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SHANON'S RATE BASED OPTIMIZED SCHEME FOR RADIO RESOURCE ALLOCATION IN COGNITIVE RADIO NETWORK

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ABSTRACT

Leveraging on opportunistic communication for improving the efficient utilization of the radio spectrum is a huge success of Cognitive Radio (CR) concept. The ability for software defined radio to sense spectrum and detect vacant frequency spectrum at any time from the high capacity but congested wireless radio spectrum presents an effective approach to manage the scarce radio resources. In a dynamic environment, many parameters and situations have to be considered which affect the total data rate of the system. This work presents an optimized resource allocation scheme for scarce radio resource management considering; subcarrier allocation to secondary users and power allocation on subcarriers. An algorithm was designed with the aim of improving the total throughput of the CR system. Simulation results shows that when performing channel estimation with a larger number of training symbols, the sum capacity is largely increased.

INTRODUCTION

Wireless standards and networks are now designed to follow a fixed spectrum assignment strategy, because the electromagnetic radio spectrum is scarce resource, the use of these electromagnetic spectrum bands have to be licensed by government agencies. This implies that a huge portion of assigned spectrum are mostly being used only intermittently or maybe not used at all due to various factors such as amount of traffic load on licensed users (Ian F. Akyildiz, 2006).

Due to limited availability of radio spectrum and high inefficiency in its usage, new perceptions into the use of spectrum have challenged the traditional methods to spectrum management. This is powered by the concept of opportunistic communication. This new communication technology is referred as Dynamic Spectrum Access (DSA) or Cognitive Radio (J. Mitola, 2000). A cognitive radio is an intelligent wireless communication system that relies on opportunistic communication between unlicensed or secondary users (SUs) over temporarily unused spectral bands that are licensed to their (PUs) (. Z.H. Hashmi, 2008). However, the evolution and development of cognitive radio is still at a conceptual stage and has not evolved into tangible application due to a number of challenges it faces in how it learns and adjusts to the local spectral activity at each end of the link.

A Cognitive radio based intelligent communication system allows a complete SU system to simultaneously or opportunistically operate in the same frequency band as the PU. The rough edges in CR features of these CR systems to recognize their communication environment and adapt the parameters of their communication scheme to maximize the quality of service for the SUs while minimizing the interference to the PUs is the reason why CR technology is largely approached as conceptual. Improving spectrum efficiency and use is a constantly a concern to regulatory authorities worldwide. Spectrum utilization and Measurement studies of have indicated that spectrum is irregularly used in many geographical areas and times. The Low utilization and increased demand for the radio spectrum resource gives rise to the thought of secondary use, which allows unused parts of spectrum to become available temporarily for commercial purposes, being referred to as opportunistic communication. The secondary use of spectrum is one of the promising ideas that can reduce unsatisfied spectrum demand effectively. This paper however, seeks to present an improved resource allocation scheme for power and sub-channel allocation, finding its footing on the optimization of shanon's rate. Cognitive radio stands as a technological breakthrough for maximizing the utilization of the limited radio bandwidth while accommodating the increasing amount of services and applications in wireless networks. The most prominent and key features of a CR transceiver are awareness of the radio environment and intelligence. This intelligence is achieved through sampled learning and adaptive tuning of system parameters such as transmit power, carrier frequency, and modulation strategy (E. Hossain and V. K. Bhargava, 2007).

The key enabling techniques for cognitive radio networks (also referred to as dynamic spectrum access networks) are wideband signal processing techniques for digital radio, advanced wireless communications methods, artificial intelligence and machine learning techniques, and cognitive radio-aware adaptive wireless/mobile networking protocols (B.Ackland and I.Seskar, 2004).

MATERIALS AND METHODS

The proposed approach will be capacity maximization based, improving throughput of the network within the power and interference constraint. Subsequent subsections will reveal progressive premises on which the model approach and problem formulation is based. Since Shannon's rate presents possibilities to adopt simpler approach in handling throughput maximization, the work will present information on Shannon's rate based capacity maximization and spectral footprint minimization. Progressively, algorithm to optimize the RA scheme based on is proposed as an improved way of radio resource allocation.

