e-ISSN:2349-9745
p-ISSN: 2393-8161

Scientific Journal Impact Factor (SJIF): 1.711

International Journal of Modern Trends in Engineering and Research

www.ijmter.com

ANALYSIS OF CHANNEL PERFORMANCE IN RATE AND POWER ALLOCATION SYSTEM FOR MIMO COGNITIVE RADIO NETWORKS

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Abstract -In this paper, the hybrid system allocates the power and rate in MIMO cognitive radio networks. It increases the efficiency of spectrum utilization. Cognitive radio is a form of wireless communication in which a transceiver can intelligently detect which communication channels are in use and instantly move in to vacant channels. Here the primary system employs a HARQ protocol. When the primary system retransmits the data signal, the secondary system serves as a relay for the retransmission of the primary system and simultaneously transmits its data signal. The average throughput of primary and secondary systems can be determined by using (LAT) Long- term average throughput. The main constraint is that the average throughput of primary system with secondary system is not less than primary system alone. Numerical results show that the primary system does not lose the average throughput, and rather achieves an additional throughput gain by adjusting the fraction of the transmit power of the secondary system.

I. INTRODUCTION

Spectrum is a scarce valuable resource in today wireless communication networks; with ever-increasing number of wireless devices communicating at high data rates, there is growing demand for spectrum resources. In cognitive radio networks, an unlicensed system referred to as a secondary system and it shares licensed bands which is dedicated to a primary system. Spectrum sharing networks are communication setups in which unlicensed secondary users are permitted to work within the spectrum resources of primary licensees. There are three basic operational models used to implement the CR networks: overlay, underlay, and cooperation models. In the overlay model, the secondary system senses the temporal spectrum holes in the licensed bands, and then uses these holes to avoid interference to the primary system.

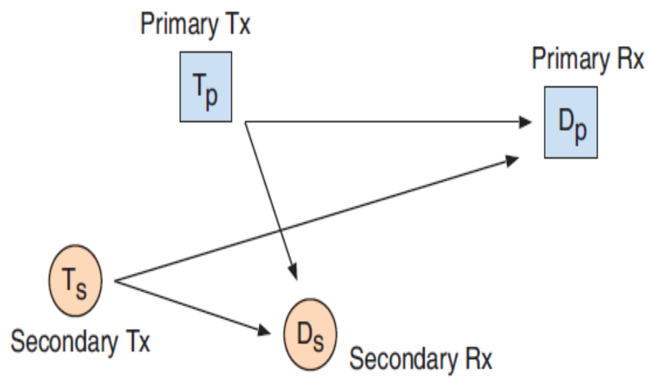

Fig.1. Cognitive Radio Channel Model

Although this approach can improve the spectral efficiency, the improvement depends on the accuracy of spectrum sensing. In the underlay model, the secondary system coexists with the primary system and can simultaneously use the licensed bands while the primary system occupies the bands. Along with the standard interference channel, in which two independent transmitters transmit independent messages to two independent receivers, there are other ways to exploit the idea of spectrum sharing. For instance, in a method normally called as interference-avoiding paradigm, provided that the secondary transmitter can sense the spatial, temporal or spectral gaps of the primary resources, it can adjust its transmission parameters to fill these white spaces.

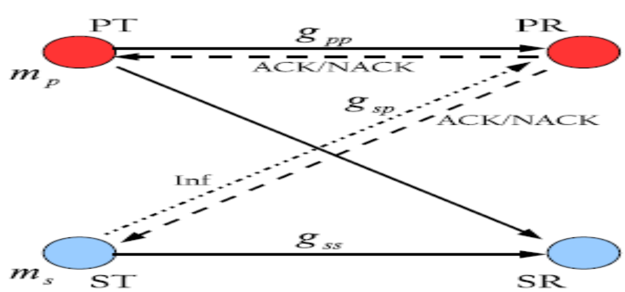

Fig.2. ARQ Based Spectrum Sharing Without CSI

II. SYSTEM MODEL AND PROBLEM STATEMENT

A. Protocol Description

We consider a cognitive network in which a secondary system coexists with a HARQ-based primary system over block-fading channels. The network consists of a pair of PS and PD and a pair of SS and SD. The protocol works as follows.

- During initial transmission, the PS transmits a data signal; the PD, SS and SD receive it.

• If the PD fails to decode the data signal, it sends an NACK signal to report the failure.

