International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 10, October-2015

Performance Improvement of Hybrid Cognitive Radio Networks with AF Relay

Satheesan U
Electronics and Communication Engineering
NSS College of Engineering
Palakkad, Kerala, India

Sudha T
Electronics and Communication Engineering
NSS College of Engineering
Palakkad, Kerala, India

***Abstract*—In this paper, we consider the achievable data rate for the multiband cognitive radio networks with both Amplify-and-Forward (AF) and Decode-and-Forward (DF) relay in the cooperative transmission (CT) path. The DF relay performs the power auction mechanism to allocate optimum power to the secondary users (SUs). The SU participate in the auction mechanism and bids for maximum utility. After power allocation the AF relay performs the amplification process to achieve high data rate at the receiver.**

Keywords-Cognitive Radio (CR), Power Auction,, DF Relay, AF Relay, Achievable Data Rate, Bit Error Rate.

I. INTRODUCTION

For wireless communication systems the radio spectrum is considered as the key resource. Throughout the world, the spectrum is divided into licensed and unlicensed bands. The licensed band is underutilized and the vacant frequency band in the spectrum is called the spectrum hole. CR is an upcoming and promising technology to utilize the spectrum in an efficient manner. Cognitive radio can be viewed as an intelligent wireless system built up of software defined radios which are able to constantly monitor the environment and adapt their communication in order to efficiently allocate the unused spectra. The power allocated to the SU should be controlled to reduce interference to primary users (PUs) [1]-[5].

In a CR system, SUs senses the spectrum licensed by the PUs. The vacant spectrum holes in the spectrum are used by the SUs. In sensing based spectrum sharing, the SU first senses the status of PU and select an appropriate spectrum sharing mode based on the sensing result. If the PU is active, spectrum underlay mode is selected for communication. If the PU is idle, spectrum overlay mode is used for transmission. Hybrid cognitive radio network works in both overlay and underlay mode. In such network, after selecting the mode operation, the SR conducts a power auction mechanism to sell its power and SUs acts as players to bid for maximum utility. The power auction mechanism helps to reduce the interference to PUs. The DF relay performs the auction mechanism by using power bidding and allocation algorithm [6]. The power bidding and allocation algorithm is used to allocate optimum power to the SUs, according to its transmission mode. In the existing hybrid system model, DF relay performs the power bidding mechanism. DF relay does not amplify the signal in the cooperative path. As a result, the achievable data rate is limited in such networks. In this paper, AF relay is introduced in between the DF relay and secondary destination (SD), to provide improved signal to noise ratio (SNR) at the receiver. It is seen that achievable data rate and bit error rate of system are improved with the addition of an AR relay.

The rest of this paper is organized as follows. In section II, system model is described. Section III gives the power auction mechanism used. Section IV describes the theory of AF relay. Simulation results are presented in Section V. Section VI concludes the findings of the paper.

II. SYSTEM MODEL

Consider a CR system consisting of a primary network, which is divided into M nonoverlapping narrowband channels and the secondary network is composed of N ($N<M$) secondary links. The primary network has a primary transmitter (PT) and a primary destination (PD). The secondary network consists of N secondary transmitters (STs), N secondary destinations (SDs), and a secondary relay (SR). The SR consists of a DF relay and an AF relay. The network model for both overlay and underlay mode is shown in Fig. 2. We had made the assumption that each channel of the primary network can be accessed by only one ST. The DF relay performs the power auction mechanism by organizing an auction game to sell its power. The SUs participate in the auction to buy its required power for data transmission. The AF relay in the system model amplifies the signal to give a high SNR at the receiver. So the achievable data rate is increased and BER is decreased.

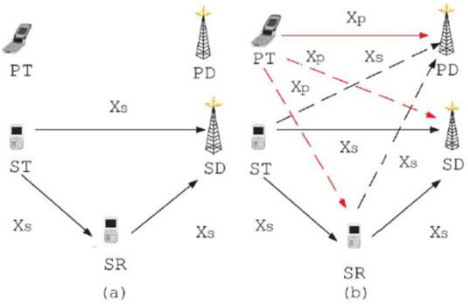

Fig. 1 Network model for Overlay and Underlay

In spectrum overlay, the achievable data rate is given by

$$R_i^{00} = \frac{1}{2}Wlog_2(1 + \Gamma_i^{00}(1) + \Gamma_i^{00}(2)) \quad (1)$$

where W is the signal bandwidth, $\Gamma_i^{00}(1)$ and Γ_i^{00} (2) are the signal to noise ratio (SNR) in direct path and relay path of the *i*th user respectively.

In spectrum underlay, the achievable data rate is given by

$$R_i^{00} = \frac{1}{2}Wlog_2(1 + \gamma_i^{10}(1) + \gamma_i^{10}(2)) \quad (2)$$

where γ_i^{10} (1) and $\gamma_i^{10}(2)$ are the SNR in direct path and relay path of the *i*th user respectively.

