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An Efficient Cognitive Radio Network Technique to Share Spectrum by Using Optimal Power Allocation

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Abstract: Cognitive radio technology helps in conspiring wireless system for adequate deployment of radio spectrum with it's anticipate technique, self-adaptation and spectrum allocation. Spectrum allocation is an adequate method of allay the scarcity of radio spectrum dilemma by allowing unlicensed users (secondary users) to coincide with licensed users (primary users) under the plight of protecting the later from adverse interference. In this study, we attention on the throughput maximization of spectrum allocation cognitive radio networks and introduce an innovative cognitive radio scheme that will significantly advance their achievable throughput more correctly, a novel receiver and a cage structure for spectrum allocation is introduced. The problem of excellent power allocation approach that maximizes the erotic quantity of the system under moderate transmits and interference power restraint is also studied.

Key words: Cognitive radio, optimal power allocation, spectrum sharing, throughput maximization, conspiring wireless

INTRODUCTION

As wireless communication techniques establish rapidly, heterogeneous wireless communication system need to be accommodated in defined frequency bandwidth. Traditional orthogonal eerie separation of heterogeneous system is not adequate enough to backing the continuous advance of wireless accessory deploying condition which makes spectrum allocation among heterogeneous system more and more critical. There are two major objections for the future of wireless scheme: wireless spectrum show and the high data rate application of increasing number of users. Cognitive Radio (CR) is a novel attitude of telecommunication systems to solve the dilemma of spectrum availability by restates underutilized licensed density bands. In a cognitive radio system, unlicensed wireless users (secondary users) are grant to access the licensed bands dynamically under the pressure of acceptable conflict to the Primary Users (PU's). Spectrum glaze and underlay are the actual techniques which can expedite the spectrum allocation among Secondary Users SUs and PUs (Kang *et al*., 2009a, b). In the glaze approach, the SU shares part of its power assets with the PU to arrange a relay benefit transmission. Therefore, the secondary network atone the demand interference by increasing the Signal to Intrusion plus Noise Ratio (SINR) of primary acceptor. Then the basic idea of glaze approach is to apportion power and channel backing to whole network, while employ the requirements of PUs. Recently, to affect the spectral capability loss of one-way half duplex, two-way broadcast has been implemented. In the underlay access, the SU uses the same spectrum all at once with the PU while maintaining or bettering the transmission of the PU by employ signal processing and classify (Kang *et al*., 2009a, b). Cooperative communications and networking is another new communication technology archetype that allows distributed incurable in a wireless network to conspire through some distributed transmission or signal convert so as to recognize a new form of space assortment to combat the detrimental chattels of fading channels (20). Cooperative Communication (CC) can offer high channel quantity and accuracy efficient and low-cost way by assemble a virtual antenna array among single antenna bulge that cooperatively dividend their antennas.

Cognitive radio: Cognitive radio will lead to a innovation in wireless communication with compelling impacts on technology as well as adjustment of spectrum usage to affected existing barricade. Cognitive radio, counting SDR

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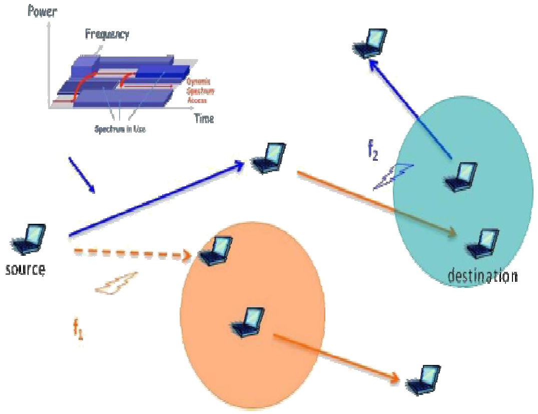