• After the SS and SD overhear the NACK signal of the PD, the SD decodes the data signal of the PS for the initial transmission. If decoding is successful, the SD sends an ACK signal to the SS.

• If the SS successfully decodes the data signal, it is ready to cooperate with the primary system.

• During retransmission, while the PS transmits the additional parity of the data signal, the SS transmits the Alamouti coded parity of the PS data signal and its own data signal simultaneously.

B. Transmitted and Received Signals

All the links among the PS, PD, SS and SD are represented as normalized Rayleigh channels with block-fading, i.e., the channel gains in the initial transmission and retransmission are independent. Let h_{ab},l be the channel gain of the AB link in the lth (re)transmission. The probability density function (PDF) and cumulative density function of $|h_{ab},l|^2$ are respectively given by

$$P_{|hab,l|^2}(t) = e^{-t}, \quad F_{|hab,l|^2}(t) = 1-e^{-t} \quad (1)$$

C. Problem Statement

To efficiently design the protocol, we find the optimal α and transmission rate Rs of the SS to maximize the average throughput of the secondary system. Additionally, the average throughput of the primary system with the secondary system should be no less than that of the primary system alone.

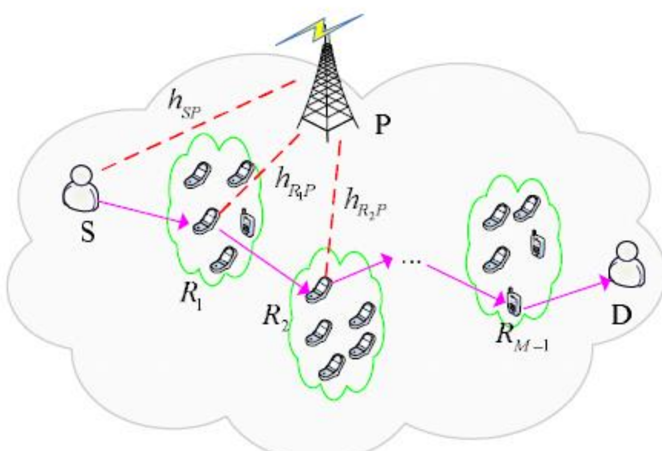

Fig.3. SYSTEM MODEL

III. LONG-TERM AVERAGE THROUGHPUT

We call the transmission of a codeword along with all its possible retransmission rounds a *packet*. The long-term throughput (in nats-per-channel-use (npcu)) is defined as,

$$\eta = \frac{\overline{D}}{\overline{l}}$$

where η denote the expected value of the successfully decoded information nats to the total number of channel uses within a fading block, respectively. Both continuous and bursting communication schemes are considered. Under the continuous communication model, it is assumed that there is an infinite amount of information available at the SU transmitter and it is always active. Thus, multiple packets, each packet containing multiple HARQ rounds, are transmitted within one fading block of length L_c.

$$\eta = \sum_{i=1}^{I+1} Rm \quad \Pr\{A_m\} \qquad (2)$$

where R_m represents the equivalent data rate after m (re)transmission rounds. Also, the data is lost and an outage happens if the data cannot be decoded after $M + 1$ (re)transmission rounds. Therefore, the outage probability is

$$P_r\{\text{outage}\} = 1 - \sum_{i=1}^{I+1} Pr \quad \{Am\} \qquad (3)$$

To find the system throughput under the bursting communication model, assume that D information nats are transmitted in each packet transmission. Provided that the data is decoded at any (re)transmission round, all the D nats are received by the SU receiver. Therefore, the expected number of received information nats in each packet is

$$= D\,(1 - P_r\{\text{outage}\})\,. \qquad (4)$$

The results emphasize a number of points listed as follows:

• INR out performs the RTD scheme in terms of both the throughput and the outage probability.

• Depending on the fading pdfs, HARQ does not necessarily increase the system throughput. For Rayleigh fading channels in particular, the HARQ-based throughput with the continuous (bursting) communication model is higher (lower) than the throughput when no HARQ is considered.

