ISSN(Online) : 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 4, April 2016

Spectral - Energy Efficiency and Trust-Aware Scheme for Cognitive Radio Networks

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ABSTRACT: Cognitive Radio (CR) is one of the prominent techniques for improving the utilization of the radio spectrum. A Cognitive Radio Network (i.e., secondary network) opportunistically shares the radio resources with a licensed network (i.e., primary network). In an existing system, the spectral-energy efficiency trade-off for CR networks is analyzed at both link and system levels against varying Signal to-Noise Ratio (SNR) values. A general analytical framework to evaluate the spectral-energy efficiency trade-off of CR-based cellular network is established for all SNR values using peak-power interference constraint. Extreme value theory is used to derive the spectral and energy efficiency. The framework takes into an account the numbers of primary and secondary receivers transmit power, and interference threshold. However extreme value theory does not consider the trustworthiness of Secondary Users (SUs). To overcome this problem, the trustworthiness of each SU is calculated based on the Primary User's (PU's) strategy. By using PU's strategy, the selected SU determines its optimal transmission power. The system usesStackelberg game to model the interactions between PU and SU. The utility functions are defined for both PU and SU, taking energy efficiency and trustworthiness into consideration.

KEYWORDS: Extreme value theory; Stackelberggame; Trust awaremodel; Average power constraint; Peak power constraint.

I. INTRODUCTION

There is an increasing number of smart phones and laptops every year. All of them are demanding advanced multimedia and high data rate services. Wireless sensor nodes with cognitive radio capabilities can help to address these challenges. Cognitive Radio sensor network in used to improve the bandwidth and Quality-of-Service of wireless sensor nodes. Devices with cognitive capabilities can be networked to create Cognitive Radio Networks (CRNs). CRNs improve the spectrum utilization, and multiple sensor networks can be deployed in a specific region. CRs are able to monitor, sense, and detect the conditions of their operating environment, and dynamically reconfigure their own characteristics to best match those conditions.PUs uses ordinary wireless communication systems with static spectrum allocation, whereas SUs are equipped with CRs which utilizes spectrum opportunities without disturbing the PU's transmissions.

In this paper, the spectral-energy efficiency trade-off for CR networks is analyzed at link and system levels against varying SNR values with multiple primary and secondary users. Trust value for each SU is calculated according to the SNR value.Then the system fixes an appropriate threshold value for these trust values. Based on threshold condition, the SUs will be selected for spectrum sharing.In this paper,we compared the results of spectral-energy efficiency of link level and system level with and without trust values respectively.

II. RELATED WORK

In[5]Gradient Based Iteration algorithm is used to obtain the Stackelberg equilibrium solution to the energy-efficient resource allocation problem. Authors proposed a pricing-based spectrum leasing framework between one PU and multiple SUs.The intuitive explanation of GBI algorithm is that the cognitive BS expects to allocate the spectrum

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to FBSs or MSUs with higher energy-efficient transmission. The serious disadvantage of this method is, it is difficult to have the perfect knowledge of a dynamic channel. In [6] Water Filling Factors Aided Search method deals with the energy efficient optimization problem with multiple interference power constraint. This method consists of two WFAS: simplified WFAS and general WFAS. Authors had analyzed the energy efficient power allocation problems of OFDM-based CR under single and multiple interference power constraints respectively. The main drawback of this method is Energy-efficient power allocation problem is more complicated in multi-cellular networks or MIMO broadcast networks.In [9] Efficient Barrier Method is used toinvestigate the energy-efficient resource allocation in OFDM-based CRNs, Authors had proposed a time sharing method and hypograph form to convert intractable mixed integer programming into a convex optimization problem making it possible to work out optimal solutions and finally developed a fast barrier method by exploiting the special structure to speed up the computation of Newton step. The problem with this method is imperfect channel state information.