Fig. 1: Radio cognitive network with spectrum

as permissive technology is advised for the first time in (Musavian and Aissa, 2007; Srinivasa and Jafar, 2007) to realize a malleable and efficient acceptance of spectrum. Cognitive radio is an enhancement of SR which again appear from SDR. Thus, cognitive radio is the indirect step from a malleable physical layer to a flexible system as a whole analogous to reconfigurable radio. The term cognitive radio is borrowed from "cognition". According to Wikipedia cognition is assign to as o mental processes of an original with particular affiliation o mental states such as beliefs aspiration and intentions o information convert involving learning and awareness o description of the appearing development of knowledge and approach within a group resulting from this explanation, the cognitive radio is a self-aware communication scheme that efficiently uses spectrum in an astute way. It autonomously coordinates the usage of spectrum in classify unused radio spectrum on the basis of alert spectrum usage. The classification of spectrum as being untapped and the way it is used involves governance as this spectrum might be basically assigned to a licensed communication system. This secondary usage of spectrum is referred to as steep spectrum sharing which is imported as. To enable transparency to the consumer, emotional radios provide besides cognition in radio capability management also cognition in account and applications. The mental action of a cognitive radio established on the cognition circle from (Kang *et al*., 2009a, b) is illustrating in Fig. 1 cognition is illustrated at the example of malleable radio spectrum acceptance and the application of user preferences. In observing the climate, the cognitive radios choose about its action. An introductory switching on may lead to an actual action while usual activity implies a agreement making based on learning from consideration history and the consideration of the certain state of the environment. The Federal Communications Commission (FCC) has analyzed in (Suman and Sabhasree, 2012) the following (less revolutionary) appearance that cognitive radios can incorporate to empower a more adequate and flexible usage of spectrum:

Frequency agility: Radio is able to change its performing frequency to advance use in adapting to the environment.

Dynamic Frequency Selection (DFS): The radio senses signals from nearby transmitters to choose an optimal operation environment.

Adaptive modulation: The transmission characteristics and waveforms can be reconfigured to exploit all opportunities for the usage of spectrum.

Transmit Power Control (TPC): The transmission power is adapted to full power limits when necessary on the one hand and to lower level on the other hand to allow greater sharing of spectrum.

Location awareness: The radio is able to determine its location and the location of other devices operating in the same spectrum to optimize transmission parameters for increasing spectrum re-use.

Negotiated use: The cognitive radio may have algorithms enabling the sharing of spectrum in terms of prearranged agreements between a licensee and a third party or on an ad-hoc/real-time basis.

MATERIALS AND METHODS

Cognitive radio: Cognitive Radio (CR) is the enabling technology for supporting dynamic spectrum access: the policy that addresses the spectrum scarcity problem that is encountered in many countries. Thus, CR is widely regarded as one of the most promising technologies for future wireless communications. CR differs from conventional radio devices in that a cognitive radio can equip users with cognitive capability and reconfigurability. Cognitive capability refers to the ability to sense and gather information from the surrounding environment such as information about transmission frequency, bandwidth, power, modulation, etc. With this capability, secondary users can identify the best available spectrum. Reconfigurability refers to the ability to rapidly adapt the operational parameters according to the sensed information in order to achieve the optimal performance. By exploiting the spectrum in an opportunistic fashion, cognitive radio enables secondary users to sense which portion of the spectrum are available, select the best

