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Fragmented Spectrum Allocation in Cognitive Radio Networks for Energy Efficiency and Improved Throughput

Kokila V and Aruna Jeeva Bharathi B*

B.S. Abdur Rahman University, Chennai, India

Research Article

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***For Correspondence**

Aruna Jeeva Bharathi B, Assistant Professor, B.S. Abdur Rahman University, Chennai, India

E-mail: arunaece@bsauniv.ac.in

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ABSTRACT

In the fragmented spectrum allocation, wireless spectrum of various frequency bands is fragmented which are spectrally distant from each other. Spectrum allocation is done at the cognitive base station (CBS) in the cognitive radio network which allocates frequency at each frame beginning. Scheduling of frequency considers channel switching cost and channel capacities. This work focus on the problem of scheduling. To this aim, proposed an energy efficient heuristic scheduler, which greedily assigns an idle frequency to the cognitive radio that attains highest energy efficiency. As energy efficient heuristic scheduler (EEHS) cannot provide fairness in the spectrum allocation and may fall short of throughput efficiency. We then present a spectrum allocation based on minimum energy consumption with throughput guarantees scheduler and throughput maximization energy guarantee scheduler was proposed under non homogeneous condition. Energy and throughput of the scheduler were analyzed which provides fairness in resource allocation.

INTRODUCTION

Cognitive Radio derives its name from the word "cognitive" which means process of acquiring knowledge by the use of reasoning, intuition or perception. It is a new technology which scans the radio spectrum and searches for white spaces in it. It enables the unlicensed user to use the licensed bands without causing any significant interference to the licensed user. The licensed user is also known as primary user (PU). The users which are having no rights to access the licensed bands are known as secondary users (SU). The cognitive radio cycle starts from the sensing of the radio environment and it is the first and most important step in cognitive radio. The analysis performs spectrum sensing in order to study the radio characteristics and find unused channels. Channel estimation [1] is also performed in this section in order to determine the channel characteristics on the received signal, which in turn will help in better reception of the licensed user signal. Energy costs are constantly increasing, and energy expenditure of a wireless network is a significant fraction (20%–30% [2]) of the total operator expenditures (site rental, licensing etc.). Hence, energy should be consumed effectively for cost-effective systems. Reducing energy consumption and energy-efficient operation are, therefore, at the interest of the operators. From the user viewpoint, energy efficiency means longer battery lifetime. It is a fact that short durations between two battery charging instances annoy the users and reduce the practicality of wireless communications. Thus, energy efficiency is vital for both actors of wireless communications. Another driving factor for increasing energy efficiency of communications is the environmental concerns. As CRs are expected to possess operation capability within a wide range of spectrum owing to power-intense spectrum sensing tasks, they are expected to operate with high energy efficiency. Most of the prior studies are on the energy efficiency of spectrum sensing and, accordingly, on spectrum access [2-5]. Hence, cognitive protocols must also be designed with an energy efficiency perspective. In this sense, a cognitive scheduler located at the cognitive base station (CBS) should consider the energy efficiency while determining a schedule.

SYSTEM MODEL

System model consider a cognitive radio network serving many cognitive radios [6-10]. The primary channel occupancy is modelled as two state markov chain representing the idle and busy states of the channel. The primary user spectrum occupancy is retrieved from cognitive base station called white space database. The informed retrieved is assumed to be reliable and the frequency assigned to cognitive radios without spectrum sensing. If the cognitive radio selected for transmission then it switches to the related channel and transmit in that channel and stays in idle mode if it is not assigned a frequency. Network scheduler acts as a base station and it assigns to the cognitive nodes. Each node acts as transmitter and receiver **(Figure 1).**

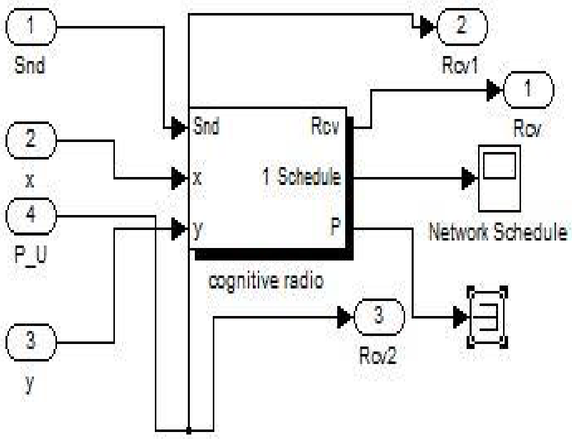

Figure 1. Single Cognitive node with scheduler.

