ISSN 2348-375X

Unique Journal of Engineering and Advanced Sciences

Available online: www.ujconline.net

Research Article

RESOURCE ALLOCTION IN COGNITIVE RADIO RELAY NETWORKS

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Received: 22-02-2014; Revised: 21-03-2014; Accepted: 19-04-2014

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ABSTRACT

A “cognitive radio” is a system that senses its operational electromagnetic environment and can dynamically and autonomously adjust its radio operating parameters to modify system operation, such as maximize throughput, mitigate interference, facilitate interoperability, access secondary markets. It is an upgraded wireless spectrum sensing technology which differs from the traditional radios.. The users in cognitive radio networks are two types Primary user and another one is secondary user. Primary user have licensed bandwidth with higher priority, secondary users have unlicensed bandwidth with lowest priority. Cognitive radio does some important job they are spectrum sensing, sharing, decision, and mobility. In this paper I analyzed some important tasks that performing cognitive action they are (1) signal strength (2) number of free channels (3) bandwidth allocation for secondary users (4) Interference mitigation (5) power optimization. A relay network is proposed in addition with a cognitive radio. Relay networks forms a cognitive Relay stations. To avoid interference with primary users relays are accompanying with (CR). To allocate a bandwidth or a frequency set we introduce a Proportional Fair Scheduling (PFS) to maximize the throughput for its end users though QoS is improved. For that it uses some scheduling algorithms. Proportional fair metric bases two types of power controls they are Fixed Transmission Power and Adjustable Transmission Power.

Keywords: Relay Network, Signal Strength, Bandwidth, Power Optimization.

INTRODUCTION

Cognitive Radio technology was initially deployed in mid 1990’s that time mobile radio applications started to get a paradigm shift with increasing users. After the late 2000 mobile applications starts to add Multimedia, graphical applications such as 3D games and other. For each application mobile bandwidth needs to be occupied. So beyond voice and text based applications mobile bandwidths were tightly occupied with increasing users[1].

To optimize such bandwidth requirements we found new trends that can allow multiple users to use wireless bandwidth. No one going to occupy a bandwidth for a whole day or more. Whenever user starts to use some bandwidth should be allocated to him. But if they not using the channel left free. In a Round-Robin fashion we allocate free channels for the waiting users. In case the primary users try to use at middle simply we cannot avoid them to use their own bandwidth, so cognitive radio redirects the bandwidth to the primary user. We are not going to despair the secondary users by terminating the signal at the middle. Within instant another free channel is probed to them therefore both the users can share the bandwidth without interruption[2]. This is how possible by means of Proportional fair Scheduling. Like subnets we are splitting a huge mobile network into small divisions. Each secondary terminals are considered as cognitive terminals. The entire network consists of relay and sensor nodes to find signal strength and to do a fast switching.

Proportional fair scheduling does two things (1) power allocation for each user (2) connection establishment and termination. We discuss about this proportional Fair Scheduling and what it contributes to. What is the use of algorithms here? In fact all radio bandwidth are controlled monitored, and issued by software controlled network unlike analog transceivers in vintage days. So they need algorithms to compute any task. So to operate the PFS task some feasible algorithms are implemented in a software form they are Greedy algorithm, random algorithm, and brute force. Those algorithm concepts have inputted to computer and tested with cognitive radio environment thus some parameters are observed and tabulated here[3-6].

Proportional Fair Scheduling

The goal of Proportional Fair Scheduling (PFS) is to allocate bandwidth to each node proportionally to their rates[7]. In wireless networks, channel conditions usually are time varying. Thus, the available data rate of each Mobile Station (MS) may be different at different time. One way to schedule resources is to serve all MSs equally by using round-robin scheduling to maximize fairness. The other way is to always serve the MS with the best channel condition which has the highest data rate to maximize throughput. By using PFS, however, the scheduling algorithm aims at maximizing total throughput while also maintaining long-term fairness for all MSs. That is, the scheduling algorithm tries to serve the MS with best channel condition while also maintain acceptable level of performance for other MSs[8-10]. A simple example can be found in[11].