IV. RATE ADAPTATION AND POWER ALLOCATION

When the network load is low, all requesting secondary links with minimum transmission rates can be supported while satisfying the QoS and the interference constraints in and , respectively. If this is the case, secondary links would increase their transmission rates above the minimum values and share the spectrum in a fair manner. For notational convenience, we will arrange power, rate and other quantities of all secondary links into the corresponding vectors. On the basis of these LATs, we now formulate the optimization problem to maximize the LATs of the secondary system subject to the condition that the LAT of the primary system with the secondary system is not less than that of the primary system without the secondary system. Because the primary system is not responsible for maximizing the throughput of the secondary system, we assume that R_p is given for the QoS of the primary system during the optimization. To consider the transmission opportunity of the secondary system, the objective of the optimization problem should be based on $C_{S,t}$. However, with Rp given, we can discover that $C_{S,t} \propto C_{S,u}$ and the two LATs have the same optimal α and R_s. Thus, for simplicity we formulate the optimization problem based on $C_{S,u}$ as follows.

$$\text{Argmax}\ \alpha,\ R_s\ C_{S,u}\ (\alpha, R_s)\ , \quad (5a)$$

$$s.t.\ R_s \geq 0,\ 0 \leq \alpha \leq 1, \qquad (5b)$$

A. Reward to the Primary System

To provide a reward to the primary system for resource sharing, the constraint of α can be adjusted as

$$\alpha_l < \alpha \leq \alpha_u - \alpha_r \qquad (6a)$$

where α_r is the reserve parameter for the reward to the primary system. For the feasibility of α_r is limited to

$$0 \leq \alpha_r < \alpha_u - \alpha_{l.} \qquad (6b)$$

When $\alpha_r = 0$, the average throughput of the primary system with the secondary system is almost the same as that of the primary system without the secondary system. If α_r increases, the SS uses more transmit power to relay the data signal of the primary system, and thus the primary system that coexists with the secondary system can achieve a higher average throughput than the primary system alone.

B. Outage Probability

For direct transmission with HARQ, the mutual information between source and destination at each HARQ round is

$$I_{sd} = \log 2(1 + \rho\gamma_{sd}) \qquad (7)$$

Since the total mutual information after l HARQ rounds for long-term quasi static channels is

$$I_{tot,d} = lI_{sd}, \qquad (8)$$

V. MULTIPLE SECONDARY RECEIVERS

We extend the above protocols to multiple secondary users. Consider a secondary broadcast channel, where the secondary transmitter (base station) is interested in communicating independent messages to K secondary users. The secondary transmitter is assumed to possess CSI to its receivers, possibly through a dedicated feedback channel. It is our goal to investigate the benefits of multiple secondary receivers to the secondary as well as the primary networks.

As a result, the existence of K secondary users provides the following advantages:

1) Increasing the probability that at least one secondary node will decode the message of the primary user.

2) Similarly if $K \rightarrow \infty$, the outage of the cognitive link will approach zero. Therefore, the outage of secondary transmission will occur in this case only if the primary's first transmission round is successful.

3) Expecting a very good channel at each transmission block and with the truncated channel inversion power control policy leads to lowering the transmission power and hence less interference is impinged on the primary user. Therefore, we expect that the coexistence penalty to diminish which is the goal we strive to achieve in this work.

VI. NUMERICAL RESULTS

There exist the primary and secondary systems that consist of PS, PD, SS, and SD. The number of (re)transmissions of the PS is limited to two. The normalized block-fading Rayleigh channel is considered for each link as the small-scale channel model. We assume that the transmit power of the SS is 30 dB (P_s = 30 dB) and the noise power of each receiver is 1. For comparison, a genie-aided scheme is considered where the SS knows the instantaneous CSIs of all the links for the (re)transmission. For efficient evaluation of performance, throughput is defined as the transmission rate over the number of (re)transmissions until the data signal is successfully decoded. If the decoding of the data signal fails for the retransmission, the throughput is zero.

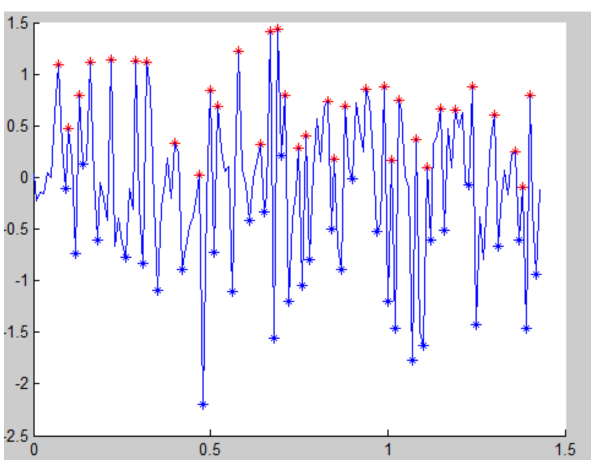

Fig.4. Peak Detection In The Channel Of User 1

We investigate the average throughput for the proposed protocol where the HARQ-based primary system coexists with the secondary system. we compare the average throughputs of the primary systems for the proposed scheme and the conventional scheme where the HARQ-based primary system alone exists for P_p = 20, 30 and 40 dB when R_p = 2 bpcu.