III. POWER AUCTION MECHANISM

If the ST works in spectrum overlay, it will transmit with high power budget P_i ,for a high data rate. If the ST works in spectrum underlay, it adapts its power to $P_i^{'}$to provide Quality of Service (QoS) guarantee to the PU [7].

$$R_p^{10}(1) \geq R_{req} \Rightarrow P_i' = min\left\{\frac{1}{|G_{ST_i}^{PD}|^2}\left(\frac{P_u|G_{ST_i}^{PD}|^2}{M} - \sigma^2\right), P_i\right\}$$

The power value is updated according to the bid $f_i(t)$ during each iteration . The DF relay updates the power in proportion to its payment $f_i(t)$ $P_{r_i}(t)$, i.e.,

$$P_{r_i}(t+1) = \min\left\{\widetilde{P_{r_i}}, \frac{f_i(t)P_{r_i}(t)}{\sum_{j\in N}(f_i(t)P_{r_i}(t))} P_r\right\}$$

where t is the iteration index, P_r is the total power of DF relay and

$$\widetilde{P_{r_i}} = \begin{cases} P_r & , Overlay\ mode \\ \frac{1}{|G_{ST_i}^{PD}|^2}\left(\frac{P_u|G_{ST_i}^{PD}|^2}{M} - \sigma^2\right) & , Underlay\ mode. \end{cases}$$

The power bidding algorithm is given below. The SR decodes the data sent by the STs. If it decode successfully, that user can only participate in the current auction mechanism.

Algorithm: Power bidding and allocation algorithm [6]

Step 1. Request for cooperation

ST_i:sends a request to the relay for cooperation.

SR:responds the cooperation request of ST_i.

ST_i:transmits data in first phase.

SR:if the received signal is not decoded successfully, it informs ST_i of the failure; else it allows ST_i to participate in the auction and goes to step 2.

Step 2. Initialization

STi:initializes the required power $P_{r_i}(0)$ and original bid $f_i(0)$ and then submits these values to the relay.

Step 3. Power Allocation

SR:updates the allocated power $P_{r_i}(t+1)$ and informthese values to each STs.

Step 4. Bid Update

STi:updates the bid value $f_i(t+1)$ and sends it back to the relay.

Step 5. Convergence

Repeat Step 3 and Step 4 untill the value of $f_i(t)$ no longer changes with additional iterations.

IV. AF RELAY

In AF scheme, the relay first amplifies signals from the source and then cooperates with source to transmit secret information to the destination. In our model, the AF relay amplifies the signal from the DF relay and transmit it into the SD. As a result the SNR is improved at the receiver to provide high data rate and hence low BER [8]-[10].

In amplify-and-forward transmission, the received signals of the source-destination, source-relay, and relay-destination links, respectively, are

$$y_0 = \alpha_0 s + z_0 \quad (3)$$

$$y_1 = \alpha_1 s + z_1 \quad (4)$$

$$y_2 = \alpha_2 \beta y_1 + z_2 \quad (5)$$

$$= \alpha_1 \alpha_2 \beta s + \alpha_2 \beta z_1 + z_2 \quad (6)$$

and it is straightforward to show that its SNR is

$$\mu_{AF} = \frac{1}{\sigma^2}\left(\Gamma_0 + \frac{\Gamma_1\Gamma_2\beta^2}{1+\Gamma_2\beta^2}\right) = \frac{1}{\sigma^2}\left(\Gamma_0 + \frac{\Gamma_1\Gamma_2\beta^2}{1+\Gamma_2+\sigma^2}\right) \quad (7)$$

where β is the amplification factor, α_0, α_1 and α_2 are the scaling factors and z_0, z_1, z_2 are the corresponding noise in the above links. Γ_0, Γ_1 and $\Gamma_2$are the SNR in the three links and σ^2 is the noise variance.

V. SIMULATION RESULTS

For simulation results we are considering 10 secondary users. Fig. 2 shows the achievable data rate of each user under three different scenarios. We are considering three cases for data transmission. In the first case, direct transmission (DT) between ST and SD is considered. In the second case data is transmitted with the help of a DF relay. This type of communication is called cooperative transmission (CT). In the third case an AF relay is introduced between the DF relay and SD. From the simulation results, it is clear that the achievable data rate is maximum with AF relay, then with DF relay and minimum for direct transmission (DT).