Next, we discuss how to present PFS mathematically[7]. Considering a network with M nodes, let ri(t) be the allocated rate of node i at time-slot t, where,

1≤ i≤ M let Ri (t) be the average rate the node I has been serviced until the beginning of time slot t. the set Ri (t), 1≤ i ≤ M are said to be proportional fair if Ri (t) is feasible and for other feasible rates Si (t)'s the following equation gives

$$\sum_{i} \frac{Si(t) - Ri(t)}{Ri(t)} < 0$$

the set of long-term rates also maximize the proportional fair metric:

$$\sum_{i} \log(Ri(t))$$

over all other feasible long-term rates [7]. Eq. (2) is actually another form of Eq. (1). However, Eq. (2) is easier to use to measure the fairness of a scheduling algorithm. Therefore, it is called proportional fair metric. The above definition is based on long-term observation. In each scheduling round, the feasible set of ri(t)'s may change due to channel fluctuations. When performing real time scheduling, we have only the information about the available rates of each each node up to the time when the scheduling decisions are to be made. No future information regarding the rates of each node is available. Hence, we need a way to make the scheduling decisions, which are based on short term information, to achieve long-term proportional fairness. In[12], conditions under which short-term rates converge to long-term proportional fairness are provided. Let ρi(t) be the long-term average throughput of node i up to time t, which is define as:

$$\rho i(t)=\alpha\, Ri(t)+ (1-\alpha)\, \rho i\,(t-1) \quad 0<\alpha<1$$

If in each scheduling round we schedule the rates ri(t)'s such that the objective function

$$O(r) = \sum_{i} \frac{Ri(t)}{\rho i(t)}$$

is maximized among other feasible allocation of ri(t)'s, the long-term rates Ri(t)'s will converge to proportional fairness. Based on above argument, one may have a way to achieve proportional fairness. However, the inherent nature of cognitive radio relay networks poses great challenge on the optimization problem. The feasible space of the rates ri(t)'s in each scheduling round can be large due to frequency diversity, node mobility, variations in transmit power of nodes, and interference among nodes, which make the complexity of the optimization problem grows exponentially. As a result, it is computationally infeasible to derive the optimal ri(t)'s during each scheduling round because the frame duration usually is only 5 to 20 ms in wireless network systems. Thus, we need a real time algorithm that is computationally light, and the results should be as close to the optimal as possible[13].

Fixed transmit power

In this section, we formally state the problem of proportional fair scheduling for cognitive relay networks with fixed transmit power in relay stations. The scheduling is done in a per frame basis. The goal of the scheduling is to allocate available tiles in each frame so that proportional fairness can be achieved among CR MSs in a long-term scale. In each frame t, we aim to maximize the equation is

$$O(\lambda) = \sum_{m\epsilon M} \frac{\lambda m(t)}{\rho m(t)}$$

where λm**(t)** is the scheduled rate of CR MS m in frame t, and **ρm(t)** is the long-term average rate of CR MS m until frame t. The scheduling is subject to several constraints which will be discussed later. Since we are concerned with the allocation of resource in each frame, we do not incorporate frame sequence t in the problem formulation.

Let **Il (c, t)** be the indicator variable such that:

Il (c, t) =1 if sub channel c at time slot t is allotted to link l
= 0 otherwise.

We take interference among CR RSs into consideration in our problem formulation. Two CR RSs that do not interfere with each other can transmit on the same sub-channel at the same time, which will result in better spatial reuse. On the other hand, two interfering CR RSs cannot transmit on the same sub-channel at the same time, and the scheduling algorithm needs to decide which CR RS the sub-channel should be allocated to. Here, we say a CR RS i interferes a CR RS j if i's transmission will degrade the channel quality of an CR MS attaching to j when i and j are transmitting on the same sub-channel. Let **e (i,j)** be the indicator variable such that:

e (i,j) = 1 if CR RS i interferes CR RS j = 0 otherwise

Note that in the fixed CR RS transmit power scenario, the value of **e (.,.)** is fixed and can be viewed as input parameters.

Let **v (i,c)** be a 0-1 parameter such that:

v (i,c) = 1 if sub-channel c is vacant around node i = 0 otherwise.

v (i,c) can be obtained by making the cognitive radio on node i detecting vacant channels in its vicinity and report to the CR BS periodically.

Proposed Greedy algorithm for PFSCRN-FTP

If we solve the PFSCRN-FTP problem by brute force algorithm, the complexity is O((MR)NC). In real systems, however, the frame duration is less than 20 ms. Thus, brute force algorithm cannot meet the requirement of real time scheduling[14].