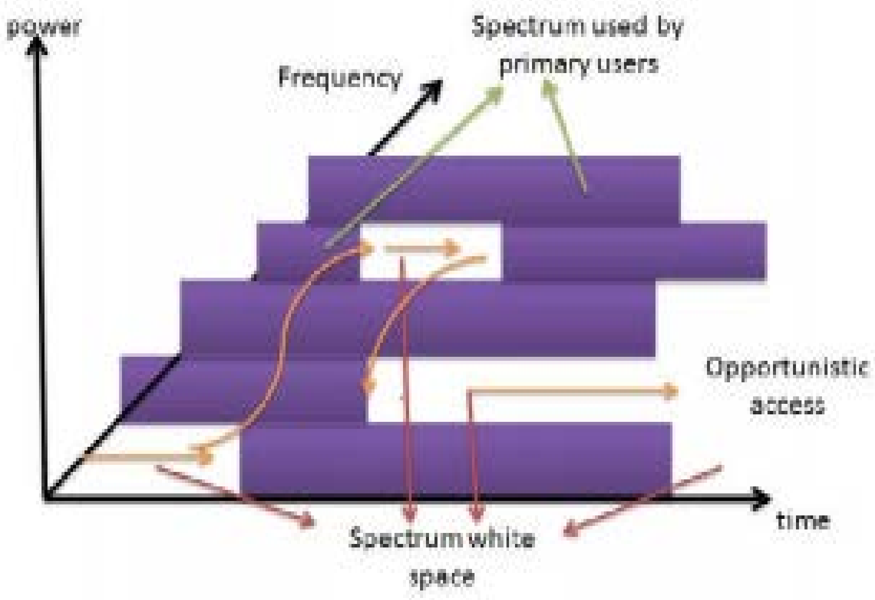

Fig. 2: Spectrum white space

available channel, coordinate spectrum access with other users and vacate the channel when a primary user reclaims the spectrum usage right.

Through spectrum sensing and analysis, CR can detect the spectrum white space Fig. 2, i.e., a portion of frequency band that is not being used by the primary users and utilize the spectrum. On the other hand, when primary users start using the licensed spectrum again, CR can detect their activity through sensing, so that no harmful interference is generated due to secondary users' transmission. Thus spectrum management is done efficiently. Because CRs are able to sense, detect and monitor the surrounding RF environment such as interference and access availability and reconfigure their own operating characteristics to best match outside situations, cognitive communications can increase spectrum efficiency and support higher bandwidth service. Moreover, the capability of real-time autonomous decisions for efficient spectrum sharing also reduces the burdens of centralized spectrum management. As a result, CRs can be employed in many applications. The main functions of cognitive radios are:

- Spectrum sensing
- Power control
- Spectrum management

Spectrum sensing: Detecting unused spectrum and sharing it, without harmful interference to other users; an important requirement of the cognitive-radio network to sense empty spectrum. Detecting primary users is the most efficient way to detect empty spectrum. Spectrum-sensing techniques may be grouped into three categories such as transmitter detection, cooperative detection and Interference-based detection. Transmitter detection cognitive radios must have the capability to determine if a signal from a primary transmitter is locally present in a certain spectrum. There are several proposed approaches to transmitter detection namely Matched filter detection, energy detection, cyclo-stationary feature detection. Cooperative detection refers to spectrum sensing methods where information from multiple cognitive-radio users is incorporated for primary-user detection.

Power control: Power control is used for both opportunistic spectrum access and spectrum sharing CR systems for finding the cut-off level in SNR supporting the channel allocation and imposing interference power constraints for the primary user's protection respectively. In a joint power control and spectrum sensing is proposed for capacity maximization.

Spectrum management: Capturing the best available spectrum to meet user communication requirements, while not creating undue interference to other (primary) users. Cognitive radios should decide on the best spectrum band (of all bands available) to meet quality of service requirements; therefore, spectrum-management functions are required for cognitive radios. Spectrum-management functions are classified as:

- Spectrum analysis
- Spectrum decision

RESULTS AND DISCUSSION

Implementation: In the cognitive radio system presented in Fig. 1, let g and (hergodic, stationary)denote the instantaneous channel power gains from the Secondary Transmitter (SU-Tx) to the Secondary Receiver (SU-Rx) and the Primary Receiver (PU-Rx), respectively. In the following, it is described how the proposed spectrum sharing scheme operates and present the receiver and frame structure employed in this cognitive radio system. In practice, the channel power gain h can be obtained via, e.g., estimating the received signal Power from the PU-Rx when it transmits, under the assumptions of the pre-knowledge on the PU-Rx transmit power level and the channel reciprocity.