Downlink Power minimization approach

For downlink transmission, the power minimization objective intends to mitigate harmful interference at the PUs while satisfying the QoS requirements for the CRs. The power minimization objective function for downlink transmission in a CRN can be expressed as follows:

$$min_{X_{n,k}P_{n,k}} \sum_{n=1}^{N} \sum_{k=1}^{K} X_{n,k} P_{n,k}$$

An optimization problem with power minimization objective function utilizes as much bandwidth as possible to minimize power allocation to sub-channels while satisfying cognitive transmission-specific constraints. We can refer to the corresponding power resource allocation scheme as a margin adaptive allocation scheme since it allocates power to sub-channels until the QoS requirements (set margins) of the CRs are satisfied.

Rate maximization (Throughput maximization):

The optimization problems in CRNs with the objective of rate maximization aim to maximize the total system throughput in CRNs under interference (i.e., interference at the PUs) and total power constraints. We can refer to this sum-rate type of problem as rate-adaptive optimization problems. The sum-rate maximization objective that maximizes the spectral efficiency in CRNs can be written as follows:

$$max_{X_{n,k}P_{n,k}} R_T \sum_{n=1}^{N} \sum_{k=1}^{K} X_{n,k} B \, log \left(1 + \frac{P_{n,k} h_{n,k}}{\eta + \sum_{p\epsilon P} I_{p,n,k}} \right)$$

The sum-rate maximization problems in CRNs may not guarantee the satisfaction of individual CR's minimum rate requirement to achieve efficient throughput maximization except with the complementation of utility maximization approach.

Shannon's rate based System model:

The system model is premised on constant gain assumption, which implies that the wireless channel considered in the system model is a flat Rayleigh block fading channel. Furthermore, we also assume that the channel changes slowly so that the gains will be constant during transmission. If the entire spectrum band shared by subchannels is denoted by B Hz and is shared into K number of subchannels or sub-channels, each sub-channel with its own bandwidth of $\frac{B}{K} Hz$, then the sub-channel bandwidth is of course much smaller than the entire bandwidth.

$$\frac{B}{K} Hz << \; B \; Hz.$$

Furthermore, each sub-channel, k, from the total number of **K** subchannels can only support transmissions for one secondary user, n from total no of secondary users N.

This means that

$\sum_{n=1}^{N} x_{n,k} \leq 1, \forall k = 1,2, \dots, K$

Where N = total no. of secondary users (SU)

K= total no. of subchannels

n= a single secondary user

k = single subchannel

The equation

$$\sum_{n=1}^{N} x_{n,k} \leq 1, \forall k = 1,2, \dots, K$$

Is a capacity maximization problem formulation, taking totality of all the secondary users (cognitive users) and the number of subchannels. The solution to this equation is vital to the entirety of this work, since we aim at maximizing the throughput.

Since the equation is a rate maximization problem, to get the maximum rate at which information can be transmitted over a channel of a specified bandwidth in the presence of noise, the equation can be applied to Shannon's rate (Rn).

Shannon's rate for each SU M is computed as

$$R_n = \sum_{k=1}^{K} x_{n,k}\, r_{n,k}$$

The summation is over K since one subchannel can only support transmissions for one secondary user. The sum rate maximization problem may not solve or guarantee the satisfaction of individual CR's minimum rate to achieve efficient throughput.Thus, we will induce a utility maximization parameter or function which is logarithmic and considers both efficiency and fairness in resource allocation. From Shannon's rate,

$$R_n = \sum_{k=1}^{K} x_{n,k}\, r_{n,k}$$

We have that:

$$R_n = \sum_{k=1}^{K} x_{n,k} * \frac{B}{K} * \log_2\left(\frac{1 + h_{n,k}P_{n,k}}{\Gamma\, I_{n,k}}\right)$$

Where $r_{n,k}$ is the transmit rate of SU n on subchannel k.

$h_{n,k}$ = channel gain of SU n on subchannel k.

$P_{n,k}$ = transmit power of SU n on subchannel K.

$I_{n,k}$ is the noise plus interference power experienced by SU n on subchannel k.

