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Analysis of Energy Efficiency for Cognitive Radio Networks

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***Abstract* - CR-based technology aims to combat scarcity in the radio spectrum using dynamic spectrum access (DSA).It improves the performance of spectrum efficiency by allowing secondary users to share the spectrum owned by primary users. In this paper, different techniques have been analyzed to improve the energy efficiency of a CRNs.Gradient based iteration algorithm is used to obtain the Stackelberg equilibrium solution. Water filling factors aided search method deals with the Energy Efficient optimization problem with multiple interference power constraint. Efficient barrier method is used to provide optimal solution with reasonable complexity. Extreme-value theory characterize the impact of the multi-user diversity gain of both kinds of users.**
***Keywords:* Dynamic Spectrum Access, Cognitive Radio Networks.**

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. One way to meet the continuously increasing demand for high-speed data is to secure new spectrum bands. This is a very difficult task as we all know that the spectrum is a rare resource. Wireless sensor nodes with cognitive radio capabilities can help to address these challenges. Cognitive radio sensor network in used to optimize the bandwidth and Quality-of-Service of a wireless sensor nodes.CRNs improve the spectrum utilization, and multiple sensor networks can be deployed in a specific region. It has an ability to self-organize, self-plan, and self-regulate. They can sense a wide range of spectrum, dynamically identify currently unused spectrum blocks for data communications, and access the unoccupied spectrum called spectrum opportunities. Devices with cognitive capabilities can be networked to create CRNs.The most general CRNs differentiate two types of users sharing a common spectrum portion with different rules:

a. Primary (licensed) users (PUs) who have priority in spectrum utilization within the band and
b. Secondary users (SUs) who must access the spectrum in a nonintrusive Manner.

PUs use conventional wireless communication systems with static spectrum allocation, whereas SUs are equipped with CRs which exploit spectrum opportunities without disturbing the PU's transmissions. In this paper, we have analyzed the different techniques to improve the spectral-energy efficiency which is given below in section[2],[3],[4] and [5].

II. GRADIENT BASED ITERATION ALGORITHM

Consider a wireless network in which both the macrocell and the femtocell have the cognitive capability. We analyzed the energy-efficient resource allocation problem in a cognitive radio network with femtocells. A gradient based iteration algorithm is used to obtain the Stackelberg equilibrium solution to the energy-efficient resource allocation problem.We proposed a pricing-based spectrum leasing framework between one PU and multiple SUs.

Algorithm:
Stage 1:The primary network offers spectrum selling prices.
Stage 2:The cognitive BS decides to buy & allocates to femtocells or macro secondary users.
Stage3: Femtocell BS performs power allocation for femtocell secondary users.

The intuitive explanation of GBI algorithm is that the cognitive BS expects to allocate the spectrum 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.

III.WATER FILLING FACTORS AIDED SEARCH METHOD

Water filling factors aided search method deals with the Energy Efficient optimization problem with multiple interference power constraint. As if the spectrum-efficient power allocation problem is convex, the corresponding energy efficient power allocation problem can be solved by WFAS method. The main advantage of WFAS is its broad applicability, since it does not restrict the system rate function with respect to the total transmit power and can be used in the wireless systems where the transmit power is tuned according to given power levels. This method consist of two WFAS: simplified WFAS and general WFAS.We have analyzed the energy efficient power allocation problems of OFDM-based CR under single and multiple interference power constraints respectively.

Simplified WFAS : In the single interference power constraint case the interference power constraint obstruct the interference power of all active primary bands.General WFAS : In the multiple interference power constraint case each interference power constraint protects each active primary bands.

Simulation results show that the proposed WFAS method can converge to the optimal point very quickly. In addition, we also use the general WFAS method to solve the Energy Efficient optimization problem of OFDM based CR systems with rate proportional fairness. In Comparison with the conventional spectrum-efficient power allocation, the energy-efficient power allocation has significant improvement on energy efficiency for OFDM-based CR systems.The main drawback of this method is Energy-efficient power allocation problem is more complicated in wireless networks such as multi-cellular networks or MIMO broadcast networks.