Energy Efficient Heuristic Scheduler

Algorithm 1: Energy-efficient heuristic scheduler Need: Sidle,R,E

Ensure: Assignment vector x: [(f,CRi)],f∈Sidle and CRi∈Nt

1: if|Sidle|<Ntx then

2: for all f∈Sidle do

3: ηi,f=Ci,f/Ei,f,∀CRi∈Ntx

4: i*←arg maxiηi,f

5: Add(f,CRi*)to the assignment vector

6: Nt←Nt\CRi*

7: end for

8: else

9: for allCRi∈Nt do

10: ηi,f=Ci,f/Ei,f∀f∈Sidle

11: f*←arg maxfηi,f

12: Add(f*,CRi)to the assignment vector

13: Sidle←Sidle\f*

14: end for 15:end if

The above algorithm greedily assigns each idle frequency to the cognitive radio that attains maximum energy efficiency at this idle frequency.

In the first case if there are more cognitive radios than the number of idle frequencies, then the best node is denoted by CRi*.

In the second case, the cognitive radio with higher effective rate is selected at this frequency. In the third case, if there are more number of frequencies the best frequency is denoted by f* and it is selected for the cognitive radio. The frequency at which cognitive radio maintains the highest energy efficiency is the best frequency for this cognitive radio. After assigning the frequency to cognitive radio, it is removed from the set of idle frequencies. If cognitive radio is assigned with frequency it is removed from the Ntx. The above algorithm operates in polynomial time for a constant F.

Channel Switching Cost With Link Capacity

Calculation

The capacity of li, f depends on the bandwidth of channel W and the SNR of the link. In addition, number of bits that can be sent through this link in a frame is determined by the time spent for tuning the CR"s RF front end to this frequency. The total time spent during all these necessary RF front-end hardware configurations is referred to as channel switching latency, and it is considered as a linear function of the total frequency distance between the former(f")and the latter frequencies (f) [11-15].

Let *Bi, f* be the channel capacity of *li, f* calculated by Shannon"s formula and *Ri, f* be the maximum number of bits that can be sent by CR*i* at link *li, f* during a frame. *Bi, f* and *Ri, f* are calculated as follows:

Bi, f = *W* log 2(1=SNRi *i*) bits/second (1)

Ri, f= Bi,f(T-Tcs) (2)

Where,

W is the channel bandwidth, SNR*i, f* is the SNR of *li, f.* However, CR*i* cannot transmit more than the number of bits in its buffer. Hence, the effective rate of *li, f* denoted by *Ci, f* is restricted by both *Ri, f* and the number of bits in CR*i*"s buffer. *Ci, f* is calculated as follows:

Ci, f= min(Ri, f,Oi) bits (3)

The total cognitive radio network throughput is given by

R = ΣΣ Xi,f(Ci,f) (4)

Where,

Xi,f standing for the binary decision variable that represents the allocation state of CRi at frequency f, i.e.,Xi,f=1,if f is assigned to CRi, and Xi,f=0 if otherwise.

Modeling of Energy Consumption

Considering the frame format in **Figure 2** we can model energy consumption of a CRN. If CR*i* is assigned with a frequency (CR*i*∈*A*), it first tunes its antenna to the assigned frequency that takes *T*cs time units. Next, the CR begins transmission. As the transmission is completed, it switches to the idling state and keeps idle until the end of the frame. If Cr is not assigned with a frequency (i.e., CR*i*_∈*A*), CR*i* waits idle in this frame. Since wireless interfaces are the dominant sources of energy consumption in a wireless device, we ignore energy consumption due to information processing. Energy consumption of a CR in such a CRN setting is due to various tasks and components