Γ = constant signal to noise ratio (SNR) relevant to get required BER.

$$\Gamma = ln\frac{(5\, BER_{req})}{1.5}$$

Problem formulation for Shannon's rate based allocation model

Since Shannon's rate gives a premise on which to progressively head towards obtaining the maximum transmit rate $r_{n,k}$ of SU n on subchannel k, the subchannel and power allocation for capacity maximization can be expressed mathematically as:

Max $x_{n,k}$ Pn, k $\sum_{n=1}^{N} \boldsymbol{R_n}$

Such that

$\sum_{n=1}^{N} x_{n,k} \leq 1, \forall k = 1,2,\dots,K$
As mentioned above, by implementing Shannon's rate, the subchannel and power allocation for capacity maximization can be expressed mathematically as:

$$\underset{x_{n,k}P_{n,k}}{max} \sum_{n=1}^{N} R_n$$

Such that,

$$\sum_{n=1}^{N} x_{n,k} \leq 1, \forall k = 1,2,\dots,K.$$

$$\sum_{k=1}^{K} P_{n,k} \leq P_{max}^{n}, \forall n = 1,2,\dots,N.$$

$$P_{n,k} + I_{n,k} \leq P_{th}$$

$$P_{n,k} > 0$$

Where,

P_{max}^{n} is the power budget of SU n,

P_{th} is the permissible interference power level of PU.