Radio system: The receiver structure of the proposed cognitive radio system is presented in Fig. 3-4 The received signal at the secondary receiver is given by:

$$y = \theta x_P + x_S + n \tag{1}$$

Where:

θ = The actual status of the frequency band (θ = 1 if the frequency band is active, whereas θ = 0 if the frequency band is idle)
xp and xs = The received signal from the primary users and the secondary transmitter, respectively
n = The additive noise, the received signal
y = The initially passed through the decoder, where the signal from the secondary transmitter is obtained

In the following, the signal from the secondary transmitter is cancelled out from the aggregate received signal y and the remaining signal (Eq. 2):

$$y = \theta x_P + n \tag{2}$$

Is used to perform spectrum sensing. As a result, instead of using a limited amount of time t almost the whole duration of the frame T can be used for spectrum sensing under the proposed cognitive radio system. This way, we are able to perform spectrum sensing and data transmission at the same time and therefore maximize the duration of both. In the receiver facilitates the use of more complex spectrum sensing techniques that exhibit increased spectrum sensing capabilities but require higher sensing time (such as cyclostationary detection, generalized likelihood ratio test based or covariance based spectrum sensing techniques) which prohibits their application for quick periodical spectrum sensing under the frame structure (Fig. 5). The frame structure of the proposed cognitive radio system presented in Fig. both spectrum sensing and data transmission are performed at the same time using the receiver structure as discussed earlier. The advantage of the proposed frame structure is that the spectrum sensing and data transmission times are simultaneously maximized. The increased sensing time enables the detection of very weak signals from the primary users thus reducing false alarm probability that would significantly remove discontinuity hence increasing the throughput of the cognitive radio

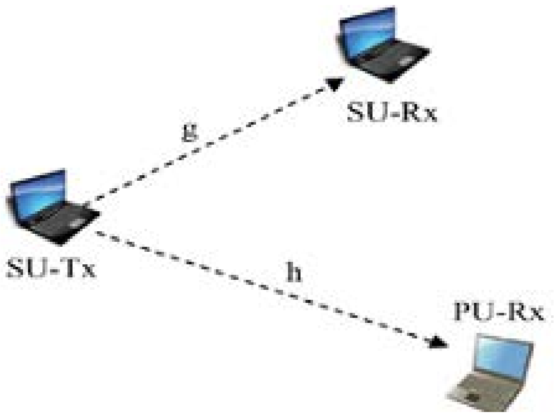

Fig. 3: System model

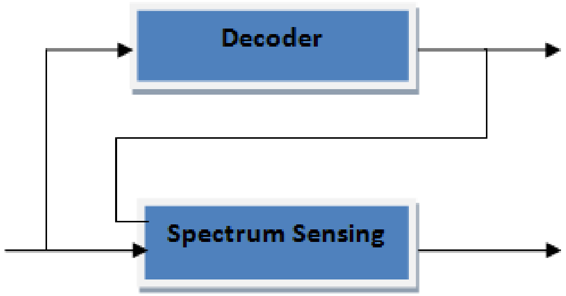

Fig. 4: Receiver structure proposed cognitive radio system

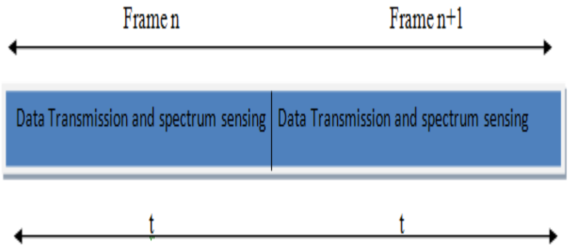

Fig. 5: Frame structure of the proposed cognitive radio system

system. Using the proposed frame structure leads to an improved detection probability, thus better protection of the primary users from harmful interference which enables a better use of the available unused spectrum. The false alarm prevents the secondary users from accessing an idle frequency band using higher transmit power and therefore limits their throughput as per requirement. The continuous spectrum sensing can be achieved under the proposed cognitive radio system which ensures better protection of the primary networks.