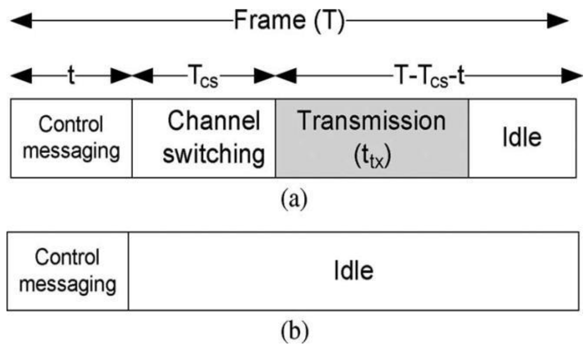

Figure 2. Frame format
(a) Cognitive radios assigned to idle frequency and transmit in that channel (b) Cognitive radios not assigned a frequency.

During Transmission: The Cognitive radios that are allocated for transmission consume transmission energy, whereas those that are not assigned any frequencies stay in an idling state. The transmission power *P*tx is assumed as constant. Consumption of energy during transmission *E*tx is proportional to the transmission duration and transmission power. The transmission time of the cognitive radio [16-18].

ttx = Cif/Bi,f (s) (5)

Energy consumption of Circuitry Ec: Energy/power consumed by electronic circuits (digital-to-analog converters, mixers, filters) of a mobile device during transmission is referred to as *circuit power Pc*. It is assumed to be constant and the consumption of energy due to circuitry equals to Pcttx

Energy consumption of Channel switching Ecs: *E*cs represents the energy consumed for configuring the hardware from current transmission frequency (*f'*) to the assigned transmission frequency (*f*). The energy consumption due to channel switching is given by

Ecs = PcsTcs (J) (6)

Energy consumption in idle state Ed: CRs that are not selected for transmission stay idle, they consume idling power *Pd* for a duration of *T*, which results in energy Consumption $Ed = PdT$. Moreover, the CRs selected for transmission switch to the idling state until the end of the frame once they complete transmission of all the bits in their buffers and its idle time is given by T−Tcs−ttx (s).

Therefore the total energy consumption of the cognitive radio at the frequency is given by

$$E_{i,f}=(P_{tx}+P_c)t_{tx}+ P_d(T-T_{cs}-t_{tx})+P_{cs}T_{cs} \quad (7)$$

The energy efficiency of the cognitive radio network is given by

$$\eta=\text{Throughput}(R)/\text{Energy}(E) \text{ (bits/J)} \quad (8)$$

ROUTING IN COGNITIVE RADIO NETWORKS

The physical layer is responsible for spectrum sensing, detecting the active primary users and estimating the quality of available channels. The network layer performs scheduling and routing. If the spectrum being detected can be divided into n channels. When a node is turned on, it may choose to stay on one of the channels available. When there is no flow across a node, or there are flows only on the channel the node selects to stay, we say that this node is in a single channel state, and we call this node a single channel node. It is possible that multiple flows can intersect at a node. When the flows distribute on different channels, the node is in a switching state, and we call this node a switching node [19-22].

ENERGY MINIMIZATION THROUGHPUT GUARANTEE

The first process in the routing of cognitive radio networks is the route discovery. Cognitive radio(node) initiates a route discovery by broadcasting a Route Request (RREQ) packet to every nodes in the network when it has packet to send.. Because nodes may stay on different channels, the route request packet should be broadcasted to all available channels,. When an intermediate node receives route request, it transmits the packet also on all available channels. The information of channels available which is piggybacked by RREQ messages is forwarded in the broadcast process. When the node relay this route request, the working channel information and node state is also included. So when a node receives a route request, it knows the path of the route request passing through and working channels of nodes and also knows the number of nodes on each channel, which is an important parameter in assigning the channel. As the route request is forwarded, the nodes set up a reverse path.