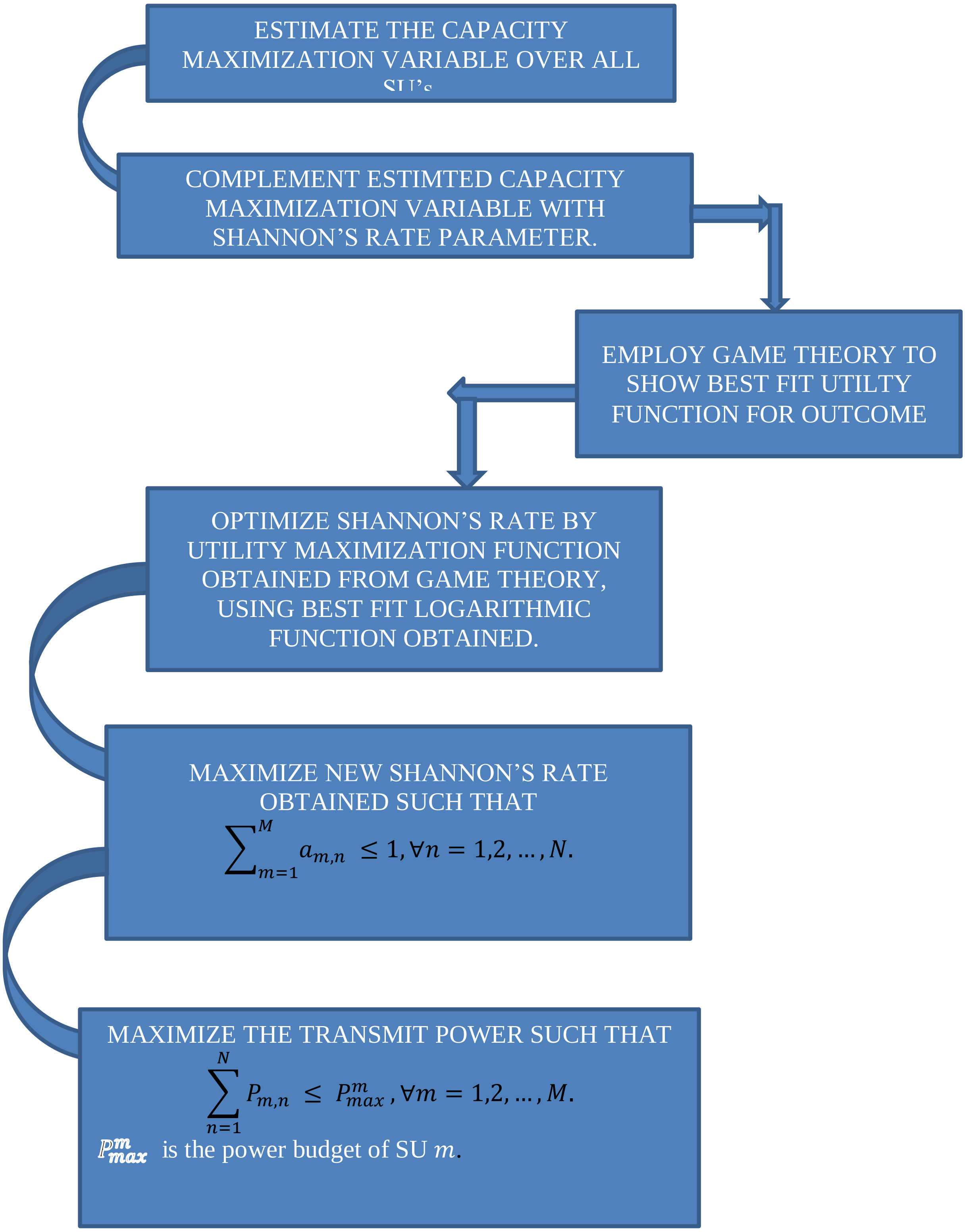

Figure 1: Shanon's flow diagram for resource allocation in one PU, N SU CRN.

RESULTS

Simulating the Signal in MATLAB

As we know that CR promises the secondary users access the spectrum which is allocated to a primary user, so avoiding interference to potential primary users is a basic requirement. Therefore, we should detect the primary user status through the continuous spectrum sensing. When CR users start spectrum sensing to detect the status of the primary user, they will get the received signal expressed as Eq. (4.1).

Maximum Energy Detection for Spectrum Sensing

When CR users start the spectrum sensing to detect the primary users' status, the received signal $r(t)$, can be expressed according to Yuhang (2011) as:

$$r(t) = \begin{cases} n(t) & H_0 \\ s(t) + n(t) & H_1 \end{cases} \quad (4.1)$$

where, H_0 represents no signal transmitted, and H_1 is the signal transmitter, s(t) is the signal waveform and n(t) is a zero-mean AWGN. The detection probability P_d and the false alarm probability P_f .

Then the received signal $r\ (t)$ will goes into the A/D converter select by the bandapss filter where we will get a threshold according to the noise floor. To measure the energy of the signal, the bandwidth W of the signal will be squared and integrated (Diagham, 2003). At last the output signal of integrator Y as we express in Eq. (4.2), is the signal we simulated.

According to Proakis (2001), If the number of samples are large with the central limit theorem, we assume a chi-square distribution is approx. as Gaussian distribution:

$$Y \sim \begin{cases} N(n\sigma_n^2, 2n\sigma_n^4) & H_0 \\ N(n(\sigma_n^2 + \sigma_s^2, 2n(\sigma_n^2 + \sigma_s^2)^2) & H_1 \end{cases} \quad 4.2)$$

We use MATLAB program to encode the output signal from the integrator with zero-mean AWGN. So, we can encode the output signal from the integrator as: sig=sqrt(sigmas^2+sigman^2)*randn (100, N), which obeys the Gaussian distribution. Sigmas^2 is the variance of the signal waveform, sigman^2 is the variance of AWGN, the operation randn distributes random numbers and arrays. Then we set the values of the parameters to simulate the signal: $\mathrm{SNR} = -10\mathrm{dB}$ (for instance; the band with $\mathrm{W} = 1 \times 10^5$) the observed time $\mathrm{t_s} = 1 \times 10^{-2}\mathrm{s}$, samples $\mathrm{N} = 2 \times \mathrm{t_s} \times \mathrm{W}$, the variance of the noise $\sigma_n^2 = 1 \times 10^{-12}$, the variance of the received signal $\sigma_s^2 = (\sigma_n \times 10^{-1})^2$ $(\mathrm{SNR} = -10\mathrm{dB})$.