Ergodic capacity of proposed spectrum sharing scheme: In this study, the problem of deriving the optimal power allocation strategy that maximizes the ergodic capacity of the cognitive radio network that operates under the proposed spectrum sharing scheme is discussed. In the proposed cognitive radio system, the secondary users adapt their transmit power at the end of each frame based on the decision of spectrum sensing and transmit using higher power P0 when the frequency band is detected to be idle and lower power P1 when it is detected to be active. Following the approach of (Liang *et al*., 2008) the instantaneous transmission rates when the frequency band isidle (H_0) and active (H_1) are given by

$$\begin{aligned} r_0 &= \log_2(1+\frac{gp_0}{\sigma_n^2}) \\ r_1 &= \log_2(1+\frac{gp_1}{\sigma_n^2+\sigma_p^2}) \end{aligned} \tag{3}$$

respectively where σ^2p denotes the received power from the primary users. The latter parameter restricts the achievable throughput of all spectrum sharing cognitive radio networks and indicates the importance of spectrum sensing and optimal power allocation on the throughput maximization of spectrum sharing cognitive radio networks. However, the perfect spectrum sensing may not be achievable in practice, where the actual status of the primary users might be falsely detected. Therefore, the four different cases of instantaneous transmission rates based on the actual status of the primary users (active/idle) and the decision of the secondary users (primary user present/absent) as follows:

$$\begin{aligned} r_{00} &= \log_2(1+\frac{gp_0}{\sigma_n^2}) \\ r_{01} &= \log_2(1+\frac{gp_1}{\sigma_n^2}) \end{aligned} \tag{4}$$

$$\begin{aligned} r_{10} &= \log_2(1+\frac{gp_0}{\sigma_n^2+\sigma_p^2}) \\ r_{11} &= \log_2(1+\frac{gp_1}{\sigma_n^2+\sigma_p^2}) \end{aligned} \tag{5}$$

Here, the first index number of the instantaneous transmission rates indicates the actual status of the primary users ("0" for idle, "1" for active) and the second index number, the decision made by the secondary users ("0" for absent, "1" for present) In order to keep the long term power budget and effectively protect the primary users from harmful interference. We consider averages (over all fading states) transmit and interference power constraint that can be formulated as follows:

$$\begin{aligned} &E_{g.p}\{P(H_0)(1-P_{fa})P_0 + P(H_0)P_{fa}P_1 \\ &\quad + P(H_1)(1-P_d)P_0 \\ &\quad\quad + P(H_1)(1-P_d\} \leq P_{av} \\ &E_{g.p}\{P(H_1(1-P_d)hP_0 + P(H_1)P_d hP_1\} \leq T \end{aligned} \tag{6}$$

Where:

$P(H_0)$ and $P(H_1)$ = The probability that the frequency band is idle and active, respectively

P_d and P_{fa} = The detection and false alarm probability, respectively

P_{av} = The maximum average transmit power of the secondary users

Γ = The maximum average interference power that is tolerable by the primary users

The reason for choosing an average interference power constraint is based on the results in and which indicate that an average interference power constraint leads to higher ergodic through put for the cognitive radio system and provides better protection for the primary users compared to a peak interference power constraint. Finally, the optimization problem that maximizes the ergodic through put of the proposed spectrum sharing cognitive radio system under joint average transmit and interference power constraints can be formulated as follows:

$$\begin{aligned} &\text{Maximize}\, C = E_{g.h}\{P(H_1)P_d r_{11} + P(H_0)P_{fa}r_{01} + \\ &P(H_1)(1-P_d)r_{10} + P(H_0)(1-P_{fa})r_{00}\} \end{aligned} \tag{7}$$

Subject to Eq. 4 and 5, $P0 \geq 0$, $P1 \geq 0$ (Eq. 6) the lagrangian with respect to the transmit powers P0 and P1 is given by:

$$\begin{aligned}&L = (P_0, P_1\lambda, \mu) = E_{g.h}\{P(H_1)P_d r_{11} + P(H_0)P_{fa} r_{01} + \\ &P(H_1(1-P_d)r_{01}P(H_0)(1-P_{fa})r_{00}\} - \lambda \\ &E_{g.h}\{P(H_0)(1-P_{fa})P_0 + P(H_0)(P_{fa})P_1\} + \\ &P(H_1(1-P_d)P_0 + P(H_1)P_dP_1\} + \lambda P_{av} - \\ &\mu E_{g.h}\{P(H_1)(1-P_d)hP_0 + P(H_1)P_dhP_1\} + \mu r\end{aligned} \tag{8}$$