In the route reply, destination node knows the available channel information of all nodes on the path after receiving route request, and assigns a channel for that flow. It sends back a Route Reply to the source by encapsulating the assigned channel. The node establishes route to the destination through its cognitive radio transceiver and generates new route reply message to send back to the source

EMTG scheduler can be formaulated as follows

$$R_{min} = \beta * K * T_{avg} * R_{avg} \quad (9)$$

THROUGHPUT MAXIMIZATION ENERGY RESTRICTION SCHEDULER

In this scheduler, it focuses on improving the throughput as well as minimum energy consumption. It uses Hungarian algorithm which is used to identify the minimum energy efficiency consumption of a node there it achieves higher throughput. Emax is the constant value obtained by the scheduler.

$$E_{max}=\beta(K[(P_{tx}+P_c)(T-\alpha * t_{cs}-T_d)+P_d * T_d+P_{cs} * \alpha * t_{cs}]+(N-K)P_dT) \quad (10)$$

Emax denotes the maximum energy consumption for a frame. Let β is the energy throughput tradeoff parametre and K is the number of nodes in transmision

$$K = \min(N_{tx}, |c_{idle}|) \quad (11)$$

$$T_d = T-\alpha * t_{cs}-T_{avg} \quad (12)$$

Let Tavg is the average transmission time to transmit all bits in the buffer and Td is the idle time. α is the average number of channel switching.

$$T_{avg}=\min(Q_{avg}/R_{avg},T-\alpha * t_{cs}) \quad (13)$$

Qavg denotes the average queue size and Ravg is the average rate of idle channels. Let Ntx is the number of nodes with the transmission request

$$Q_{avg} = \Sigma/N_{tx} \quad (14)$$

Qi is the number of bits in the buffer.

Simulation is performed using MATLAB tool and the network creation is done using true time toolbox

SIMULATION AND RESULTS

The above results shows **(Figure 3)** the probability of success with the number of cognitive radio nodes used and it shows 68% success was achieved in the successful packet transmission. The success rate was degraded from 1, 0.9, 0.8, and 0.72 to 0.68

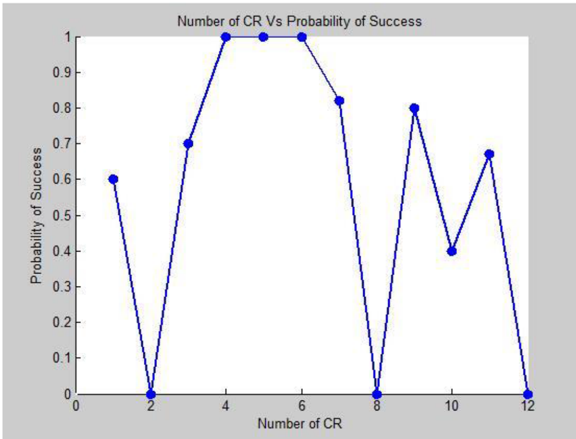

Figure 3. Probability of success varies with number of nodes for energy efficient heuristic scheduler.

The **Figure 4** provided the results of energy consumed in the transmission from source node to destination node to deliver the packets. It consumes 35 mj of energy for the transmission.

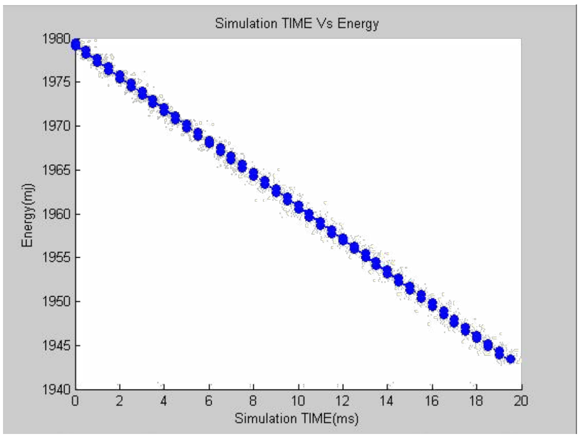

Figure 4. Energy consumption of EEHS Scheduler.