IV.EFFICIENT BARRIER METHOD

In this method, we investigated the energy-efficient resource allocation in orthogonal frequency division multiplexing (OFDM)-based cognitive radio (CR) networks, where we tried to increase the system energy-efficiency under the consideration of practical limitations, such as transmission power budget of the CR system, interference threshold of primary user and traffic demands of secondary users.We 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 (near) optimal solutions and finally we developed a fast barrier method by exploiting the special structure to speed up the computation of Newton step to meet the requirement for the considered energy-efficient RA problem that should be handled real time.The problem with this method is an imperfect channel state information.

V. EXTREME VALUE THEORY

This method has investigated the spectral and energy efficiency interference-tolerant CR networks.We analyzed the spectral-energy efficiency trade-off at both link-level and system CR network under transmit power and interference constraints.In low SNR regime, average power constraint provides effective energy efficiency than peak power constraint. In high SNR regime transmitting signals with either power constraint gives the same energy efficiency. We have also proposed a cellular network in which a secondary network shares a spectrum belonging to an indoor system of a primary network.This method has also demonstrated that with CR technology, cellular operators can share their spectrum opportunistically with each other to increase the performance of their network. One way to meet the requirement is to share a spectrum in the uplink phase of an indoor system.The challenge is how to estimate the interference channels by the STs. Relying on channel side can give some insight to solving this issue. Extreme value theory is used to derive the spectral efficiency of the system-level CR network with optimal power allocation. We have studied the effect of multi-user diversity gain in both the primary and secondary receivers on the spectral and energy efficiency. The spectral efficiency is relatively large when the number of primary receivers is small. The spectral efficiency rapidly decreases with increase in the number of primary receivers. This reduction can be compensated by adjusting the interference threshold or by increasing the number of SRs that are within a short distance from the ST.

VI.SIMULATION RESULTS AND DISCUSSIONS

In this section, we used computer simulations to evaluate the performance of various techniques.

Table I. shows the comparison of various techniques to improve the energy efficiency of Cognitive Radio Network.Two parameters are considered for the comparison: Energy Efficiency and Transmit Power.

TABLE I COMPARISON OF VARIOUS TECHNIQUES

Parameters	GBIA	WFAS	EBM	EVT
Energy efficiency (kbps/J)	0-4.3	2-4	50- 80	70-120
Transmit Power(W)	100-15	50-100	50-70	10-50

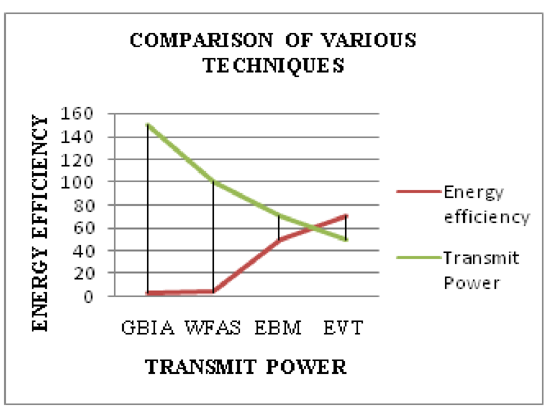

Fig.1 Comparison graph of various techniques

As we compared to other techniques Extreme Value Theory has achieved higher energy efficiency. Energy efficiency ranges from 70-120 kbps/J under low transmit power from 10-50W.Figure 1 shows the comparison graph of various techniques. Red line indicates the energy efficiency and green line indicates the transmit power.It shows the increase in energy efficiency according to transmit power used in each technique.

VII. CONCLUSION

This paper fully deals with analyzing the performance of energy efficiency of Cognitive Radio Network by using various techniques. Output of each technique has been mentioned in section [6].So far we have discussed only the techniques used to improve the energy efficiency. In our future work, we will consider security issues for the emerging cooperative networking.

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