In [10]existing method, the spectral-energy efficiency in interference tolerant CR networks has investigated. In this work, the spectral-energy efficiency for CR networks is analyzed at link and system levels against varying SNR values. The spectral efficiency for the proposed network with multiple primary and secondary users is analyzed using extreme value theory. At the link level, analysis is made on the energy required to achieve a definite spectral efficiency for a CR channel under two types of power constraint in various fading environments. In this condition, besides the transmit power constraint, interference constraint at the Primary Receiver (PR) is also considered to protect the PR from a destructive interference. Whereas at the system level, analysis is made on the spectral and energy efficiency for a CR network that shares the spectrum with an indoor network. Extreme value theory (EVT) is used to calculate the spectral efficiency of the system-level CR network under optimal power allocation. The spectral efficiency depends upon the number of the PRs, the interference threshold, and how far the Secondary Receivers (SRs) are located. EVT without trust value has certain drawbacks, they are,

1. It does not consider the trustworthiness of SUs.
2. The partner selection for spectrum sharing is not considered.

III. PROPOSED METHOD

In proposed method, Cognitive Radio (CR) improves spectrum efficiency by allowing Secondary Users (SUs) to dynamically access the idle spectrum owned by Primary Users (PUs). The existing system does not consider the trustworthiness of SUs. Since the PU can transmit its data at any time, it is concerned with energy efficiency due to power limitation. By the same time, the SU can value its transmission rate but it does not have much opportunity to transmit. Thus, the PU and the SU have different concerns which need to be taken into consideration. There may existsome dishonest users, even malicious ones in the system, corrupting or disrupting the normal operation of CRN. Consequently, the performance can therefore be compromised. Thus, security issues needs to be considered for this emerging cooperative networking. The system makes an effort to guarantee and improve the performance of cooperation and SU selection, byconsideringenergyefficiency and security issues. Use of Extreme Value Theory with Trust Value (EVTT) has serious advantage than existing method, they are,

1. It provides optimal power allocation.
2. Trust worthiness of secondary user is high.

IV. SYSTEM IMPLEMENTATION

4.1 CREATION OF NETWORK MODEL

In this section, we describe a Cognitive Radio Network model in which a secondary transmitter and a secondary receiver communicate over a time-selective correlated Rayleigh fading channel in the presence of primary users. The spectral-energy efficiency of a CRN is analyzed at link level as well as system level.

4.2 LINK-LEVEL SPECTRAL-ENERGY EFFICIENCY TRADE-OFF

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Consider a link-level CR channel. It consists of secondary transmitter-receiver pair that shares a spectrum with a primarytransmitter-receiver pair. Assume a point-to-point flat fading channel that iscorrupted by AWGN. All nodes in this model are assumed to be implemented with a single antenna. The channel between the ST and SR is defined as the cognitive channel, while the channel between the Secondary Transmitter (ST) and the Primary Receiver (PR) is defined as the interference channel. The cognitive and interference channel gains are denoted by $g_c$and g_i, respectively. They are random variables drawn from an arbitrary continuous distribution with an expected value of unity and they are mutually independent.

4.2.1 Fading Channels With Average Transmit PowerConstraint

Consider a CR channel under the average transmit power and peak interference power constraints, the spectral efficiency in this case can be calculated by

$$C= \max_{\gamma_s(g_c,g_i)\geq 0} E[\log_2(1+\frac{g_c\gamma_s(g_c,g_{i0}}{N_0})] \quad (1)$$

$$\text{St. } [\gamma_s(g_c,g_i)] \leq \gamma_{avg} \quad (2)$$

$\gamma_s(g_c,g_i)$, $\gamma_{avg}$and Q are the instantaneous transmit power, allowed average transmit power, and peak received interference power that the PR can tolerate, respectively,. The optimum power allocation can then be expressed by

$$\gamma_s{}^*(g_c,g_i) = \min\{(\frac{1}{\gamma_0}-\frac{N_0}{g_c})^+, \frac{Q}{g_i}\} \quad (3)$$

Where$\gamma 0$ is the water-filling cutoff value. The Channel Side Information (CSI) of both the PR and SR are needed at the ST as inputs for the power allocation algorithm. No communication is allowed as long as the CR channel gain is below the cutoff value, i.e.$g_c \leq \gamma_0$.

