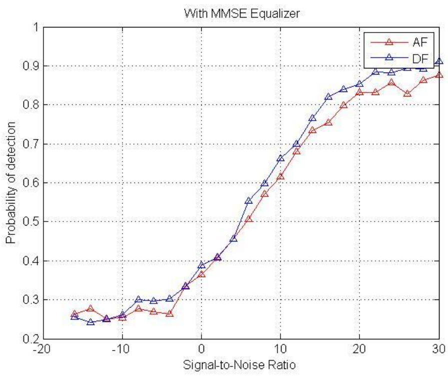

Figure 3 Comparative analysis of probability of detection for AF and DF using MMSE equalizer

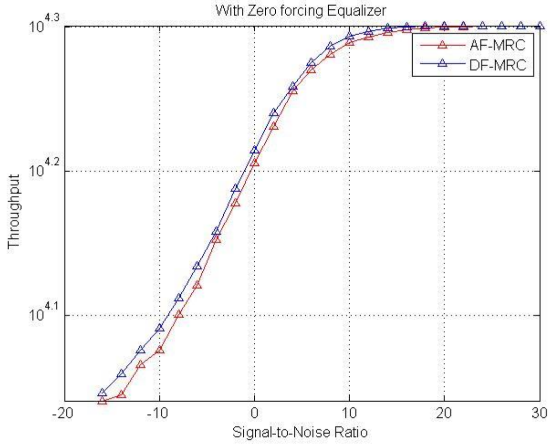

Figure 2: Comparative analysis of throughput for AF-MRC and DF-MRC using ZF equalizer

Table 1: Throughput comparison for AF-MRC and DF-MRC using ZF equalizer

SNR	Throughput	
	AF-MRC using ZF	**DF-MRC using ZF**
-16	10875	11076
-14	11083	11489
-12	11594	11771
-10	11935	12337
-8	12554	12845
-6	13212	13482
-4	14134	14429
-2	15054	15207
0	16110	16419
2	17149	17319

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4	17938	18236
6	18608	18898
8	19145	19361
10	19422	19686
12	19688	19828
14	19803	19896
16	19850	19952
18	19912	19969
20	19929	19979
22	19938	19987
24	19956	19993
26	19975	19993
28	19976	19995
30	19985	19997

IV. Conclusion

In wireless communication systems, spectrum is a tremendously precious resource, and it has been a major research area for decades. Sensing gives awareness of the radio environment, allowing spectrum opportunities to be efficiently reused while keeping interference to a minimum for the primary user. Cooperative sensing is a useful strategy for increasing detection accuracy. Wideband cooperative sensing has recently received a lot of interest. This research presents a cooperative spectrum sensing system based on relays.

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