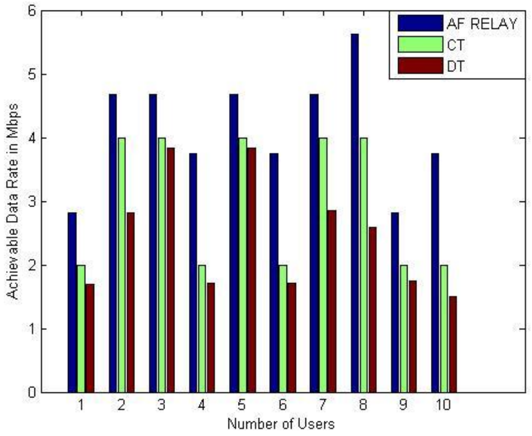

Fig. 2 Achievable data of different users

Fig. 3 shows the BER for 10 secondary users under the same three scenarios. The SNR used for simulation is 20dBm. From the results, it is clear that BER is minimum with AF relay due to the high SNR at the receiver. System with DF relay has a higher BER as compared to that of AF relay. Direct transmission has the highest BER as expected.

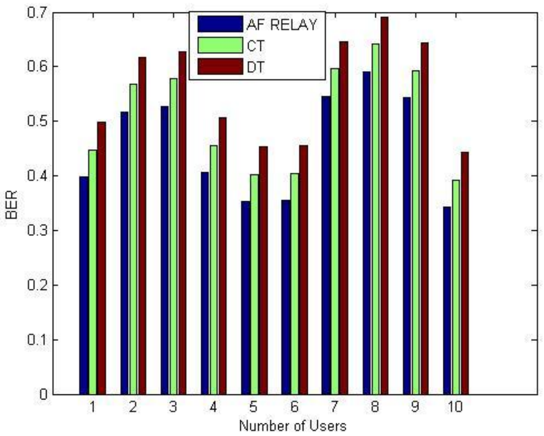

Fig. 3 BER of different users

VI. CONCLUSION

In this paper, we have investigated the effect of DF relay and AF relay on the achievable data rate and BER of the receivers in hybrid cognitive radio networks. By introducing an AF relay along with DF relay in the relay path, the performance of the hybrid cognitive radio network is improved. The DF relay performs the power bidding algorithm and AF relay improves the SNR of the signal at the receiver side. Hence the data rate and performance is improved.

ACKNOWLEDGMENT

This work is supported by AICTE, Govt. of India through the project grant under Research promotion Scheme No.20/AICTE/RIFD/RPS (POLICY- 1)59/2013-14.

REFERENCES

[1] Ian F, Akyildiz, Won-Yeol Lee,Mehmet C. Vuran, Shantidev Mohanty, *NeXt Generation/Dynamic Spectrum Access/Cognitive Radio Wireless Networks: A Survey*, Computer Networks,vol. 50, no. 13,(2006):2127-2159.

[2] K. C. Chen, Y. J. Peng, N. Prasad, Y. C. Liang, and S. Sun, *Cognitive Radio Network Architecture: Part I-General Structure*, ACM International Conference on Ubiquitous Information Management and Communication (ICUIMC) (2008).

[3] Simon,Haykin, *Cognitive Radio: Brain-Empowered Wireless Communications, Selected Areas In Communications*, IEEE journal on 23.2(2005):201-220.

[4] ShrikrishanYadav,SantoshKumarSingh,KrishnaChandra Roy, *A Smart and Secure Wireless Communication System: Cognitive Radio*, International Journal of Soft Computing and Engineering (IJSCE) ISSN:Vol.2, Issue- 1,(2012):2231-2307.

[5] Federal Communications Commission, "*Spectrum Pol icy Task Force*", Report ET Docket no. 02-135, Nov. 2002.

[6] Junni Zou, Hongkai Xiong, Dawei Wang, and Chang Wen Chen, *Optimal Power Allocation for Hybrid Overlay/Underlay Spectrum Sharing in Multiband Cognitive Radio Networks*,IEEE transactions on vehicular technology:Vol.62,no. 4,(2013).

[7] Qiong Wu, Junni Zou, and Kangning Zhu, *Power Allocation in Primary User-Assisted Multi-Channel Cognitive Radio Networks*, Communications and Networks:(2013):38-244.

[8] Seyfi, M.; Muhaidat, S.; Jie Liang, "*Relay selection in underlay cognitive radio networks*," Wireless Communications and Networking Conference (WCNC), 2012 IEEE, April 2012.

[9] Yang Yu; Chaowei Wang; Weidong Wang; Yinghai Zhang, "*Relay selection and power allocation with minimum rate guarantees for cognitive radio systems*," Wireless Communications and Networking Conference (WCNC), 2014 IEEE, April 2014.

[10] Mingrui Zou; Chengshi Zhao; Bin Shen; Kyungsup Kwak, "*Comparison of DF and AF based cooperative spectrum sensing in cognitive radio*," Communications, 2008. APCC 2008. 14th Asia-Pacific Conference, Oct 2008.