Therefore, we propose a heuristic greedy algorithm for the PFSCRN-FTP problem. As we will show later, the proposed algorithm is easy to implement and has performance comparable to the upper bound.

The design of the Greedy PFSCRN-FTP Algorithm consists of two parts: (1) To find and schedule available sub-channels for each CR RS. (2) To allocate sub-channels and time-slots of all hops in a greedy-based approach. The algorithm works as follows:

Resolve conflicts among interfering CR RSs and schedule their available sub-channels: It is possible that two CR RSs that interferes with each other have access to the same sub-channels. Thus, conflicts need to be solved and the algorithm will decide for each CR RS the sub channels that it can utilize. The algorithm scans through all the sub-channels For each sub-channel c, we scan through each CR RS r and record all CR RSs that interfere with r in the set U All of the CR RSs in the set U have access to sub-channel c, but are interfered with each other. Thus, only one of the CR RSs in U can access the sub-channel c at a given time. Others must avoid transmitting over c at that time to avoid collisions. We select the CR RS that has CR MS m with maximum value of $\frac{R1\rho m(c)}{\rho m}$ to have access to sub channel c .The procedure continues until all sub-channels are scanned and all available sub-channels of CR RSs are scheduled. Allocate the resource between the CR BS and the CR RSs

The resource between the CR BS and the CR RSs may not be enough to transmit all the data of the CR MSs selected. We allocate the resource between the CR BS and the CR RSs in a greedy approach. First, the CR MSs are sorted in descending order of their contributions to the objective function for each m in the sorted order and the CR RS u that m attaches to, the amount of service that m receives is initialized to the number of bits that can be transmitted using all the available timeslots between m and u over the scheduled sub-channel c we allocate the sub-channels between the CR BS and u in the order of transmission rate. That is, the sub-channel c with highest rate $R1\frac{p}{u}(c')$ is allocated first, and then the second highest sub-channel is allocated, and so on. The allocation continues until all m's requirement is fulfilled, or there is no available sub channels left between the CR BS and u. In the later case, the time-slots allocated between m and u over sub channel c is shrunk to match the data transmitted from the CR BS to u.

"The algorithm for PFS-CRN in FTP (Fixed Transmit Power) is not included in this paper. Only related parameters and mathematical equations are taken for the explanation"

Adjustable transmit power

The PFSCRN-FTP problem we discussed in Section V-assumes fixed transmit power of CR RSs. With the transmit power of CR RSs fixed, the interference pattern among the CR RSs and the maximum sustainable rate from CR RSs to the CR MSs are also fixed. They can be viewed as input parameters to the algorithm during the resource allocation procedure. However, power control and interference are crucial issues in wireless networks. In the case of cognitive radio networks, they are especially important because the main purpose of cognitive radio is to utilize unused spectrum resources as efficient as possible while keeping the original primary users unaffected. Better spectrum utilization and system throughput can be achieved with proper control of CR RS transmit power.

In this section, we consider the problem of resource allocation with adjustable CR RS transmit power. The problem of PFSCRN-ATP can be formulated as follows:

Given: (i) a cognitive relay network with one CR BS, multiple CR RSs, and multiple CR MSs,

(ii) The set of links L in the tree topology of the network,

(iii) The set of available transmit power levels for CR RSs,

(iv) The vacant sub-channels v (.,.) in the vicinity of the CR BS and the CR RSs,

(v) The maximum sustainable rate R. (., .) over each sub-channel on each link using each Power levels.

(vi) The long-term average rate ρm of each CR MS m϶M.

To find: a feasible schedule for the current frame, that is, to determine variables

Il(c, t), rl(c, t), and transmit power levels of CR RSs then the objective function is

$$O(\lambda) = \sum_{m\epsilon M} \frac{\lambda m(t)}{\rho m(t)}$$

Where (λm) is,

$$\lambda m = \sum_{c\epsilon C} \sum_{0\le t\le N} r1\frac{\rho}{m}(c,t)$$

The problem formulation of PFSCRN-ATP is similar to that of PFSCRN-FTP. The interference indicator e(i,j)(p) between two CR RSs (i, j) and the maximum sustainable rate Rl(c, p) on an CR RS and CR MS link l over sub-channel c are functions of the CR RS transmit power p. Note that it is possible for each CR RS to transmit with different power levels. An CR RS with its attaching CR MSs being near to it can be scheduled to transmit using low power level to minimize interference, while an CR RS that is experiencing bad channel quality can be scheduled to transmit using high power level to boost transmission speed[15].