Whereas the dual function can be obtained by:

$$D(\lambda, \mu) = \sup L(P_0, P_1, \lambda, \mu) \tag{9}$$

In order to calculate the dual function d(ë, ì), the supermom of the Lagrangian with respect to the transmit powers P_0 and P_1 needs to be obtained. We therefore apply the primal-dual decomposition method which facilitates the solution of the joint optimization problem by decomposing it into two convex single-variable optimization problems, one for each of the transmit powers P_0 and P_1 as follows:

Sub problem 1: Maximize:

$$\begin{aligned}&\{P1 \geq 0\} \\ &f_2 = E_{g.h}\{P(H_0)(P_{fa})\log_2(1+\frac{gP_1}{\sigma_n^2}) + \\ &P(H_1)(P_d)\log_2(1+\frac{gP_0}{\sigma_n^2\sigma_p^2}) - \lambda \\ &E_{gh}\{P(H_0)(P_{fa})P_1 + P(H_1)(P_d)P_1\} - \\ &\mu E_{gh}\{P(H_1)(P_d)hP_1\end{aligned} \tag{10}$$

After forming their Lagrangian functions and applying the Karush-Kuhn-Tucker (KKT) conditions, the optimal powersP0 and P1 for given λ, μ are given by

$$\begin{aligned}P_0 &= [\frac{A_0 + \sqrt{\Delta_0}}{2}] \\ P_1 &= [\frac{A_1 + \sqrt{\Delta_1}}{2}]\end{aligned} \tag{11}$$

Where [x]+ denotes max(0,x):

$$A_0 = \frac{\log_2(e)(\alpha_0 + \beta_0)}{\lambda(\alpha_0 + \beta_0) + \mu\beta_0 h} - \frac{2\sigma^2{}_n + \sigma^2{}_p}{g}$$

$$\Delta_0 = A^2{}_0 - \frac{4}{g}\{\frac{\sigma^2{}_n + \sigma^2{}_p}{g\sigma^{-2}{}_n}$$

$$- \frac{\log_2(e)(\alpha_0(\sigma^2{}_n + \sigma^2{}_p) + \beta_0\sigma^2{}_n)}{\lambda(\alpha_0 + \beta_0) + \mu\beta_0 h}\}$$

$$A_1 = \frac{\log_2(e)(\alpha_1 + \beta_1)}{\lambda(\alpha_1 + \beta_1) + \mu\beta_1 h} - \frac{2\sigma^2{}_n + \sigma^2{}_p}{g} \quad \Delta_1 = A^2{}_1 - \frac{4}{g}\{\frac{\sigma^2{}_n + \sigma^2{}_p}{g\sigma^{-2}{}_n}$$

$$- \frac{\log_2(e)(\alpha_1(\sigma^2{}_n + \sigma^2{}_p) + \beta_1\sigma^2{}_n)}{\lambda(\alpha_1 + \beta_1) + \mu\beta_1 h}\}$$

And the parameters in Eq11 are given by:

$$\begin{aligned}&\alpha_0 = P(H_0)(1 - P_{f\alpha}),\ \beta_0 = P(H_1)(1 - P_d) \\ &\alpha_1 = P(H_0)(P_{f\alpha}),\ \beta_1 = P(H_1)(P_d)\end{aligned} \tag{12}$$

CONCLUSION

Thus, in this study, throughput maximization of spectrum sharing cognitive radio networks is emphasized and an innovative cognitive radio system is proposed that significantly improves throughput more specifically, a novel receiver and a frame structure for spectrum sharing is also being introduced. The problem of optimal power allocation strategy that maximizes the ergodic capacity of the system under average transmits and interference power constraints are also studied.

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