4.2.2 Fading Channels With Peak Transmit Power Constraint

The optimum power allocation in this case is equal to

$$\gamma_s{}^*(g_c,g_i) = \min\{\gamma_{pk}, \frac{Q}{g_i}\} \quad (4)$$

Whereγ_{pk} is the peak transmit power of the ST. The minimum energy efficiency can be calculated by

$$(\frac{E_b}{N_0})_{\min} \lim_{\gamma_{pk}\to 0} \frac{E[\gamma_s(g_c,g_i)]}{N_0 E\log_2(1+\frac{E[\gamma_s(g_c,g_i)g_c}{N_0}])} \quad (5)$$

In low SNR regime,. $E[\gamma_s(g_c,g_i)] = \gamma_{pk}$and takethis into consideration $(\frac{E_b}{N_0})_{\min}$ isalways equal to −1.59.

4.3 SYSTEM-LEVEL SPECTRAL-ENERGY EFFICIENCY TRADE-OFF

Assume that a CRN consists of a single ST, i.e., macro Base Station (BS), which transmits signals to multiple SRs. The CRN shares a spectrum owned by an indoor primary network. The primary network also consists of multiple PRs, i.e., primary indoor Access Points. The SRs and PRs are indexed by $n \in N = \{1, . ,N\}$ and $k \in K = \{1, .., K\}$, respectively. The SRs and PRs are evenly distributed in a cell of radius d and a cell of radius $D(d \leq D)$.

4.3.1 The Distribution of the Channel Gain

The power gain of cognitive channel between ST and nthSR is denoted by $g_c(n)$,while the gain of interference channel between the ST and theKth PR is denoted by $g_i(k)$. The focus in this section will be on the cognitive channel. However, the same analysis can be applied to the interference channel.The combined channel gain $g_c(n)$ is given by

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ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

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$g_c(n)=\frac{g_{m(n)}g_s(n)}{g_p(n)}$

(6)

Where$g_s(n)$ and $g_m(n)$ represent the power gain of the shadowing and multi-path fading of the nth SR, respectively.

4.3.2 Spectral-Energy Efficiency Trade-Off

The average energy efficiency is given by$(\frac{E\quad b}{N_0})$ sys = $\frac{\overline{\gamma\quad avg}}{N_o C_{sys}}$, where, $\overline{\gamma\quad avg}$ is the average transmit power.

$\overline{\gamma\quad avg}$=E[$\gamma\ s$] = $\int\quad\gamma\quad _s(y)fY(y)dy$ (7)

WherefY (y) is the PDF of Fréchet distribution. Allow the ST to transmit to the best user who has the maximum channel gain. Then the maximum spectral efficiency and energy efficiency that the CR network can reach are given by

C_{max} = $\int$ log $(1+\gamma'\frac{k}{2(k+\gamma'^{-0.5})\quad 2\gamma'^{\frac{3}{2}}}d\gamma'$

(8)

$\left(\frac{E\quad b}{N_0}\right)\quad max = \frac{P_1}{N_0 C_{max}}$

(9)

4.4TRUST AWARE MODEL BASED SECONDARY USER ASSIGNMENT

In this section, one PU and ten SUs are implemented to access the spectrum. Trust value is calculated for each SU according to SNR. The values of SNR are taken from 0 to 9.The proposed system selects the SU based on the trust value. The system fixes appropriate threshold value according to SNR. Based on the threshold condition, the SUs will be selected for spectrum sharing. The PU maintains a table for recording identities and the corresponding trust values of its one-hop neighboring SUs. In addition, the BSkeeps the trust values of all SUs in its domain. Each time after cooperation, the behavior of the SU will be evaluated and the trust value will be updated accordingly. The trust value will be exchanged periodically between the PUs and the BS.The cognitive radio network has finite number of PUs and infinite number of SUs. SUs periodically check the channel and send the packets if the channel is idle. When SUs accessing the channel, at that time a primary user arrives and then collision occurs between primary and secondary transmissions. Due to collision between these two transmissions SUs suffer a delay to access the channels. Assume that at most i_{max} times a SU tries to access the channel. Let Di be the random delay for thei^{th} attempt for accessing the channel and D is the random channel access delay. So average channel access delay is given by,

D= $\sum_{i=1}^{i_{max}} pr\quad _i \sum_{j=1}^{i} D_j$

(10)

Where $pr\quad _i$- Probability that secondary users get access the channel after (i-1) th attempt.