In the energy minimization throughput guarantee scheduler it consumes 25 mj of energy for the transmission **(Figure 5).**

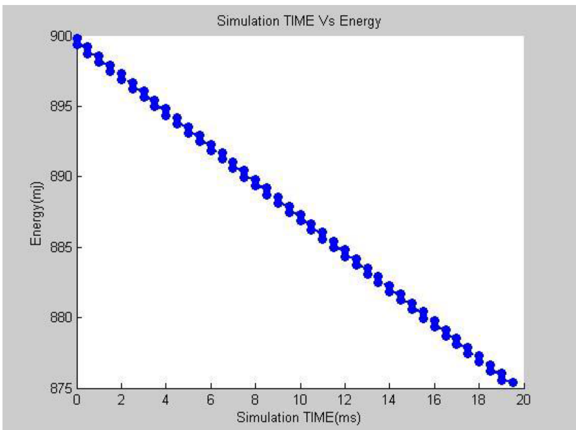

Figure 5. Energy with time in energy minimization throughput guarantee scheduler.

In this EMTG scheduler it achieves minimum throughput of 320 bps **(Figure 6).**

Proper assigning of frequency in the TMER scheduler minimizes the energy consumption and it consumes 12 mj of energy for the transmission under non homogeneous traffic condition **(Figure 7).**

TMER scheduler it achieves better throughput of 400 bps compared with the previous scheduler **(Figure 8).**

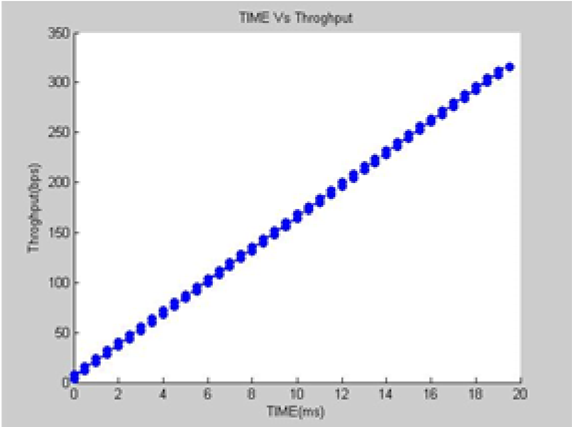

Figure 6. Throughput with time in the Energy minimization throughput guarantee scheduler.

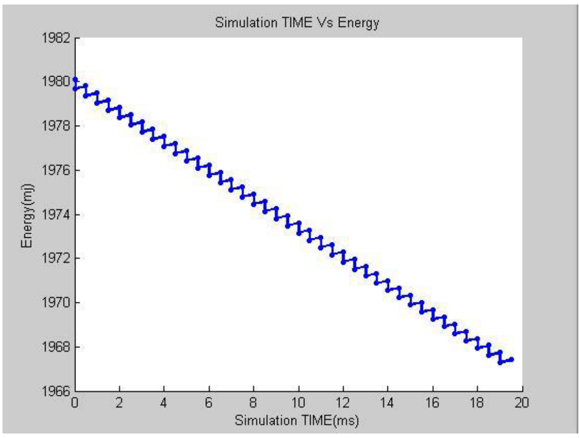

Figure 7. Energy with time in throughput maximization with energy restriction scheduler.

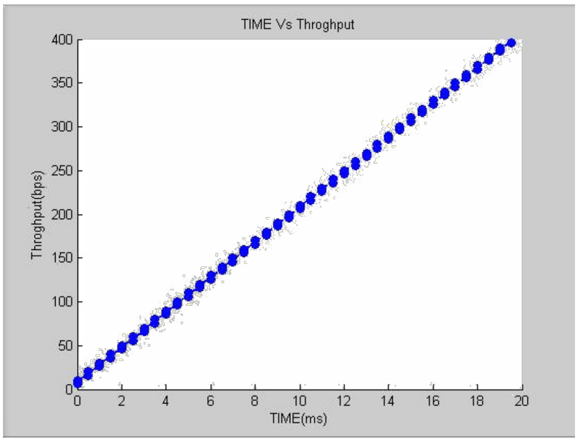

Figure 8. Throughput with time in TMER scheduler.

CONCULSION

In this paper formulated an energy efficient heuristic algorithm may fall short of throughput efficiency and does not provide fairness in resource allocation To overcome this EMTG and TMEG schedulers under traffic condition are proposed which provides fairness and improves the throughput and minimizes the energy consumption.

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