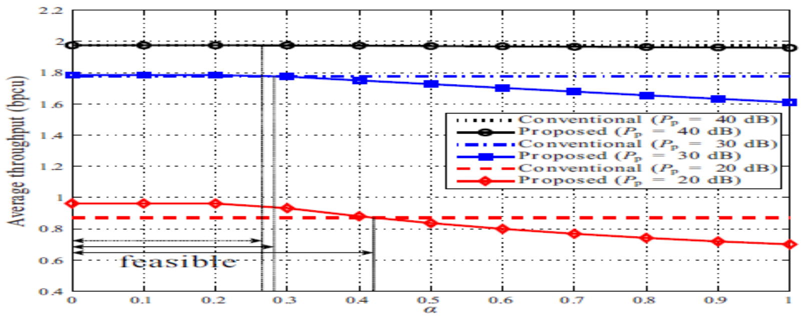

Fig.5. Average throughput of the primary systems of the conventional and proposed schemes versus α for *p*p = 20, 30 and 40 db when *r*p = 2 bpcu.

The gain provided by the cooperative scenario to the primary source is between 10% and 20%. It can be observed that cooperation causes a small decrease of the throughput of S that is sacrificing part of its available rate to cooperate with P. If we introduce coordination, the gain due to cooperation is only slightly decreased, and the region of dps with the highest reduction occurs where cooperation is less profitable. On the other hand, the throughput achieved by the secondary source is boosted by coordination, resulting in a significant incentive to cooperate. The throughput gain at the secondary source due to coordination is particularly evident when S is close to D, *i.e.*, where rate adaptation allows the secondary source to transmit at high rate more often.

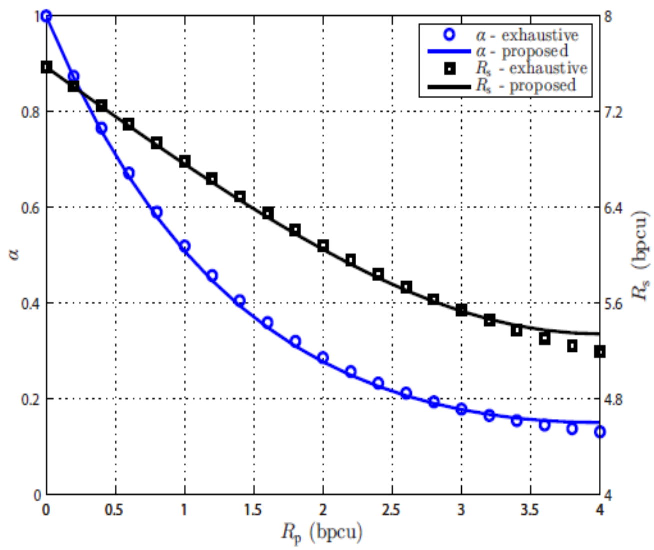

Fig.6. Comparison of the *α* and *R*s parameters obtained by the optimization problem and exhaustive search when *P*p = 30 dB.

For different values of the transmission probability of the primary source ν when dps=60m.The throughput gain in the coordinated case is smaller than that achieved with a pure cooperative case, especially when the primary access rate is small. Nevertheless, in this case coordination is not necessary, as the secondary source achieves a satisfactory throughput and thus is encouraged to cooperate even in exchange of access only.

VII. CONCLUSION

The hybrid system protocol in MIMO cognitive radio networks the system capacity has been improved. It provides high data rate. the system performance can be improved by using multiple systems. If the PD fails to decode the initial transmission, the SS serves as a relay for the primary system by using Alamouti coding, and simultaneously transmits its data signal in the retransmission of the primary system. The long term average throughput can be determined by multiple antennas and it improves the throughput compared to SISO systems.

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