V. SIMULATION RESULT

In this section, the proposed method is implemented using MATLAB. Thus from the experimental result, we can prove that Extreme Value Theory with Trust value is superior to Extreme Value Theory without Trust value.

5.1 LINK LEVEL

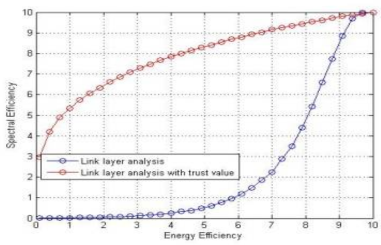

Fig.1Per-link spectral-energy efficiency trade-off for the Rayleigh fading channel

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ISSN (Print) : 2320-9798

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Link level is analyzed with and without trust value. The red dots clearly show that analysis is made in the presence of trust value where the spectral efficiency increases linearly with energy efficiency from a point 3 bps/Hz. The blue dot shows that analysis is made in the absence of trust value where the spectral efficiency increases gradually from 0 bps/Hz. Thus, the experimental result concludes that the link level analysis with trust value shows the highest spectral-energy efficiency and it is superior to link level without trust values.

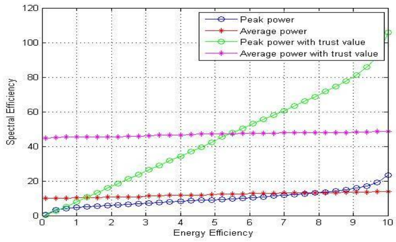

Fig.2Per-link spectral-energy efficiency trade-off for CR channel withaverage and peak power constraints

In link level, spectral and energy efficiency are computed for peak power, average power, peak power with trust value and average power with trust value. In proposed, peak power with trust values shows highest spectral efficiency where it increases linearly with energy efficiency from a point 0 bps/Hz. Average power with trust value shows constant spectral efficiency at a point 49 bps/Hz for different values of energy efficiency .Thus, the experimental result concludes that the link level analysis with trust value is superior toexisting method.

5.2 SYSTEM LEVEL

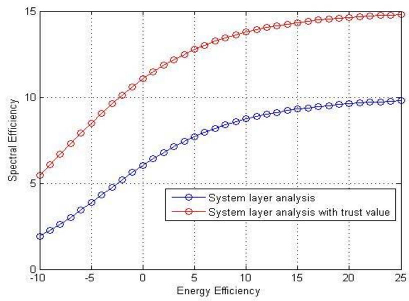

Fig.3 Per-network spectral-energy efficiency trade-off for the Rayleigh fading channel

System level is analyzed with and without trust value. The red dots clearly show that analysis is made in the presence of trust value where the spectral efficiency increases linearly with energy efficiency from a point 5 bps/Hz. The blue dots show that analysis is made in the absence of trust value where the spectral efficiency increases gradually from 3 bps/Hz. Thus, the experimental result concludes that the systemlevelanalysis with trust value shows the highest spectral-energy efficiency and it is superior to system level without trust value.

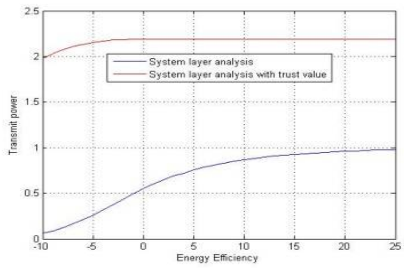

Fig.3 Per-network transmit power vs. Energy efficiency for the Rayleigh fading channel

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ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

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In system level, energy efficiency increases according to transmit power. System level analysis with trust value shows highest energy efficiency with high transmit power of 2 W whereas system level without trust value consumes less power of 0.2W.

VI. CONCLUSION AND FUTURE WORK

This paper fully deals with analyzing the performance of Spectral-energy efficiency with and without use of trust value.Extreme Value Theory with trust value shows highest performance than Extreme Value Theory without trust value. Delay related channel access of secondary users is implemented to avoid the collision between PUs and SUs. The experimental result shows that the proposed system achieves high performancewhencompared with an existing system.CRNis a new area of interests for researchers and a new technology for the next generation wireless networks. Transmission errors occur during the packet detection due to the network interfering signals. In future various mechanisms are implemented to solve this problem.

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