Proposed Greedy Algorithm for PFSCRN-ATP

In general, the decision on which power level a CR RS should use involves two major issues. First, the power level should be chosen such that the interference to other CR RSs is minimized. Second, the power level should not be too low such that the spectrum cannot be fully utilized. In a cell with R CR RSs and P possible power levels, a brute force algorithm needs to explore all of the PR combinations of power levels. Together with the complexity of the PFSCRNFTP problem, a brute force algorithm that solves the problem of PFSCRN-ATP has complexity of O(PR(MR)NC).thus brute force algorithm cannot meet the requirement of real time scheduling. In this section, we present an algorithm to decide transmit power levels of CR RSs. We first calculate a score for each combination of (CR RS, power level) (r, p) (line 1-9). The score is determined by selecting the CR MS m with most contribution $\frac{R1\rho m(c,p)}{\rho m}$ to the objective function on each available sub-channel c of r and summing up the contribution of these CR MSs The power levels of CR RSs are determined as follows.

Priority is given to the (r, p) combination with highest score. That is, for each CR RS r, its transmit power level p is set to the one that has highest score among all other (r, p) combinations). If there are multiple (r, p) combinations that have the same scores, ties are broken by giving priority to the lowest power level. Generally, the power level of a CR RS is chosen to be the lowest one such that maximum contribution to the objective function can be achieved.

With the transmit power of CR RSs determined using arg max algorithm, the scheduling problem is solved by using a modified version of greedy algorithm. The modified heuristic greedy algorithm for PFSCRN-ATP is shown in Algorithm 3. The flow basically follows Algorithm 1, with the interference indicator e(i,j)(p) between two CR RS (i, j) and maximum sustainable rate Rl(c, p) on link l over sub-channel c being changed to functions of transmit power level p.Proposition 2: The computational complexity of the proposed Greedy PFSCRN-ATP is O(CPR + CR2). The computational complexity of the proposed Greedy PFSCRN-ATP which have time complexity O(C × P × R) and O(C × R × R), respectively. Therefore, the total complexity is O(CPR + CR2).

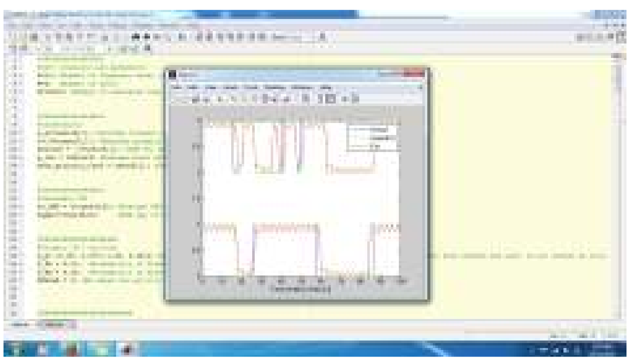
The algorithm for PFS-CRN in ATP (Adjustable Transmit Power) is not included in this paper. Only related parameters and mathematical equations are taken for the explanation".