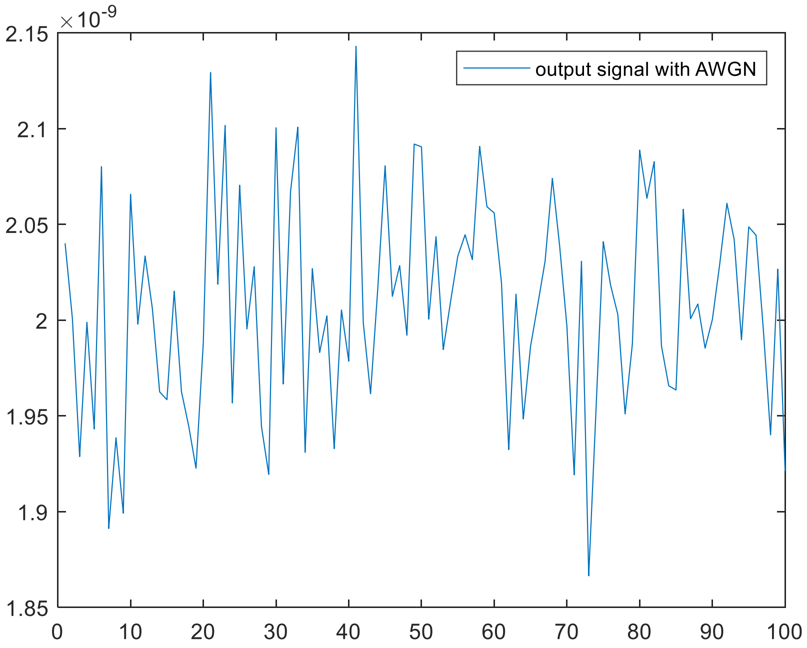

Figure 2: Output signal with AWGN

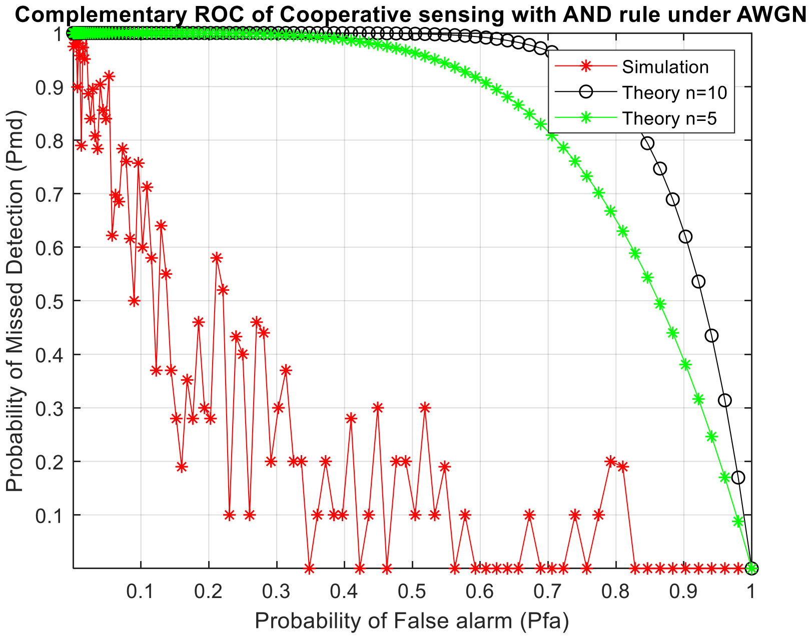

Figure 3: Probability of false alarm

CONCLUSION:

The subcarrier and power allocation problem with imperfect CSI in cognitive radio systems have investigated and studied. The resource allocation algorithm has been proposed, a two-step scheme with low computational complexity, in which subcarrier and power allocation are operated separately. Simulation results shows that when performing channel estimation with a larger number of training symbols, the sum capacity is largely increased. The system model used is such that a primary band is operating side by side to the secondary band in a multi user system. The assumption that the transmitter always receives the channel state information perfectly is impractical for wireless systems, thus the proposed resource allocation scheme is based on the imperfect channel state information. The power resource allocation is approached as a minimization problem. The subchannel allocation scheme factors in the possibility of varying scenarios and anomalies like interference at the PU and very high or low tresh hold.

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