Algorithm Running Time

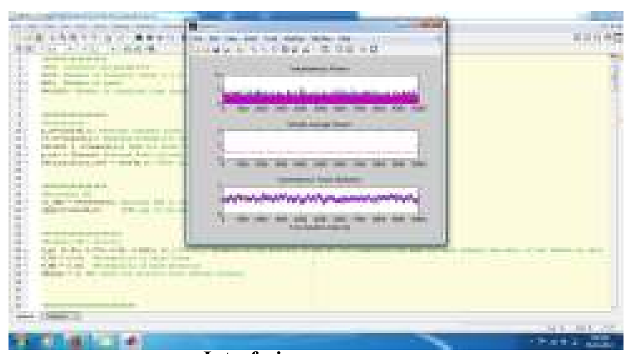
We have also implemented the proposed algorithms with C++ and compiled them by using GNU g++ v4.1.2 with optimization flag O3. The implemented algorithms are executed with 64 sub-channels, 48 time-slots, 4 CR RSs, 40 CR MSs, and 2000 frames. As discussed earlier, frame duration usually is only **5 to 20ms**. Table shows the average running time retrieved using GNU profiler. It indicates that the proposed Greedy PFSCRN-FTP and Greedy PFSCRN-ATP require **0.38 ms** and **0.75 ms**, respectively. Because it is computationally infeasible to run the brute force algorithms, we can only estimate the running time. For brute force FTP, we use the same setting of 40 CR MSs, 4 CR RSs, 64 sub-channels, and 48 time-slots as parameters. Because we have already known the running time of the proposed PFSCRN-FTP is 0.38 ms, by using the time complexity shown in the 2nd column of Table II, we can estimate that it takes more than 100 years for the brute force FTP. By using the same way, the estimated running time of the brute force ATP algorithm is also more than 100 years. As shown in the table, both of the proposed greedy algorithms have running times much less than **5 ms**, which can meet the requirement of scheduling frames in real-time.. The random FTP and random ATP require 0.14 ms and 0.23 ms, respectively. Although they are slightly less than our proposed algorithms, our proposed algorithms outperform random scheduling algorithms.

Algorithm running time

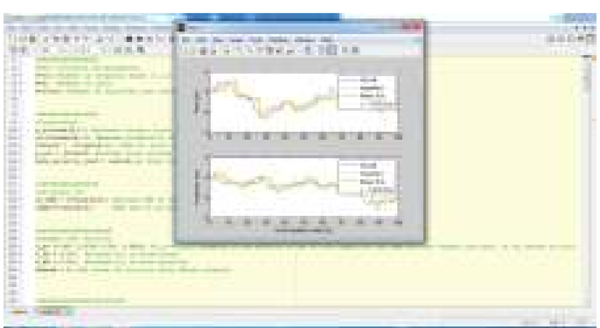
ALGORITHM	Time complexity	
Brute force algorithm (FTP)	O(MR)^NC	>100 years
Brute force algorithm (ATP)	O(P^R (MR)^NC	>100 years
Greedy PFS-CRN(FTP)	$O(CR^2)$	0.38 ms
Greedy PFS-CRN(ATP)	$O(CPR+CR^2)$	0.75ms
Random algorithm (FTP)	$O(CR^2)$	0.14ms
Random algorithm (ATP)	$O(CR^2)$	0.23ms



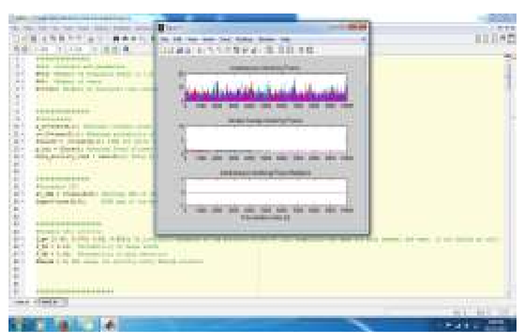
Quality of the estimation occupancy



Interfering power ranges



Quality of the estimated analog channels



Reduction in interference

here we are using the greedy algorithms to estimate the proportional Fair Scheduling because the algorithm running time should be less as possible if the computation time goes larger ends up with signal interlace. Because the spectrum switching time will increase leads to collision between primary and secondary users facing on same frequency. Brute force algorithm takes long time to complete one task in cognitive radio. Random algorithm gives similar performance but not be discussed here. Unlike cell splitting, clustering frequency reuse techniques Cognitive Radio allocates frequency for each user by picking up the idle frequencies. Another consideration depends upon computation time the power consumption is made. Wireless power always is fickle in nature but it can be sensed and allocated in different power ranges such as Fixed and Variable power transmissions.

CONCLUSION

Cognitive Radio technology having new verticals beyond signal allocation and power management but we focused on Proportional fair scheduling and interference mitigation. Interference problem fixed by reducing time complexity and other filtering techniques which is not discussed here. Instantaneous power multiplier is used to improve signal power and to reduce collision. If collided signals are neutralized then data loss would be the result. Even we cannot say the performance is ideal. Because wireless channels are more sensitive to interference rather than wired one. we try to reduce time complexity more and interference.

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Source of support: Nil, Conflict of interest: None Declared